SIEMENS

7UT51 V3 Protective Relay

Differential Protection for Transformers, Generators, Motors, and Busses
Instruction Manual

Document No. PRIM-2330C

This manual supercedes PRIM-2330B-0199. There are only formatting/structural changes.

	⚠ DANGER
	Hazardous voltages and high-speed moving parts. **Will cause death, serious personal injury, or equipment damage.** Always de-energize and ground equipment before maintenance. Read and understand this instruction manual before using equipment. Maintenance should be performed only by qualified personnel. The use of unauthorized parts in the repair of the equipment or tampering by unqualified personnel will result in dangerous conditions that will cause severe personal injury or equipment damage. Follow all safety instructions contained herein.

The use of unauthorized parts in the repair of the equipment or tampering by unqualified personnel will result in dangerous conditions which will cause severe personal injury or equipment damage. Follow all safety instructions contained herein.

IMPORTANT

The information contained herein is general in nature and not intended for specific application purposes. It does not relieve the user of responsibility to use sound practices in application, installation, operation, and maintenance of the equipment purchased. Siemens reserves the right to make changes at any time without notice or obligations. Should a conflict arise between the general information contained in this publication and the contents of drawings or supplementary material, or both, the latter shall take precedence.

QUALIFIED PERSON

For the purposes of this manual, a qualified person is one who is familiar with the installation, construction, or operation of the equipment and the hazards involved. In addition, that person has the following qualifications:

(a) **is trained and authorized** to de-energize, clear, ground, and tag circuits and equipment in accordance with established safety practices.

(b) **is trained** in the proper care and use of protective equipment such as rubber gloves, hard hat, safety glasses, or face shields, flash clothing,etc., in accordance with established safety procedures.

(c) **is trained** in rendering first aid.

SUMMARY

These instructions do not purport to cover all details or variations in equipment, nor to provide for every possible contingency to be met in connection with installation, operation, or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser’s purposes, the matter should be referred to the local sales office.

The contents of the instruction manual shall not become part of or modify any prior or existing aggreement, commitment or relationship. The sales contract contains the entire obligation of Siemens Energy & Automation, Inc. The warranty contained in the contract between parties is the sole warranty of Siemens Energy & Automation, Inc. Any statements contained herein do not create new warranties or modify the existing warranty.

Contents

Contents

Contents

1 Introduction

1.1 Using This Manual

This operator's manual provides the information required to install and operate a Siemens 7UT51 Differential Protective Relay. In addition to describing how to interface with the relay, the manual offers general information about the functions and features, along with some application examples.

This manual assumes the operator is using the 7UT51 relay's operator panel to program, maintain, and operate the relay; however, the manual gives a general overview of using a PC interface along with WinDIGSI and WinDIGSI software. Refer to the *WinDIGSI User's Manual* or the *WinDIGSI Instruction Manual* for more detailed instructions.

Event annunciations and setting options for the addresses mentioned are as they appear in the WinDIGSI software or the relay front panel. The titles can vary between the software and the front panel of the 7UT51.

1.2 Definitions of Terms

Adaptation factor – See *Matching Factors*

CT – Current Transformer

CTR – Current Transformer Turns Ratio

Cross-Block – Harmonic blocking across phases

Discrete Input – Binary Input

ENABLED/DISABLED – The available protective and additional functions can be programmed "**Enabled/ Existent**". Functions which are configured "**Disabled**" will not be processed. There will be no annunciations and the associated setting parameter will not be requested during setting.

Password – A password is required to change any settings, or to run any test routines. A password is **not** required to view annunciation logs, measured values, or settings. The password is six zeroes: **000000**

In or I_N – Nominal rated current of the monitored winding or side of the transformer

I_{NsecWx} – Rated secondary current of winding x or side x.

I_{Objsec} – Rated secondary current of the virtual object.

IxLy – Winding x (or Side x), Phase y

Marshalling – A special-use term that refers to the programming assignment of a set of logical functions to various physical I/O devices.

Matching Factors – (see Section 4.1.1 on page 39 and Figure 4.3 on page 41) Based on the transformer setting information entered into Address Block 1100, the relay will match the currents to be process by the relay. The relay matches these currents mathematically for any chosen vector group (see Table 4.1 on page 46 and Table 4.2 on page 47).

Note: The "**k**" matching factors are calculated by the relay from the entered rated data and can be read out in the operational annunciation in Address Block 5100.

Megger – A high-range ohmmeter having a built-in, hand-driven generator as a direct voltage source, used for measuring insulation resistance values and other high resistances. Also used for continuity, ground, and short circuit testing in general electrical power work.

MMI – Man machine interface, example the relay front panel or PC.

Nonexistent/Existent – The available protective and additional functions can be programmed "**Disabled/ Nonexistent**". Functions which are configured **Disabled** will not be processed. There will be no annunciations and the associated setting parameter will not be requested during setting.

NV-RAM – Non-volatile random access memory

Parameterizing – Setting up/programming the parameters of the relay.

RGF or REF – Restricted ground-fault.

Star-point – The common point or the non-polarity connection of a "**Y**" connected transformer.

SWITCH-OFF – The switch-off of a function means that the protective function has been established as **Enabled**; however, the function is turned **Off**.

VA – Rated Apparent Power

Vn or V_N – Rated phase to phase voltage or if the transformer is a LTC, Vn = (2 X Vmax X Vmin) / (Vmax + Vmin).

Vector Group – Integer n that represents the phase shift from the first winding to the second winding of a power transformer, n x 30°. See Table 4.1 and Table 4.2 for list of vector groups.

WinDIGSI – Windows based, Siemens software that will enable the user to perform all settings and data requisition with a PC through the relay's communication port. At the computer, the data can be easily read on the screen, changed, saved to disk, or printed.

WinDIGRA – A full-function digital oscillographic analysis (Windows based) software that will allow the user to view captured waveforms.

Winding – In this document it will refer to the side of the transformer or tertiary. ***Winding 1 is defined as the reference winding.*** The reference winding is normally that of the higher voltage; however, if a CT is installed in the ground lead of a grounded wye connected transformer, that winding must be used as the reference winding in order to ensure increased ground-fault sensitivity by correction of the zero sequence current.

2 Description of Relay

2.1 Overview

The Siemens 7UT51 multifunction protective relay provides three-phase protection for two (7UT512) or three (7UT513) winding transformers, shunt reactors, motors, generators, short lines, or buses. The 7UT513 model has two ground current inputs that can be used to increase the sensitivity of the differential protection. The relay matches currents mathematically, so complicated CT wiring schemes are not necessary.

The 7UT51 features selectable variable percentage differential and selectable harmonic restraints. An active algorithm recognizes CT saturation and unequal CT performance and restrains pickup. These abilities provide typical trip times of one cycle or less with high security.

In addition to the differential protection (87T/87HS, 87M/G, or 87B), the 7UT51 relay provides current-model based thermal overload protection (49-1 and 49-2) for two selected windings. High-set (50HS) and definite/inverse time overcurrent protection (50/51) are available for one selected winding. The 7UT513 model can provide either ground differential protection (87N) of one winding or tank leakage protection (64T). See Figure 2.1 and Table 2.1 for the possible combinations of protection functions.

The model 7UT513 relay's third set of three-phase inputs can apply the additional protection functions to an
additional zone, which may be independent or overlap the main zone containing the main protected device. This additional-zone protection provides added flexibility and security in a range of applications.

2.2 Features

2.2.1 Protection Overview

- Microprocessor-based full numerical implementation with self-diagnostics of internal operation and CT circuits.
- Mathematically matched currents enable use of simple wye-connections of CTs.
- Three-phase, variable-slope percentage differential protection (87T, 87M/87G, or 87B).
- Unrestrained high-set differential protection (87HS) when protecting a transformer.
- Restraint of differential protection when a through-fault causes CT saturation.
- Zero sequence current elimination (7UT512 or 7UT513) or correction (7UT513 only).
- 2nd harmonic restraint (inrush) and higher-harmonic restraint (3rd, 4th or 5th) when protecting a transformer.
- Thermal overload protection (49-1 and 49-2, current-based thermal model) for any two windings.
- High-set (50HS) and definite/inverse (50/51) time overcurrent protection for any one winding.
- Ground differential protection (87N) of any one winding, or tank leakage protection (64T) (7UT513 only).
- Any protection function (except for differential protection) can be used to protect a separate, additional device or zone (7UT513 only).

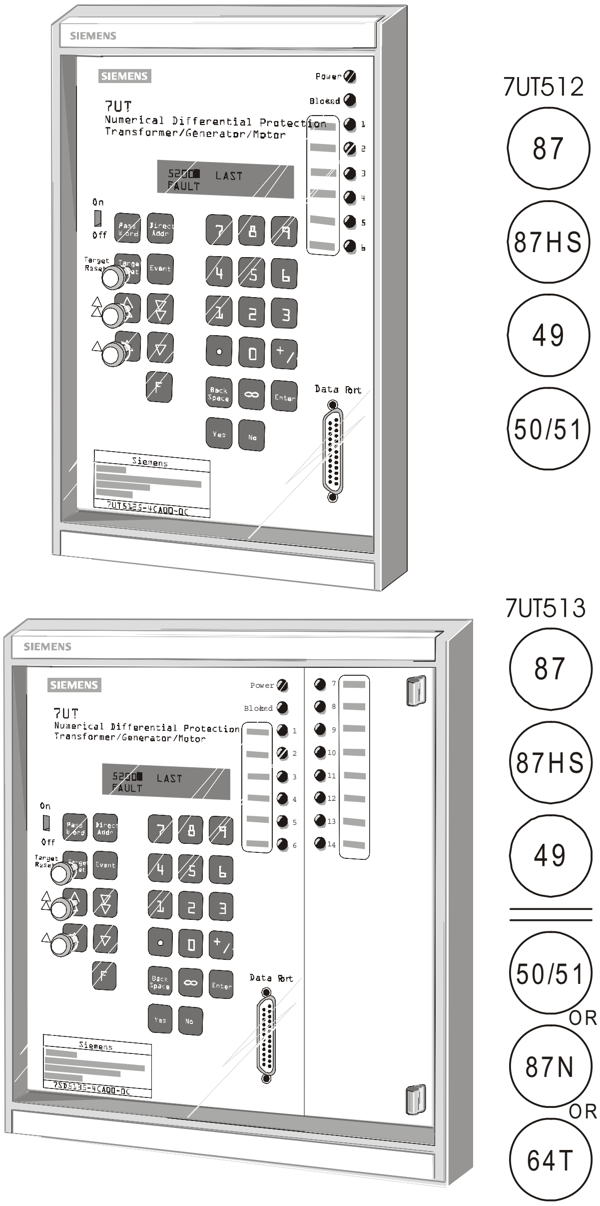


Figure 2.1 *Model 7UT512 Relay (left) and Model 7UT513 Relay (right)*

2.2.2 Differential Protection (87T/87HS, 87M/G, 87B)

Differential protection works differently for transformers and rotating machines, but in each case, the relay uses its user-programmable settings to recognize a differential current condition and respond to the condition. The variable percentage differential characteristic of the relay provides fast, sensitive, and reliable tripping for internal faults, and security against operation on external faults. The relay develops restraint and differential operating quantities to accomplish this level of protection.

Transformer differential protection requires special considerations for inrush and overexcitation. Second harmonic current is used as additional restraint during inrush conditions, and the fifth harmonic current is used as additional restraint during overexcitation conditions. These restraints prevent erroneous tripping.

Differential protection for transformers can be further complicated by transformation ratios and phase shift. The 7UT51 relay will automatically accommodate these factors based on the system settings, relay configuration settings, and protection settings programmed into the relay.

2.2.3 Overcurrent Protection (50/51, 50HS)

Overcurrent protection can be used as backup protection for any selected winding or bus-branch, or be applied to a separate additional protection zone (7UT513 only). The overcurrent protection can operate as definite time or inverse time overcurrent protection with a selectable characteristic. It can operate with an independent high-set overcurrent stage.

2.2.4 Thermal Overload Protection (49-1, 49-2)

Two independent thermal overload functions can be assigned to any two desired windings or bus-branches of the protected device (or to a separate additional protection zone with a 7UT513). The thermal overload protection function calculates the temperature increase for transformer or machine windings. During an overload condition, the thermal tripping time takes preloading into consideration. An adjustable, warning signal is available to correct the condition, such as for load shedding.

2.2.5 Ground Differential Protection (87N)

Most phase-current differential protection schemes for transformers are not sensitive enough to detect an internal phase-to-ground-fault, if the fault is located near the neutral point of the transformer. Also, it is difficult to detect a ground-fault if the transformer is resistance or reactance grounded, since the current will be limited.

The Siemens 7UT51 ground differential protection function (7UT513) offers a superior advantage of detecting internal ground-faults over existing electromechanical relays. Electromechanical relays are impaired in the event of CT saturation. They might trip when the fault is external (or not trip when the fault is internal). In addition, inrush effects can also cause undesirable protection behavior.

Ground differential protection applies the principle of differential protection to a winding with a grounded common point. The three phase currents are used to compute the expected zero sequence current, which is then compared to the measured ground current. An excessive ground current indicates that a ground-fault exists. The function can be configured to distinguish a ground-fault inside the protected zone from one outside the protected zone (see Section 4.3.6 on page 50).

2.2.6 Tank Leakage Protection (64T)

Tank leakage protection monitors the current flowing between the tank and earth, based either on the fundamental wave or the rms value. It can be applied to transformers with tanks that are installed with isolated or high-resistive against ground. It can be connected either to a normal relay current input or to a special highly sensitive measured current input that can sense a ground current as small as 10 mA. This function requires a 7UT513.

2.2.7 Metering

The 7UT51 relay provides access to measured data, which can be displayed on the front display or via the communications port to a PC running WinDIGSI®. The values can also be sent to a remote indicator via IEC-870-5.

- Load Currents
  - Primary winding
  - Secondary winding
  - Tertiary winding
- Ground Current
  - Calculated from Phase Currents
  - Measured from Ground CT (87N application)
- Overload values
  - Calculated Temperature Rise (T/T_{max})

2.2.8 Commissioning Data

The 7UT51 can be placed in test mode to aid in commissioning the transformer and protection system.

- Restraint Values
  - 3 Phases, Segregated
  - Ground Restraint (87N application)
- Differential Values
  - 3 Phases, Segregated
  - Ground Differential (87N application)
- Phase Angle Relationship Between
  - Phases of Same Winding
  - Same Phases of Different Windings
  - Calculated Residual and Actual Ground Currents
  - Actual Ground Current and Phase Currents

2.2.9 Data Acquisition

- 12 Samples per Cycle Sampling Rate
- Event Log: 50 Events (1 s resolution)
- 3 Fault Logs: 80 Events per Log (1 ms resolution)
- Real-Time Clock with Time Stamping
- Waveform Capture: 8 Waveform Records
  - 5 s Buffer Total
  - Selectable Pre/Post-Fault
  - Individual Record Maximum Duration
  - Internal or External Trigger or Both. (External trigger may be used to initiate capture from sudden pressure or other relay operations.)
  - Manual waveform capture via PC or front panel
- Battery Backup Memory for Data

2.2.10 Configuration & Analysis Software (WinDIGSI®)

- Windows-Based Graphical User Interface
- Menu-Driven for Settings, Configuration, Metering, Log Interrogation, & Waveform Viewing
- Advanced Oscillographic Analysis Capability
- COMTRADE Compatible (import, export, storage)

2.2.11 Data Communication Ports

- Front RS-232 Communications Port (Engineer/ technician can access through PC.)
  - Selectable Data Rates to 19.2k Baud
  - IEC 870-5 Compliant Communication Protocols
- Rear RS-232 Communications Port Galvanically Isolated Wire Port or Optional Fiberoptic (820nm) Port
  - Selectable Data Rates to 19.2k Baud
  - IEC 870-5 Compliant Communication Protocols
  - Substation RTU Applications (11 bit)
  - Modem Applications (10 bit)

2.2.12 Control

- Programmable inputs, LEDs, alarm contacts & trip contacts
- External Trips with Timers
- Process or Re-Transmit External Signals or Commands
- Combines External Signals into Alarm Processing

2.2.13 Construction

- Compact Case for Flush Mounting
- Screw Terminals: #10 Current, #8 Voltage
- Drawout Case
- Integral HMI (Human-Machine Interface) for Local Programming & Data Readout
- Meets ANSI and IEC Relay Standards

2.3 Catalog Number

The catalog number (or “model number”) is generated by inserting the option codes into the appropriate boxes:

7 U T 5 1 ☐ ☐ - ☐ G B 1 1 - ☐ ☐

Application	
Two windings	2
Three windings, or two windings and additional protected device	3

Rated Current	
1A	1
5A	5

Rated Power Supply	
24, 48 VDC	2
60, 110, 125 VDC	4
220, 250 VDC	5

Additional Protective Functions	
No Additional Functions (only option for a 7UT512)	0
Restricted Ground Fault Protection (7UT513 only)	1
Tank Leakage Protection (7UT513 only)	2

Data Communications Rear Port	
None	A
RS-232 isolated terminals	B
Fiber optic SMA connectors (820 nm)	C

2.4 Protection Functions Available At 60Hz

7UT513									
87T-3	**87T-2**	**87G**	**87B-3**	**87B-2**	**50/51**	**64T**	**87N**	**49-A**	**49-B**
x					x			x	x
	x				x			x	x
	x					x		x	x
	x						x	x	x
			x		x			x	x
				x	x			x	x
			x			(x)		x	x
			x				(x)	x	x
				x		(x)		x	x
				x			(x)	x	x
		x			x			x	x
		x				(x)	x	x	x
7UT512									
	87T-2	**87G**		**87B-2**	**50/51**			**49-A**	**49-B**
	x				x			x	x
				x	x			x	x
		x			x			x	x

Table 2.1 *Protection Functions @ 60 Hz*

Table 2.1 lists the protection functions that are available for the 7UT513 and 7UT512 at 60Hz.

Note: The choice of frequency affects the availability the auxiliary protection functions. With rated frequency 60Hz, the backup overcurrent time protection or the restricted earth fault protection/tank leakage protection (dependent on the ordered model) can be used besides the differential protection for transformers. If the three-winding transformer protection is to be used, only the backup overcurrent time protection is available.

With rated frequency 50Hz, the backup overcurrent time protection or the restricted earth fault protection/tank leakage protection (dependent on the ordered model) can be used in addition to the differential protection for transformers.

With rated frequency 16 2/3 Hz, no restriction concerning the additional functions are present.

2.5 Inputs and Outputs

Current Inputs	
Rated current, In	1 A or 5A (specified when ordered, or by hardware modification)
Rated frequency	50 Hz, 60 Hz, or 16-2/3 Hz (selectable)
Power consumption	
1A rated current input	approximately 0.1 VA
5A rated current input	approximately 0.4 VA
Highly sensitive tank current input (if ordered) at 1A	approximately 0.2 VA
Overload handling capability (normal current inputs)	
Thermal (rms)	100 × rated current for ≤ 1 s 20 × rated current for ≤ 10 s 4 × rated current continuous
Dynamic (pulse current)	250 × rated current for one-half cycle
Overload handling capability for highly sensitive tank current detection Thermal (rms)	300 A for ≤ 1 s 100 A for ≤ 10 s 15 A continuous

DC Supply Power			
Rated supply voltage (specified when relay is ordered)	24/48 Vdc	60/110/125 Vdc	220/250 Vdc
Permissible voltage range	19 to 56 Vdc	48 to 144 Vdc	176 to 288 Vdc
Superimposed a.c. voltage, peak-to-peak	≤ 12% at rated voltage ≤ 6% at limits of permissible voltage		
Power consumption	7UT512	7UT513	
Quiescent	10 W (approximately)	13 W (approximately)	
Energized	14 W (approximately)	22 W (approximately)	
Bridging time during failure or short-circuit of supply power	≥ 50 ms at rated supply voltage ≥ 110 Vdc		
Trip Contacts			
	7UT512	7UT513	
Programmable (trip) relays	2 dual-ganged Form A (N.O.)	3 dual-ganged Form A (N.O.), and 2 Form A (N.O.)	
Switching capacity			
Make	1000W/VA		
Break	30W/VA		
Switching voltage	250V		
Permissible current	5 A continuous 30 Afor 0.5 s		
Signal Contacts			
	7UT512	7UT513	
Programmable	4 Form C	5 Form A and 5 Form C	
Self-monitoring relay failure outputs status	1 Form C	1 Form C	
Switching capacity			
Make	20W/VA		
Break	20W/VA		
Switching voltage	250V		
Permissible current	1A		
Binary-Signal Inputs			
	7UT512	7UT513	
Programmable	2	5	
Switching voltage	24 to 250 Vdc		
Current consumption	approximately 2.5mA, independent of operating voltage		

Table 2.2 *Specifications for Inputs and Outputs of the Relay*

2.6 Phase Differential Protection of a Transformer (87T and 87HS)

Settings	
Operational status	Active, inactive, or block-contacts; can be temporarily changed using binary-signal inputs
Minimum differential current required for pickup (87T)	0.15 to 2.00 times I_n (0.01 steps)
Maximum differential current allowed before pickup (87HS)	0.5 to 20.0 times I_n (0.01 steps)
Restraint based on total current level	Characteristic with two sloped segments (see Figure 4.9)
Restraint for through-fault causing CT saturation	Through current 5.00 to 15.00 times I_n (step 0.01); duration of restraint (2 to 250 cycles, or ∞); relay can detect an evolving internal fault and release this restraint.
Inrush restraint based on 2nd harmonic current	10% to 80% of fundamental current (step 1%); option to crossblock other phases for a selectable duration (in cycles); is released when the differential current exceeds 87HS.
Restraint based on 3rd, 4th, or 5th harmonic current	10% to 80% of fundamental current (step 1%); option to crossblock other phases for a selectable duration (in cycles); is released when the differential current exceeds a set value (0.5 to 20.0 times I_n, step 0.1)or 87HS.
Time delay before trip (separate settings for 87T and 87HS)	0.00 to 60.00 s (step 0.01 s), or ∞
Time delay before reset	0.00 to 60.00 s (step 0.01 s)
Events that can control signal contacts or trip contacts	Change in operational status; pickup events, start of time delay before trip; start and end of restraint; trip events. All events are logged, as are the differential and restraint current levels at the time of a trip.

Inherent Operating Times			
Pickup time with single-ended infeed:	60 Hz	50 Hz	16-2/3 Hz
$I_{DIFF} \geq$ 1.5 times 87T pickup threshold level (approx.)	35 ms	35 ms	85 ms
$I_{DIFF} \geq$ 1.5 times 87HS pickup threshold level (approx.)	25 ms	25ms	55 ms
$I_{DIFF} \geq$ 5.0 times 87HS pickup threshold level (approx.)	17 ms	18 ms	25 ms
Dropout time (approximate)	25 ms	30 ms	90 ms

Dropout Ratios	
87T and 87HS dropout ratios (dropout/pickup; approximate)	0.7

Operating Tolerances (with default settings)	
Pickup characteristic	±5% of characteristic value (for $I < 5\times I_n$)
Inrush restraint	±5% of setting value (for $I_{2nd\ harmonic} \geq$ 15% of $I_{fundamental}$)
Set time delays	±1% of setting value or 10 ms, whichever is greater

Effect of Environmental Influences on Times and Tolerances	
Supply power voltage	≤ 1% if between 80% and 115% of nominal voltage
Ambient temperature	≤ 0.5% / 10 K if between 0°C and 40°C (32°F and 104°F)
System frequency	≤ 1% if between 95% and 105% of nominal frequency. **Note:** 87T function is blocked when frequency is less than about 85% of the nominal frequency, or more than about 120%; see Figure 4.12.

Table 2.3 *Phase Differential Protection of a Transformer (87T and 87HS)*

2.7 Phase Differential Protection of a Transformer (87T and 87HS)

Settings	
Operational status	Active, inactive, or block-contacts; can be temporarily changed using binary-signal inputs
Minimum differential current required for pickup (87T)	0.15 to 2.00 times I_n (0.01 steps)
Maximum differential current allowed before pickup (87HS)	0.5 to 20.0 times I_n (0.01 steps)
Restraint based on total current level	Characteristic with two sloped segments (see Figure 4.9)
Restraint for through-fault causing CT saturation	Through current 5.00 to 15.00 times I_n (step 0.01); duration of restraint (2 to 250 cycles, or ∞); relay can detect an evolving internal fault and release this restraint.
Inrush restraint based on 2nd harmonic current	10% to 80% of fundamental current (step 1%); option to crossblock other phases for a selectable duration (in cycles); is released when the differential current exceeds 87HS.
Restraint based on 3rd, 4th, or 5th harmonic current	10% to 80% of fundamental current (step 1%); option to crossblock other phases for a selectable duration (in cycles); is released when the differential current exceeds a set value (0.5 to 20.0 times I_n, step 0.1)or 87HS.
Time delay before trip (separate settings for 87T and 87HS)	0.00 to 60.00 s (step 0.01 s), or ∞
Time delay before reset	0.00 to 60.00 s (step 0.01 s)
Events that can control signal contacts or trip contacts	Change in operational status; pickup events, start of time delay before trip; start and end of restraint; trip events. All events are logged, as are the differential and restraint current levels at the time of a trip.

Inherent Operating Times			
Pickup time with single-ended infeed:	60 Hz	50 Hz	16-2/3 Hz
I_{DIFF} ≥ 1.5 times 87T pickup threshold level (approx.)	35 ms	35 ms	85 ms
I_{DIFF} ≥ 1.5 times 87HS pickup threshold level (approx.)	25 ms	25ms	55 ms
I_{DIFF} ≥ 5.0 times 87HS pickup threshold level (approx.)	17 ms	18 ms	25 ms
Dropout time (approximate)	25 ms	30 ms	90 ms

Dropout Ratios	
87T and 87HS dropout ratios (dropout/pickup; approximate)	0.7
Operating Tolerances (with default settings)	
Pickup characteristic	±5% of characteristic value (for $I < 5\times I_n$)
Inrush restraint	±5% of setting value (for $I_{2nd\ harmonic} \geq 15\%$ of $I_{fundamental}$)
Set time delays	±1% of setting value or 10 ms, whichever is greater
Effect of Environmental Influences on Times and Tolerances	
Supply power voltage	≤ 1% if between 80% and 115% of nominal voltage
Ambient temperature	≤ 0.5% / 10 K if between 0°C and 40°C (32°F and 104°F)
System frequency	≤ 1% if between 95% and 105% of nominal frequency. **Note:** 87T function is blocked when frequency is less than about 85% of the nominal frequency, or more than about 120%; see Figure 4.12.

Table 2.4 *Specifications for Phase Differential Protection of a Transformer (87T and 87HS) (details in Chapter 4)*

2.8 Phase Differential Protection of a Generator or Motor (87G/M)

Settings			
Operational status	Active, inactive, or block-contacts; can be temporarily changed using binary-signal inputs		
Minimum differential current required for pickup	0.05 to 2.00 times I_n (steps 0.01)		
Restraint based on total current level	Characteristic with two sloped segments (see Figure 5.3)		
Restraint for through-fault causing CT saturation	Through fault current restraint minimum 5.00 to 15.00 times I_n (step 0.01); duration of restraint 2 to 250 cycles, or ∞; relay can detect an evolving internal fault and release this restraint.		
Time delay before trip	0.00 to 60.00 s (step 0.01 s), or ∞		
Drop-off time delay	0.00 to 60.00 s (step 0.01 s)		
Events that can control signal contacts or trip contacts	Change in operational status; pickup events, start of time delay before trip; start and end of restraint; trip events. All events are logged, as are the differential and restraint current levels at the time of a trip.		
Inherent Operating Times			
Pickup time with single-ended infeed:	60 Hz	50 Hz	16-2/3 Hz
$I_{DIFF} \geq$ 1.5 times pickup threshold level (approx.)	25 ms	25 ms	70 ms
$I_{DIFF} \geq$ 5.0 times pickup threshold level (approx.)	16 ms	17 ms	25 ms
Dropout time (approximate)	25 ms	30 ms	90 ms
Dropout Ratio			
87G/M dropout ratio (dropout/pickup; approximate)	0.7		
Operating Tolerances (with default settings)			
Pickup characteristic	±5% of characteristic value (for $I < 5 \times I_n$)		
Set time delays	±1% of setting value or 10 ms, whichever is greater		
Effect of Environmental Influences on Times and Tolerances			
Supply power voltage	≤ 1% if between 80% and 115% of nominal voltage		
Ambient temperature	≤ 0.5% / 10 K if between 0°C and 40°C (32°F and 104°F)		
System frequency	≤ 1% if between 80% and 120% of nominal frequency. (Trip area is dependent on frequencies; see Figure 5.4.)		

Table 2.5 *Specifications for Phase Differential Protection of a Generator or Motor (87G/M) (details in Chapter 5)*

2.9 Phase Differential Protection of a Bus (87B)

Settings			
Operational status	Active, inactive, or block-contacts; can be temporarily changed using binary-signal inputs		
Minimum differential current required for pickup (87B)	0.30 to 2.50 times I_n (steps 0.01)		
Restraint based on total current level	Characteristic with two sloped segments (see Figure 6.3)		
Restraint for through-fault causing CT saturation	Through fault current restraint minimum 5.00 to 15.00 times I_n (step 0.01); duration of restraint 2 to 250 cycles, or ∞; relay can detect an evolving internal fault and release this restraint.		
Time delay before trip	0.00 to 60.00 s (step 0.01 s), or ∞		
Time delay before reset	0.00 to 60.00 s (step 0.01 s)		
Events that can control signal contacts or trip contacts	Change in operational status; pickup, dropout, trip, and reset events, start of time delay before trip; start and end of restraint. All events are logged, as are the differential and restraint current levels at the time of a trip.		
Inherent Operating Times			
Pickup time with single-ended infeed:	60 Hz	50 Hz	16-2/3 Hz
$I_{DIFF} \geq$ 1.5 times 87B pickup threshold level (approx.)	25 ms	25 ms	70 ms
$I_{DIFF} \geq$ 5.0 times 87B pickup threshold level (approx.)	16 ms	17 ms	25 ms
Dropout (approximate)	25 ms	30 ms	90 ms
Dropout Ratio			
87B dropout ratio (dropout/pickup; approximate)	0.7		
Operating Tolerances (with default settings)			
Pickup characteristic	±5% of characteristic value (for $I < 5\times I_n$)		
Set time delays	±1% of setting value or 10 ms, whichever is greater		
Effect of Environmental Influences on Times and Tolerances			
Supply power voltage	≤ 1% if between 80% and 115% of nominal voltage		
Ambient temperature	≤ 0.5% / 10 K if between 0°C and 40°C (32°F and 104°F)		
System frequency	≤ 1% if between 80% and 120% of nominal frequency		

Table 2.6 *Specifications for Phase Differential Protection of a Bus (87B) (details in Chapter 6)*

2.10 Ground Differential Protection (87N) (Optional with 7UT513)

Settings			
Operational status	Active, inactive, or block-contacts; choice can be temporarily changed using binary-signal inputs		
Minimum differential current required for pickup (87N)	0.05 to 2.00 times I_n (step 0.01)		
The critical limit angle that determines the restraint of the protection (corresponding value of k)	130° (k≈1), 120° (k≈1.4), 110° (k≈2), 100° (k≈4), 90° (k→∞),		
Inrush restraint based on 2nd harmonic current	10% to 80% of fundamental current (step 1%); restraint is released when the differential current exceeds a set value (1.0 to 20.0 times I_n, step 0.1).		
Time delay before trip	0.00 to 60.00 s (step 0.01 s), or ∞		
Time delay before reset	0.00 to 60.00 s (step 0.01 s)		
Events that can control signal contacts, trip contacts, or LEDs	Change in operational status; pickup, dropout, trip, and reset events, start of time delay before trip. All events are logged, as are the amplitude of the ground current and the phase-angle difference at the time of a trip.		
Inherent Operating Times			
Pickup time with single-ended infeed:	60 Hz	50 Hz	16-2/3 Hz
I_{DIFF} ≥ 1.5 times 87N pickup threshold level (approx.)	25 ms	25 ms	75 ms
I_{DIFF} ≥ 5.0 times 87N pickup threshold level (approx.)	17 ms	17 ms	25 ms
Dropout (approximate)	25 ms	30 ms	90 ms
Dropout Ratio			
87N dropout ratio (dropout/pickup; approximate)	0.7		
Operating Tolerances (with default settings)			
Pickup characteristic	±5% of characteristic value (for $I < 5\times I_n$)		
Set time delays	±1% of setting value or 10 ms, whichever is greater		
Effect of Environmental Influences on Times and Tolerances			
Supply power voltage	≤ 1% if between 80% and 115% of nominal voltage		
Ambient temperature	≤ 0.5% / 10 K if between 0°C and 40°C (32°F and 104°F)		
System frequency	≤ 1% if between 80% and 120% of nominal frequency		

Table 2.7 *Specifications for Ground Differential Protection (87N) (details in Chapter 7)*

2.11 Overcurrent Protection (50/51 and 50HS)

Settings			
Operational status	Active, inactive, or block-contacts; choice can be temporarily changed using binary-signal inputs		
50HS Minimum current required for pickup	0.10 to 30.00 times I*n* (0.01steps)		
50HS Delay Time	0.00 to 32.00 s, (0.01s steps) or ∞		
50T Minimum current required for definite time pickup	0.10 to 30.00 times I*n* (0.01steps)		
50T Delay Time for definite time pickup	0.00 to 32.00 s, (0.01s steps) or ∞		
51 Minimum current required for inverse time pickup	0.10 to 20.00 times I*n* (0.01steps)		
51HS Delay Time for inverse time pickup	0.50 to 32.00 s, (0.01s steps) or ∞		
Pickup Threshold (approximate)	1.1 times 51PU		
Reset Time Delay	0.00 to 60.00s (0.01s steps)		
Events that can control signal contacts, trip contacts, or LEDs	Change in operational status; pickup, dropout, trip, and reset events, start of time delay before trip. All events are logged, as are the amplitude of the current at the time of a trip.		
Inherent Operating Times			
	60 Hz	50 Hz	16-2/3 Hz
50 and 50HS measuring time (when current is at two times setting level, without parallel operation of other protection functions)	60 ms	60 ms	150 ms
51 Tripping Time Characteristics	see Section 8.4.2 on page 101	see Section 8.4.2 on page 101	see Section 8.4.2 on page 101
Dropout time (50 and 50HS; approximate)	75 ms	75 ms	210 ms
Overshot time (approximate)	75 ms	75 ms	210 ms
Dropout Ratios			
50/51 and 50HS dropout ratios (dropout/pickup; approximate)	0.95		
Operating Tolerances			
50 and 50HS functions	±3% of setting value		
50 and 50HS time delays	greater of 10 ms or ±1% of setting value		
51 function	pickup occurs when current between is 105% and 115% of setting		
51 time delay	greater of 30 ms or ±5% of setting value		
Effect of Environmental Influences on Times and Tolerances			
Supply power voltage	≤ 1% if between 80% and 115% of nominal voltage		
Ambient temperature	≤ 0.5% / 10 K if between 0°C and 40°C (32°F and 104°F)		
System frequency for 50 and 50HS protection	≤ 1.5% if between 98% and 102% of nominal frequency ≤ 2.5% if between 95% and 105% of nominal frequency		
System frequency for 51 protection	≤ 8% of theoretical time if system frequency between 95% and 105% of nominal frequency		

Table 2.8 *Specifications for Overcurrent Protection (50/51 and 50HS) (details in Chapter 8)*

2.12 Thermal Overload Protection (49-1 and 49-2)

Settings	
Operational status	Active, inactive, or block-contacts; choice can be temporarily changed using binary-signal inputs
Maximum Continuous Overload Current k factor (Imax/In)	0.10 to 4.00 (0.01 steps)
Time Constant τ	1.0 to 999.9 min (0.1 min. steps)
Thermal Warning Stage $(\Theta warn)/(\Theta trip)$	50 to 100% referred to trip temperature rise
Current Warning Stage	0.10 to 4.00 times In (0.01 steps)
Events that can control signal contacts, trip contacts, or LEDs	Change in operational status; pickup, dropout, trip, and reset events, start of time delay before trip. All events are logged, as are the amplitude of the ground current and the phase-angle difference at the time of a trip.
Trip Time Characteristic	
$t = \tau \times In \left[\frac{\langle \frac{I_{load}}{I_{max}} \rangle^2 - \langle \frac{I_{preload}}{I_{max}} \rangle^2}{\langle \frac{I_{load}}{I_{max}} \rangle^2 - 1} \right]$	τ is a constant describing the thermal behavior of the object (see Section 9.3.2 on page 108). I_{load} is the present measured load current. $I_{preload}$ is the previous measured load current. I_{max} is the maximum allowed continuous overload current (a setting, see Section 9.3.1 on page 108) ln means “the natural logarithm of…”
Dropout Ratios	
$\Theta/(\Theta trip)$ (approx.)	0.99
$\Theta/(\Theta warn)$ (approx.)	0.99
I/I*warn (approx.)*	0.99
Operating Tolerances (with default settings)	
k times In	±10% of characteristic value (for k× I_n)
Trip time	±10% of setting value or 2s, whichever is greater
Effect of Environmental Influences on Times and Tolerances	
Supply power voltage	≤ 1% if between 80% and 115% of nominal voltage
Ambient temperature	≤ 0.5% / 10 K if between -5°C and 40°C (23°F and 104°F)
System frequency	≤ 1% if between 95% and 105% of nominal frequency

Table 2.9 *Specifications for Thermal Overload Protection (49-1 and 49-2)*

2.13 Tank Leakage Protection (64T)

Measuring Principle	Measurement of the leakage current from the isolated tank to ground.
Settings	
Ground leakage current pickup (dependent on connection)	10mA to 1000mA (1mA steps) Sensitive CT B
	0.10 to 10.00 In (0.01In steps) Insensitive CTA
Trip Delay Time	0.00 to 60.00 s or ∞ for no trip (0.01 s steps)
Drop-off Delay Time	0.00 to 60.00 s (0.01 s steps)
Drop-off Ratio	0.25 to 0.95 (0.01 steps)
Events that can control signal contacts, trip contacts, or LEDs	Change in operational status; pickup, dropout, trip, and reset events, start of time delay before trip. All events are logged, as are the amplitude of the ground current and the phase-angle difference at the time of a trip.
Inherent Operating Times	
Pick-up Time at 2 times setting value (without parallel operation of other protection functions) (approx.)	25 to 35 ms (60 ms at 16 2/3 Hz)
Drop-off Time (approx.)	35 ms (100 ms at 16 2/3 Hz)
Operating Tolerances (with default settings)	
Pickup Current	±5% of setting value
Delay Times	±1% of setting value or 10 ms, whichever is greater

Table 2.10 *Specifications for Tank Leakage Protection (64T)*

2.14 Service, Storage, and Transport Conditions

The relay is designed for use in industrial and electric-utility environments. It should be installed in standard relay rooms and compartments so that with proper installation electromagnetic compatibility (EMC) is ensured. The relay is not designed for use in residential, commercial or light-industrial environment. The following should also be heeded:

> All contactors and relays which operate in the same cubicle or on the same relay panel as the digital protection equipment should, as a rule, be fitted with suitable spike quenching elements.

All external connection leads in substations from 100 kV upwards should be screened with a screen capable of carrying power currents and grounded at both sides. No special measures are normally necessary for substations of lower voltages.

Do not withdraw or insert relay module into its housing when under voltage.

When the relay module is withdrawn from its housing, some internal components are vulnerable to damage by electrostatic discharges; therefore, handling standards for electrostatically endangered components should be observed. The relay module is not electrostatically endangered when plugged in.

The removable front panel of the relay must be securely in place when the relay is in service (to ensure a complete and secure electrical connection between the relay module and the terminal blocks on the rear of the relay housing).

Specifications for service, storage, and transport conditions are listed in Table 2.11, following this paragraph.

Climatic Conditions	
Permissible ambient temperature	
during service	–5 °C to +55 °C (23°F to +131°F)
during storage (in original packaging)	–25 °C to +55 °C (–13°F to +131°F)
during transport (in original packaging)	–25 °C to +70 °C (–13°F to +158°F)
Permissible humidity	Mean value per year: ≤ 75% relative humidity; up to 95% relative humidity for up to 30 days per year. Condensation is not permitted!
Note: Siemens recommends that all units be installed such that they are not subjected to direct sunlight, nor to large temperature fluctuations which may result in condensation.	
Electrical Insulation	
Standard	IEC 255-5
High voltage test (routine test) except d.c. voltage supply input	2 kV (rms), 50 Hz, 1 min.
High voltage test (routine test) only d.c. voltage supply input	2.8 kV d.c., 30s per polarity
Impulse voltage test (type test) all circuits, class III	5 kV (peak); 1.2/50 µs; 0.5 J; 3 positive and 3 negative shots at intervals of 5 s
Electromagnetic Compatibility (Immunity)	
Standards	IEC 255-6, IEC 255-22 (product standards); EN 50082-2 (generic standard) VDE 0435 /part 303
High Frequency IEC 255-22-1 class III	2.5 kV (peak); 1 MHz; τ = 15 µs; 400 shots/s; duration 2 s
Electrostatic discharge IEC 255-22-2 class III and IEC 1000-4-2 class III	4 kV/6 kV contact discharge; 8 kV air discharge; both polarities; 150 pF; R_i = 300 Ω
Radio-frequency electromagnetic field, non-modulated IEC 255-22-3 (report) class III	10 V/m; 27 MHz to 500 MHz
Radio-frequency electromagnetic field, amplitude modulated IEC 1000-4-3, class III	10 V/m; 80 MHz to 1000 MHz; 80% AM; 1 kHz
Radio-frequency electromagnetic field, pulse modulated IEC 1000-4-3/ENV 50204, class III	10 V/m; 900 MHz; repetition frequency 200 Hz; duty cycle 50%
Fast transients IEC 255-22-4 and IEC 1000-4-4, class III	2 kV; 5/50 ns; 5 kHz; burst length 15 ms; repetition rate 300 ms; both polarities; R_i = 50 Ω; duration 1 min
Conducted disturbances induced by radio-frequency fields, amplitude modulated; IEC 1000-4-6, class III	10 V; 150 kHz to 80 MHz; 80% AM; 1 kHz
Power frequency magnetic field IEC 1000-4-8, class IV; IEC 255-6	30 A/m continuous; 300 A/m for 3 s; 50 Hz 0.5 mT; 50 Hz
Electromagnetic Compatibility (Emission)	
Standard	EN 50081-* (generic standard)
Conducted interference voltage, aux. voltage CISPR 22, EN 55022, class B	150 kHz to 30 MHz
Interference field strength CISPR 11, EN 55011, class A	30 MHz to 1000 MHz

Vibration and Shock when In Service	
Standards	IEC 255-21 and IEC 68-2
Vibration IEC 255-21-1, class 1 IEC 68-2-6	sinusoidal 10 Hz to 60 Hz; ± 0.035 mm amplitude; 60 Hz to 150 Hz; 0.5 g acceleration sweep rate 1 octave/min 20 cycles in 3 orthogonal axes
Shock IEC 255-21-2, class 1	half sine acceleration 5 g, duration 11 ms, 3 shocks in each direction of 3 orthogonal axes
Seismic vibration IEC 255-21-3, class 1 IEC 68-3-3	sinusoidal 1 Hz to 8 Hz; ± 7.5 mm amplitude (horizontal axis) 1 Hz to 8 Hz; ± 1.5 mm amplitude (vertical axis) 8 Hz to 35 Hz; 1 g acceleration (horizontal axis) 8 Hz to 35 Hz; 0.5 g acceleration (vertical axis) sweep rate 1 octave/min 1 cycle in 3 orthogonal axes
Vibration and Shock during Transport	
Standards	IEC 255-21 and IEC 68-2
Vibration IEC 255-21-1, class 1 IEC 68-2-6	sinusoidal 5 Hz to 8 Hz; ± 7.5 mm amplitude; 8 Hz to 150 Hz; 2 g acceleration sweep rate 1 octave/min 20 cycles in 3 orthogonal axes
Shock IEC 255-21-2, class 1 IEC 68-2-27	half sine acceleration 15 g, duration 11 ms, 3 shocks in each direction of 3 orthogonal axes
Continuous shock IEC 255-21-2, class 1 IEC 68-2-29	half sine acceleration 10 g, duration 16 ms, 1000 shocks in each direction of 3 orthogonal axes

Table 2.11 *Specifications for Service, Storage, and Transport Conditions*

3 Application Examples

The Siemens 7UT51 multifunction protective relay provides secure, high speed protection for phase and/ or ground-faults (depending upon system grounding) in a wide variety of power system equipment. The primary protection is based upon the current differential operating principle. The relay also provides several ancillary protection functions that make it a valuable part of any robust protection scheme. These include thermal overload protection — highly valuable for transformers, motors, and industrial generators — and backup time and instantaneous overcurrent protection. In addition, the 7UT513 mode can provide a choice of overcurrent backup, ground differential, or tank leakage current protection.

Typical 7UT51 applications are illustrated in the figures and descriptions which follow. These by no means exhaust the range of possible applications, but do demonstrate the relay's flexibility and some common ways of applying it. Note that the relay can accommodate wye-configured current transformers (CTs) regardless of the transformer winding configurations. No auxiliary CTs are necessary to match phase angles, which avoids the possibility of errors when designing or connecting the CT scheme.

3.1 Transformer Protection

Typical two- and three-winding transformer protection schemes are shown in Figure 3.1 and Figure 3.2 on page 32 below. In Figure 3.1, the relay is either the 7UT512 or 7UT513 model and is wired and configured to provide sensitive differential (primary) protection for any phase fault in its zone of protection. Depending upon relay settings, fault location and magnitude, and system grounding, the 7UT512/513 may provide primary protection for ground-faults as well.

This application also provides high-set differential or through-fault protection (87HS), thermal overload protection for both transformer windings (49-1 for the delta winding, 49-2 for the wye winding), and backup overcurrent protection (50, 51) for the wye winding and connected system downstream of the transformer.

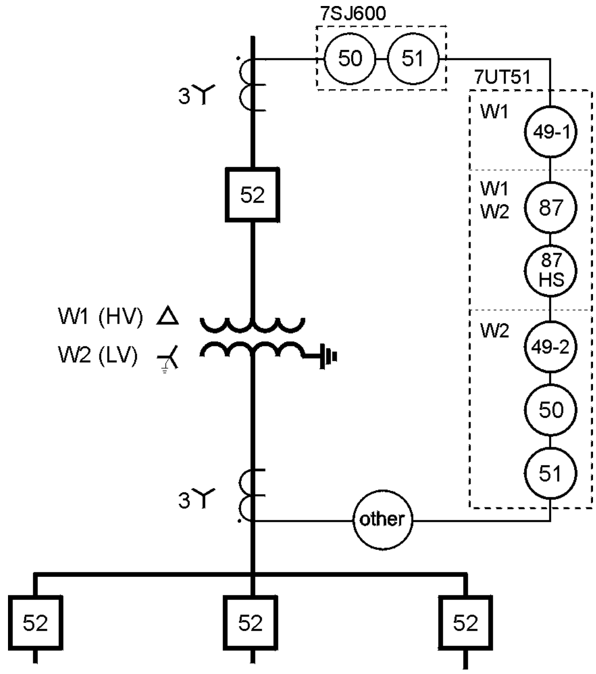


Figure 3.1 *Two-Winding Transformer Protection with Overcurrent Backup for the Bus*

For three-winding transformer protection, the 7UT513 model is required, as shown in Figure 3.2. The protection provided for in this scheme is similar to that of Figure 3.1 but with a few important differences. Primary differential protection is provided for all three transformer windings (87, 87HS) and thermal overload protection is provided for the high voltage wye winding (49-1). However, the second thermal overload element (49-2) and the backup overcurrent elements (50,51) are wired to protect the delta tertiary winding, W3, and connected load through the load breaker.

The relay has independently configurable trip contacts (the 7UT513 model has five) that allow for the design of flexible tripping schemes depending upon load criticality. For example, the thermal overload and backup overcurrent elements associated with the delta tertiary winding, W3, can be configured to trip only the load breaker, leaving the rest of the system intact, while the differential elements can be configured to trip all transformer breakers to clear a fault.

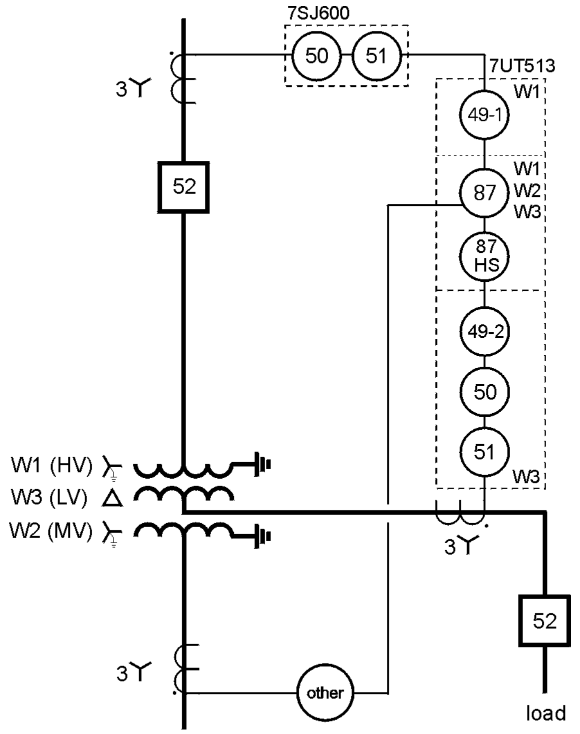


Figure 3.2 *Three-Winding Transformer Protection with Overcurrent Backup for Tertiary Load*

For protection utilizing the ground differential protection element. A 7UT513 model is required, as shown in Figure 3.3. The transformer protection is the same as that illustrated in Figure 3.1 except that the 87N element is used instead of the 50/51 element. A single CT in the transformer grounded-neutral provides wye-winding ground-fault and turn-to-turn protection with increased sensitivity.

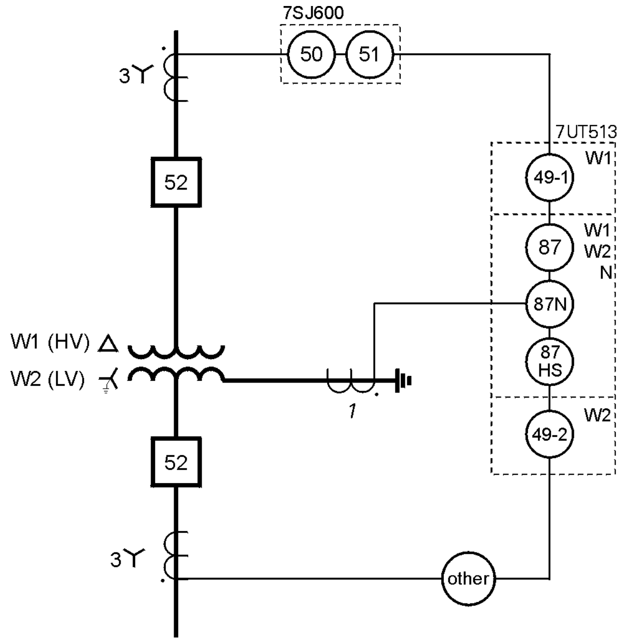


Figure 3.3 *Two-Winding Transformer Protection using the Ground Differential Protection Element*

The 7UT513 model can be used for a unique application involving paired transformers in the same yard or facility. As shown in Figure 3.4 below. Before the high voltage winding currents are taken to their respective thermal overload and differential elements in their own relays, they are first brought to the adjacent transformer relay's backup overcurrent elements (50, 51 W3). This way, if there is a relay failure associated with T1, backup protection is still provided for T1 through the 7UT513 associated with T2, and vice versa. Using the five independently configurable trip contacts available on a 7UT513, the cross-connected backup overcurrent elements can trip the other transformer's breakers, maintaining system reliability.

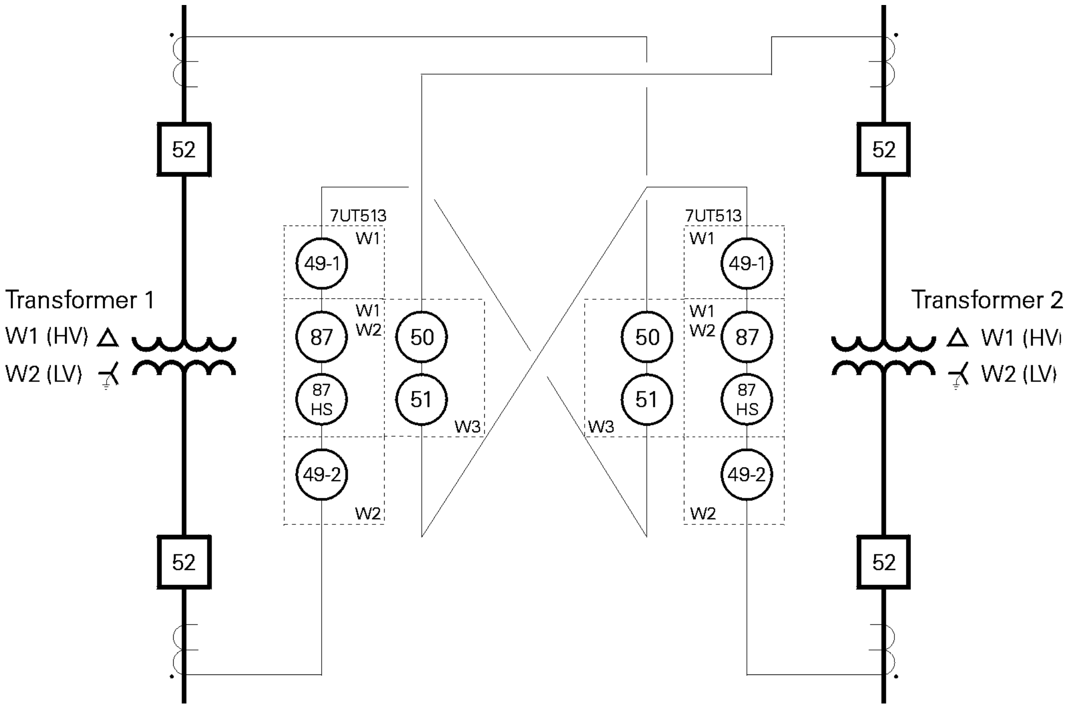


Figure 3.4 *Parallel Transformers using Cross-Connected Overcurrent Backup Protection*

3.2 Reactor Protection

The ground differential element of a model 7UT513 can protect a reactor in at least two different ways. Figure 3.5 shows a reactor bank made up of three single-phase reactors with CTs available at the breaker and one CT available in the grounded neutral. Because three ground-side CTs are not available on the single-phase reactors, the 87 and 87HS elements cannot be used. Instead, the overcurrent elements (50,51) provide primary protection, with the 87N element providing reactor ground-fault and turn-to-turn protection with increased sensitivity. If the system voltage is abnormally high, the reactors will draw higher-than-rated current, so a thermal overload element (49-1) can provide backup protection.

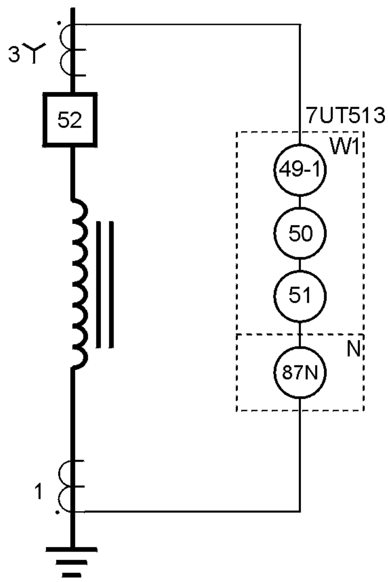


Figure 3.5 *Reactor Protection for Bank Comprised of Single-Phase Units*

If the reactors are part of a three-phase, oil immersed type bank, CTs may be provided at each end of the winding and in the grounded neutral, as shown in Figure 3.6. If so, the differential elements (87, 87HS, 87N) can provide primary protection, while backup protection is provided by one of the thermal overload elements (49), the internal overcurrent elements (not shown), or external overcurrent elements (as shown in Figure 3.6).

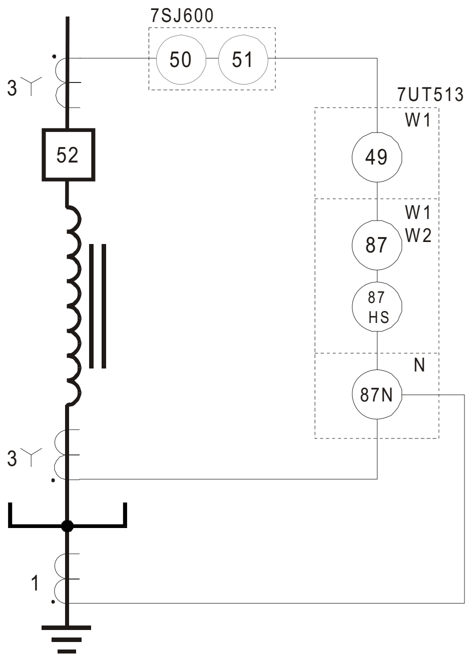


Figure 3.6 *Reactor Protection for Three-Phase, Oil Immersed Type Reactor Bank*

3.3 Motor and Generator Protection

A 7UT51 relay can protect a single motor or generator as shown in Figure 3.7), or a system comprised of a generator and main power transformer connected as a unit (as shown in Figure 3.8). The protection afforded in the single machine scheme is straightforward and consists only of primary (87) protection. For smaller, simpler generators (without elaborate cooling systems) and for most motors, one or both of the thermal overload elements could be employed in the protection scheme. In addition, the backup overcurrent elements could be configured but would be set to protect the machine from fault contributions from the system rather than to protect the system from fault contributions from the machine. This is due primarily to the short duration of (induction) motor contributions to faults and to the dynamics which characterize fault contributions from a generator to external faults ($X''_d X'_d X_s$ trajectory).

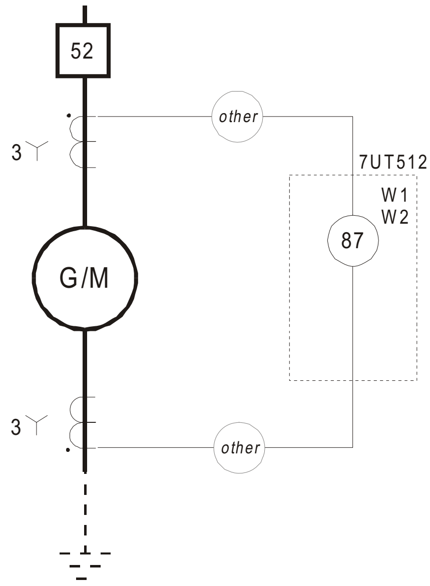


Figure 3.7 *Generator or Motor Protection*

For the unit-connected generator-transformer system shown in Figure 3.8, a 7UT513 model is required. The protection in this scheme is essentially identical to that shown in Figure 3.2. Primary protection (87, 87HS) is provided for the generator and transformer along with the section of buswork connecting to the unit auxiliary transformer breaker. Thermal overload protection is provided for the main power transformer wye winding (49-1), and thermal overload (49-2) and backup overcurrent protection (50,51) are provided for the unit auxiliary transformer. As with the other 7UT513 applications, the independently configurable trip contacts provide flexible tripping schemes.

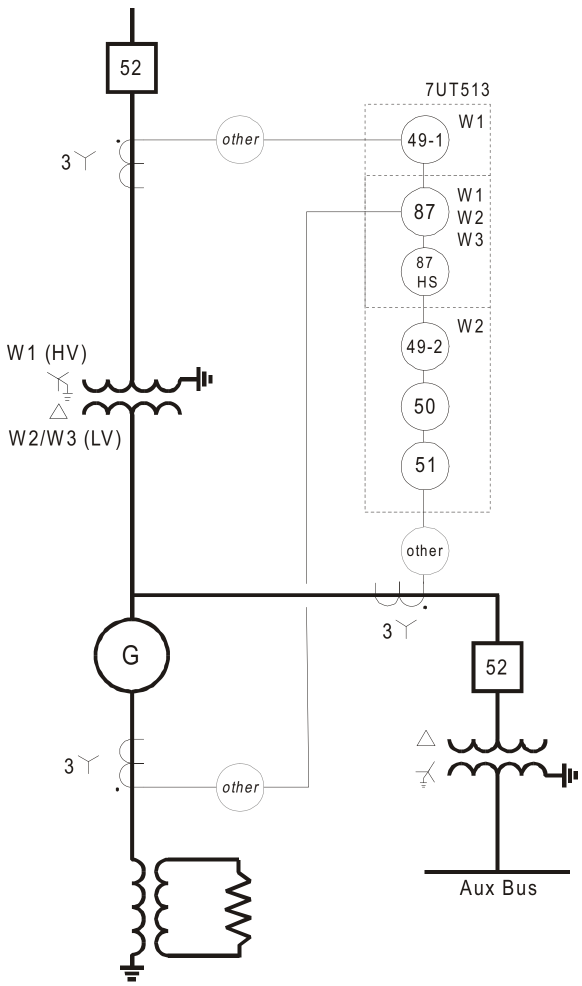


Figure 3.8 *Protection of Unit Connected Generator and Main Power Transformer with Overcurrent Backup for Unit Auxiliary Transformer*

3.4 Bus Protection

Because of the very high fault currents associated with bus faults, primary bus protection is normally implemented with a high-impedance type differential relays. However, when fault currents are of lower magnitudes, as they tend to be with radial distribution systems, the 7UT513 can be used in bus protection schemes. Figure 3.9 shows a typical two-bus radial distribution system with a tie breaker for greater reliability. Because the CT ratios of the source breakers, tie breaker, and feeder breakers are typically different from one another, a 7UT513 is required since it has three sets of phase-current inputs. The supply-branch CTs are connected to one set of phase-current inputs, the tie breaker CTs to another, and the feeder breaker CTs (all of the same ratio and tied together external to the relay) to the third. Backup overcurrent protection (not shown in the figure) can also be implemented internally by the 7UT513s.

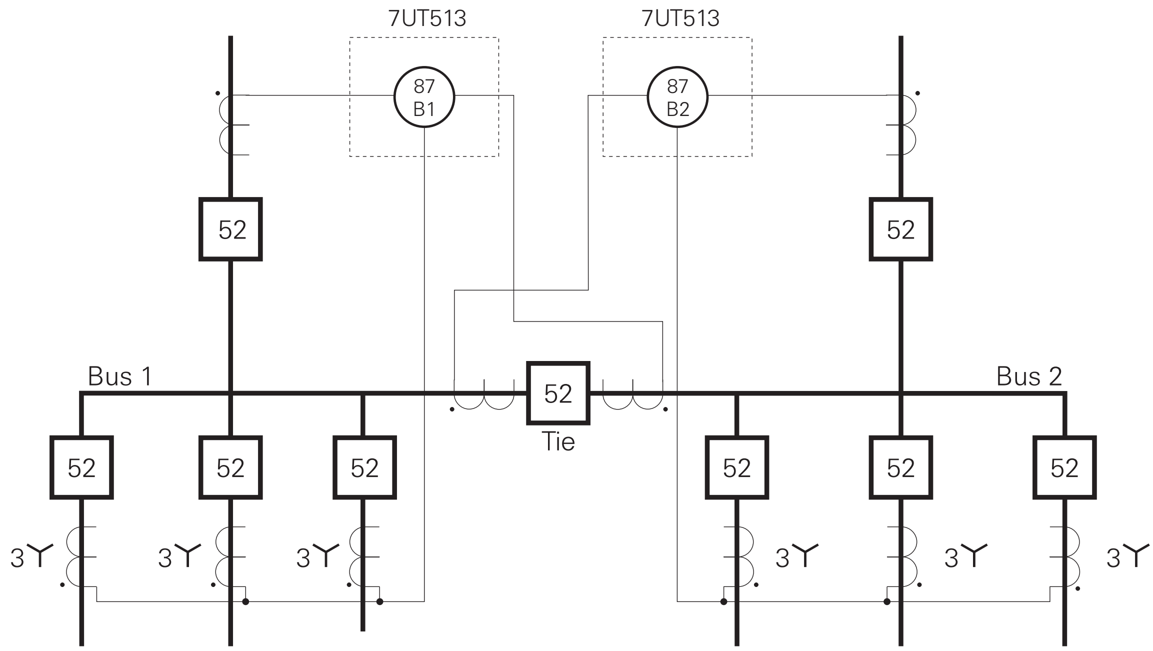


Figure 3.9 *Radial Bus Differential Protection Including Bus Tie Breaker for Two-Bus Distribution System*

A typical radial transformer and feeder breaker combination is illustrated in Figure 3.10. A 7UT513 is shown providing primary differential protection (87, 87HS) for the transformer and distribution buswork, excluding the feeder breakers. Assuming identical CT ratios on the feeder breaker CTs, they can all be tied together and brought to one set of phase-current inputs on the 7UT513. Backup protection in the form of thermal overload for both windings and overcurrent for the transformer high voltage winding is also provided.

If it is desired to include the feeder breakers in the protected zone, connections can be made as shown in Figure 3.8 on page 35.

Ground differential protection could also be implemented using a 7UT513 with connections from a grounded-neutral CT to the 87N element, as shown in Figure 3.3 on page 32.

Note: There must not be any source(s) on the feeders. The relay will not operate correctly for a phase-to-ground-fault on a feeder if there is an active source connected to a non-faulted feeder.

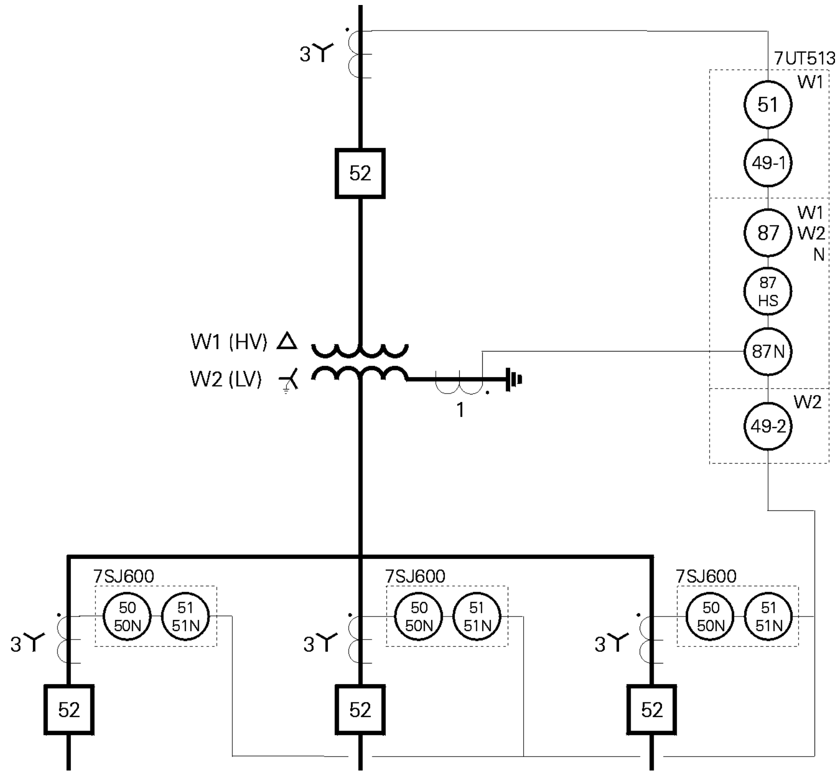


Figure 3.10 *Differential Protection for Radial Distribution Transformer and Bus Configuration, Feeder Breakers Excluded*

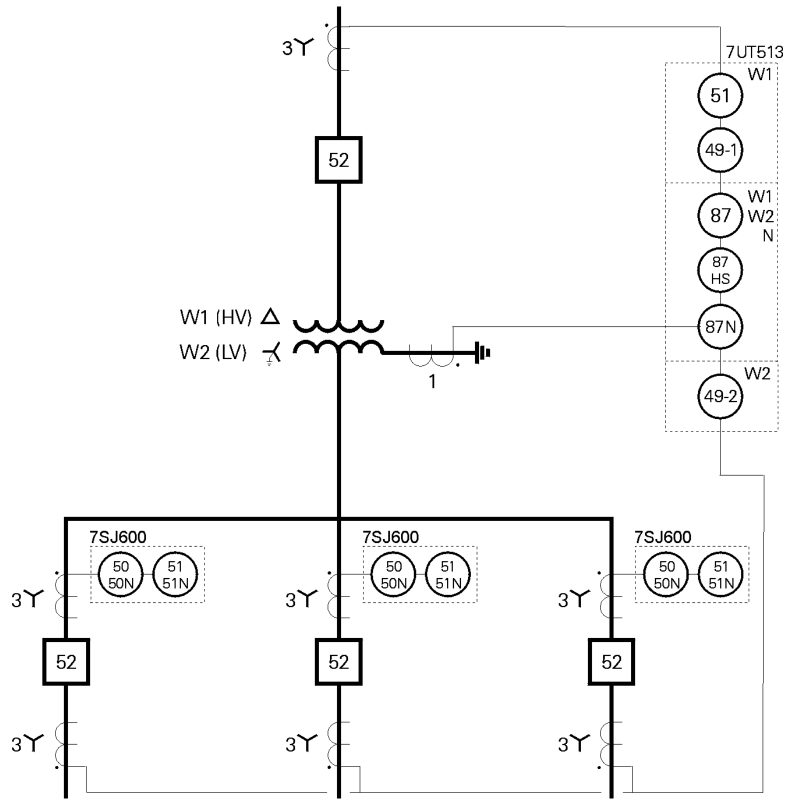


Figure 3.11 *Differential Protection for Radial Distribution Transformer and Bus Configuration, Feeder Breakers Included*

4 Transformer Differential Protection (87T and 87HS)

The transformer differential protection functions (87T and 87HS) provide high speed, secure primary protection for faults within a transformer. The trip characteristic is configurable; as is restraint based on the second-harmonic component of the differential current; a choice of either third, fourth, or fifth harmonic current; or detection that a through-fault is causing CT saturation. The algorithm responds to instantaneous current measurements, and so can often detect a short circuit in less than one cycle.

The relay can also provide ground differential protection 87N (see Chapter 7).

4.1 Method of Operation

Transformer differential protection is an application of Kirchoff's current law — the sum of all the currents entering and leaving a node must be zero. If the sum of all the *measured* currents into a node is not zero, then there must exist an *unmeasured* current — a fault. Since a transformer is not a passive node; the differential protection must first "match" the measured currents to take into account the behavior of currents in the transformer. Also, the protection must allow for the non-ideal behavior of real system and protection components.

4.1.1 Matching Currents

Because the differential protection is comparing currents for the same phase of different windings of the transformer, it must *match* the measured currents to take into account the behavior of currents within the transformer. In particular, it must handle the different power ratings of the windings, the phase shift across the transformer, and the zero sequence current that results from uneven loads on the three phases. Using the transformer information entered by the user (see Section 4.2 on page 43), the relay mathematically matches the currents. Complicated CT wiring schemes to match currents are not needed. Information about the actual CT wiring and CTs is required and entered in the 1100 Address Block (see Section 4.3 on page 48).

Note that the relay can still be installed in an existing scheme that has matching CTs (see Section 4.3.1 on page 48 and Section 4.3.2 on page 48).

The relay computes the matched-current (I') values according the following matrix equation:

$$[I'] = k \times [K] \times [I] \tag{4.1}$$

where:

- I' = matrix of matched currents I'_A, I'_B, I'_C
- *k* = scalar factor for matching current amplitudes
- K = matrix of factors for phase-angle matching and processing of zero sequence current
- I = matrix of measured currents I_A, I_B, I_C.

For example, for a delta-wye transformer with a 30° phase lag, the relay would match currents using the following matrix equation for the delta winding:

$$\begin{bmatrix} I'_A \\ I'_B \\ I'_C \end{bmatrix} = \frac{1}{3} \times \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \times \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix} \tag{4.2}$$

and the following equation to match the currents of the grounded wye winding:

$$\begin{bmatrix} I'_a \\ I'_b \\ I'_c \end{bmatrix} = \frac{1}{\sqrt{3}} \times \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \tag{4.3}$$

If a winding is grounded and has a CT measuring the ground current, the measured ground current (I_G) can be used by a 7UT513 relay to correct for (rather than just mathematically eliminate) the zero sequence current. equation 4.1 then becomes:

$$[I'] = k \times [K] \times [I] + \frac{1}{3} \times [I_G] \tag{4.4}$$

The ground current of one or two grounded wye windings can be input to a 7UT513 relay. As an example, the current-matching matrix equation for the "reference" wye winding would be:

$$\begin{bmatrix} I'_A \\ I'_B \\ I'_C \end{bmatrix} = k \times \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix} + \frac{1}{3} \times \begin{bmatrix} I_G \\ I_G \\ I_G \end{bmatrix} \qquad (4.5)$$

See Section 1.2 on page 11, Definition of Terms, for an explanation of "reference" winding and Section 4.3.5 on page 49 for further discussion of options for handling the zero sequence current.

Once the vector group (see Table 4.1 on page 46 and Table 4.2 on page 47) and rated transformer data, such as rated power, rated voltage and rated primary current of the current transformers, has been entered, the relay is capable of performing the current comparison according to fixed formulae.

Conversion of the currents is performed by the programmed coefficient matrices that simulate the difference currents in the transformer windings (see Figure 4.3). All conceivable vector groups are possible.

The following factors are available:

k CT 1 = <u>current processed by 7UT51</u>
current through the relay terminals

for Side 1 of the protected object and similar for the other sides: k CT2 =

k CT3=(only 7UT513)

ksCT 1=(only 7UT513)

ksCT 2=(only 7UT513)

ksCT 3=(only 7UT513)

where ksCT are the factors for inputs from the CT in the star-point connection of a grounded transformer winding (if used).

Note: The "k" matching factors are calculated by the relay from the entered rated data and can be read out in the operational annunciation in Address Block 5100.

Electromechanical Relays require
Delta-Wye CT's to eliminate
the zero-sequence current and to
achieve correct phase angle

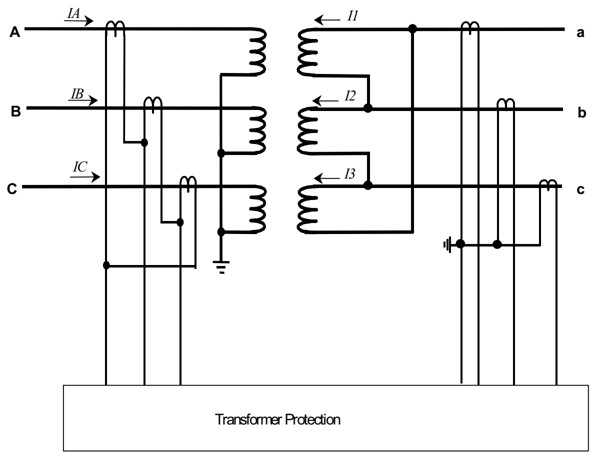


Figure 4.1 *Classic Phase Shift Correction*

No Delta-Wye CT connection is necessary.
Phase-shift correction is done internally.
Result: Waveform Capture records original
current waveforms !

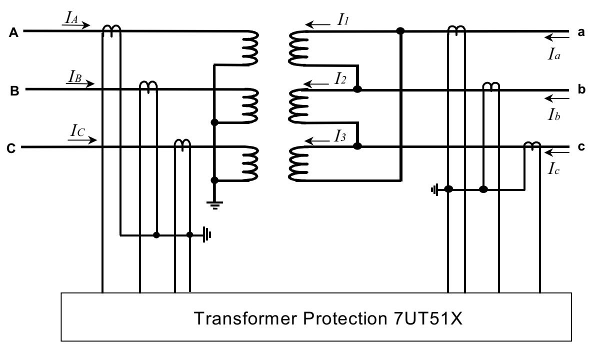
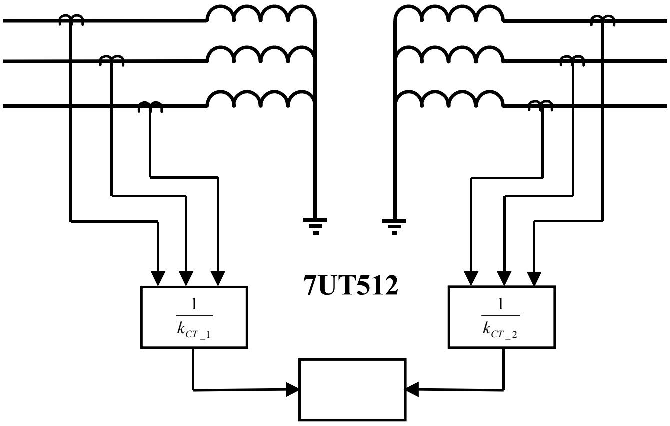


Figure 4.2 *7UT51 Phase Shift Correction*



$$k_{CT\_n} = \frac{I_{n\_CT\_Wn}}{I_{n\_Tr\_Wn}} = \frac{I_{n\_Relay}}{I_{n\_Tr\_Wn\_sec}}$$

k_CT_n:
Matching Factor for Winding n
In_CT_Wn:
Nominal CT Current of Winding n
In_Tr_Wn:
Nominal Transformer Current
for Winding n.
In_Relay:
Nominal Current of the Relay=5A
In_Tr_Wn_sec
Nominal Current of the Transformer
on the CT secondary

Measured currents are multiplied by $1/k_{CT\_n}$.
Result: If the primary current of the transformer equals to the nominal current, the relay will also measure nominal current = 5A.
k_CT_n must be in a range 1/4 to 4. Otherwise, interposing transformers are required.

Figure 4.3 *CT Mismatch Correction*

4.1.2 Handling Non-Ideal Behavior

Since actual applications do not use ideal components, the differential protection must take into account the non-ideal behavior of the protected transformer, the CTs monitoring it, and the rest of the power distribution system. In particular:

- A small, constant differential current may exist (due, for example, to a magnetizing current). To prevent this current from causing a pickup, the differential protection has a minimum 87T pickup level (see Section 4.4.1 on page 56).
- The effects of variation in the behavior of different CT's increase as the total current flowing through the transformer increases (either a normal load or a high through-current to an external fault). Hence, the differential current required for a pickup should be larger for larger transformer currents (see Section 4.4.3 on page 57 and Section 4.4.4 on page 58).
- On the other hand, if the differential current becomes so large that it cannot be due to an external fault, the differential protection should pickup (87HS protection, see Section 4.4.2 on page 56).
- During an external fault with a large through-current, an internal fault may also occur. If this happens, the relay should pickup (see Section 4.5 on page 58).
- When the protected transformer is energized, the inrush current may result in a transient differential current. As is standard practice, the relay can use the second- harmonic component of the differential current to restrain the differential protection during inrush (see Section 4.6 on page 59).
- Asymmetrical currents in the transformer windings and/or overexcitation of the transformer can also cause a differential current. The relay can restrain tripping by measuring the higher-harmonic components of the differential current, while still handling the possibility that the CTs themselves might produce higher-harmonic components in the differential current during an actual fault (see Section 4.7 on page 60).
- Finally, the relay must rapidly respond to a differential current so large that it can only be due to an internal fault, regardless of any restraint addresses. To do so, the relay has an 87HS function whose algorithm can detect an evolving fault in less than one cycle (see Section 4.4.2 on page 56).

The relay performs a Fourier analysis of the differential current using numerical filters optimized for transient behavior. Hence, no additional restraining measures are necessary.

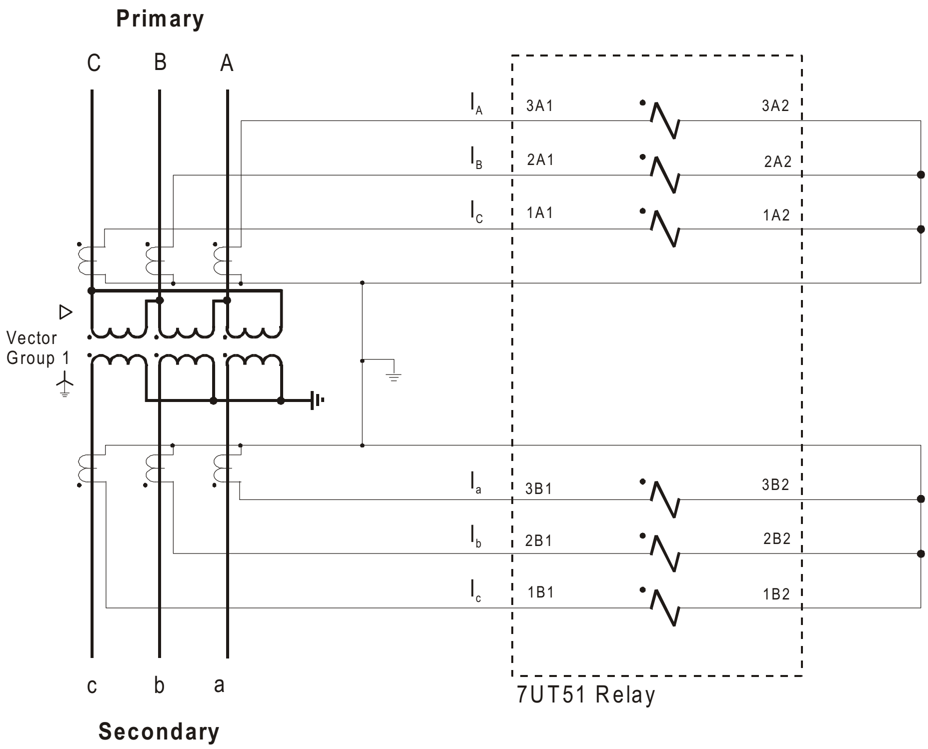


Figure 4.4 *Typical CT Wiring for a Two-Winding, Delta-Wye Transformer*

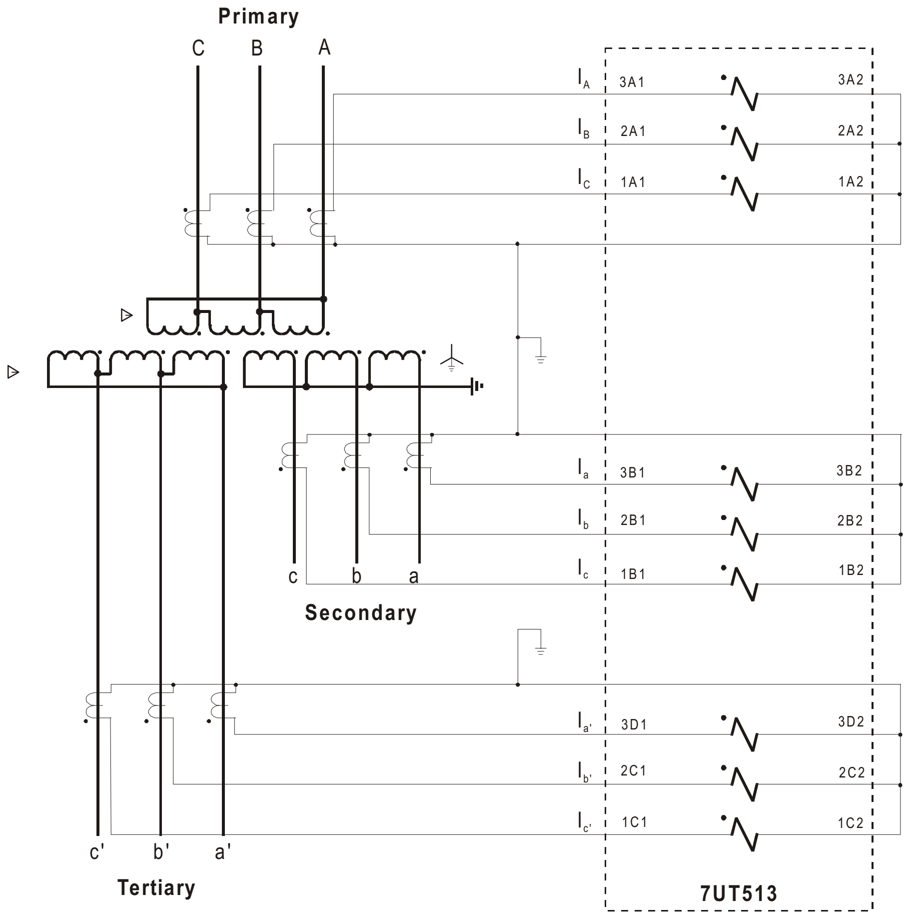


Figure 4.5 *Typical CT Wiring for a Three-Winding, Delta-Wye-Delta Transformer*

4.2 Describing the Transformer

This section describes the addresses used to provide the relay with information about the protected transformer, including:

- The number of windings the transformer has
- The rated frequency of the protected transformer
- The rated phase-to-phase voltage (V_n) of each winding of the protected transformer
- The rated apparent power (VA) of each winding of the protected transformer
- The phase shift (lag angle relative to Winding 1) of winding 2 (and, if applicable, of winding 3) of the protected transformer

In the following discussion, “Winding 1” is the reference winding, which is usually the high-side winding of the protected transformer. If a CT is installed in the ground lead of a grounded wye connected transformer, that winding must be used as the reference winding in order to ensure increased ground-fault sensitivity by correction of the zero sequence current.

4.2.1 Type of Transformer

The relay uses different addresses and algorithms for different types of protected objects. Address 7801 specifies what type of device or equipment is being protected.

7801 PROT.OBJ Type of device or equipment the relay is protecting.	
Option	**Description**
2-WIND-TRANSF	two-winding transformer (default)
3-WIND-TRANSF	three-winding transformer (7UT513 only)
MOTOR/GENERA-TOR	motor or generator (see Chapter 5)
2 ENDED TIE PT.	two-branch bus (see Chapter 6)
3 ENDEDTIE PT.	three-branch bus (see Chapter 6)
1Ph.-TRANSF	single-phase transformer

Model 7UT513 is required if the protected transformer has three windings, or if the application includes measurement of a ground (or neutral) current. A 7UT513 can also be used to simultaneously protect both a two-winding transformer and an additional protected device.

4.2.2 Normal Operational Status

The differential functions (87 and 87HS) can be set either to exist or not to exist in Address 7816. Functions that are configured as NONEXISTENT (or DISABLED) will not process annunciations and the associated setting parameters will not be requested during setting.

7816 87 STATUS Choice of whether transformer differential protection functions (87T and 87HS) exist.	
Option	**Description**
EXISTENT/ ENABLED	87T and 87HS functions exist (default).
NONEXISTENT/ DISABLED	87T and 87HS functions do not exist.

Once the 87T and 87HS functions exist, they can be configured. Additionally, Address 7801 must be set as a transformer. The function's operational status is set in Address 1601. If the status is set to OFF, it will have no effect on the result of the protective process; therefore, no tripping is initiated. If BLOCK TRIPPING is chosen, all functions are active except the trip contacts and signal contacts; therefore, no tripping is initiated

Note that the default setting is OFF. Without correct parameter settings the relay may show unexpected reactions which include false tripping.

1601 87 STATUS Operational status of transformer differential protection (87T and 87HS).	
Option	**Description**
OFF	87T and 87HS functions are inactive (default).
ON	87T and 87HS functions are active.
BLOCK TRIPPING	87T and 87HS functions are active except that trip contacts and signal contacts will not respond to 87T and 87HS events.

4.2.3 System Frequency

The rated nominal frequency of the protected transformer is specified in Address 7899.

7899 FREQUENCY Rated nominal frequency of the protected transformer.	
Option	**Description**
FREQ 50 Hz	50 Hertz
FREQ 60 Hz	60 Hertz (default)
FREQ 16 2/3 Hz	16-2/3 Hertz

Note: The choice of frequency affects the availability the auxiliary protection functions. With rated frequency 60Hz, the backup overcurrent time protection or the restricted earth fault protection/tank leakage protection (dependent on the ordered model) can be used besides the differential protection for transformers. If the three-winding transformer protection is to be used, only the backup overcurrent time protection is available.

With rated frequency 50Hz, the backup overcurrent time protection or the restricted earth fault protection/ tank leakage protection (dependent on the ordered model) can be used in addition to differential protection for transformers.

With rated frequency 16 2/3 Hz, no restriction concerning the additional functions are present.

If, during configuration, more functions have been selected than the device is able to process, the relays will give a corresponding message after configuration has been finished. These messages can be read out in the operational annunciations.

4.2.4 Rated Phase-to-Phase Voltage

The rated phase-to-phase voltage (V_n) of each winding of the protected transformer is specified in addresses 1102, 1122, and 1142.

1102 Vn WIND 1 **1122 Vn WIND 2** **1142 Vn WIND 3 (7UT513 only)** Rated phase-to-phase voltage (Vn) of each winding of the protected transformer.
Range: 0.4 - 800.0 kV Default: 110.0 kV for Winding 1, 11.0 kV for windings 2 and 3

$$Vn = 2 \times \frac{Vmax \times Vmin}{Vmax + Vmin} = \frac{2}{\frac{1}{Vmin} + \frac{1}{Vmax}} \qquad (4.6)$$

where V_{max} is the highest winding-voltage rating and V_{min} is the lowest winding-voltage rating. This is not a critical calculation, but rather a better fit than using the mid-tap nominal value.

4.2.5 Rated Apparent Power

The rated apparent power of each winding of the protected transformer must be specified in addresses 1103, 1123, and 1143.

1103 VA WIND 1 **1123 VA WIND 2** **1143 VA WIND 3 (7UT513 only)** Rated apparent power of each winding of the protected transformer.
Range: 0.2 – 5000.0 MVA Default: 38.1 MVA for windings 1 and 2, 10.0 MVA for winding 3

For three-winding transformers with different MVA ratings of the windings, the relay automatically references all currents to the power base of the largest winding.

Note that for FOA transformers, choosing the lowest rating will provide the most sensitive protection; however, there is a possibility the relay will be continuously “picked up” if the load approaches the maximum FOA rating.

4.2.6 Phase Shift Between Windings

The phase shift from the first winding to the second winding (and, if the transformer has three windings, from the first winding to the third winding) must be specified in addresses 1121 and 1141. The phase shift is described by a vector group number, which is an integer *n* in the range 0 to 11 such that the phase shift is a lag angle of $n \times 30°$ (see Table 4.1 on page 46 and Table 4.2 on page 47).

1121 VECTOR GR2 **1141 VECTOR GR3 (7UT513 only)** Phase shift from Winding 1 to winding 2 (Address 1121) and from Winding 1 to winding 3 (Address 1141) of the protected transformer. An integer vector group number *n* specifies the phase shift as a lag angle of $n \times 30°$.
Range: 0 – 11 (unitless) Default: 0 Table 4.1 on page 46 (for a delta reference winding) and Table 4.2 on page 47 (for a wye reference winding) show for each vector group the corresponding phase shift in degrees, a diagram of the transformer wiring that would result in that phase shift, the phase diagram.

Example: A two-winding delta-wye transformer connected according to ANSI standards has the low-side (secondary) winding lagging the high-side by 30°. So Address 1121 should usually be set to 1 (not the default value of 0).

Note: The relay assumes a phase-angle rotation order of A-B-C. If the order is instead C-B-A, connect the CTs so the relay sees an A-B-C rotation order and use the vector group corresponding to 360° minus the lag-angle of the C-B-A order. (For example, a C-B-A order lag-angle of 30° corresponds to an A-B-C order advance-angle of 30°. But since the vector group setting must describe a lag-angle, specify vector group 11, corresponding to 330° (360° – 30°).

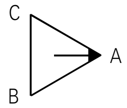
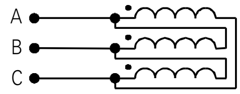
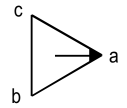
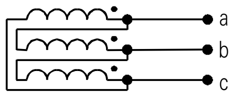
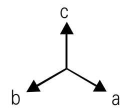
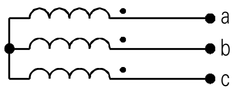
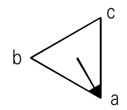
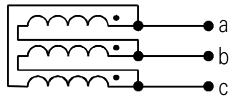
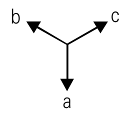
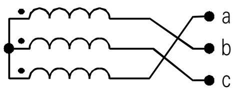
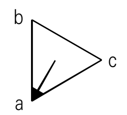
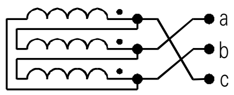
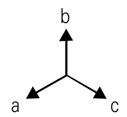
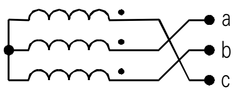
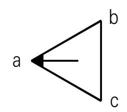
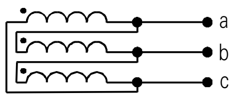
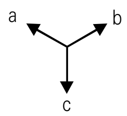
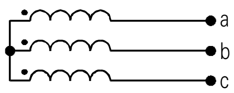
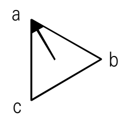
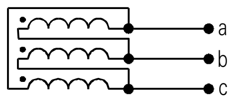
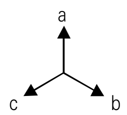
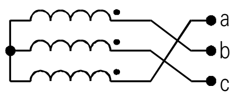
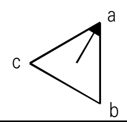
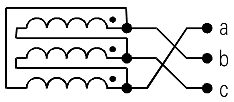
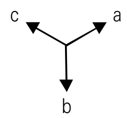
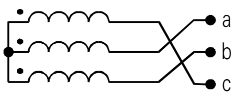
Group	Lag	Type	Symbol	Winding Wiring	Elimination	Correction	Without
Delta Reference Winding					●		●
0	0°	Dd0			●		●
1	30°	Dy1			●		
2	60°	Dd2			●		●
3	90°	Dy3			●		
4	120°	Dd4			●		●
5	150°	Dy5			●		
6	180°	Dd6			●		●
7	210°	Dy7			●		
8	240°	Dd8			●		●
9	270°	Dy9			●		
10	300°	Dd10			●		●
11	330°	Dy11			●		

Table 4.1 *Vector Group Options and Zero Sequence Current Handling Options for a Delta Reference Winding*

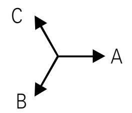
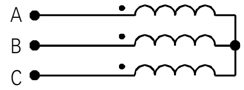
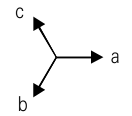
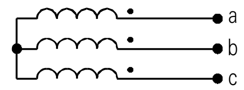
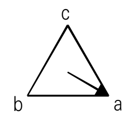
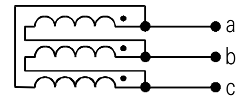
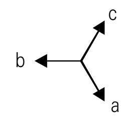
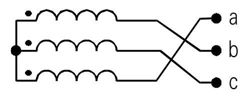
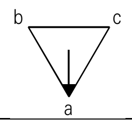
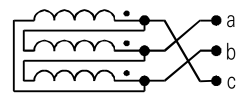
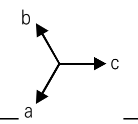
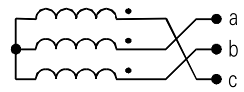
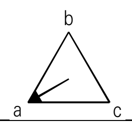
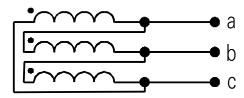
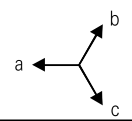
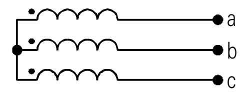
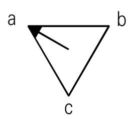
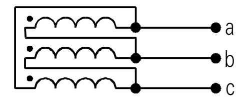
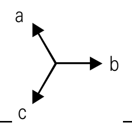
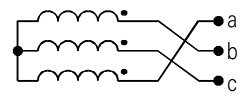
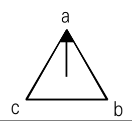
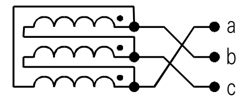
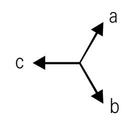
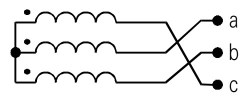
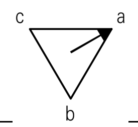
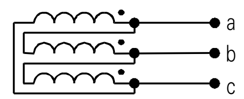
Group	Lag	Type	Symbol	Winding Wiring	Elimination	Correction	Without
Wye Reference Winding					●	●	●
0	0°	Yy0			●	●	●
1	30°	Yd1			●		
2	60°	Yy2			●	●	●
3	90°	Yd3			●		
4	120°	Yy4			●	●	●
5	150°	Yd5			●		
6	180°	Yy6			●	●	●
7	210°	Yd7			●		
8	240°	Yy8			●	●	●
9	270°	Yd9			●		
10	300°	Yy10			●	●	●
11	330°	Yd11			●		

Table 4.2 *Vector Group Options and Zero Sequence Current Handling Options for a Wye Reference Winding*

4.3 Describing the CT Scheme

Unlike electromechanical relays, numerical relays do not require a complicated current transformer (CT) scheme to match the measured currents. Instead, the relay uses entered information about the protected object and the current transformers to calculate the matched currents from the measured currents. The relay must know the following information about the current transformers and how they are wired:

- Nominal secondary current rating of the CTs
- Nominal primary current of each CT set
- Orientation of the CTs relative to the protected transformer
- Choice of how to process the zero-sequence current
- How the ground-current inputs are used (7UT513 only, and, if used, information about the ground current CT(s)

4.3.1 Nominal Secondary Rating of CTs

The relay is manufactured with either 1A or 5A current inputs. The choice should match the rated nominal secondary current of the current transformers (CTs) monitoring the protected transformer. The relay is shipped with the same rating for all current inputs (except for the tank leakage current input, if ordered). A hardware modification can be made to have the rated currents (1A or 5A) for different current inputs (see Section 17.9 on page 189). If any current input will be rated 5A, order the relay with 5A current inputs.

4.3.2 Nominal Primary Rating of CTs

When designing the protection application, choose CTs whose nominal primary current rating results in a secondary current close to 5A (or 1A, if the relay is ordered with 1A current inputs) when the transformer winding's rated nominal current is flowing through the winding. Enter the CT primary current rating of each winding in addresses 1104, 1124, and 1144.

1104 In CT WIND1 (for Winding 1) **1124 In CT WIND2 (for winding 2)** **1144 In CT WIND3 (for winding 3, 7UT513 only)** Nominal primary current rating of each winding's CTs.
Range: 1 – 100,000 A Default: 200 A for Winding 1, 2000 A for windings 2 and 3

If a winding has an interposing current transformer set (see Sections 4.3.3), divide the actual CT primary rated current by the winding ratio of the interposing CT.

When using delta connected CTs, divide the rated CT primary current by $\sqrt{3}$.

4.3.3 Three-Winding Transformers with Considerably Different Rated Powers

In most cases, all current matching is performed mathematically by the relay. The ratings of the reference winding (Winding 1, and usually the winding with the highest MVA power), is used to calculate a current, **In**.

For three-winding transformers with different MVA ratings of the windings, the unit automatically refers all currents to the power of the largest winding. When the power ratings of the windings differ significantly from each other (more than the factor 4), interposing transformers are recommended.

Since the current inputs in the 7UT51 are galvanically isolated from each other, the interposing transformers may be designed as auto-transformers. This better utilizes the power rate of the interposing transformers and the smaller transformer type 4AM5170-7AA is sufficient.

The ratio of the interposing transformers is chosen such that the winding with the lower rating (usually the tertiary winding of the transformer) is roughly matched to the winding with the highest rating, i.e. the current ratio of the interposing transformers should be:

$$TR_1 = \frac{S_N \text{ of the high-power winding}}{S_N \text{ of the low-power winding}}$$

Thus, the winding ratio of the interposing CTs is

$$\frac{N_1}{N_2} = \frac{S_N \text{ of the low-power winding}}{S_N \text{ of the high-power winding}}$$

where:

N_1 - Number of winding turns on the side facing the main CTs

N_2 - Number of winding turns on the side facing the 7UT51 relay

The exact current matching is performed when setting the parameters for this winding.

Example: The following data should apply for the winding with the highest power rating:

rated power	S_N=57 MVA
rated voltage	U_N=110 kV
current transformers	300 A/ 1A

The following data should apply for the winding with the lowest power rating:

rated power	S_N=12.5 MVA
rated voltage	U_N=10 kV
current transformers	800 A/ 1A

This results in a winding ratio of the interposing transformers of:

$$\frac{N_1}{N_2} = \frac{S_N \text{ of the low-power winding}}{S_N \text{ of the high-power winding}}$$

$$= \frac{12.5\text{ MVA}}{57\text{ MVA}} = 0.22$$

$$\approx 11/50 \text{ turns}$$

which results in a current transformer ratio of:

$$\frac{800\text{ A}/1\text{ A}}{11/50} = 3636\text{ A}/1\text{ A}$$

Thus, a primary rated current of 3636A for the current transformers is to be set to the protection unit in this example case.

4.3.4 Orientation of CTs

The orientation of the CTs monitoring each winding of the protected transformer must be specified in order to ensure that the correct polarity is used when calculating the differential currents.

1105 CT1 STARPT (for Winding 1) **1125 CT2 STARPT (for winding 2)** **1145 CT3 STARPT (for winding 3, 7UT513 only)** Orientation of which end of each winding's CTs are connected to the corresponding non-polarity terminal of the relay's phase current inputs. For wye connected CTs, this is the non-polarity ends of the CTs, which are usually connected to a common point (or star-point).	
Option	**Description**
TOWARDS TRANSF	Towards the transformer (default).
TWDS LINE/BUSBAR	Away from the transformer.

For example, if terminal 3A2 (non-polarity, phase A input of Winding 1) is connected to the end of the CT closest to the transformer (as shown in Figure 4.4), Address 1105 should be set to "**Towards Transformer.**"

4.3.5 Processing the Zero Sequence Current

If a winding of the protected transformer has any connection to ground (as is usually the case for a wye-winding), there is likely to exist a zero sequence current in the winding. Any zero sequence current will by itself cause a differential current for one or more of the phases (A, B, and/or C). Using the measured phase currents, the relay can calculate the expected zero sequence current for each winding and mathematically *eliminate* it when calculating the matched currents for the differential protection; however, if the measured ground current(s) are available (see Section 4.3.6 on page 50) the relay can *correct* the matched currents, resulting in more sensitive differential protection.

The settings in Addresses 1106, 1126, and 1146 tell the relay how to process the zero sequence current of each winding. These addresses only affect the transformer differential protection functions (87T and 87HS).

1106 Io1PROCESS (for Winding 1) **1126 Io2PROCESS (for winding 2)** **1146 Io3PROCESS (for winding 3, 7UT513 only)** How to process the zero sequence current for each transformer winding when calculating the matched-currents for the transformer differential protection functions (87T and 87HS).	
Option	**Description**
Io-ELIMINATION	The winding has a ground connection within the protected zone that is not fitted with a ground-current CT. Using all three phase currents, the relay calculates the zero sequence current, then eliminates it from each phase current when calculating the matched phase currents (default).
Io-CORRECTION (7UT513 only)	The winding has a ground connection within the protected zone that is fitted with a ground-current CT connected to the relay. The measured zero sequence current is used to correct each phase current when calculating the matched phase currents.
WITHOUT	The winding has no ground connection within the protected zone.

The following mathematical model, Section 4.3.6 on page 50, illustrates how the relay processes zero sequence current for Io-Elimination and Io-Correction. The model clearly shows that Io-Correction offers the maximum sensitivity and selectivity for internal faults.

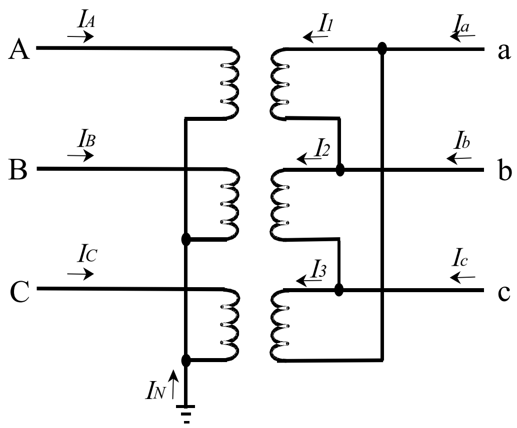


Figure 4.6 *Delta-Wye Circuit*

4.3.6 Zero-Sequence Current Elimination vs. Correction Mathematical Illustration

Io-Elimination – Refer to Figure 4.6. And Section 4.3.5 on page 49

I* = Normalized Current

Wye-Winding: Setting “I0-Elimination”

$$I^*_{A,E\lim} = I^*_A - I^*_0$$
$$I^*_{B,E\lim} = I^*_B - I^*_0 \quad I^*_0 = \frac{1}{3}\left[I^*_A + I^*_B + I^*_C\right]$$
$$I^*_{C,E\lim} = I^*_C - I^*_0$$

Delta-Winding: Setting “I0-Elimination”
Phase-Shift Correction and I0-Elimination

$$I^*_a - I^*_1 + I^*_3 = 0$$
$$I^*_b - I^*_2 + I^*_1 = 0 \qquad I^{**}_0 = \frac{1}{3}\left[I^*_1 + I^*_2 + I^*_3\right]$$
$$I^*_c - I^*_3 + I^*_2 = 0$$
$$I^*_a - I^*_b = I^*_1 - I^*_3 - I^*_2 + I^*_1$$
$$I^*_a - I^*_b = 3I^*_1 - I^*_1 - I^*_3 - I^*_2 = 3I^*_1 - 3I^{**}_0$$
$$\frac{1}{3}(I^*_a - I^*_b) = I^*_1 - I^{**}_0 = I^*_{1,E\lim}$$

Delta-Winding Currents after Transformation to primary side

$$\begin{bmatrix} I^*_{1,E\lim} \\ I^*_{2,E\lim} \\ I^*_{3,E\lim} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} \text{...1....1....0} \\ \text{...0....1....1} \\ \text{−1....0....1} \end{bmatrix}\begin{bmatrix} I^*_a \\ I^*_b \\ I^*_c \end{bmatrix}$$

Differential Currents calculated by the relay

$$I^*_{D,A} = I^*_{A,E\lim} + I^*_{1,E\lim}$$
$$I^*_{D,B} = I^*_{B,E\lim} + I^*_{2,E\lim}$$
$$I^*_{D,C} = I^*_{C,E\lim} + I^*_{3,E\lim}$$

Io-Correction - Refer to Figure 4.6. And Section 4.3.5 on page 49

I* = Normalized Current

Wye-Winding: I0-Correction

$$I^*_{A,Corr} = I^*_A + \frac{1}{3} I^*_N$$

$$I^*_{B,Corr} = I^*_B + \frac{1}{3} I^*_N$$

$$I^*_{C,Corr} = I^*_C + \frac{1}{3} I^*_N$$

Delta-Winding:
Phase-Shift Correction and I0-Elimination

$$I^*_a - I^*_1 + I^*_3 = 0$$

$$I^*_b - I^*_2 + I^*_1 = 0 \qquad I^{**}_0 = \frac{1}{3}\left[I^*_1 + I^*_2 + I^*_3\right]$$

$$I^*_c - I^*_3 + I^*_2 = 0$$

$$I^*_a - I^*_b = I^*_1 - I^*_3 - I^*_2 + I^*_1$$

$$I^*_a - I^*_b = 3I^*_1 - I^*_1 - I^*_3 - I^*_2$$

$$\frac{1}{3}(I^*_a - I^*_b) = I^*_1 - I^{**}_0 = I^*_{1,E\lim}$$

Delta-Winding Currents after Transformation to primary side

$$\begin{bmatrix} I^*_{1,E\lim} \\ I^*_{2,E\lim} \\ I^*_{3,E\lim} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} ...1....1....0 \\ ...0....1....1 \\ -1....0....1 \end{bmatrix} \begin{bmatrix} I^*_a \\ I^*_b \\ I^*_c \end{bmatrix}$$

Differential Currents calculated by the relay

$$I^*_{D,A} = I^*_{A,Corr} + I^*_{1,E\lim}$$

$$I^*_{D,B} = I^*_{B,Corr} + I^*_{2,E\lim}$$

$$I^*_{D,C} = I^*_{C,Corr} + I^*_{3,E\lim}$$

External Single Phase to Ground Fault, Io-Elimination

Refer to Figure 4.7

Wye-Winding Currents:

$$I^*_A = 1\angle 180^0$$

$$I^*_B = 0$$

$$I^*_C = 0$$

$$I^*_0 = 1/3 \angle 180^0$$

$$I^*_N = 1\angle 0^0$$

Delta-Winding Currents:

$$I^*_1 = 1\angle 0^0$$

$$I^*_2 = 0$$

$$I^*_3 = 0$$

$$I^*_a = I^*_1 - I^*_3 = 1\angle 0^0$$

$$I^*_b = I^*_2 - I^*_1 = 1\angle 180^0$$

$$I^*_c = I^*_3 - I^*_2 = 0$$

Wye-Winding Currents after I0-Elimination:

$$I^*_{A,E\lim} = I^*_A - I^*_0 = 2/3 \angle 180^0$$

$$I^*_{B,E\lim} = I^*_B - I^*_0 = 1/3 \angle 0^0$$

$$I^*_{C,E\lim} = I^*_C - I^*_0 = 1/3 \angle 0^0$$

Delta-Winding Currents after I0-Elimination and Phase-Shift Correction:

$$\begin{bmatrix} I^*_{1,E\lim} \\ I^*_{2,E\lim} \\ I^*_{3,E\lim} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} ...1....1...0 \\ ...0....1...1 \\ -1....0...1 \end{bmatrix} \begin{bmatrix} I^*_a \\ I^*_b \\ I^*_c \end{bmatrix} = \begin{bmatrix} 2/3 \angle 0^0 \\ 1/3 \angle 180^0 \\ 1/3 \angle 180^0 \end{bmatrix}$$

Differential Current:

$$I^*_{D,A} = I^*_{A,E\lim} + I^*_{1,E\lim} = 0$$

$$I^*_{D,B} = I^*_{B,E\lim} + I^*_{2,E\lim} = 0$$

$$I^*_{D,C} = I^*_{C,E\lim} + I^*_{3,E\lim} = 0$$

No Trip !

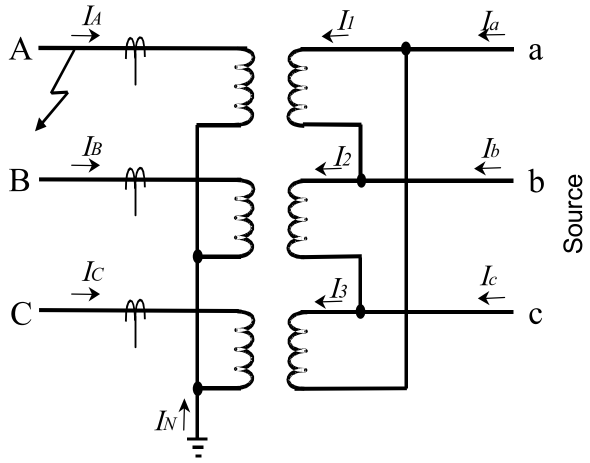


Figure 4.7 *External Phase to Ground Fault*

External Single Phase to Ground Fault, Io-Correction

Refer to Figure 4.7

Wye-Winding Currents:	*Delta-Winding Currents:*
$I_A^* = 1\angle 180^0$	$I_1^* = 1\angle 0^0$
$I_B^* = 0$	$I_2^* = 0$
$I_C^* = 0$	$I_3^* = 0$
$I_0^* = 1/3 \angle 180^0$	$I_a^* = I_1^* - I_3^* = 1\angle 0^0$
$I_N^* = 1\angle 0^0$	$I_b^* = I_2^* - I_1^* = 1\angle 180^0$
	$I_c^* = I_3^* - I_2^* = 0$

Wye-Winding Currents after I0-Correction:

$$I_{A,Corr}^* = I_A^* + \frac{1}{3} I_N^* = 2/3 \angle 180^0$$

$$I_{B,Corr}^* = I_B^* + \frac{1}{3} I_N^* = 1/3 \angle 0^0$$

$$I_{C,Corr}^* = I_C^* + \frac{1}{3} I_N^* = 1/3 \angle 0^0$$

Delta-Winding Currents after I0-Elimination and Phase-Shift Correction:

$$\begin{bmatrix} I_{1,E\lim}^* \\ I_{2,E\lim}^* \\ I_{3,E\lim}^* \end{bmatrix} = \frac{1}{3} \begin{bmatrix} ...1....1...0 \\ ...0....1...1 \\ -1....0...1 \end{bmatrix} \begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix} = \begin{bmatrix} 2/3 \angle 0^0 \\ 1/3 \angle 180^0 \\ 1/3 \angle 180^0 \end{bmatrix}$$

Differential Current:

$$I_{D,A}^* = I_{A,Corr}^* + I_{1,E\lim}^* = 0$$

$$I_{D,B}^* = I_{B,Corr}^* + I_{2,E\lim}^* = 0$$

$$I_{D,C}^* = I_{C,Corr}^* + I_{3,E\lim}^* = 0$$

No Trip !

Internal Single Phase to Ground Fault with Io-Elimination

Refer to Figure 4.8

Wye-Winding Currents:

$$I_A^* = 0$$
$$I_B^* = 0$$
$$I_C^* = 0$$
$$I_0^* = 0$$
$$I_N^* = 1\angle 0^0$$

Delta-Winding Currents:

$$I_1^* = 1\angle 0^0$$
$$I_2^* = 0$$
$$I_3^* = 0$$
$$I_a^* = I_1^* - I_3^* = 1\angle 0^0$$
$$I_b^* = I_2^* - I_1^* = 1\angle 180^0$$
$$I_c^* = I_3^* - I_2^* = 0$$

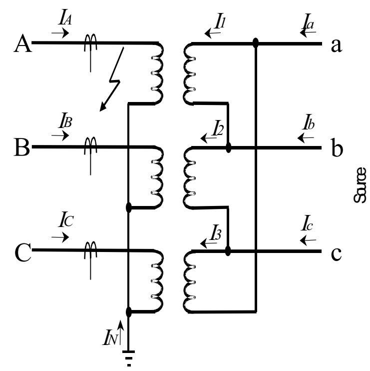


Figure 4.8 *Internal Single Phase to Ground-Fault*

Wye-Winding Currents after I0-Elimination:

$$I_{A,E\lim}^* = I_A^* - I_0^* = 0$$
$$I_{B,E\lim}^* = I_B^* - I_0^* = 0$$
$$I_{C,E\lim}^* = I_C^* - I_0^* = 0$$

Delta-Winding Currents after I0-Elimination and Phase-Shift Correction:

$$\begin{bmatrix} I_{1,E\lim}^* \\ I_{2,E\lim}^* \\ I_{3,E\lim}^* \end{bmatrix} = \frac{1}{3}\begin{bmatrix} ...1....1...0 \\ ...0....1...1 \\ -1....0...1 \end{bmatrix}\begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix} = \begin{bmatrix} 2/3\angle 0^0 \\ 1/3\angle 180^0 \\ 1/3\angle 180^0 \end{bmatrix}$$

Differential Current:

$$I_{D,A}^* = I_{A,E\lim}^* + I_{1,E\lim}^* = 2/3\angle 0^0$$
$$I_{D,B}^* = I_{B,E\lim}^* + I_{2,E\lim}^* = 1/3\angle 180^0$$
$$I_{D,C}^* = I_{C,E\lim}^* + I_{3,E\lim}^* = 1/3\angle 180^0$$

Trip ! with reduced sensitivity

Internal Single Phase to Ground Fault with Io-Correction

Refer to Figure 4.8

Wye-Winding Currents:	*Delta-Winding Currents:*
$I_A^* = 0$	$I_1^* = 1\angle 0^0$
$I_B^* = 0$	$I_2^* = 0$
$I_C^* = 0$	$I_3^* = 0$
$I_0^* = 0$	$I_a^* = I_1^* - I_3^* = 1\angle 0^0$
$I_N^* = 1\angle 0^0$	$I_b^* = I_2^* - I_1^* = 1\angle 180^0$
	$I_c^* = I_3^* - I_2^* = 0$

Wye-Winding Currents after I0-Correction:

$$I_{A,Corr}^* = I_A^* + \frac{1}{3} I_N^* = \frac{1}{3}\angle 0^0$$

$$I_{B,Corr}^* = I_B^* + \frac{1}{3} I_N^* = \frac{1}{3}\angle 0^0$$

$$I_{C,Corr}^* = I_C^* + \frac{1}{3} I_N^* = \frac{1}{3}\angle 0^0$$

Delta-Winding Currents after I0-Elimination and Phase-Shift Correction:

$$\begin{bmatrix} I_{1,E\lim}^* \\ I_{2,E\lim}^* \\ I_{3,E\lim}^* \end{bmatrix} = \frac{1}{3}\begin{bmatrix} ...1....1...0 \\ ...0....1...1 \\ -1....0...1 \end{bmatrix}\begin{bmatrix} I_a^* \\ I_b^* \\ I_c^* \end{bmatrix} = \begin{bmatrix} 2/3\angle 0^0 \\ 1/3\angle 180^0 \\ 1/3\angle 180^0 \end{bmatrix}$$

Differential Current:

$$I_{D,A}^* = I_{A,Corr}^* + I_{1,E\lim}^* = 1$$

$$I_{D,B}^* = I_{B,Corr}^* + I_{2,E\lim}^* = 0$$

$$I_{D,C}^* = I_{C,Corr}^* + I_{3,E\lim}^* = 0$$

Trip ! with maximum sensitivity

4.3.7 Using a Ground or Neutral Current CT

If the protection application includes measuring one or two ground currents (or neutral currents), relay model 7UT513 must be used. If the relay is ordered with the optional tank-leakage protection, one of the relay's two ground-current inputs measures the absolute ground current. If instead the relay was ordered with the ground-differential protection option, both ground-current inputs measure the ground current as a multiple of the rated nominal current of the reference winding of the protected transformer, I_n. Addresses 7806 and 7807 tell the relay how the corresponding ground current input is to be used.

7806 STAR-POINT A (7UT513 only)
7807 STAR-POINT B (7UT513 with 87N option only)
What is connected to each ground-current input of the relay.

Option	Description
NO ASSIGNMENT	No CT is connected to this ground-current input (default).
SIDE 1	A CT monitoring the ground or neutral current of Winding 1 of the protected transformer.
SIDE 2	A CT monitoring the ground or neutral current of winding 2 of the protected transformer.
SIDE 3 / V. OBJ	A CT monitoring the ground or neutral current of winding 3 of the principal protected transformer, or the ground or neutral current of a separate, additional protected device (see Chapter 11).

As for the ground-current inputs, the relay must know the rated nominal primary current and orientation of the CT(s) measuring ground or neutral currents. The addresses corresponding to each winding are used only if a CT is connected to relay's ground current inputs and assigned in addresses 7806 and 7807.

1107 In CT STP1 (7UT513 only) **1127 In CT STP2 (7UT513 only)** **1147 In CT STP3 (7UT513 only)** Rated nominal primary current of each winding's ground-current or neutral-current CT (if the winding has one).
Range: 1 – 100,000 A Default: 200 A for Winding 1, 2000 A for windings 2 and 3

1108 CT1 GND-PT (7UT513 only) **1128 CT2 GND-PT (7UT513 only)** **1148 CT3 GND-PT (7UT513 only)** Orientation of which end of each winding's ground-CT is connected to the non-polarity terminal of a ground-current input of the relay. This is usually the non-polarity end of the CT (see Figure 4.5 and Figure 4.4).	
Option	**Description**
TOWARDS TRANSF	Towards the transformer (default).
TWDS LINE/BUSBAR	Away from the transformer.

4.4 Trip Characteristic

As shown in Figure 4.9, current transformers (CTs) measure the currents flowing into and out of the protected transformer. As described in Section 4.1.1 on page 39, the relay matches the currents to take into account the winding ratio(s) of the protected transformer, the winding ratios of the CTs, the phase shift(s) of the protected transformer, and the processing of the zero sequence current. The differential protection function then calculates (separately for each phase) the "differential current," I_{diff}:

$$I_{diff} = |I'_1 + I'_2| \quad \text{(two winding transformer)} \tag{4.7}$$

$$I_{diff} = |I'_1 + I'_2 + I'_3| \quad \text{(three winding transformer)} \tag{4.8}$$

The differential current, I_{diff}, is a scalar quantity that is the absolute value of the amplitude of the vector sum of the fundamental component of each matched phase-current flowing into the protected transformer. In a system composed of ideal components, a non-zero differential current is a certain indication of a fault somewhere within the protected transformer.

As described in Section 4.1.2 on page 41, the non-ideal behavior of a real system may result in a differential current when in fact no fault exists within the protected transformer. In these cases, the differential protection must be restrained. To do so, the relay calculates (separately for each phase) a "restraining current," I_{rest}:

$$I_{rest} = |I'_1| + |I'_2| \quad \text{(two winding transformer)} \tag{4.9}$$

$$I_{rest} = |I'_1| + |I'_2| + |I'_3| \quad \text{(three winding transformer)} \tag{4.10}$$

The restraining current, I_{rest}, is the scalar sum of the absolute value of the amplitude of the fundamental component of each matched phase-current flowing into the protected transformer. It is proportional to the total amount of current flowing through the transformer.

Note: By definition both I_{diff} and I_{rest} are positive values, and that I_{rest} is always greater than or equal to I_{diff}.

To illustrate the use of the restraining current, consider three operating situations for a two-winding transformer:

- During normal operation, or through fault (outside of the protected transformer), $I'_2 = -I'_1$, so:

$$I_{diff} = |I'_1 + I'_2| = |I'_1 - I'_1| = 0 \tag{4.11}$$

$$I_{rest} = |I'_1| + |I'_2| = |I'_1| + |-I'_1| = 2 \cdot |I'_1| \tag{4.12}$$

- If there is a short circuit within the protected transformer with equal currents entering from each side, $I'_2 = I'_1$, so:

$$I_{diff} = |I'_1 + I'_2| = |I'_1 + I'_1| = 2 \cdot |I'_1| \tag{4.13}$$

$$I_{rest} = |I'_1| + |I'_2| = |I'_1| + |I'_1| = 2 \cdot |I'_1| \tag{4.14}$$

- If there is a short circuit within the protected transformer with current entering from only one side, $I'_2 = 0$, so:

$$I_{diff} = |I'_1 + I'_2| = |I'_1 + 0| = |I'_1| \qquad (4.15)$$

$$I_{rest} = |I'_1| + |I'_2| = |I'_1| + 0 = |I'_1| \qquad (4.16)$$

Note: For an internal short-circuit fault, $I_{diff} = I_{rest}$.

The differential protection function uses the instantaneous values of I_{diff} and I_{rest} to plot the location of the "operating point" on the trip characteristic shown in Figure 4.9. The shape of the trip characteristic is configured using the addresses described in the following subsections.

The 87T or 87HS function will pickup if either (1) the operating point of any phase moves above 85% of the height of the trip characteristic for the simultaneous restraining current, or (2) the restraining current of any phase exceeds four times the rated nominal current of the reference winding of the protected transformer ($I_{rest} > 4I_n$). This makes it possible for the saturation-detection algorithms to become active **prior to actual trip conditions**, as well as for the relay to record waveform data (see Section 14.7 on page 147) for the entire fault event, including during external faults indicated by a high restraining current. The operating point must be on or above the trip characteristic for a trip event to occur. Individual pickup and trip events are stored and annunciated that report which phase(s) have picked up or tripped (see Section 4.10 on page 62).

After pickup or trip occurs, the 87T or 87HS function will dropout (or reset) once the operating point stays below 70% of the trip setting for two full cycles.

4.4.1 Minimum 87T Trip Threshold

Constant error currents, such as magnetizing currents, can result in a small, continuous differential current. To prevent this current from causing a pickup or trip, the differential current, I_{diff}, must be at or above the threshold set in Address 1603 before an 87T trip can occur.

1603 87 PICKUP Minimum trip level of the 87T differential protection function specified as a fraction (or multiple) of the rated nominal current of the protected transformer's reference winding, I_n.
Range: 0.15 – 2.00 I_n Default: 0.20 I_n

If the transformer has a tap changer, then the setting should be increased by 10% for every 10% of tap changing range. For example, if the pickup value would otherwise be 0.20, but there is 10% tap changing, the setting should be 0.22.

$$Setting = 0.2 + \frac{(\text{tap setting range }(\%))}{0.10} \times 0.10 \times 0.20$$

4.4.2 High Set (87HS) Trip Threshold

If the level of the differential current becomes so high that it cannot be due to an external fault, the differential protection should trip regardless of the level of restraining current. A differential current above the level set in Address 1604 will cause an 87HS pickup regardless of any restraint measures in effect (unless the entire 87/87HS function is being blocked by a binary-signal input).

1604 87HS RMS High-set pickup level of the differential protection (87HS) specified as a fraction (or multiple) of the rated nominal current of the protected transformer's reference winding, I_n.
Range: 0.5 – 20.0 I_n Default: 7.5 I_n

The 87HS function features an algorithm that responds to the instantaneous current value (sampled 12 times per cycle), so the 87HS function can trip even if the fundamental wave is being clipped due to CT saturation.

The 87HS pickup level should be set as low as possible, but not so low that it will trip in the event of an external fault causing unequal CT saturation. If Z is the transfer impedance of the transformer, then a bolted, through fault will result in a through current of $(1/Z)\times I_n$, where I_n is the rated nominal current of the transformer. A setting of 75% of this value should enable the 87HS function to trip for a fault on a transformer terminal. For example, if Z is 10%, then $1/Z = 1/0.10 = 10$, so the suggested setting is $0.75\times 10 = 7.5$ (since the unit of this setting is I_n). This setting should be set higher than the minimum 87T pickup level (Address 1603).

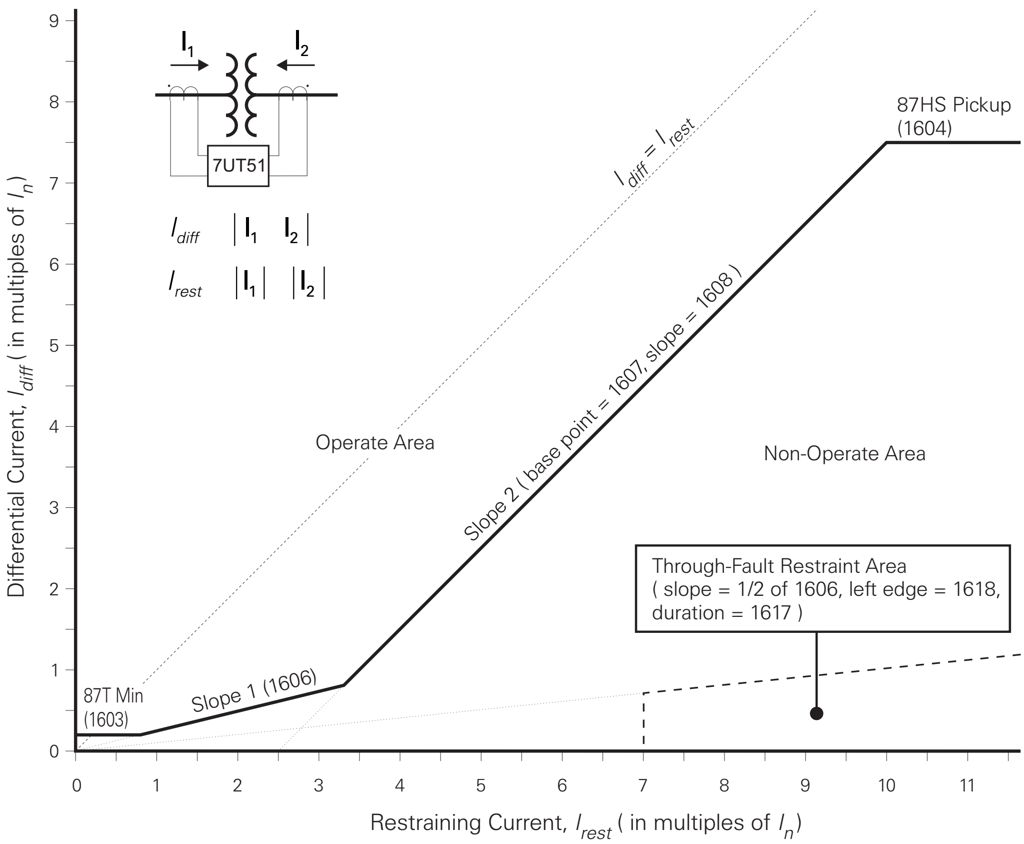


Figure 4.9 *Differential Protection Trip Characteristic when the Protected Object is a Transformer*

4.4.3 Lower Slope of Pickup Characteristic

The lower sloped-segment of the trip characteristic (Slope 1) deals with a differential current resulting from transformation errors in the CTs, the current inputs of the relay, or from the position of the tap changer of the voltage regulator. The baseline intercept of this segment is the origin; its slope is entered Address 1606.

1606 87SLOPE 1 Slope of lower sloping segment of 87T pickup characteristic (Slope 1). This segment intercepts the horizontal axis at the origin.
Range: 0.10 – 0.50 (unitless ratio) Default: 0.25

The default value (a slope of 0.25) should be sufficient for regulating ranges up to 20%. If the transformer has a larger regulated range, or there are in-zone loads (e.g., auxiliary transformers), then the slope must be increased accordingly.

4.4.4 Upper Slope of Pickup Characteristic

The upper sloped-segment of the trip characteristic (Slope 2) provides higher pickup levels in the range of high through currents during normal operation that may cause current transformer saturation (CT saturation due to a high through current caused by an external fault is dealt with separately, see Section 4.5 on page 58). The baseline intercept and slope are set in addresses 1607 and 1608.

1607 87BASE PT2 Baseline intercept of the upper sloping segment of 87T pickup characteristic (Slope 2).
Range: 0.0 – 10.0 I_n Default: 2.5 I_n

1608 87SLOPE 2 Slope of upper sloping segment of 87T pickup characteristic (Slope 2).
Range: 0.25 – 0.95 (unitless) Default: 0.50

4.5 Through-Fault Restraint

CT saturation caused by a high-current internal fault (or by long system time constants) affects the differential current, I_{diff}, and the restraining current, I_{rest}, about equally. Hence, the trip characteristic (see Section 4.4 on page 55) can handle this situation. However, a high-current through-fault can cause considerable differential current due to unequal CT saturation at the different CT measuring locations. To restrain tripping in this situation, the differential protection function has a special feature.

A high-current external fault is characterized by an initial rise in the restraining current that is much more rapid than the initial rise in the differential current. Hence, if the operating point moves quickly (within 0.5 cycle) into the through-fault-detection area shown in Figure 4.9, the 87T function (but not the 87HS function) will be restrained for a configurable duration. The restraint will be released if for two complete cycles the ratio of the differential current to the restraining current is less than 0.9 (that is, the operating point moves up to within 90% of the $I_{diff}=I_{rest}$ line on Figure 4.9), indicating an internal fault is evolving during the external fault.

1617 T-SAT-BLK Maximum duration of through-fault CT-saturation restraint of the 87T function.
Range: 2 – 250 cycles, or ∞ (until drop-off of pickup) Default: 8 cycles The timer starts when the operating point **exits** the through-fault restraint area (see Figure 4.9 on page 57). Enter ∞ for the restraint to continue until dropout of the differential protection pickup.

1618 SAT-RESTR. Minimum restraint current required to activate through-fault CT-saturation restraint. This value sets the left edge of the through-fault restraint area shown in Figure 4.9 on page 57. The top of the area is a line passing through the origin whose slope is one-half the slope of Slope 1 (Address 1606).
Range: 5.00 – 15.00 I_n Default: 7.00 I_n

4.6 Second-Harmonic Restraint

When a transformer is energized, the resulting inrush current usually causes a transient differential current. This inrush current, which can be several times greater than the transformer's rated nominal current, is characterized by a considerable second harmonic content that is practically absent from a short-circuit current. Hence, the presence of a relatively large second harmonic current is often used to block the differential protection during inrush. The second harmonic restraint is set **On** or **Off** in Address 1610.

1610 2nd HARMN RSTR Blocking the differential protection for inrush (second harmonic) current exceeding the threshold setting is chosen in Address 1611. Inrush restraint operates independently for each phase, unless crossblocking is set in Address 1612.	
Option	**Description**
ON	Use inrush restraint (default).
OFF	Do not use inrush restraint.

1611 %2nd HARMN Minimum amount of second harmonic differential current (as a percentage of the fundamental component of the differential current) that will block the differential protection (if Address 1610 is set to ON).
Range: 10 – 80% Default: 15%

In most applications, inrush restraint should operate independently for each phase since it is possible for a fault to occur on only one phase during inrush. If this happens, the differential current of that phase will not contain the high percentage of second-harmonic current characteristic of inrush, and so the differential protection of that phase will not be blocked. However, if desired, the relay can be configured to have the inrush restraint of any phase "crossblock" the differential protection of all three phases for a specified duration. The choice and duration are set in Address 1612.

1612 X-BLK 2HRM Duration (in cycles) after pickup of the differential protection to block differential protection on all phases (crossblock) if inrush restraint is blocking it on at least one phase.
Range: 0 – 1000 cycles, or ∞ Default: 0 (no crossblocking) Specify (in cycles) the duration of crossblocking. Enter 0 for no crossblocking (each phase blocked independently). Enter ∞ for crossblocking to continue for as long as the differential protection of any phase is blocked by inrush-current restraint.

The effect of second-harmonic restraint is illustrated in Figure 4.10. Note that if the differential current becomes larger than the 87HS trip threshold, a trip will occur (see Section 4.4.2 on page 56). This will result in a trip even if a large DC component, in a large fault current causing CT saturation, is being interpreted as a large second-harmonic component.

See Section 4.10 on page 62 for the events that control and annunciate the start and end of harmonic restraint.

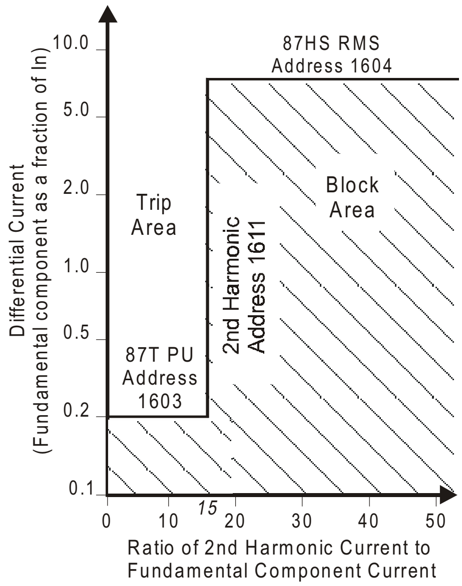


Figure 4.10 *Inrush (2nd Harmonic) Restraint Characteristic*

4.7 Higher-Harmonic Restraint

In addition to inrush, other non-fault conditions can create a differential current containing excessive harmonic components. For example, a differential current resulting from unsymmetrical currents in the transformer windings will contain an excessive fourth-harmonic component (in addition to the second-harmonic component). As another example, a differential current, resulting from overexcitation of the protected transformer when a breaker opens and there is a strong current source near the transformer, will contain excessive third-harmonic and fifth-harmonic components. Since a delta connection will eliminate the third-harmonic current, the fifth-harmonic current is usually used for this restraint. Hence, independently of the second-harmonic inrush restraint, the relay can restrain the differential protection based on excessive third, fourth, or fifth harmonic currents.

1613 n. HARMN RSTR
Blocking of the differential protection when the third-, fourth-, or fifth-harmonic current exceeds the threshold is set in Address 1614. Operates independently for each phase, unless crossblocking is set in Address 1615.

Option	Description
5TH HARMONIC	Base restraint on fifth-harmonic current (default).
4TH HARMONIC	Base restraint on fourth-harmonic current.
3RD HARMONIC	Base restraint on third-harmonic current.
OFF	No restraint based on third-, fourth-, or fifth-harmonic current.

1614 %n. HARMN
Minimum amount of higher-order harmonic differential current (as a percentage of the fundamental component of the differential current) that will block the differential protection (unless Address 1613 is set to OFF).

Range: 10 – 80%
Default: 80%

As in the case of inrush restraint based on the second-harmonic, restraint based on higher-order harmonics should operate independently for each phase since it is possible for a fault to occur on only one phase. If this happens, the differential current of that phase will not contain the high percentage of higher-order harmonic current characteristic of the non-fault condition, and so the differential protection of that phase will not be blocked; however, when appropriate, the relay can be configured to have the higher-order harmonic restraint of any phase "crossblock" the differential protection of all three phases for a configurable duration.

1615 X-BLK nHM
Duration (in cycles) after pickup of the differential protection to block differential protection on all phases (crossblock) if higher-order harmonic restraint is blocking it on at least one phase.

Range: 0 – 1000 cycles, or ∞
Default: 0 (no crossblocking)
Specify (in cycles) the duration of crossblocking. Enter 0 for no crossblocking (each phase blocked independently). Enter ∞ for crossblocking to continue for as long as the differential protection of any phase is blocked by higher-order harmonic restraint.

CTs can also produce odd-harmonic content which is practically absent in the differential current caused by a fault. To prevent higher-harmonic restraint from blocking tripping during an internal fault, set a maximum differential current level above which the n-th harmonic restraint is rendered ineffective.

1616 IDIFFmax n
Differential current value above which n-th harmonic restraint is released.

Range: 0.5 – 20.0 I_n
Default: 1.5 I_n

The effect of higher-order-harmonic restraint is illustrated in Figure 4.11 on page 61. Note that if the differential current becomes larger than the 87HS trip threshold, a trip will occur (see Section 4.4.2 on page 56).

See Section 4.10 on page 62 for events that control and annunciate the start and end of harmonic restraint.

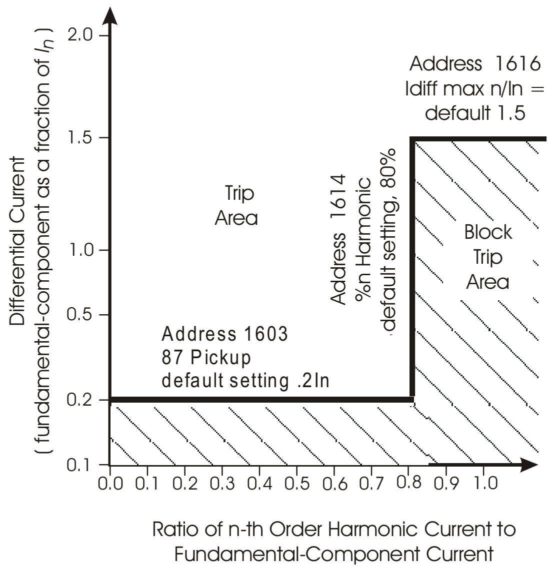


Figure 4.11 *Higher-Harmonic Restraint Characteristic*

4.8 Blocking by Frequency Variance

If the system frequency varies too far from the rated nominal frequency, the transformer differential protection will be blocked, as illustrated in Figure 4.12.

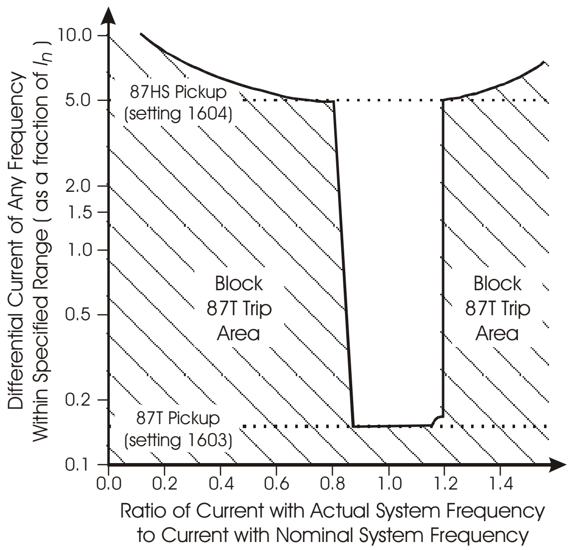


Figure 4.12 *Blocking of Transformer Differential Protection (87T and 87HS) by Variance from Nominal System Frequency.*

4.9 Time Delays

If an 87T pickup occurs, and the 87T function is not being restrained, the function will immediately trip unless a time delay has been set in Address 1625. If an 87HS pick up occurs, the 87HS function will immediately trip unless a time delay has been set in Address 1626 (restraint does not apply to the 87HS function).

1625 87 DELAY Time delay between pickup and trip for 87 differential protection (in addition to the inherent operating time of the relay).
Range: 0.00 – 60.00 s, or ∞ Default: 0.00 s

1626 87HS DELAY Time delay between pickup and trip for 87HS differential protection (in addition to the inherent operating time of the relay).
Range: 0.00 – 60.00 s, or ∞ Default: 0.00 s

To ensure that the trip state lasts long enough for the circuit breaker to operate, the trip state can be prolonged by a reset time delay that is set in Address 1627.

1627 T-RESET Additional time to remain in trip state of the 87 and/or 87HS functions, after the trip signal has disappeared (in addition to the inherent reset time of the relay).
Range: 0.00 – 60.00 s Default: 0.10 s

All times are pure delay times which do not include the inherent operating time.

If a trip occurs, the contacts and LEDs marshalled to the event will remain activated until the corresponding function (87T or 87HS) drops out.

4.10 Events and Actions

Figure 4.13 shows the logic of these events.

Table 4.3 describes the events that control and are generated by the 87T/87HS function. They are listed in the order that they are likely to occur, which is roughly in numerical order by their event identification number (shown in the “Event” column). The text in the “LCD Abbreviation” column is the corresponding text that will appear when viewing logs on the front panel LCD display. In the “Oper” column, a letter “C” or “G” indicates that the “Coming” and/or “Going” events are logged in the Operational Log, while if in the “Fault” column they indicate that the events are logged in the open fault log. A letter in the “In/Out” column indicates that the event can be controlled by a binary-signal input (“I”), control an LED and/or signal contact (“S”), and/or control a trip contact (“T”).

Transformer Differential Protection (87T and/or 87HS) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Change in Operational Status					
When the operational status of the 87T/87HS function changes, a going-event for the old status occurs followed by a coming-event for the new status. The normal operational status is set in Address 1601.	87Diff OFF 87Diff BLOCK 87Diff ACTIVE	5615 5616 5617	CG CG CG		S S S
A binary input can temporarily change the operational status of the function (see Section 13.2 on page 126). Any outputs marshalled to these events will remain actuated for as long as the binary input remains actuated.	>87Diff BLOCK >87DiffBlkTrip	5603 5605			I S I S
Pickup and Dropout					
If the operating point of any phase rises above 85% of the height of the pickup characteristic, or if the restraint current (I_{rest}) exceeds four times rated nominal current (I_n), the 87T/87HS function will pickup (event 5631C). If no fault log is already open, a new one will open. If the operating point for all phases remains below 70% of the height of the pickup characteristic for two full cycles, the 87T/87HS function will dropout (event 5631G). See Section 4.4 on page 55.	87Diff GenFlt	5631		CG	S T
An 87T phase-pickup occurs if the operating point of a phase rises above the pickup characteristic. Outputs marshalled to these events will remain actuated until dropout of the corresponding phase.	87Diff PhA 87Diff PhB 87Diff PhC	5681 5682 5683		C C C	S S S
An 87HS pickup occurs if the operating point of a phase rises above the 87HS threshold level. Outputs marshalled to these events will remain actuated until dropout of the corresponding phase.	87HS PhA 87HS PhB 87HS PhC	5684 5685 5686		C C C	S S S
Time Delay Before Trip					
If an 87T or 87HS pickup occurs, the corresponding time-delay-before-trip timer will start (see Section 4.9 on page 61). These events will not occur if the corresponding time delay setting is zero. Outputs marshalled to these events will remain actuated until the corresponding time delay expires.	87Diff Pickup 87Diff HS PU	5621 5622		C C	S T S T

Transformer Differential Protection (87T and/or 87HS) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Restraint					
If the 87T/87HS function is in pickup, harmonic restraint conditions (inrush and/or overexcitation) are reported separately for each phase. If crossblocking is in effect, all three events occur in parallel. The corresponding going-event occurs when restraint conditions end or the 87T/87HS function drops out or resets (see Sections 4.6 and 4.7).	87Blk HarmPhA 87Blk HarmPhB 87Blk HarmPhC	5641 5642 5643		CG CG CG	S S S
If the motion of the operating point suggests that a high-current fault outside the protected zone is saturating the CTs, the event is reported for each phase. The corresponding going-event occurs when the duration timer (Address 1617) runs out, or the 87T/87HS function detects that an internal fault is also occurring (see Section 4.5 on page 58).	87Blk SatPhA 87Blk SatPhB 87Blk SatPhC	5651 5652 5653		CG CG CG	S S S
Trip and Reset					
Any 87T or 87HS trip event will also cause event 5671 to occur. With the default marshalling, event 5671 will actuate all the trip contacts, signal contact 2, and (as for the general trip of any protection function) signal contact 1. Outputs actuated by 87T/87HS trip events will remain actuated until the 87T/87HS function resets (the same conditions for dropout, event 5631G), plus the additional reset time (Address 1627).	87Diff GenTrip	5671		C	S T
The 87T function will trip if and when ALL the following are true: • an 87T pickup has occurred, and it has not yet dropped out or already caused a trip, • the 87T time-before-trip time delay (if there is one) has expired, • any restraint has ended, There are separate 87T trip events for each phase, and one (event 5691) that reports the 87T trip of any phase. With the default marshalling, event 5691 will light and latch LED 2 and (as for any protection function trip event) LED 1.	87Diff TripPhA 87Diff TripPhB 87Diff TripPhC 87 Trip	5672 5673 5674 5691		C C C C	S T S T S T S T
The 87HS function will trip if and when ALL the following are true: • an 87HS pickup has occurred, and it has not yet dropped out or already caused a trip, • the 87HS time-before-trip time delay (if there is one) has expired, (Note that restraint has no effect on the 87HS function.) Event 5692 reports the 87HS trip of any phase. With the default marshalling, it will light and latch LED 3 and (as for any protection function trip event) LED 1.	87HS Trip	5692		C	S T
If an 87T or 87HS trip event occurs, the values of the differential currents and restraining currents for each phase at the time of the trip are recorded in the then open fault log.	Diff Ia= *value* Diff Ib= *value* Diff Ic= *value* Rest Ia= *value* Rest Ib= *value* Rest Ic= *value*	5701 5702 5703 5704 5705 5706		C C C C C C	

Transformer Differential Protection (87T and/or 87HS) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Configuration Errors					
Configuration Error (7UT513 only): Both ground-current inputs are set to monitor the same winding (addresses 7806 and 7807). (With default marshalling, any configuration error will light LED 14.)	Err 2 CT star	5711	C		S
Configuration Error (7UT513 only): The 87T/87HS function is set to use a measured ground-current to correct the corresponding winding's zero sequence current, but neither ground current input has been assigned that winding. (With default marshalling, any configuration error will light LED 14.)	Err no CTstar	5712	C		S
Configuration Events					
If the transformer-description addresses are changed, the current-matching factors for the phase currents are recalculated and reported.	k CT 1= *factor* k CT 2= *factor* k CT 3= *factor*	5713 5714 5715	C C C		
If the transformer-description addresses are changed, the current-matching factors for the ground currents being measured are recalculated and reported.	ksCT 1= *factor* ksCT 2= *factor* ksCT 3= *factor*	5716 5717 5718	C C C		

Table 4.3 *Events Related to Differential Protection of a Transformer (87T and 87HS)*

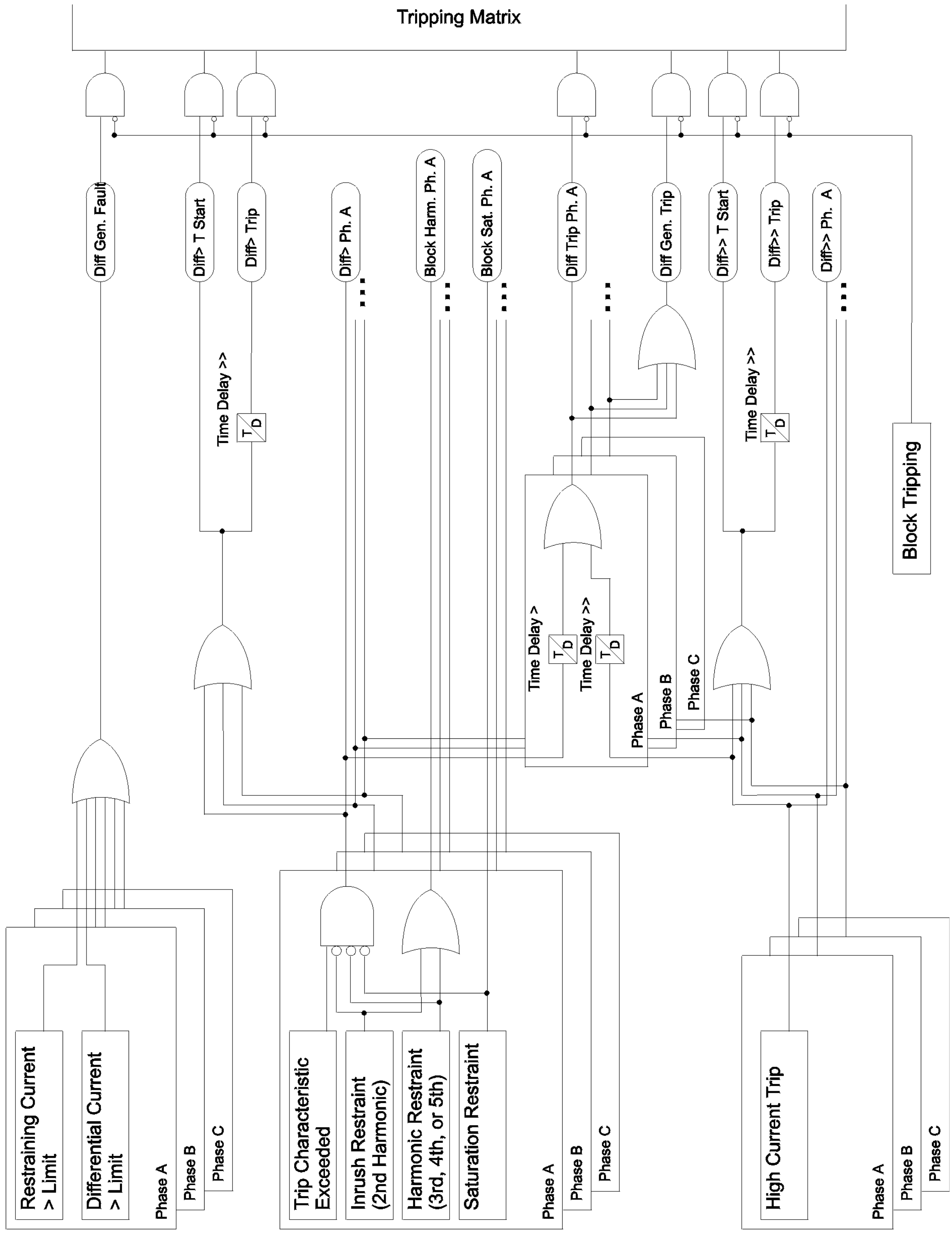


Figure 4.13 *Tripping Logic of Transformer Differential Protection (87T and 87HS)*

4.11 Single-Phase Transformers

Single-phase transformers can be designed with one or two phases per winding; in the latter case, the winding phases can be wound on one or two iron cores. To ensure that optimum matching of the currents is possible, always use two measured current inputs even if only one current transformer is installed on one phase. In the following, the currents are called I_a and I_c.

If two winding phases are available, they may be connected either in series (which corresponds to a wye-winding) or in parallel (which corresponds to a delta-winding). The phase displacement between the windings can only be either 0° or 180°. Figure 4.14 shows an example of a single-phase power transformer with two phases per winding.

The matrix equation for computing the matched currents is the same as for a three-phase transformer, but since the phase displacement between the windings can only be 0° or 180°, there are only two ways to handle the zero sequence current. If the common of the protected transformer winding is not grounded, the phase currents can immediately be used. The current-matching matrix equation is then:

$$\begin{bmatrix} I_A' \\ I_C' \end{bmatrix} = 1 \times \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \times \begin{bmatrix} I_A \\ I_C \end{bmatrix} \qquad (4.17)$$

If the common is grounded, the zero sequence current must be eliminated. The current-matching matrix equation is then:

$$\begin{bmatrix} I_A' \\ I_C' \end{bmatrix} = 1 \times \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \times \begin{bmatrix} I_A \\ I_C \end{bmatrix} \qquad (4.18)$$

The disadvantage of eliminating the zero sequence current is reduced sensitivity in the event of a ground-fault in the protected zone (by a factor of 1/2). Higher ground-fault sensitivity is possible if the ground current is measured (see Figure 4.14). The current-matching equation is then:

$$\begin{bmatrix} I_a' \\ I_c' \end{bmatrix} = 1 \times \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \times \begin{bmatrix} I_a \\ I_c \end{bmatrix} + \frac{1}{2} \times \begin{bmatrix} I_G \\ I_G \end{bmatrix} \qquad (4.19)$$

where I_g is the ground current of the grounded winding. The zero sequence current is eliminated by this correction during an external fault but fully recognized in the event of an internal ground-fault.

Further processing of the measured quantities and the tripping logic do not differ from the three-phase transformer differential protection.

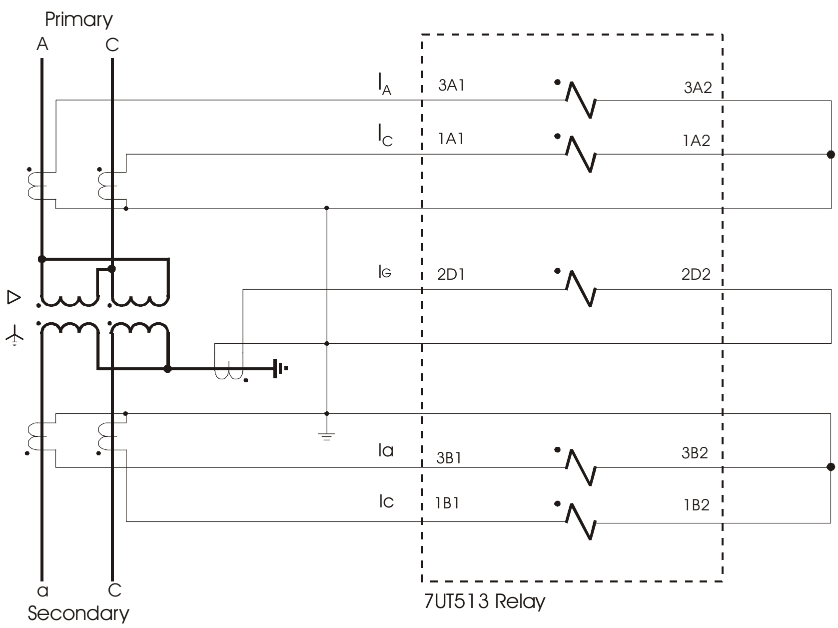


Figure 4.14 *Single-Phase Transformer Wiring with a Ground-Current CT*

5 Motor or Generator Differential Protection (87M/G)

The motor/generator differential protection function (87M/G) provides high speed, secure primary protection for faults within a motor or generator. The trip characteristic is configurable; as is restraint based on detection that a through-fault is causing CT saturation. The algorithm responds to instantaneous current measurements, and so can often detect a short circuit in less than one cycle.

The relay can also provide ground differential protection (see Chapter 7).

5.1 Method of Operation

Differential protection is an application of Kirchoff's current law—the sum of all the currents entering and leaving a node must be zero. In a system consisting of ideal components, if the sum of all the *measured* currents (called the "differential current") is not zero, then there must exist an *unmeasured* current — a fault.

Actual applications do not use ideal components; therefore, the differential protection must take into account the non-ideal behavior of the protected machine, the CTs monitoring it, and the rest of the power distribution system. Specifically:

- A small, constant differential current may exist (due, for example, to a magnetizing current). To prevent pickup due to this current, the relay has a minimum 87 pickup level (see Section 5.4.1 on page 72).
- A fault outside the protected zone may cause large currents to flow through the protected zone that saturate the CTs. The pickup characteristic is configurable to compensate for this (see Section 5.4 on page 71), while separate settings limit this restraint so that the relay can detect an internal fault that occurs during an external fault (see Section 5.5 on page 74).

5.2 Describing the Protected Motor or Generator

The 7UT51 relay provides differential protection for motors and generators with either longitudinal windings or transverse windings (see Figure 5.1 on page 70 and Figure 5.2 on page 70).

If the relay is used as differential protection for motors or generators, all currents are measured as multiples of the nominal current of the protected object. This data is set during device configuration and includes rated apparent power, rated voltage, and rated currents of the current transformers.

The following information is needed for all types of protected objects and the associated current transformers:

- What the protected object is
- What the rated phase-to-phase voltage (Vn) of the protected motor or generator is
- What the rated frequency of the motor or generator is
- What the rated apparent power (VA) of the motor or generator is

This section describes these choices and settings.

5.2.1 Type of Protected Object

The relay uses different settings and algorithms for different types of protected objects. Address 7801 specifies what type of device or equipment is being protected.

7801 PROT.OBJ Type of object the relay is protecting.	
Option	**Description**
2-WIND-TRANSF	two-winding transformer (default) (see Chapter 4)
3-WIND-TRANSF	three-winding transformer (see Chapter 4)
MOTOR/ GENERATOR	**motor or generator**
2 ENDED TIE PT.	two-branch bus (see Chapter 6)
3 ENDEDTIE PT.	three-branch bus (see Chapter 6)
1Ph.-TRANSF	single-phase transformer (see Chapter 4)

Model 7UT513 is required (instead of a 7UT512) only if the application includes measurement of a ground (or neutral) current. A 7UT513 can also be used to protect simultaneously both a motor/generator and an additional protected device.

5.2.2 Normal Operational Status

The 87M/G differential function can be set either to exist (ENABLED) or not exist. The choice is made in Address 7816.

7816 87 STATUS Choice of whether motor/generator differential protection function (87M/G) exists.	
Option	**Description**
EXISTENT	87M/G function exists (default).
NONEXISTENT	87M/G function does not exist.

Once the 87M/G function is set to exist, it can be configured. Its normal status is set in Address 1701.

1701 87 STATUS Operational status of differential protection (87M/G) when the protected object is a motor or generator.	
Option	**Description**
OFF	87M/G function is inactive (default).
ON	87M/G function is active.

1701 87 STATUS Operational status of differential protection (87M/G) when the protected object is a motor or generator.	
BLOCK TRIPPING	87M/G function is active except that trip contacts and signal contacts will not respond to 87M/G events.

5.2.3 System Frequency

The rated nominal frequency of the protected equipment is specified in Address 7899.

7899 FREQUENCY Rated nominal frequency of the protected motor/ generator.	
Option	**Description**
FREQ 50 Hz	50 Hertz
FREQ 60 Hz	60 Hertz (default)
FREQ 16 2/3 Hz	16-2/3 Hertz

Note: The choice of frequency affects the availability the auxiliary protection functions. With rated frequency 60Hz, the backup overcurrent time protection or the restricted earth fault protection/tank leakage protection (dependent on the ordered model) can be used besides the differential protection for the motor/generator.

With rated frequency 50Hz, the backup overcurrent time protection or the restricted earth fault protection/ tank leakage protection (dependent on the ordered model) can be used besides the differential protection for the motor/generator.

With rated frequency 16 2/3 Hz, no restriction concerning the additional functions are present.

5.2.4 Motor/Generator Information

The phase-to-phase voltage and rated apparent power of the protected motor/generator is specified in Addresses 1202 and 1203. The relay automatically calculates the primary measured values based on this information.

1202 Vn M/G Rated phase-to-phase voltage of the motor or generator
Range: 0.4 – 800.0 kV Default: 21.0

5.3 Describing the CT Scheme

1203 VA M/G Rated apparent power of the motor or generator
Range: 0.2 – 5000.0 MVA Default: 400.0

Unlike electromechanical relays, numerical relays do not require a complicated current transformer scheme to match measured currents. Instead, information about the protected object and the current transformers is entered into the relay's memory. Then, using the measured currents, the relay performs any necessary calculations to match the currents. The relay must be configured with the information about the CTs attached to the motor/generator and how they are connected, including:

- The orientation of the current transformers
- The nominal *primary* rating of the current transformers
- The nominal *secondary* rating of the current transformers
- The manner in which the ground-current inputs are used (7UT513 only)

This section describes the associated settings.

5.3.1 CT Orientation

In normal operation, the current has the same magnitude and phase on both sides of the motor or generator. Hence, the only information required is the orientation of the CTs (relative to each other) and the rated nominal primary current of each CT set.

If both CT commons are toward or away from the motor or generator, the CT orientation is **SAME SIDE** (as in Figure 5.1 on page 70); otherwise the CT orientation is **OPPOSITE SIDES**; however, when using the relay for transverse differential protection, the CT commons must be on the same side, but specify **OPPOSITE SIDES**.

1206 CT STARPT Orientation of CTs	
Option	**Description**
SAME SIDE	Both CT commons on same side of motor or generator (default)
OPPOSITE SIDES	CT commons on opposite sides of motor or generator

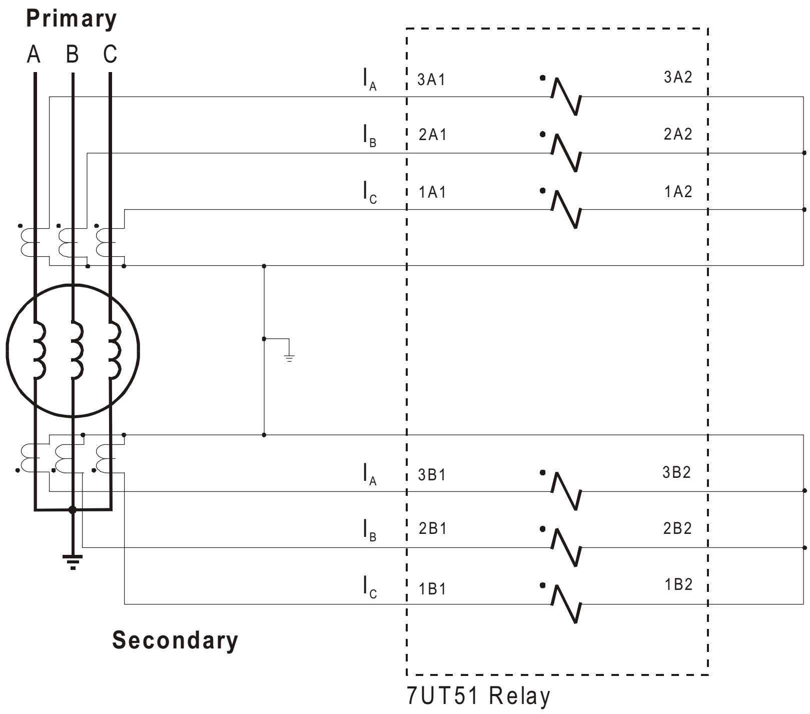


Figure 5.1 *Typical CT Wiring for a Longitudinal-Winding Motor/Generator*

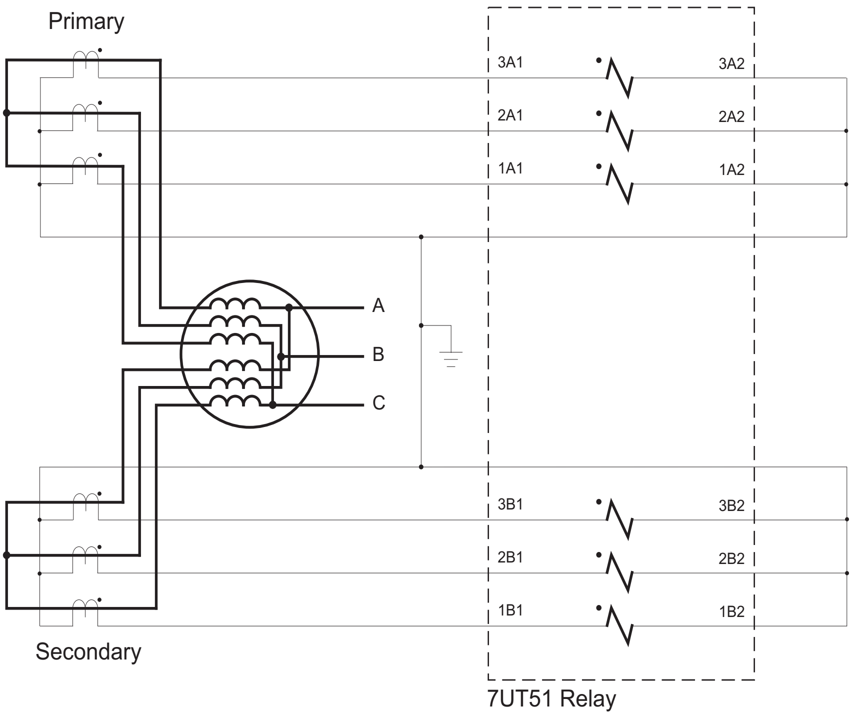


Figure 5.2 *Typical CT Wiring for a Transverse-Winding Motor or Generator*

5.3.2 Nominal Primary Rating of CTs

Specify the primary rated current for each CT set.

1207 In CT 1 **1208 In CT 2** Rated nominal primary current of the CT on the common side (Side 1, Address 1207) and the CT on the terminal side (Side 2, Address 1208) of the motor or generator.
Range: 1 – 100,000 A Default: 11,000 A

5.3.3 Nominal Secondary Rating of CTs

The relay is ordered with either 1A or 5A current inputs. The choice should match the rated nominal secondary current of the current transformers (CTs) monitoring the protected transformer. The relay is shipped with the same rating for all current inputs (except for the tank leakage current input, if ordered). A hardware modification can be made to have the rated currents (1A or 5A) for different current inputs (see Section 17.9 on page 189). If any current input will be rated 5A, order the relay with 5A current inputs.

5.4 Trip Characteristic

As shown in Figure 5.3, current transformers (CTs) measure the currents flowing in and out of the protected transformer. The relay matches the currents by taking into account the characteristics of the motor or generator, as well as the winding ratios of the CTs. The differential protection function then calculates (separately for each phase) the “differential current,” I_{diff}:

$$I_{diff} = \left| I_1' + I_2' \right| \quad (5.1)$$

The differential current, I_{diff}, is a scalar quantity that is the absolute value of the amplitude of the vector sum of the fundamental component of each matched phase-current flowing into the protected motor/generator. In a system composed of ideal components, a non-zero differential current is a certain indication of a fault somewhere within the protected motor/generator.

As described in Section 5.1 on page 67, the non-ideal behavior of a real system may result in a differential current when in fact no fault exists within the protected transformer. In these cases, the differential protection must be restrained. To do so, the relay calculates (separately for each phase) a “restraining current,” I_{rest}:

$$I_{rest} = \left| I_1' \right| + \left| I_2' \right| \quad (5.2)$$

The restraining current, I_{rest}, is the scalar sum of the absolute value of the amplitude of the fundamental component of each matched phase-current flowing into the protected motor/generator. It is proportional to the total amount of current flowing through the motor/generator.

Note that by definition both I_{diff} and I_{rest} are positive values, and that I_{rest} is always greater than or equal to I_{diff}.

To illustrate the use of the restraining current, consider three operating situations for a motor/generator:

- During normal operation, or through fault outside of the protected motor/generator, $I_2' = -I_1'$, therefore:

$$I_{diff} = \left| I_1' + I_2' \right| = \left| I_1' - I_1' \right| = 0 \quad (5.3)$$

$$I_{rest} = \left| I_1' \right| + \left| I_2' \right| = \left| I_1' \right| + \left| -I_1' \right| = 2 \cdot \left| I_1' \right| \quad (5.4)$$

- If there is a short circuit within the protected motor/generator with equal currents entering from each side, $I_2' = I_1'$, so:

$$I_{diff} = \left| I_1' + I_2' \right| = \left| I_1' + I_1' \right| = 2 \cdot \left| I_1' \right| \quad (5.5)$$

$$I_{rest} = \left| I_1' \right| + \left| I_2' \right| = \left| I_1' \right| + \left| I_1' \right| = 2 \cdot \left| I_1' \right| \quad (5.6)$$

- If there is a short circuit within the protected motor/generator with current entering from only one side, $I_2' = 0$, so:

$$I_{diff} = \left| I_1' + I_2' \right| = \left| I_1' + 0 \right| = \left| I_1' \right| \quad (5.7)$$

$$I_{rest} = \left| I_1' \right| + \left| I_2' \right| = \left| I_1' \right| + 0 = \left| I_1' \right| \quad (5.8)$$

Note that for an internal short-circuit fault, $I_{diff} = I_{rest}$.

The differential protection function uses the instantaneous values of I_{diff} and I_{rest} to plot the location of the "operating point" on the trip characteristic shown in Figure 5.3. The shape of the trip characteristic is configured using settings.

The 87M/G function will pickup if either (1) the operating point of any phase moves above 85% of the setting threshold of the trip characteristic for the simultaneous restraining current, or (2) the restraining current of any phase exceeds four times the rated nominal current of the reference winding of the protected transformer ($I_{rest} > 4I_n$). This makes it possible for the saturation-detection algorithms to become active prior to actual trip conditions, as well as for the relay to record waveform data (see Section 14.7 on page 147) for the entire fault event, including during external faults indicated by a high restraining current. The operating point must be on or above the trip characteristic for a trip event to occur.

Individual pickup and trip event annunciations report which phase(s) have picked up or tripped (see Section 5.8 on page 75).

After pickup or trip occurs, the 87M/G function will dropout (or reset) once the operating point stays below 70% of the trip setting for two full cycles.

5.4.1 Trip Characteristic Settings

Constant error currents can result in a small, continuous differential current. To prevent this current from causing a pickup or trip, the differential current, I_{diff}, must be at or above the threshold setting in Address 1703 before an 87M/G trip can occur. This value can be set lower than Address 1603 setting (for transformer protection) since differential currents, due to tap-changers and matching errors, are not expected; however, settings below 0.2 are reasonable only if the CT sets on both sides of the machine are identical and equally burdened.

1703 87 PICKUP
Minimum trip level of the 87M/G differential protection function specified as a fraction (or multiple) of the rated nominal current of the motor/generator, I_n.
Range: 0.05 – 2.00 I_n Default: 0.10

The lower sloped-segment of the trip characteristic (Slope 1) deals with a differential current resulting from transformation errors in the CTs or the current inputs of the relay. The baseline intercept of this segment is the origin; its slope is Address 1706:

1706 87SLOPE 1
Slope of lower sloping segment of 87M/G trip characteristic (Slope 1). This segment intercepts the horizontal axis at the origin.
Range: 0.10 – 0.50 Default: 0.12

The upper sloped-segment of the trip characteristic (Slope 2) provides higher pickup levels in the range of high through currents during normal operation that may cause current transformer saturation. (CT saturation due to a high through current caused by an external fault is dealt with separately, see Section 5.5 on page 74) The baseline intercept and slope are set in addresses 1707 and 1708.

1707 87BASE PT 2
Baseline intercept of the upper sloping segment of 87M/G trip characteristic (Slope 2).
Range: 0.0 – 10.0 I_n Default: 2.5

1708 87SLOPE 2
Slope of upper sloping segment of 87M/G trip characteristic (Slope 2).
Range: 0.25 – 0.95 Default: 0.5

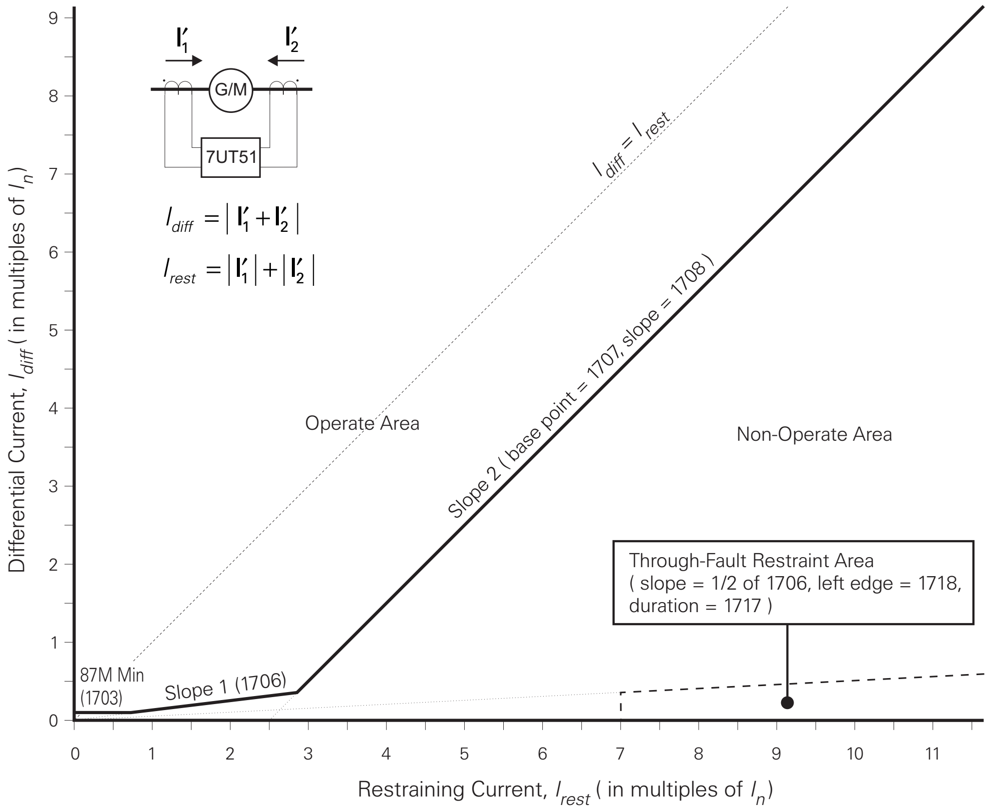


Figure 5.3 *Differential Protection Characteristic for a Motor or Generator*

5.5 Through-Fault Restraint

CT saturation caused by a high-current internal fault (or by long system time constants) affects the differential current, I_{diff}, and the restraining current, I_{rest}, about equally; therefore, the trip characteristic (see Section 5.4 on page 71) can handle this situation. However, a high-current through-fault can cause considerable differential current due to unequal CT saturation at the different CT measuring locations. To restrain tripping in this situation, the differential protection function has a special feature.

High-current external fault is characterized by an initial rise in the restraining current that is much more rapid than the initial rise in the differential current. If the operating point moves quickly (within 0.5 cycle) into the through-fault-detection area shown in Figure 5.3, the 87M/G function will restrained for a configurable duration. The restraint will be released if for two complete cycles the ratio of the differential current to the restraining current is less than 0.9 (that is, the operating point moves up to within 90% of the $I_{diff} = I_{rest}$ line on Figure 5.3), which would indicate an internal fault is evolving during the external fault.

1717 T-SAT-BLK Maximum duration of through-fault CT-saturation restraint of the 87M/G function.
Range: 2 – 250 cycles, or ∞ (until drop-off of pickup) Default: 8 cycles The timer starts when the operating point enters the through-fault restraint area (see Figure 5.3). Enter ∞ for the restraint to continue until dropout of the differential protection pickup.

1718 SAT-RESTR. Minimum restraint current required to activate through-fault CT-saturation restraint. This value sets the left edge of the through-fault restraint area shown in Figure 5.3. The top of the area is a line passing through the origin whose slope is one-half the slope of Slope 1 (Address 1706).
Range: 5.00 – 15.00 I_n Default: 7.00 I_n

5.6 Blocking by Frequency Variance

If the system frequency varies too far from the rated nominal frequency, the motor/generator differential protection will be blocked, as illustrated in Figure 5.4.

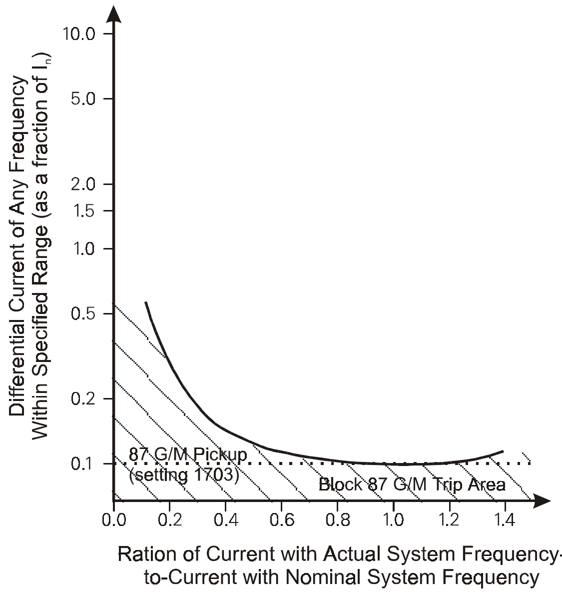


Figure 5.4 *Blocking of Motor/Generator Differential Protection (87M/G) by Variance from Nominal System Frequency.*

5.7 Time Delays

If an 87M/G pickup occurs, the 87M/G function will immediately trip unless a corresponding time delay has been set in Address 1725.

1725 87 DELAY Time delay between pickup and trip for 87 differential protection (in addition to the inherent operating time of the relay).
Range: 0.00 – 60.00 s, or ∞ Default: 0.00 s

To ensure that the trip state lasts long enough for the circuit breaker to operate, the trip state can be prolonged by a reset time delay that is set in Address 1727.

1727 T-RESET Additional time to remain in trip state after the 87 function trip state disappears (in addition to the inherent reset time of the relay).
Range: 0.00 – 60.00 s Default: 0.10 s

5.8 Events and Actions

Table 5.1 describes the events that control and are generated by the 87M/G function. They are listed in the order that they are likely to occur, which is roughly in numerical order by their event identification number (shown in the “Event” column). The text in the “LCD Abbreviation” column is the corresponding text that will appear when viewing logs on the front panel LCD display. In the “Oper” column, a letter “C” or “G” indicates that the “Coming” and/or “Going” events are logged in the Operational Log, while if in the “Fault” column they indicate that the events are logged in the open fault log. A letter in the “In/Out” column indicates that the event can be controlled by a binary-signal input (“I”), control an LED and/or signal contact (“S”), and/or control a trip contact (“T”).

Motor or Generator Differential Protection (87M/G) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Change in Operational Status					
When the operational status of the 87M/G function changes, a going-event for the old status occurs followed by a coming-event for the new status. The normal operational status is set in Address 1701.	87Diff OFF 87Diff BLOCK 87Diff ACTIVE	5615 5616 5617	C G C G C G		S S S
A binary input can temporarily change the operational status of the function (see Section 13.2 on page 126). Any outputs marshalled to these events will remain actuated for as long as the binary input remains actuated.	>87Diff BLOCK >87DiffBlkTrip	5603 5605			I S I S
Pickup and Dropout					
If the operating point of any phase rises above 85% of the setting threshold of the pickup characteristic, or if the restraint current (I_{rest}) exceeds four times rated nominal current (I_n), the 87M/G function will pickup (event 5631C). If no fault log is already open, a new one will open. If the operating point for all phases remains below 70% of the setting threshold of the pickup characteristic for two full cycles, the 87M/G function will dropout (event 5631G). See Section 5.4 on page 71.	87Diff GenFlt	5631		C G	S T
An 87M/G phase-pickup occurs if the operating point of a phase rises above the pickup characteristic. Outputs marshalled to these events will remain actuated until dropout of the corresponding phase.	87Diff PhA 87Diff PhB 87Diff PhC	5681 5682 5683		C C C	S S S

Motor or Generator Differential Protection (87M/G) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Time Delay Before Trip					
If an 87M/G pickup occurs, the corresponding time-delay-before-trip timer will start (see Section 5.7 on page 75). This event will not occur if the time delay setting is zero. Outputs marshalled to this event will remain actuated until the time delay expires (Address 1725).	87Diff Pickup	5621		C	S T
Restraint					
If the motion of the operating point suggests that a high-current fault outside the protected zone is saturating the CTs, the event is reported for each phase. The corresponding going-event occurs when the duration timer (Address 1717) runs out, or the 87M/G function detects that an internal fault is also occurring (see Section 5.5 on page 74).	87Blk SatPhA 87Blk SatPhB 87Blk SatPhC	5651 5652 5653		CG CG CG	S S S
Trip and Reset					
Any 87M/G trip event will also cause event 5671 to occur. With the default marshalling, event 5671 will actuate all the trip contacts, signal contact 2, and (as for the general trip of any protection function) signal contact 1. Outputs actuated by 87M/G trip events will remain actuated until the 87M/G function resets (the same conditions for dropout, event 5631G), plus the additional reset time (Address 1727).	87Diff GenTrip	5671			S T
The 87M/G function will trip if and when ALL the following are true: • an 87M/G pickup has occurred, and it has not yet dropped out or already caused a trip, • the 87M/G time-before-trip time delay (if one is set Address 1725) has expired, • any restraint has ended, There are separate 87M/G trip events for each phase, and one (event 5691) that reports the 87M/G trip of any phase. With the default marshalling, event 5691 will light and latch LED 2 and (as for any protection function trip event) LED 1.	87Diff TripPhA 87Diff TripPhB 87Diff TripPhC 87 Trip	5672 5673 5674 5691		 C	S T S T S T S T
If an 87M/G trip event occurs, the values of the differential currents and restraining currents for each phase at the time of the trip are recorded in the then open fault log.	Diff Ia= *value* Diff Ib= *value* Diff Ic= *value* Rest Ia= *value* Rest Ib= *value* Rest Ic= *value*	5701 5702 5703 5704 5705 5706		C C C C C C	
Configuration Events					
If the motor/generator-description settings are changed, the current-matching factors for the phase currents are recalculated and reported.	k CT 1= *factor* k CT 2= *factor*	5713 5714	C C		

Table 5.1 *Events Related to Differential Protection of a Motor or Generator (87M/G)*

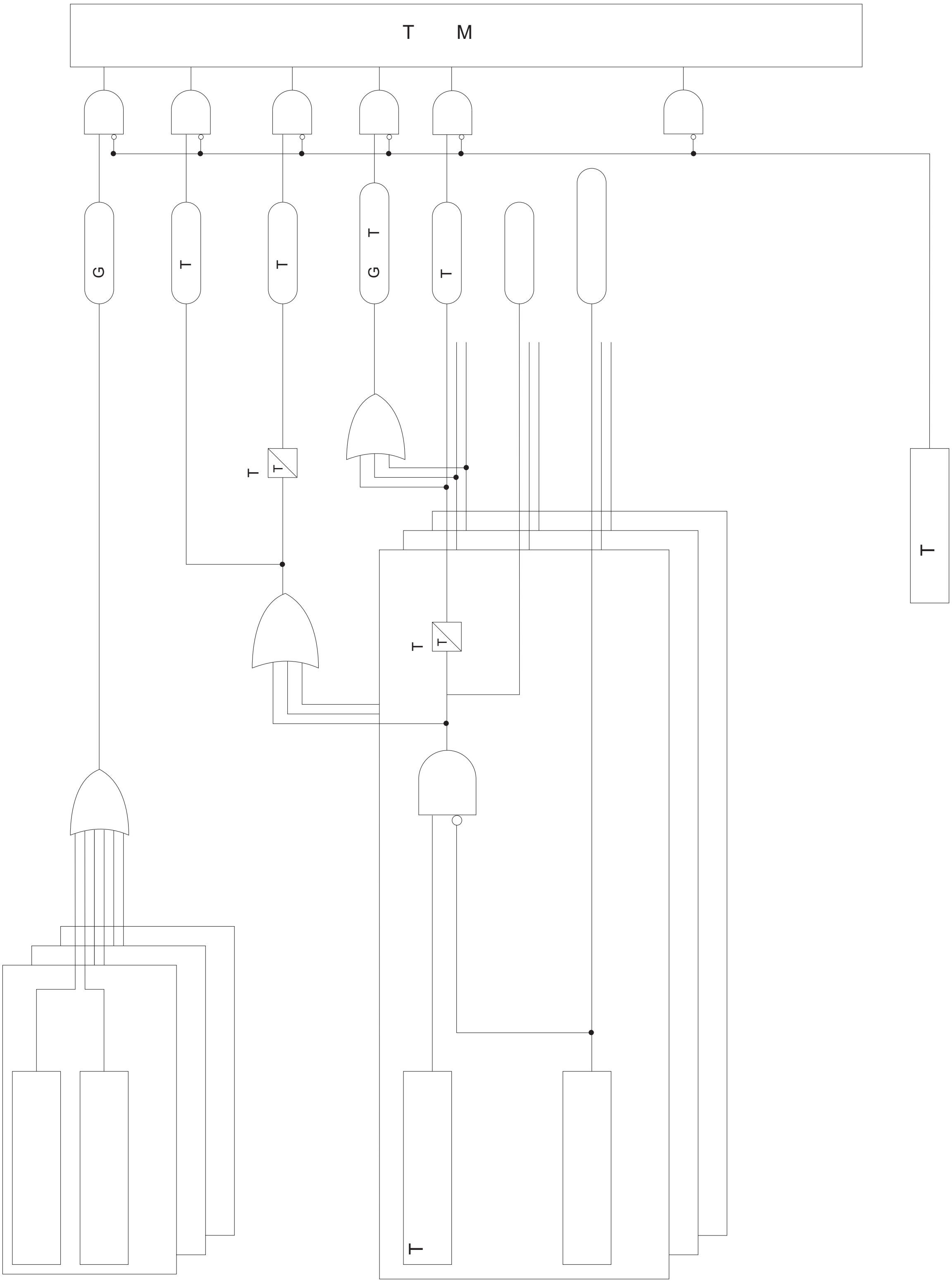


Figure 5.5 *Tripping Logic of Generator or Motor Differential Protection (One Measuring System) - Scheme*

6 Bus Differential Protection (87B)

The bus differential protection function (87B) provides high speed, secure primary protection for faults on a two-branch or three-branch bus. The trip characteristic is configurable; as is restraint based on detection that a through-fault is causing CT saturation, or that a CT circuit is apparently open. The algorithm responds to instantaneous current measurements, and so can often detect a short circuit in less than one cycle.

The relay can also provide ground differential protection (see Chapter 7).

6.1 Method of Operation

Differential protection is an application of Kirchoff's current law — the sum of all the currents entering and leaving a node must be zero. In a system consisting of ideal components, if the sum of all the *measured* currents (called the "differential current") is not zero, then there must exist an *unmeasured* current — a fault.

Since actual applications do not use ideal components the differential protection must take into account the non-ideal behavior of the protected machine, the CTs monitoring it, and the rest of the power distribution system. Specifically:

- A small, constant differential current may exist (due, for example, to a magnetizing current). To prevent pickup due to this current, the relay has a minimum 87B pickup level (see Section 6.4 on page 83).
- A fault outside the protected zone may cause large currents to flow through the protected zone that saturate the CTs. The pickup characteristic is configurable to compensate for this (see Section 6.4 on page 83), while separate settings limit this restraint so that the relay can detect an internal fault that occurs during an external fault (see Section 6.5 on page 85).

If the 7UT51 relay is used as differential protection for busses, all currents are referred to the nominal current of the protected bus. This data is set during device configuration. Thus, if the CTs at the ends of the bus have different primary current, no external matching devices are necessary.

6.2 Describing the Protected Bus

The following information is needed for all types of protected objects and the associated CTs:

- What the protected object is,
- What the nominal secondary rating of the CT is
- What the rated frequency of the protected object is
- The manner in which the ground-current inputs are used (7UT513 only).

This section describes these choices and settings.

6.2.1 Type of Protected Object

The relay uses different settings and algorithms for different types of protected objects. Address 7801 specifies what type of device or equipment is being protected.

7801 PROT.OBJ Type of device or equipment the relay is protecting.	
Option	**Description**
2-WIND-TRANSF	two-winding transformer (see Chapter 4)
3-WIND-TRANSF	three-winding transformer (see Chapter 4)
MOTOR/ GENERATOR	motor or generator (see Chapter 5)
2 ENDED TIE PT.	two-branch bus
3 ENDEDTIE PT.	three-branch bus
1Ph.-TRANSF	single-phase transformer (see Chapter 4)

The relay can protect a three-phase bus with two branches (7UT512 or 7UT513) or three branches (7UT513 only). The protected zone is defined by the location of the CTs (see Figure 6.1 and Figure 6.2). The protected zone should not contain any series or shunt reactors, or any other devices with significant inductance.

A model 7UT513 is required if the protected bus has three branches, or if the application includes measurement of a ground (or neutral) current. A 7UT513 can also be used to protect simultaneously both a two-branch bus and an additional protected device.

6.2.2 System Frequency

The rated nominal frequency of the protected bus must be specified in Address 7899.

7899 FREQUENCY Rated nominal frequency of the protected bus.	
Option	**Description**
FREQ 50 Hz	50 Hertz
FREQ 60 Hz	60 Hertz (default)
FREQ 16 2/3 Hz	16-2/3 Hertz

Note: The choice of frequency affects the availability the auxiliary protection functions. With rated frequency 60Hz, the backup overcurrent time protection or the restricted earth fault protection/tank leakage protection (dependent on the ordered model) can be used besides the differential protection for a bus. If the three-branch bus protection is to be used, only the backup overcurrent time protection is available.

With rated frequency 50Hz, the backup overcurrent time protection or the restricted earth fault protection/ tank leakage protection (dependent on the ordered model) can be used in addition to the differential protection for a bus.

With rated frequency 16 2/3 Hz, no restriction concerning the additional functions are present.

If, during configuration, more functions have been selected than the device is able to process, the relays will give a corresponding message after configuration has been finished. These messages can be read out in the operational annunciations.

6.2.3 Rated Nominal Current

The rated nominal current of the bus, I_n, which is used as the unit of measure for all measured currents must be programmed in the relay.

1301 In TIE-PT Nominal rated current of the protected bus.
Range: 1 – 100,000 A Default: 2000

6.2.4 Normal Operational Status

The bus differential function can be set either to exist or not exist. The choice is made in Address 7816.

7816 87 STATUS Choice of whether bus differential protection function (87B) exists.	
Option	**Description**
EXISTENT	87 function exists (default).
NONEXISTENT	87 function does not exist.

Once the 87B function exists, it can be configured. Its normal operational status is set in Address 1801.

1801 87 STATUS Normal operational status of bus differential protection (87B).	
Option	**Description**
OFF	87B function is inactive (default).
ON	87B function is active.
BLOCK TRIPPING	87B function is active except that trip contacts and signal contacts will not respond to 87B events.

6.3 Describing the CT Scheme

Unlike electromechanical relays, numerical relays do not require a complicated CT scheme to match measured currents. Instead, information about the protected object and the CTs is entered into the relay's memory. Then, using the measured currents, the relay performs any necessary calculations to match the currents. The following CT information is required for input into the relay:

- The nominal *primary* rating of the CTs
- The nominal *secondary* rating of the CTs
- The orientation of the CTs

This section describes these choices and settings.

6.3.1 Nominal Primary Rating of CTs

Specify the primary rated current for each CT set:

1302 In CT 1 (for branch 1) **1304 In CT 2 (for branch 2)** **1306 In CT 3 (for branch 3, 7UT513 only)** Rated primary current of the CTs fitted to each bus branch.
Range: 1 – 100,000 A Default: 2000

6.3.2 Nominal Secondary Rating of CTs

The relay is manufactured with either 1A or 5A current inputs. The choice should match the rated nominal secondary current of the current CTs monitoring the protected bus. The relay is shipped with the same rating for all current inputs (except for the tank leakage current input, if ordered), but a hardware modification can be made to have different rated currents (1A or 5A) for different current inputs (see Chapter 17.9). If any current input will be rated 5A, order the relay with 5A current inputs.

6.3.3 Orientation of CTs

The orientation of the CTs monitoring each branch of the protected bus must be specified in order to ensure that the correct polarity is used when calculating the differential currents:

1303 CT1 STARPT (for branch 1) **1305 CT2 STARPT (for branch 2)** **1307 CT3 STARPT (for branch 3, 7UT513 only)** Orientation of which end of each winding's CTs are connected to the corresponding non-polarity terminal of the relay's phase current inputs. For wye connected CTs, this is the non-polarity ends of the CTs, which are usually connected to a common point (or star-point)	
Option	**Description**
TOWARDS BUSBAR	Towards the busbar
TOWARDS LINE	Towards the line.

For example, if terminal 3A2 (non-polarity, phase A input of Winding 1) is connected to the end of the CT closest to the busbar, Address 1303 should be set to "**Towards Busbar**."

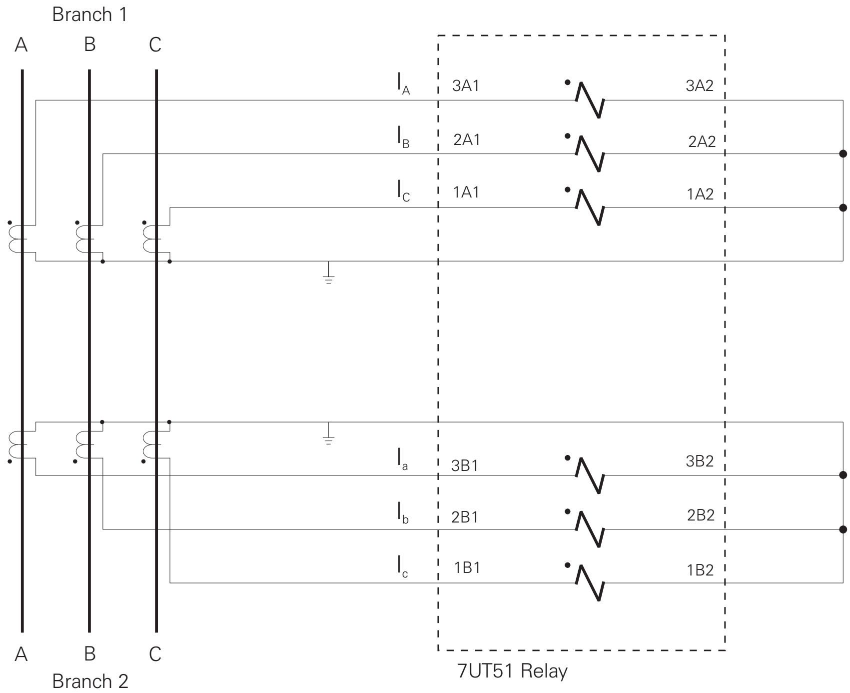


Figure 6.1 *Typical CT Wiring for a Bus with Two Branches*

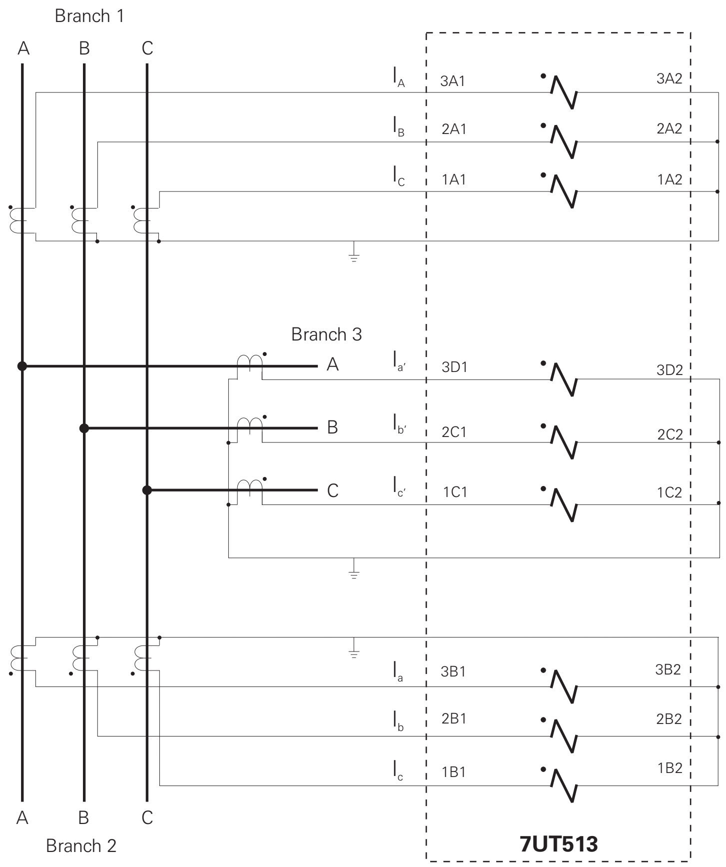


Figure 6.2 *Typical CT Wiring for a Bus with Three Branches*

6.4 Trip Characteristic

As shown in Figure 6.1, Figure 6.2, and Figure 6.3, CTs measure the currents flowing into and out of the protected zone of the bus. The relay matches the currents by taking into account the characteristics of the bus, as well as the winding ratios of the CTs. Then the differential protection function calculates (separately for each phase) the “differential current,” I_{diff}:

$$I_{diff} = | I'_1 + I'_2 | \quad \text{(two branch bus)} \qquad (6.1)$$

$$I_{diff} = | I'_1 + I'_2 + I'_3 | \quad \text{(three branch bus)} \qquad (6.2)$$

The differential current, I_{diff}, is a scalar quantity that is the absolute value of the amplitude of the vector sum of the fundamental component of each matched phase-current flowing into the protected zone of the bus. In a system composed of ideal components, a non-zero differential current is a certain indication of a fault somewhere within the protected zone.

As described in Section 6.1 on page 79, the non-ideal behavior of a real system may result in a differential current when in fact no fault exists within the protected transformer. In these cases, the differential protection must be restrained. To do so, the relay calculates (separately for each phase) a “restraining current,” I_{rest}:

$$I_{rest} = |I'_1| + |I'_2| \quad \text{(two branch bus)} \qquad (6.3)$$

$$I_{rest} = |I'_1| + |I'_2| + |I'_3| \quad \text{(three branch bus)} \qquad (6.4)$$

The restraining current, I_{rest}, is the scalar sum of the absolute value of the amplitude of the fundamental component of each matched phase-current flowing into the protected zone of the transformer. It is proportional to the total amount of current flowing through the bus.

Note: To illustrate the use of the restraining current, consider three operating situations for a two-branch bus:

- During normal operation, or if there is a fault outside of the protected zone, $I'_2 = -I'_1$, so:

$$I_{diff} = | I'_1 + I'_2 | = | I'_1 - I'_1 | = 0 \qquad (6.5)$$

$$I_{rest} = |I'_1| + |I'_2| = |I'_1| + |-I'_1| = 2 \cdot |I'_1| \qquad (6.6)$$

- If there is a short circuit within the protected zone with equal currents entering from each side, $I'_2 = I'_1$, so:

$$I_{diff} = | I'_1 + I'_2 | = | I'_1 + I'_1 | = 2 \cdot |I'_1| \qquad (6.7)$$

$$I_{rest} = |I'_1| + |I'_2| = |I'_1| + |I'_1| = 2 \cdot |I'_1| \qquad (6.8)$$

- If there is a short circuit within the protected zone with current entering from only one side, $I'_2 = 0$, so:

$$I_{diff} = | I'_1 + I'_2 | = | I'_1 + 0 | = |I'_1| \qquad (6.9)$$

$$I_{rest} = |I'_1| + |I'_2| = |I'_1| + 0 = |I'_1| \qquad (6.10)$$

Note: For an internal short-circuit fault, $I_{diff} = I_{rest}$.

The differential protection function uses the instantaneous values of I_{diff} and I_{rest} to plot the location of the “operating point” on the trip characteristic shown in Figure 6.3. The shape of the trip characteristic is configured using the settings described in Section 6.4.1 on page 84.

The 87T or 87HS function will pickup if either (1) the operating point of any phase moves above 85% of the threshold of the trip characteristic for the simultaneous restraining current, or (2) the restraining current of any phase exceeds four times the rated nominal current of the reference winding of the protected transformer ($I_{rest} > 4I_n$). This makes it possible for the saturation-detection algorithms to become active prior to actual trip conditions, as well as for the relay to record waveform data (see Chapter 14.7) for the entire fault event, including during external faults indicated by a high restraining current. The operating point must be on or above the trip characteristic for a trip event to occur. Individual pickup and trip events report which phase(s) have picked up or tripped (see Section 6.8 on page 86).

The 87T or 87HS function will dropout (or reset) after a pickup (or trip) when for two full cycles the operating point stays below 70% of the threshold of the trip characteristic for the simultaneous restraining current.

6.4.1 Trip Characteristic Settings

Constant error currents can result in a small, continuous differential current. To prevent this current from causing a pickup or trip, the differential current, I_{diff}, must be at or above the threshold in Address 1803 before an 87B trip can occur.

1803 87 PICKUP Minimum differential-current that can cause an 87B trip, specified as a multiple of the rated nominal current of the bus (Address 1301).
Range: 0.30 – 2.50 I_n Default: 1.00 I_n

The lower sloped-segment of the trip characteristic (Slope 1) deals with a differential current resulting from transformation errors in the CTs or the current inputs of the relay. The baseline intercept of this segment is the origin; its slope is Address 1806:

1806 87SLOPE 1 Slope of lower sloping segment of 87B trip characteristic (Slope 1). This segment intercepts the horizontal axis at the origin.
Range: 0.10 – 0.50 (unitless ratio) Default: 0.25

The upper sloped-segment of the trip characteristic (Slope 2) provides higher pickup levels in the range of high through currents during normal operation that may cause CT saturation. (CT saturation due to a high through current caused by an external fault is dealt with separately, see Section 6.5 on page 85) The baseline intercept and slope are set in addresses 1807 and 1808, respectively.

1807 87BASE PT 2 Baseline intercept of the upper sloping segment of 87B trip characteristic (Slope 2).
Range: 0.0 – 10.0 I_n Default: 2.5 I_n

1808 87SLOPE 2 Slope of upper sloping segment of 87B trip characteristic (Slope 2).
Range: 0.25 – 0.95 (unitless ratio) Default: 0.50

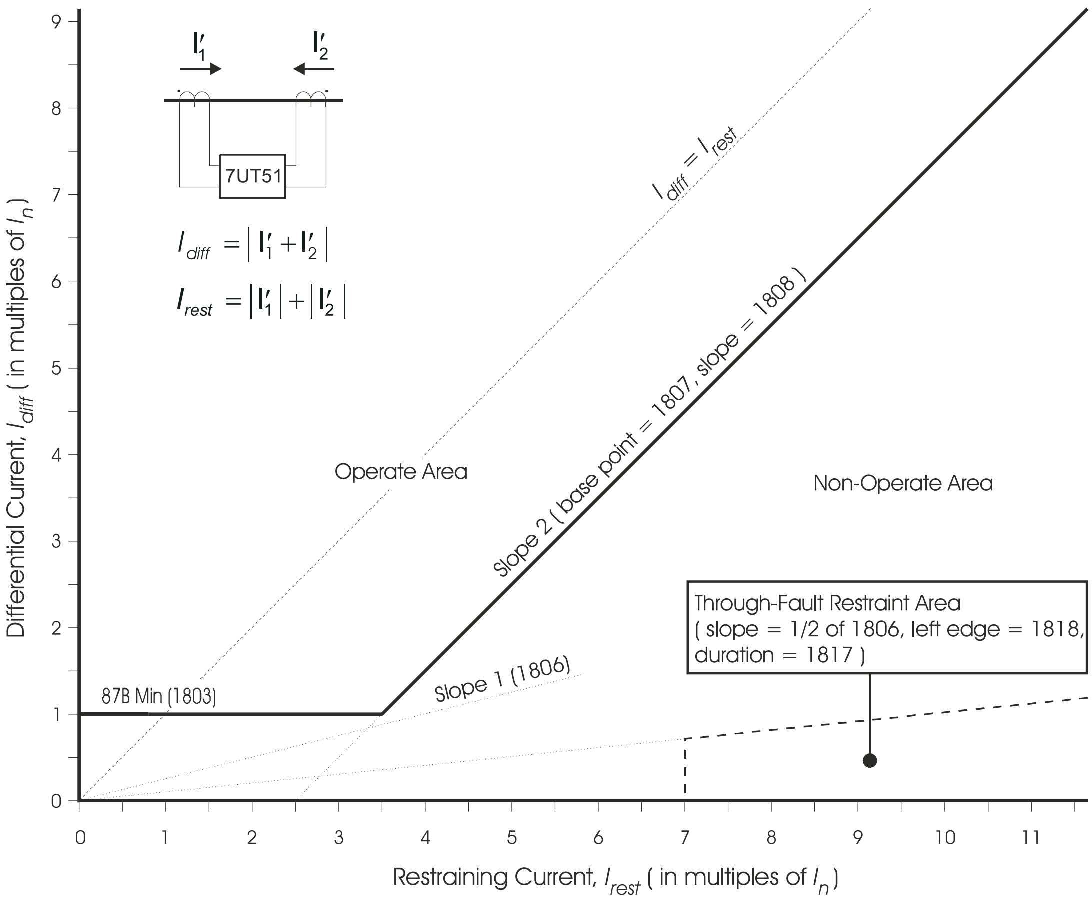


Figure 6.3 *Differential Protection Characteristic for a Bus*

6.5 Through-Fault Restraint

CT saturation caused by a high-current internal fault (or by long system time constants) affects the differential current, I_{diff}, and the restraining current, I_{rest}, about equally; however, a high-current through-fault can cause considerable differential current due to unequal CT saturation at the different CT measuring locations. For this situation, the differential protection function can be configured to achieve the desired tripping restraint.

A high-current external fault is characterized by an initial rise in the restraining current that is much more rapid than the initial rise in the differential current. If the operating point moves quickly (within 0.5 cycle) into the through-fault-detection area shown in Figure 6.3, the 87B function will restrained for a configurable duration. The restraint will be released if, for two complete cycles, the ratio of the differential current to the restraining current is less than 0.9 (that is, the operating point moves up to within 90% of the $I_{diff} = I_{rest}$ line on Figure 6.3), which would indicate an internal fault is evolving during the external fault.

1817 T-SAT-BLK Maximum duration of through-fault CT-saturation restraint of the 87B function.
Range: 2 – 250 cycles, or ∞ (until drop-off of pickup) Default: 8 cycles The timer starts when the operating point enters the through-fault restraint area (see Figure 6.3). Enter ∞ for the restraint to continue until dropout of the differential protection pickup.

1818 SAT-RESTR. Minimum restraint current required to activate through-fault CT-saturation restraint. This value sets the left edge of the through-fault restraint area shown in Figure 6.3. The top of the area is a line passing through the origin whose slope is one-half the slope of Slope 1 (Address 1806).
Range: 5.00 – 15.00 I_n Default: 7.00 I_n

6.6 CT Circuit Monitoring

The differential currents of each phase are continuously monitored on a low level. If a differential current flows (during normal load conditions) that corresponds to the load current of a feeder, (indicating a missing secondary current) a fault is in the secondary current leads. This occurrence will provide alarm annunciation and block the differential protection of the concerned phases.

The low-level monitor current pickup value should be high enough to avoid a false pick up due to transformation errors or tolerances of the current matching when the rated CT currents are different:

1831 87 MON PU Fault current during a fault in a CT's secondary leads, expressed as a multiple of the rated nominal current of the bus (Address 1301).
Range: 0.15 – 0.80 I_n Default: 0.20

The low-level monitor alarm delay must be considerably longer than the delay-before-trip time (Address 1825) to ensure that the differential protection is not blocked during a real fault in the network.

1832 87 MON DLY Time delay for fault in secondary CT leads
Range: 1 – 10 s, or ∞ Default: 2 Enter ∞ for the 87B function to never be blocked by a CT circuit problem.

For information about the other protection-monitoring features of the relay, see Chapter 12.

6.7 Time Delays

If an 87B pickup occurs, the 87B function will immediately trip unless a time delay has been set in Address 1825.

1825 87 DELAY Time delay between pickup and trip for 87B differential protection (in addition to the inherent operating time of the relay).
Range: 0.00 – 60.00 s, or ∞ Default: 0.00 s The special value ∞ will prevent any 87B trip event from ever occurring.

If an 87B trip occurs, the contacts and LEDs marshalled to the event will remain activated until the 87B function drops out. To ensure that the trip state lasts long enough for the circuit breaker to operate, the trip state can be prolonged by a reset time delay (Address 1827).

1827 87T-RESET Reset delay after trip signal has disappeared (in addition to the inherent reset time of the relay).
Range: 0.00 – 60.00 s Default: 0.10 s

6.8 Events and Actions

This table describes the events that control and are generated by the 87B function. They are listed in the order that they are likely to occur, which is roughly in numerical order by their event identification number (shown in the "Event" column). The text in the "LCD Abbreviation" column is the corresponding text that will appear when viewing logs on the front panel LCD display. In the "Oper" column, a letter "C" or "G" indicates that the "Coming" and/or "Going" events are logged in the Operational Log, while if in the "Fault" column they indicate that the events are logged in the open fault log. A letter in the "In/Out" column indicates that the event can be controlled by a binary-signal input ("I"), control an LED and/or signal contact ("S"), and/or control a trip contact ("T").

Figure 6.4 on page 89 shows the logic of these events.

Bus Differential Protection (87B) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Change in Operational Status					
When the operational status of the 87B function changes, a going-event for the old status occurs followed by a coming-event for the new status. The normal operational status is set in Address 1801.	87Diff OFF 87Diff BLOCK 87Diff ACTIVE	5615 5616 5617	CG CG CG		S S S
A binary input can temporarily change the operational status of the function (see Section 13.2 on page 126). Any outputs marshalled to these events will remain actuated for as long as the binary input remains actuated.	>87Diff BLOCK >87DiffBlkTrip	5603 5605			I S I S
If an open CT-circuit is detected, the 87B protection of the corresponding phase will be temporarily turned off.	87Blk CTPhA 87Blk CTPhB 87Blk CTPhC	5662 5663 5664	CG CG CG		S S S
Pickup and Dropout					
If the operating point of any phase rises above 85% of the threshold of the pickup characteristic, or if the restraint current (I_{rest}) exceeds four times rated nominal current (I_n), the 87B function will pickup (event 5631C). If no fault log is already open, a new one will open. If the operating point for all phases remains below 70% of the threshold of the pickup characteristic for two full cycles, the 87B function will dropout (event 5631G). See Section 6.4 on page 83.	87Diff GenFlt	5631		CG	S T
An 87B phase-pickup occurs if the operating point of a phase rises above the pickup characteristic. Outputs marshalled to these events will remain actuated until dropout of the corresponding phase.	87Diff PhA 87Diff PhB 87Diff PhC	5681 5682 5683		C C C	S S S
Time Delay Before Trip					
If an 87B pickup occurs, the corresponding time-delay-before-trip timer will start (see Section 6.7 on page 86). This event will not occur if the time delay setting is zero. Outputs marshalled to this event will remain actuated until the time delay expires.	87Diff Pickup	5621		C	S T
Restraint					
If the motion of the operating point suggests that a high-current fault outside the protected zone is saturating the CTs, the event is reported for each phase. The corresponding going-event occurs when the duration timer (Address 1817) runs out, or the 87M function detects that an internal fault is also occurring (see Section 6.5 on page 85).	87Blk SatPhA 87Blk SatPhB 87Blk SatPhC	5651 5652 5653		CG CG CG	S S S

Bus Differential Protection (87B) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Trip and Reset					
Any 87B trip event will also cause event 5671 to occur. With the default marshalling, event 5671 will actuate all the trip contacts, signal contact 2, and (as for the general trip of any protection function) signal contact 1. Outputs actuated by 87B trip events will remain actuated until the 87B function resets (the same conditions for dropout, event 5631G), plus the additional reset time (Address 1827).	87Diff GenTrip	5671		CG	S T
The 87B function will trip if and when ALL the following are true: • an 87B pickup has occurred, and it has not yet dropped out or already caused a trip, • the 87B time-before-trip time delay (if there is one) has expired, • any restraint has ended, There are separate 87B trip events for each phase, and one (event 5691) that reports the 87B trip of any phase. With the default marshalling, event 5691 will light and latch LED 2 and (as for any protection function trip event) LED 1.	87Diff TripPhA 87Diff TripPhB 87Diff TripPhC 87 Trip	5672 5673 5674 5691		C C C C	S T S T S T S T
If an 87B trip event occurs, the values of the differential currents and restraining currents for each phase at the time of the trip are recorded in the then open fault log.	Diff Ia= *value* Diff Ib= *value* Diff Ic= *value* Rest Ia= *value* Rest Ib= *value* Rest Ic= *value*	5701 5702 5703 5704 5705 5706		C C C C C C	
Configuration Events					
If the bus-description settings are changed, the current-matching factors for the phase currents are recalculated and reported.	k CT 1= *factor* k CT 2= *factor* k CT 3= *factor*	5713 5714 5715	C C C		

Table 6.1 *Events Related to Differential Protection of a Bus (87B)*

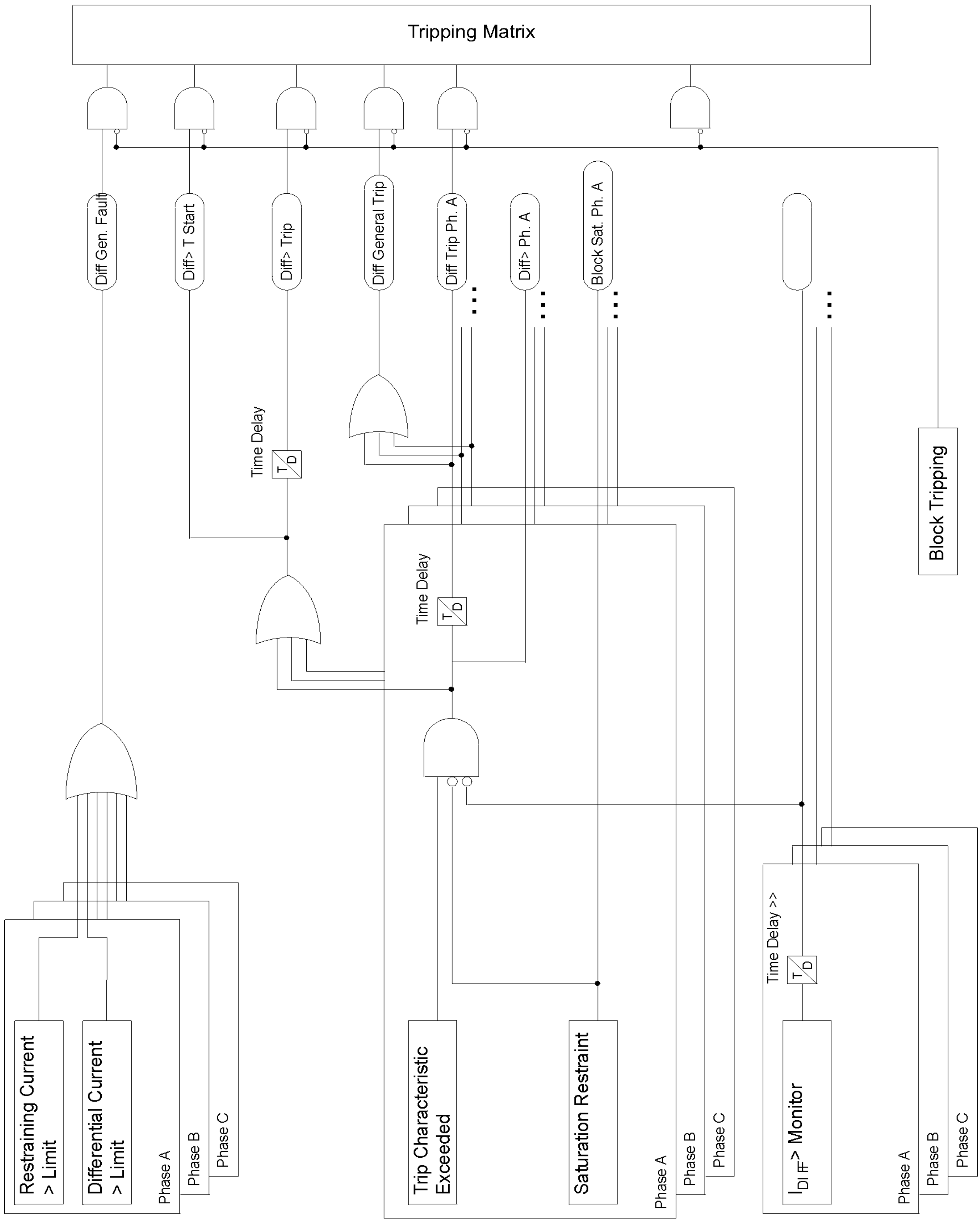


Figure 6.4 *Tripping Logic of Bus Differential Protection*

7 Ground Differential Protection (87N)

The 7UT513 relay can be ordered with a ground differential protection function (87N) to protect power transformers, shunt reactors, neutral grounding transformers, or rotating machines with a common point that is connected to an earth ground.

The ground differential protection function is highly sensitive, regardless of the phase angle between the ground current and 3Io. Even internal faults causing heavy CT saturation problems can be detected by the relay.

Ground differential protection protects one winding by comparing the calculated zero sequence current to the measured ground current of the winding. The application settings are simplified so that the many time consuming commissioning test and fine adjustments, necessary for the classical ground-differential solutions (using directional overcurrent relays), are avoided.

The low-impedance ground differential protection algorithm is base on Kirchoff's law. The information provided to the algorithm is sampled values of the phase current and the ground current.

Using the known phase and ground CT ratio information, specified in the relay settings, the sampled current values are normalized relative to the nominal current of the protected transformer winding, I_n.

Note that when protecting a 60Hz object, the relay can provide ground differential protection if the protected object has one or two windings (or sides), but not three. If desired, the ground differential protection function can protect a separate, additional object instead of the main protected object.

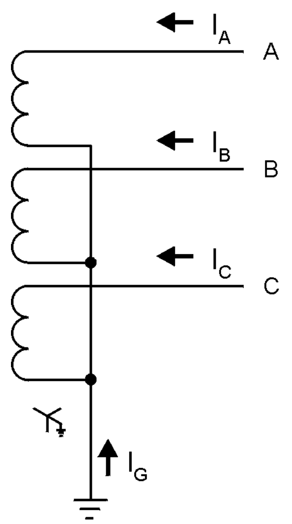


Figure 7.1 *Ground Differential Protection of a Wye-Winding*

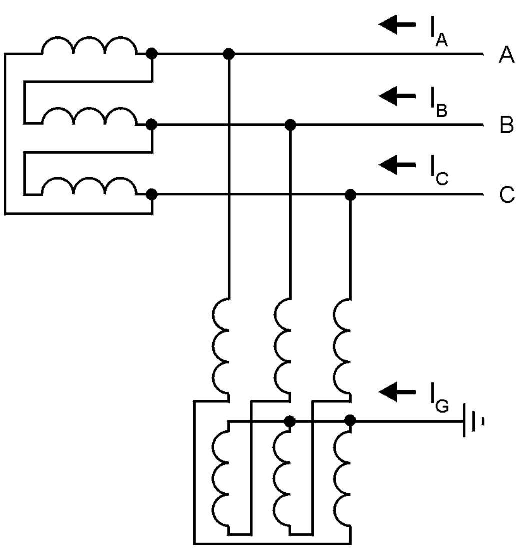


Figure 7.2 *Ground Differential Protection of a Delta Winding with an Artificial Common Point*

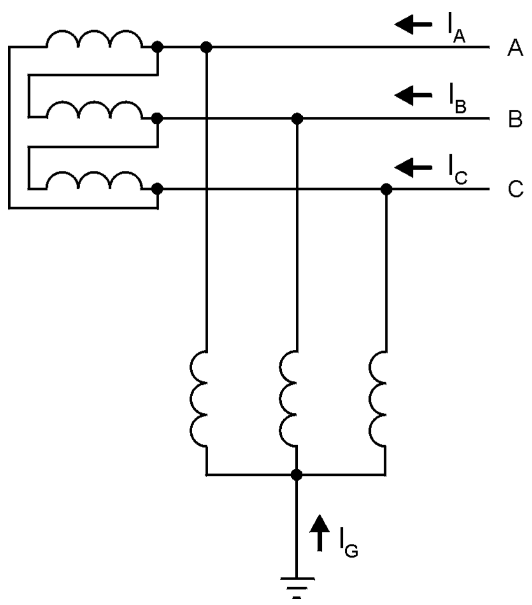


Figure 7.3 *Ground Differential Protection of a Delta Winding with a Shunt Reactor*

7.1 Calculated Quantities

The restraining current, I_R, is the scalar sum of the separate amplitudes of the measured phase and ground currents. It is a measure of the total amount of current flowing through the transformer, regardless of whether the currents are balanced. It is calculated according to equation 7.1 and equation 7.2:

$$i_R(k) = |i_A(k)| + |i_B(k)| + |i_C(k)| + |i_G(k)| \qquad (7.1)$$

$$I_R(n) = \frac{1}{N}\sum_{k=0}^{N-1} i_R(n-k) \qquad (7.2)$$

where N is the number of samples taken during each power system cycle, while $i_A(k)$, $i_B(k)$, $i_C(k)$, and $i_G(k)$ are the sampled and normalized values of the phase and ground currents.

The fundamental vector of the ground current, I_G, is calculated using Fourier analysis:

$$I_G(n) = \sqrt{[\mathrm{Re}\,(I_G(n))]^2 + [\mathrm{Im}\,(I_G(n))]^2} \qquad (7.3)$$

$$\mathrm{Re}(I_G(n)) = \frac{2}{N}\sum_{k=0}^{N-1} i_G(n-k)\cos(2\pi\frac{k}{N}) \qquad (7.4)$$

$$\mathrm{Im}(I_G(n)) = \frac{2}{N}\sum_{k=0}^{N-1} i_G(n-k)\sin(2\pi\frac{k}{N}) \qquad (7.5)$$

Two calculated current vectors, $\vec{I}_0^{*}$ and $\vec{I}_0^{**}$, are the major components of the algorithm:

$$\vec{I}_0^{*} = \vec{I}_G \qquad (7.6)$$

$$\vec{I}_0^{**} = \vec{I}_A + \vec{I}_B + \vec{I}_C = 3\vec{I}_0 \qquad (7.7)$$

Both quantities are calculated using the Fourier-analysis algorithm described in equation 7.3, equation 7.4, and equation 7.5.

The differential current, I_D, is by definition the amplitude of the vector-difference of the measured ground current and the calculated zero sequence current. By convention, any current flowing into the protected equipment is considered to have a positive magnitude; so I_D is calculated using the following equation:

$$I_D = |\vec{I}_0^{*} + \vec{I}_0^{**}| \qquad (7.8)$$

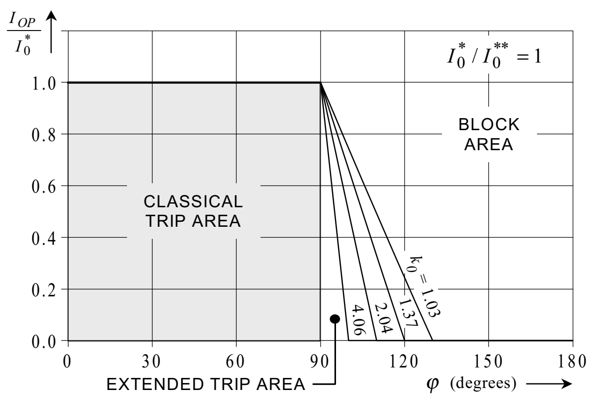


Figure 7.4 *Trip Area for I*o/Io**=1*

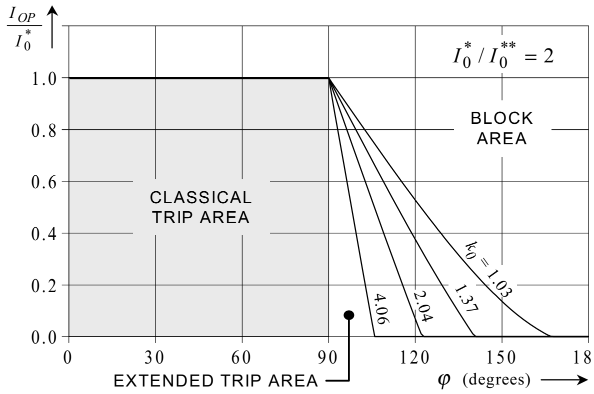


Figure 7.5 *Trip Area for I*o/Io** = 2*

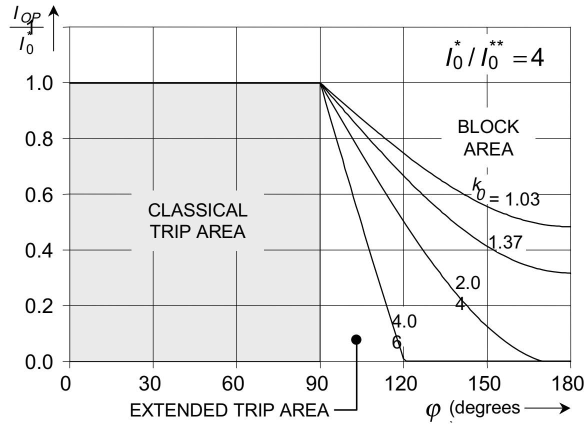


Figure 7.6 *Trip Area for I*o/Io**=4*

Fault Detection

The algorithm detects that a fault has occurred if the differential current, I_D, exceeds a relay setting (indicating that the ground current and zero sequence current differ too much), or if the restraining current, I_R, exceeds another relay setting (indicating that the total amount of current flowing through the transformer is too high). Once a fault has been detected, further analysis occurs. As with the classical solution, the question to be answered is whether the fault is internal (requiring a trip) or external (not requiring a trip).

7.2 Trip Decision

In theory, an external fault can be easily recognized since the calculated quantities I_0* and I_0** will have equal magnitudes and a phase angle difference of φ = 90°. In reality, inrush effects or CT-saturation may distort the measured currents. CT-saturation can affect both the perceived amplitudes of the fundamental current vectors and the phase angle between them.

Classical Trip Area: The algorithm calculates a value called the “stabilization current,” I_{STAB}:

$$I_{STAB} = \left|\vec{I}_0^* - \vec{I}_0^{**}\right| - \left|\vec{I}_0^* + \vec{I}_0^{**}\right| \quad (7.9)$$

Vector analysis can show that the amplitude of the stabilization current, I_{STAB}, will be negative if the phase angle φ between I_0* and I_0** is in the range –90° ≤ φ ≤ 90°. In this case, the fault is internal, so a trip is appropriate if the amplitude of a calculated “operating current,” I_{OP}, is above a minimum level (a relay setting):

$$I_{OP} = I_0^* \quad \text{(if } -90° \le \varphi \le 90°\text{)} \quad (7.10)$$

Trip if $I_{OP} \ge I_{Trip\_SET}$ (if –90° ≤ φ ≤ 90°) (7.11)

Extended Trip Area: The algorithm *extends the trip area* to recognize internal faults that the classical solution will fail to respond to, while still avoiding an improper trip if the fault is external.

If the phase angle φ is in the range 90° ≤ φ ≤ 270° (outside the classical trip area), the magnitude of I_{STAB} will be positive. In this case, the algorithm still bases the trip decision on the amplitude of the operating current, I_{OP}, but calculates I_{OP} differently:

$$I_{OP} = I_0^* - k_0 I_{STAB} \quad \text{(if } 90° \le \varphi \le 270°\text{)} \quad (7.12)$$

Trip if (if 90° ≤ φ ≤ 270°) (7.13)

where k_0, the “stabilization factor,” is a relay setting used to adjust the sensitivity of the protection when 90° ≤ φ ≤ 270°. Note that when φ is in that range, I_{OP} is a function of *four* quantities: the amplitudes of the currents $\vec{I}_0^*$ and $\vec{I}_0^{**}$, the phase angle between them, and the stabilization factor, k_0:

$$I_{OP} = f\left(k_0, \varphi, I_0^*, I_0^{**}\right)$$

Since only the ratio of I_0* to I_0** is of interest, one can imagine graphing I_{OP} as a three-dimensional surface where the dimensions correspond to I_{OP} / I_0**(the normalized value of I_{OP}), φ, and I_0* / I_0**. Different values of k_0 would correspond to different plotted surfaces. Figure 7.4, Figure 7.5, and Figure 7.6 show as graphs three cross-sections of such a plot. Each graph corresponds to one value of I_0* / I_0**, with the vertical axis corresponding to I_{OP}/I_0* and the horizontal axis corresponding to φ. (Only the range 0° ≤ φ ≤ 180° needs to be shown because of phase-angle symmetry). The different curves plotted correspond to different values of k_0 (a setting).

The interpretation of these graphs will now be explained.

For any particular combination of I_0*, I_0** and k_0 values, the value of the operating current, I_{OP}, is affected by φ (the phase angle between $\bar{I}_0^*$ and $\bar{I}_0^{**}$) in the following way. If φ is ±90°, the amplitude of the stabilization current, I_{STAB}, will be zero, and equation 7.12 will yield the same value as equation 7.10, the classical solution. However, as the phase angle φ increases into the range 90° ≤ φ ≤ 270°, the stabilization current I_{STAB} will become larger, and so the operating current I_{OP} will become smaller (equation 7.12).

If φ is in the range –90° ≤ φ ≤ 90°, then I_{OP} is equal to I_0* (by definition). This is the same behavior as for the classical protection solution, so the area is labeled the “Classical Trip Area.”

The algorithm extends the area in which a trip will be allowed. Unlike the classical solution, a trip can still occur even if φ is greater than 90° (further to the right on the graph). It is very important to realize that the curved boundary of the extended trip area moves while the relay is operating. At all times, the instantaneous values of the normalized operating current value, I_{OP} / I_0**, and the phase angle, φ, will plot to a point somewhere *on* the curve corresponding to the value of the “stabilization factor,” k_0. In Figure 7.4, Figure 7.5, and Figure 7.6 the curved boundary of the extended trip area is plotted for several values of k_0.

Compare Figure 7.4, Figure 7.5, and Figure 7.6 to see how, as the ratio of I_0* to I_0** increases, the extended trip area becomes larger. This is appropriate since a larger ratio means that the measured ground current is becoming much larger than the calculated zero sequence current. Hence, it is more likely that the fault is internal than that it is external, even if CT saturation is distorting the value of the perceived phase angle between the currents.

For any given combination of the stabilization factor, k_0, and ratio of the current amplitudes, I_0* / I_0**, there exists a maximum phase angle φ_{MAX} at which the operating current I_{OP} reaches the value zero. If the phase angle φ is greater than φ_{MAX}, the operating current I_{OP} would be negative. To handle this, the algorithm changes any negative value for I_{OP} to zero, so no trip occurs.

Address 1904 lists the corresponding value of φ_{MAX} for values of k_0 when I_0* / I_0** = 1.

7.3 Second Harmonic Restraint

The amplitude of the second harmonic of the differential current, ID (equation 7.8), is calculated to detect the effect of inrush. If this amplitude exceeds a corresponding setting (typically 15% of the fundamental value of ID), the trip signal will be blocked. But, if an internal fault with CT-saturation occurs during inrush, the trip signal must not be blocked. This situation is handled by disabling second-harmonic blocking if the magnitude of the fundamental component of the differential current ID exceeds a separate setting (typically ten-times the nominal current of the transformer winding that the ground differential algorithm is protecting).

The restraint can be limited to a specified time duration, or to a maximum ground current magnitude (see Section 7.6 on page 96).

If the operating point remains below 70% of the trip threshold settings for two full cycles, the 87N function will dropout (reset).

7.4 Normal Operational Status

Like the other protection functions, the ground differential function (87N) can be set either to exist or not exist. If it exists, it monitors the ground current of the object specified in Address 7819.

7819 REF PROT. Existence and monitored winding of the ground differential protection function (87N). The relay must be a 7UT513 that was ordered with the ground differential protection option.	
Option	**Description**
DISABLED	87N function does not exist (default).
WINDING 1	87N function exists and monitors Winding 1 of the protected object.
WINDING 2	87N function exists and monitors Winding 2 of the protected object.
WINDING 3	87N function exists and monitors Winding 3 of the protected object.
VIRTUAL OBJECT	87N function exists and monitors a separate, “virtual” object.

Once made existent, the 87N function can be configured. Its normal operational status is set in Address 1901.

1901 RGF STATUS Normal operational status of ground differential protection (87N).	
Option	**Description**
OFF	87N function is inactive (default).
ON	87N function is active.
BLOCK TRIPPING	87N function is active except that trip contacts and signal contacts will not respond to 87N trip events.

7.5 Pickup Level and Limit Angle

The critical limit angle (Address 1904) determines the restraint of the protection. It indicates at which phase displacement (between the common current and the sum of the phase currents) the restraint grows to infinity when the currents are the same magnitude and flow through the protected object. An angle of 180° means that the currents have equal phase because of the definition that all currents entering the protected zone are positive. The smaller the critical limit angle, the higher the restraint. The preset critical limit angle corresponds to a restraint factor k = 1 in the restraint equation.

1904 CRIT.ANGLE Critical limit angle for absolute restraint during through-flowing ground current	
Option	**Description**
90°	corresponds to restraint factor $k \to \infty$
100°	corresponds to restraint factor $k \approx 4$
110°	corresponds to restraint factor $k \approx 2$
120°	corresponds to restraint factor $k \approx 1.4$
130°	corresponds to restraint factor $k \approx 1$

7.6 Harmonic Restraint

Harmonic restraint of the 87N function during transformer energization can be turned off or on (Address 1910). It is based on the evaluation of the second harmonic content of the inrush current. Since the inrush current is a through-flowing current, as registered by the restricted ground-fault protection, it is preset to **OFF**. For exceptional conditions it can be switched on (Address 1910), and the second harmonic content which is necessary to block the protection can be configured (Address 1911).

1910 HARMN RSTR Inrush restraint with second harmonic protection	
Option	**Description**
OFF	turned off (default)
ON	turned on

1911 %2nd HARMN Amount of second-harmonic content in the ground-differential current that will block the 87N function (specified as a percentage of the fundamental component of the ground-differential current).
Range: 10 – 80% Default: 15%

If the differential current exceeds a certain multiple of the rated current of the protected object (Address 1912) no more restraint of the second harmonic takes place.

1912 I RGF max 2 Upper limit of the second harmonic restraint current above which restraint does not occur, specified as a multiple of the rated current of the protected object.
Range: 1.0 – 20.0 I_n Default: 10.0 I_n

7.7 Time Delays

If an 87N pickup occurs, the function will immediately trip unless a time delay has been set in Address 1925.

1925 Tdly-RGF Time delay between pickup and trip for 87N ground differential function (in addition to the inherent operating time of the relay).
Range: 0.00 – 60.00 s or ∞ Default: 0.00

If an 87N trip occurs, the function will reset when the same conditions occur that would cause the function to dropout. The time before reset (the “dwell time”) can be extended to ensure that the trip state lasts long enough for the circuit breaker to operate by specifying a time delay in Address 1927.

1927 T-RESET Reset delay after trip signal has disappeared (in addition to the inherent reset time of the relay).
Range: 0.00 – 60.00 s Default: 0.10 s

7.8 Events and Actions

Table 7.1 on page 97 describes the events that control and are generated by the 87N function. They are listed in the order that they are likely to occur, which is roughly in numerical order by their event identification number (shown in the “Event” column). The text in the “LCD Abbreviation” column is the corresponding text that will appear when viewing logs on the front panel LCD display. In the “Oper” column, a letter “C” or “G” indicates that the “Coming” and/or “Going” events are logged in the Operational Log, while if in the “Fault” column they indicate that the events are logged in the open fault log. A letter in the “In/Out” column indicates that the event can be controlled by a binary-signal input (“I”), control an LED and/or signal contact (“S”), and/or control a trip contact (“T”).

Ground Differential Protection (87N) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Change in Operational Status					
When the operational status of the 87N function changes, a going-event for the old status occurs followed by a coming-event for the new status. The normal operational status is set in Address 1901.	RGFOFF RGF ACTIVE RGF BLOCK	5811 5813 5812	CG CG CG		S S S
A binary input can temporarily change the operational status of the function (see Section 13.2 on page 126). Any outputs marshalled to these events will remain actuated for as long as the binary input remains actuated.	>RGF BLOCK >RGF BlkTrip	5803 5805			I S I S
Pickup and Dropout					
The 87N function will pickup (event 5817C) if the measured ground current I_g reaches or exceeds 75% of the pickup threshold (Address 1903). If no fault log is already open, a new one will open. The function will dropout (event 5817G) if I_g drops below 70% of the pickup threshold.	RGF GenFlt	5817		CG	S T
Time Delay Before Trip					
If a pickup occurs, the time-to-trip delay starts. If the delay (Address 1925) is zero, this event does not occur.	RGF T Start	5816		C	S T
Trip and Reset					
The 87N function will trip if and when all the following are true: • an 87N pickup has occurred, and it has not yet dropped out or already caused a trip, • the 87N restraining current (I_{rest}) is **not** zero (see Section 7.5 on page 95), • the 87N time-to-trip delay (Address 1925) has expired, • the 87N second-harmonic restraint is not presently restraining a trip (see Section 7.6 on page 96). With the default marshalling, an 87N trip will light LED 7 and activate signal contact 8; and (as for a trip of any function) light and latch LED 1, activate signal contact 1, and activate all the trip contacts. The function will reset (event 5817G, the same as for dropout) when the same conditions that would cause a dropout occur, and the reset time delay (Address 1927) expires.	RGF Gen. Trip	5821		C	S T
If an 87N trip occurs, the magnitude of the ground current (5826) and phase-angle difference (5827) values are logged.	RGF D= *value* RGF S= *value*	5826 5827		C C	
Configuration Errors and Data					
The 87N function is set to monitor Side 3 (Address 7819), but the protected object type (Address 7801) does not have three sides.	RGF Err S3	5828	C		S
Both ground CT current-inputs (I_{Ga} and I_{Gb}) are assigned to the same side of the protected object (addresses 7806 and 7807).	RGF Err2CTsta	5829	C		S
Neither ground CT current-input (I_{Ga} or I_{Gb}) has been assigned to a side of the protected object (addresses 7806 and 7807).	RGF Err 0CTsta	5830	C		S
The 87N function is set to monitor Side 1 or 2 (Address 7819) when the protected object is generator/motor or a bus (Address 7801). In these applications, the 87N function can only protect a virtual object.	RGF ErrVir ob	5831	C		S
Current-matching factor for phase-current CTs.	RGF k CT= *factor*	5832	C		
Current-matching factor for ground-current CT	RGF ksCT= *factor*	5833	C		
The 87N function is set to exist (Address 7819), but other settings (i.e.: the system frequency) make the 87N function unavailable.	RGF no exist	5834	C		S

Table 7.1 *Events Related to Ground Differential Protection (87N)*

8 Time Overcurrent Protection (50HS and 50/51)

As a backup to the differential protection, the relay provides time overcurrent protection that includes a high-set element (50HS) and a choice of either a definite-time element (50) or an inverse-time element (51). These elements monitor one winding (or side) of the protected object. A 7UT513 protecting a two-sided object can use its third set of phase-current inputs to protect an additional (virtual) object.

The overcurrent elements are for protection in the event of a short circuit. Overload conditions are handled by the thermal overload protection elements (see Chapter 8.19).

By using a binary input, the relay can change the behavior of the overcurrent protection during a manual close of a circuit breaker.

8.1 Method of Operation

The 50 and 50HS elements each operate in the same way. If the current of any phase of the monitored winding (or side) reaches a specified threshold level, the element picks up. If the current level of any phase remains above the threshold for a specified time period, the element trips.

The 51 (inverse time) element also picks up if a phase current reaches a specified threshold level. After pickup, the time delay before trip is determined by an inverse-time characteristic that emulates an electromechanical overcurrent relay (the element provides a choice of three characteristic curve types: Moderately Inverse, Very Inverse, and Extremely Inverse, and a range of time dial settings). If the level of the measured currents change after pickup, the remaining time before trip will also change. See Figure 8.1 on page 103, Figure 8.2 on page 104 and Figure 8.3 on page 105.

Each pickup threshold is specified as a multiple of the nominal rated current (I_N) of the monitored winding (or side) of the protected object. If the protected object is a transformer, motor, or generator; the rated nominal current is computed from the specified voltage and power ratings for the winding. If the protected object is a bus or virtual object, the rated nominal current is specified directly in a setting.

A binary input can be used to signal the relay that a manual close is occurring; therefore, the behavior of the overcurrent element can be changed to use either the 50HS or 50/51 pickup threshold without a time delay before a trip (see Section 8.6 on page 102).

8.2 Normal Operational Status

Like the other protection elements, the time overcurrent elements (50HS and 50/51) can be either **Non-Existent/DISABLED** or a choice is made as to which Reference side (or winding) is to be monitored. The choice is made in Configuration Address 7821.

7821 BACKUP O/C Existence and choice of monitored winding of the time overcurrent protection elements (50HS and 50/51).	
Option	**Description**
Non Existent/ DISABLED	50HS and 50/51 elements do not exist (default).
REFERENCE SIDE 1	50HS and 50/51 elements exist and monitor Winding 1 (or Side 1) of the protected object.
REFERENCE SIDE 2	50HS and 50/51 elements exist and monitor winding 2 (or Side 2) of the protected object.
REFERENCE SIDE 3	50HS and 50/51 elements exist and monitor winding 3 (or Side 3) of the protected object (7UT513 only).
VIRTUAL OBJECT	50HS and 50/51 elements exist and monitor a separate, “virtual” object (only available for a 7UT513 protecting a two-sided object).

Once made existent, the 50HS and 50/51 elements can be configured. Their normal operational status is set in Address 2101.

2101 BACKUP O/C Normal operational status of backup overcurrent protection (50HS and 50/51).	
Option	**Description**
OFF	50HS and 50/51 elements are inactive (default).
ON	50HS and 50/51 elements are active.
BLOCK TRIPPING	50HS an3d 50/51 elements are active except that trip contacts and signal contacts will not respond to 50HS and 50/51 trip events.

8.3 High-Set Element (50HS)

The high-set overcurrent element (50HS) has its own pickup threshold level (Address 2103) and time delay (Address 2104). They should be set so that the 50HS element will not trip outside the zone of protection.

2103 50HS PU
Pickup threshold level for the high-set overcurrent element (50HS), which is specified as a multiple of the rated nominal current (I_N) of the monitored winding (or side) of the protected object. A 50HS pickup will occur if the fundamental component of a measured phase-current reaches this threshold.
Range: 0.10 – 30.00 I_n Default: 4.00 I_n

2104 50HS DELAY
Time delay between high-set overcurrent (50HS) pickup and trip. At least one measured phase-current must remain above the 50HS pickup threshold for this duration for a trip to occur. This time delay is in addition to the inherent operating time of the element. The value ∞ will prevent a 50HS trip.
Range: 0.00 – 32.00 s, or ∞ Default: 0.10 s

8.4 Overcurrent Element (50 or 51)

The overcurrent element can have either a definite-time (50) time delay or an inverse-time (51) time delay with a choice of three types of ANSI characteristic curves. The choice is made in Address 2111.

2111 PH CHARACT

Type of time overcurrent element: definite-time (50) or inverse-time (51), including choice of inverse-time characteristic.

Option	Description
DEFINITE TIME	Overcurrent element has a definite-time delay (50).
MODERATELY INV.	Overcurrent element has an inverse-time delay (51) with Moderately Inverse characteristic curves (see Figure 8.1 on page 103).
VERY INVERSE	Overcurrent element has an inverse-time delay (51) with Very Inverse characteristic curves (see Figure 8.2 on page 104).
EXTREMELY INVERSE	Overcurrent element has an inverse-time delay (51) with Extremely Inverse characteristic curves (see Figure 8.3 on page 105).

8.4.1 Definite Time Element (50)

If DEFINITE TIME is selected in Address 2111, the overcurrent element operates as a definite time element (50) using its own pickup threshold level (Address 2112) and time delay (Address 2113). A typical pickup threshold level is 1.4 times the maximum expected overload current.

2112 50T PU
Pickup threshold level for the definite-time overcurrent element (50), which is specified as a multiple of the rated nominal current (I_N) of the monitored winding (or side) of the protected object. A 50 pickup will occur if the fundamental component of a measured phase-current reaches this threshold.
Range: 0.10 – 30.00 I_n Default: 2.00 I_n

2113 50T DELAY
Time delay between definite-time overcurrent (50) pickup and trip. At least one measured phase-current must remain above the 50 pickup threshold for this duration before a trip will occur. This time delay is in addition to the inherent operating time of the element. The value ∞ will prevent a 50 trip.
Range: 0.00 – 32.00 s, or ∞ Default: 0.30 s

8.4.2 Inverse Time Element (51)

If an inverse-time characteristic is selected in Address 2111, the overcurrent element operates as an inverse-time element (51). Address 2114 specifies the pickup threshold level (a typical setting is 1.4 times the maximum expected overload current). A time dial setting (Address 2115) determines which particular characteristic curve (of the type selected in Address 2111) the element uses to determine the time delay until trip. Finally, Address 2116 determines if the value used as the measured current contains only the fundamental component (without harmonics) or is the computed true root-mean-square (rms) current (with harmonics).

2114 51 PU
Pickup threshold level for the inverse-time overcurrent element (51), specified as a multiple of the rated nominal current (I_N) of the monitored winding (or side) of the protected object. By convention (to emulate an electromechanical relay), a 51 pickup will occur when a measured phase-current reaches 110% of this setting. The measured current can either include only the fundamental component, or be the true rms current (see Address 2116).
Range: 0.10 – 20.0 I_n Default: 2.00 I_n

2115 51 T-DIAL
Time dial setting to control the time delay between inverse-time overcurrent (51) pickup and trip. The remaining time delay is determined by this setting, the choice of inverse-time characteristic made in Address 2111, and the instantaneous measured-current level. At least one measured phase-current must remain above the 51 pickup threshold for the duration for a trip to occur. This time delay is in addition to the inherent operating time of the element. The value ∞ will prevent a 51 trip.
Range: 0.50 – 32.00 s or ∞ Default: 0.50 s

2116 MEAS. FORMAT	
Choice of whether the measured current value used by the inverse-time overcurrent element (51) will include only the fundamental component or the computed true rms value.	
Option	**Description**
w/o HARMONICS	51 element operates using only the fundamental component as the measured current in order to provide the fastest operation (default).
WITH HARMONICS	51 element operates using the computed true rms current to emulate an electromechanical overcurrent relay.

8.5 Reset Time Delay

To ensure that the time between a trip and reset lasts long enough for the circuit breaker to operate, the trip state can be prolonged by a reset time delay (Address 2118).

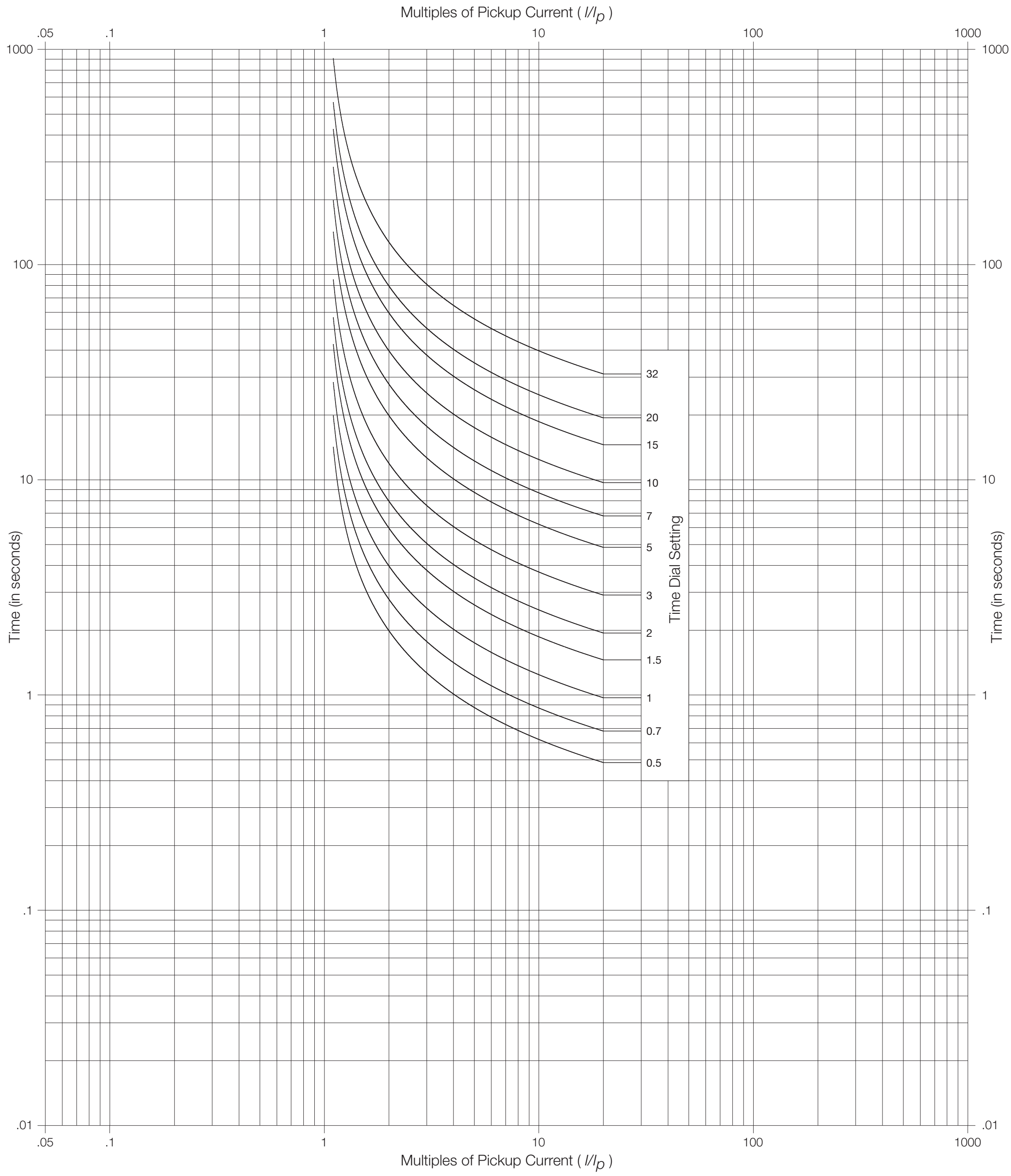
2118 TresetTRIP Additional time to remain in trip state after dropout of an overcurrent element (in addition to the inherent reset time of the relay).
Range: 0.00 – 60.00 s Default: 0.10 s

8.6 Overcurrent Protection during Manual Close of Breaker

When closing a breaker manually, there should be no time delay between an overcurrent pickup and trip. If the breaker can indicate that a manual close is in progress (by activating a binary input of the relay), the behavior of the overcurrent element can be temporarily changed, as specified in Address 2121.

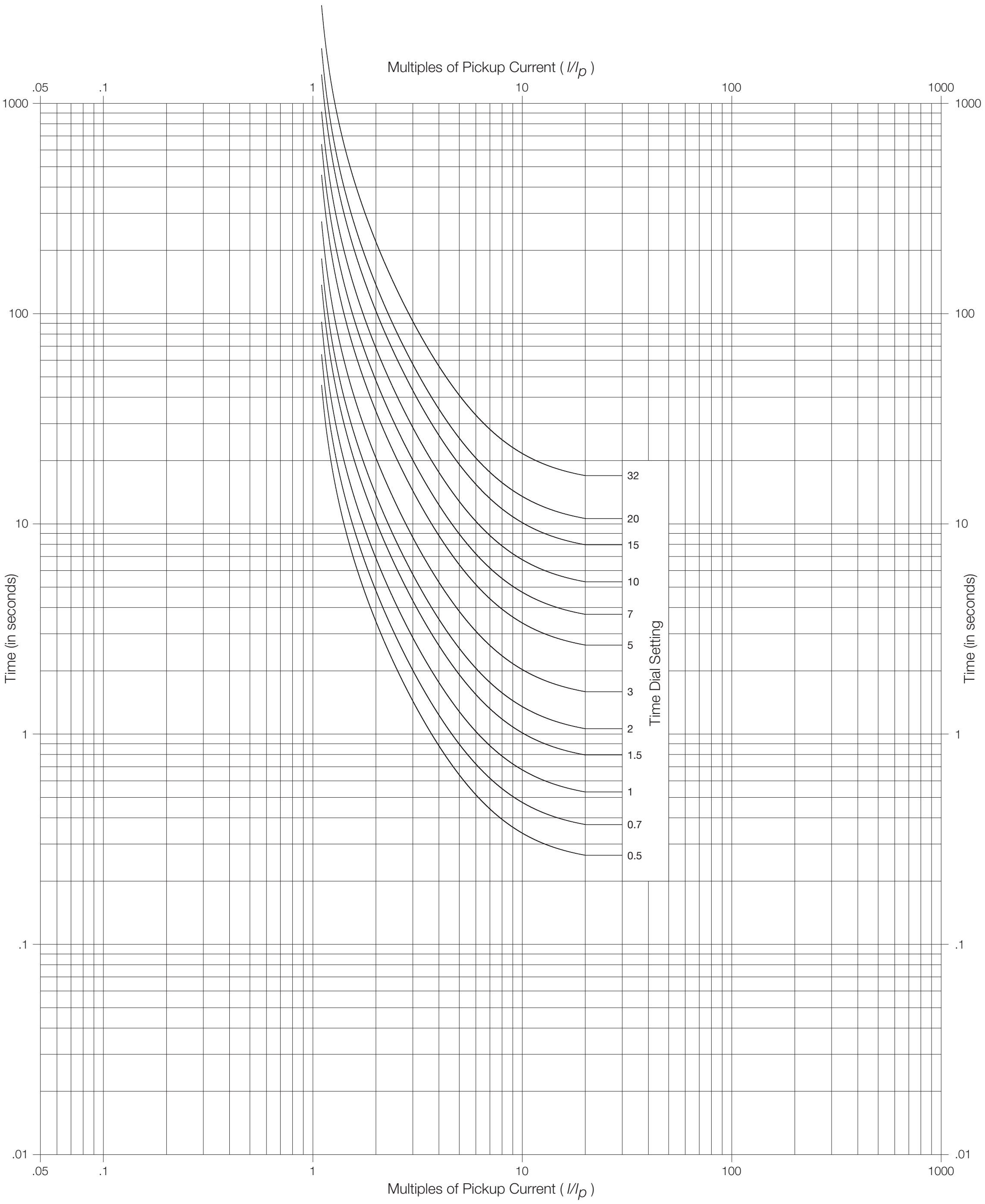
2121 M/C MODE P
Behavior of overcurrent protection element when breaker is being closed manually. A binary signal from the breaker must be wired to one of the relay's binary inputs that is marshalled to event 356, ">MANUAL CLOSE" (see Section 13.2 on page 126). The change in behavior remains in effect only as long as the binary input is being activated by the signal from the breaker.

Option	Description
INACTIVE	No change in behavior (default).
50HS w/o DELAY	Immediate trip if the fundamental component of a measured current reaches the 50HS pickup threshold (Address 2103).
51 w/o DELAY	Immediate trip if fundamental component of a measured current reaches the 50 or 51 pickup threshold (addresses 2112 or 2114, depending on which element is chosen in Address 2111).



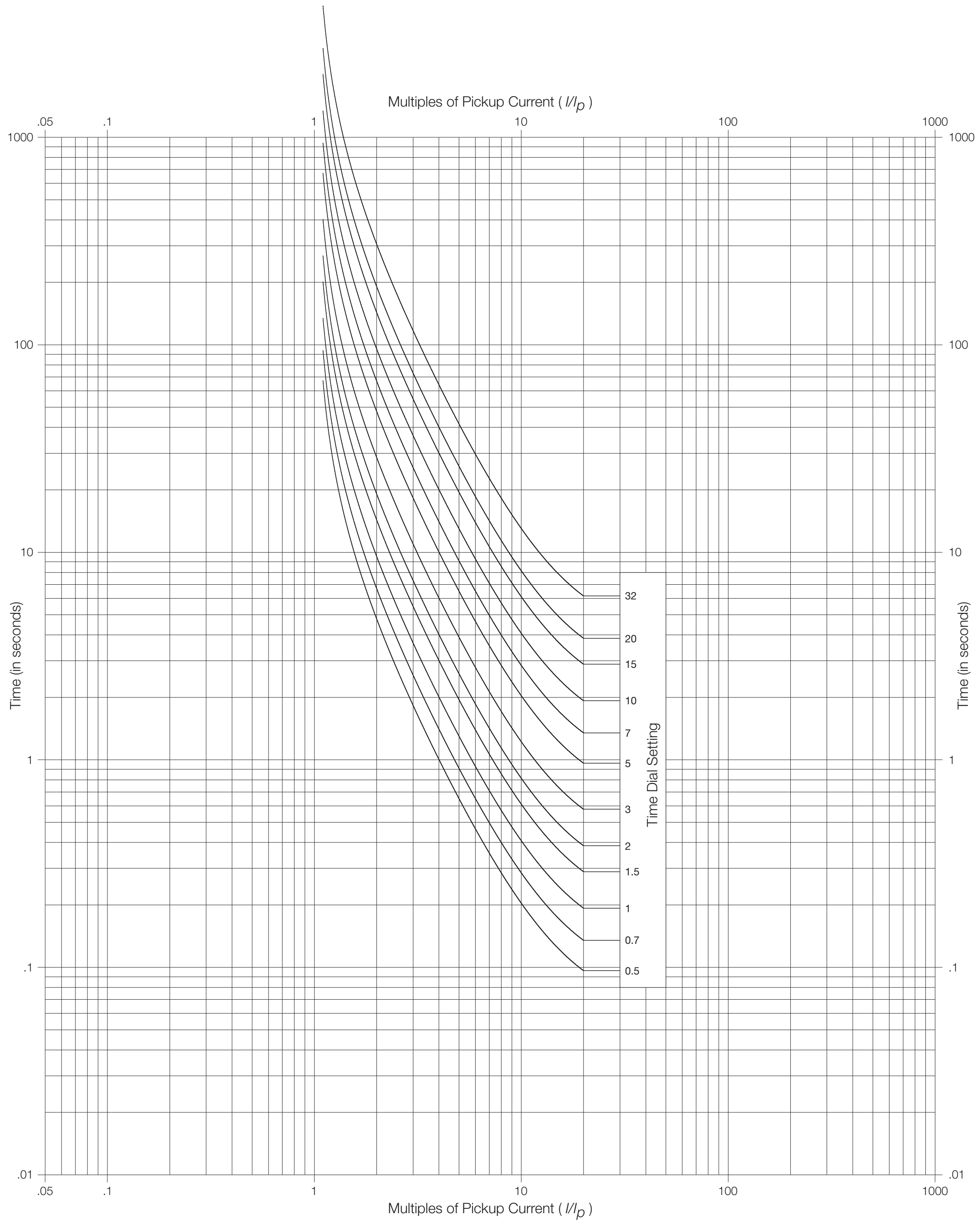
Time Overcurrent Characteristic Curves for **7UT51** Version 3.0 Protective Relay	**Moderately Inverse**	$t = \left[\frac{0.054196}{(I/I_p)^{0.02} - 1} + 0.09328 \right] \times TD$ TD = time dial setting ($0.5 \leq TD \leq 32.0$, steps of 0.01) I/I_p = current in multiples of pickup t = operating time in seconds Time value tolerance is ±5% for $I/I_p > 2$.

Figure 8.1 *Moderately Inverse Time Overcurrent Characteristic Curves*



Time Overcurrent Characteristic Curves for **7UT51** Version 3.0 Protective Relay	**Very Inverse**	$t = \left[\frac{19.138}{(I/I_p)^{2.0} - 1} + 0.48258 \right] \times TD$ *TD* = time dial setting (0.5 ≤ *TD* ≤ 32.0, steps of 0.01) I/I_p = current in multiples of pickup *t* = operating time in seconds Time value tolerance is ±5% for $I/I_p > 2$.

Figure 8.2 *Very Inverse Time Overcurrent Characteristic Curves*



Time Overcurrent Characteristic Curves for **7UT51** Version 3.0 Protective Relay	**Extremely Inverse**	$t = \left[\frac{28.2785}{(I/I_p)^{2.0} - 1} + 0.12173 \right] \times TD$ TD = time dial setting ($0.5 \le TD \le 32.0$, steps of 0.01) I/I_p = current in multiples of pickup t = operating time in seconds Time value tolerance is ±5% for $I/I_p > 2$.

Figure 8.3 *Extremely Inverse Time Overcurrent Characteristic Curves*

8.7 Events and Actions

Table describes the events that control and are generated by the 50/51 and 50HS functions. They are listed in the order that they are likely to occur, which is roughly in numerical order by their event identification number (shown in the "Event" column). The text in the "LCD Abbreviation" column is the corresponding text that will appear when viewing logs on the front panel LCD display. In the "Oper" column, a letter "C" or "G" indicates that the "Coming" and/or "Going" events are logged in the Operational Log, while if in the "Fault" column they indicate that the events are logged in the open fault log. A letter in the "In/Out" column indicates that the event can be controlled by a binary-signal input ("I"), control an LED and/or signal contact ("S"), and/or control a trip contact ("T").

Time Overcurrent Protection (50/51 and 50HS) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Change in Operational Status					
When the operational status of the 50/50HS/51 function changes, a going-event for the old status occurs followed by a coming-event for the new status. The normal operational status is set in Address 2101.	BU OFF BU ACTIVE BU BLOCK	2401 2403 2402	CG CG CG		S S S
A binary input can temporarily change the operational status of the function (see Section 13.2 on page 126). Any outputs marshalled to these events will remain actuated for as long as the binary input remains actuated.	>BU BLOCK >BU BLKTrip	2303 2304			I S I S
Event 2306 temporarily turns off just the 50HS function, while event 2307 temporarily turns off just the 50/51 function.	>BU50HS BLK >BU50/51 BLK	2306 2307	CG CG		I S I S
Pickup and Dropout					
If any overcurrent function (50, 51, or 50HS) picks up, event 2411C will occur. If no fault log is already open, a new one will open. The pickup will dropout (event 2411G) when no overcurrent element remains in pickup. Events 2412, 2413, and 2414 occur when each phase picks up or drops out. Event 2421 occurs if the 50HS function picks up, while event 2422 occurs if the 50/51 function picks up.	Back Gen. Flt BU Flt PhA BU Flt PhB BU Flt PhC BU 50HS BU 50/51	2411 2412 2413 2414 2421 2422		CG CG CG CG C C	S T S S S S S
Time Delay Before Trip					
If an overcurrent function picks up, the corresponding time-before-trip delay starts. If the delay (addresses 2104, 2113, or 2115) is zero, these events do not occur.	BU Tdly 50HS BU Tdly 50/51	2441 2442		C C	S T S T
Trip and Reset					
The backup overcurrent element will trip if and when ANY of the overcurrent elements (50, 51, or 50HS) has picked up and after the corresponding time delay has not yet dropped out or already caused a trip. With the default marshalling a time overcurrent trip will light and latch LED 4 and activate signal contact 3; and (as for a trip of any element) light and latch LED 1, activate signal contact 1, and activate all the trip contacts. The overcurrent elements will reset (event 2411G, the same as for dropout) when the same conditions that would cause a dropout occur, and the reset time delay (Address 2118) expires.	BU Gen.Trip	2451		C	S T
Configuration Error					
The overcurrent elements are set to monitor Side 3 (Address 7821), but the protected object type (Address 7801) does not have three sides (7UT513 only).	BU Err W3	2457	C		S

Table 8.1 *Events Related to Time Overcurrent Protection (50/51 and 50HS)*

9 Thermal Overload Protection (49-1, 49-2)

The thermal overload (49) protection elements respond to excessive load currents that will raise the temperature of the protected object to a damaging level. Each 7UT51 relay has two independent 49 protection elements, which are called 49-1 and 49-2. Each can protect one winding (or side) of the protected object. When a 7UT513 is protecting a two-sided object, one of its 49 elements can protect a separate, additional object.

Each 49 element has both a warning-alarm level and a trip level. The alarm level can control signal contacts to start cooling devices or shed part of the load. Also, binary inputs controlled by external devices can change which set of relay settings is in use (see Section 13.2 on page 126); therefore, each 49 element can adjust to changing conditions.

The 49 elements are used for protection against excessive load currents. For protection against overheating caused by a short-circuit current, use the backup overcurrent element (see Chapter 8).

9.1 Method of Operation

The load current passing though each winding of the protected object causes ohmic heating of the winding due to resistance. This heat flows out into the ambient environment at a rate that increases as the difference between the winding temperature and the ambient temperature increases; therefore, if the load current increases to a new steady value, the temperature of the winding will rise to a new equilibrium level. If the overload is too large, the temperature will begin to rise to a level that the winding will be damaged. But if the overload ends before a damaging temperature is reached, the winding will safely cool down. The value of importance is the amount of time that an overload can be tolerated before the thermal protection element should trip.

The element does not measure the temperature of the winding directly, but instead continuously calculates the temperature change using a single-body thermal model expressed as the following differential equation:

$$\frac{d\Theta}{dt} + \frac{\Theta}{\tau} = \frac{I_{load}^{2}}{\tau} \qquad (9.1)$$

where:

- I_{load} is the load current (the true rms thermal current, including harmonics)
- t is a constant corresponding to the thermal response of the protected object to changes in the current flowing through it, see Section 9.3.2 on page 108

- Q is the temperature rise after time *t* as a fraction of Q_{max}, (the temperature rise that would result from the maximum allowed continuous overload current, I_{max}; calculated by assuming an initial temperature of 40 °C and applying Equation 9.1 for five periods of t).

The amount of time to allow an overload before a trip event occurs is given by the solution to Equation 9.1:

$$t = \tau \times \ln\left(\frac{(I_{\mathrm{load}}/I_{\mathrm{max}})^2 - (I_{\mathrm{preload}}/I_{\mathrm{max}})^2}{(I_{\mathrm{preload}}/I_{\mathrm{max}})^2 - 1}\right) \qquad (9.2)$$

where

- *t* is the time until trip.
- t is a constant describing the thermal behavior of the object (a setting, see Section 9.3.2 on page 108).
- I_{load} is the present measured load current.
- $I_{preload}$ is the previous measured load current.
- I_{max} is the maximum allowed continuous overload current (a setting, see Section 9.3.1 on page 108)
- ln means “the natural logarithm of…”

This equation is plotted in Figure 9.1. The time to pickup is recalculated for each measurement period. Hence, the time will shorten if the object is heating more rapidly due to an increasing overload current, and lengthen if the overload current drops.

9.2 Normal Operational Status

The thermal overload elements (49-1, 49-2) can be **Non-Existent/Disabled,** or a choice is made as to which side (or winding) is to be monitored. A common practice is to monitor the lowest rated winding. The choices are made in addresses 7824 and 7825.

7824 49 Therml1 **7825 49 Therml2** Existence and monitored winding (or side) of each thermal overload protection element (49-1 and 49-2).	
Option	**Description**
Non-Existent/ DISABLED	49-1 (or 49-2) element does not exist (default).
REFERENCE SIDE 1	49-1 (or 49-2) element exists and monitors Winding 1 (or Side 1) of the protected object.
REFERENCE SIDE 2	49-1 (or 49-2) element exists and monitors winding 2 (or Side 2) of the protected object.
REFERENCE SIDE 3	49-1 (or 49-2) element exists and monitors winding 3 (or Side 3) of the protected object (7UT513 only).
VIRTUAL OBJECT	49-1 (or 49-2) element exists and monitors a separate, object (only available when a 7UT513 is protecting a two-sided object).

Once a thermal overload element is referenced to a *side*, it can be configured. Its normal status is set in Address 2401 (for the 49-1 element) or 2501 (for the 49-2 element).

2401 49Therml1 **2501 49Therml2** Normal operational status of each thermal overload element (49-1 or 49-2).	
Option	**Description**
ON	49-1 (or 49-2) element is active (default).
OFF	49-1 (or 49-2) element is inactive.
BLOCK TRIPPING	49-1 (or 49-2) element is active except that trip contacts and signal contacts will not respond to this 49 element's trip events.
ALARM ONLY	49-1 (or 49-2) element is active except that trip and signal contacts operate only for this 49 element's alarm events.

9.3 Pickup Characteristic and Warning Levels

9.3.1 Maximum Continuous Overload Current

The maximum allowed continuous overload current is specified in Address 2402 (or 2502) as a multiple or fraction of the rated nominal current of the protected object.

2402 K-fctr 1 **2502 K-fctr 2** Ratio of maximum continuous thermal overload current to rated current: I_{MAX} / I_N
Range: 0.10 – 4.00 (unitless) Default: 1.10

From the manufacturer of the protected object, obtain the protected object's maximum continuous thermal overload current (I_{max}) and rated nominal current (I_n), then calculate the "k factor" using the following equation:

$$k = \frac{I_{max}}{I_n} \qquad (9.3)$$

If the manufacturer's data for $I_{max}$is not available, a typical value is 1.1, which would require the load current to exceed 110% of the rated nominal current before a 49 pickup could occur.

9.3.2 Time Constant τ

Because the appropriate time-until-pickup depends on a thermal time constant, τ, which is related to the maximum current the protected object can tolerate for a short duration (often called the "**1 second current**"). The unit of τ is *minutes*. Consult the documentation of the protected object to obtain the duration and current of an allowed overload, then calculate τ using the following equation:

$$\tau = \text{allowed duration in minutes} \times \left(\frac{\text{short-term current}}{\text{continuous current}}\right)^2 \qquad (9.4)$$

Example: If the short-time overload capacity is stated for a duration of 1 s, then that short-term current is inserted into the above formula.

$$\tau = \left(\frac{1}{60}\right) \times \left(\frac{\text{permissible 1s current}}{\text{continuously permissible current}}\right)^2$$

Note: The result becomes more inaccurate the longer the stated duration of the current becomes.

2403 49 Tconst 1 **2503 49 Tconst 2** Thermal overload time constant τ
Range: 1.0 – 999.9 minutes Default: 100.0 minutes

The single-body thermal body model used by the relay is appropriate for small continuous overloads (up to approximately 1.2 times the rated current). For larger continuous overloads, it is sufficient to set a slightly shorter time constant which considers the faster warm-up of the winding as compared to the iron.

9.3.3 Warning Alarm Levels

The element can generate a warning-alarm event prior to the pickup event. The alarm event can be configured to trip and output contacts to take corrective actions (load shedding, activation of cooling equipment, etc.).

Two types of warning exist; one based on temperature rise, and the other based directly on the overload current.

The warning based on temperature rise occurs when the calculated temperature rise reaches a specified percentage of the trip value. Of course, the warning level should be less than 100% of the trip-level temperature rise (Q_{trip}), and higher than the temperature at the allowed maximum continuous overload current (Q_{cont}), which can be calculated from the k factor:

$$\frac{1}{k^2} = \frac{\Theta_{cont}}{\Theta_{trip}} < \frac{\Theta_{warn}}{\Theta_{trip}} < \frac{\Theta_{trip}}{\Theta_{trip}} = 100\% \qquad (9.5)$$

For example, if k is 1.1, then $1/k^2$ is 83%, so Q_{warn} should be more than 83% (the allowed continuous overload current) and less than 100% (the trip-level temperature rise).

2404 49Θ ALRM1 **2504 49Θ ALRM2** Temperature rise that will cause a warning alarm (specified as a percentage of the temperature rise that will cause a pickup).
Range: 50 – 100% of pickup temperature rise Default: 90%

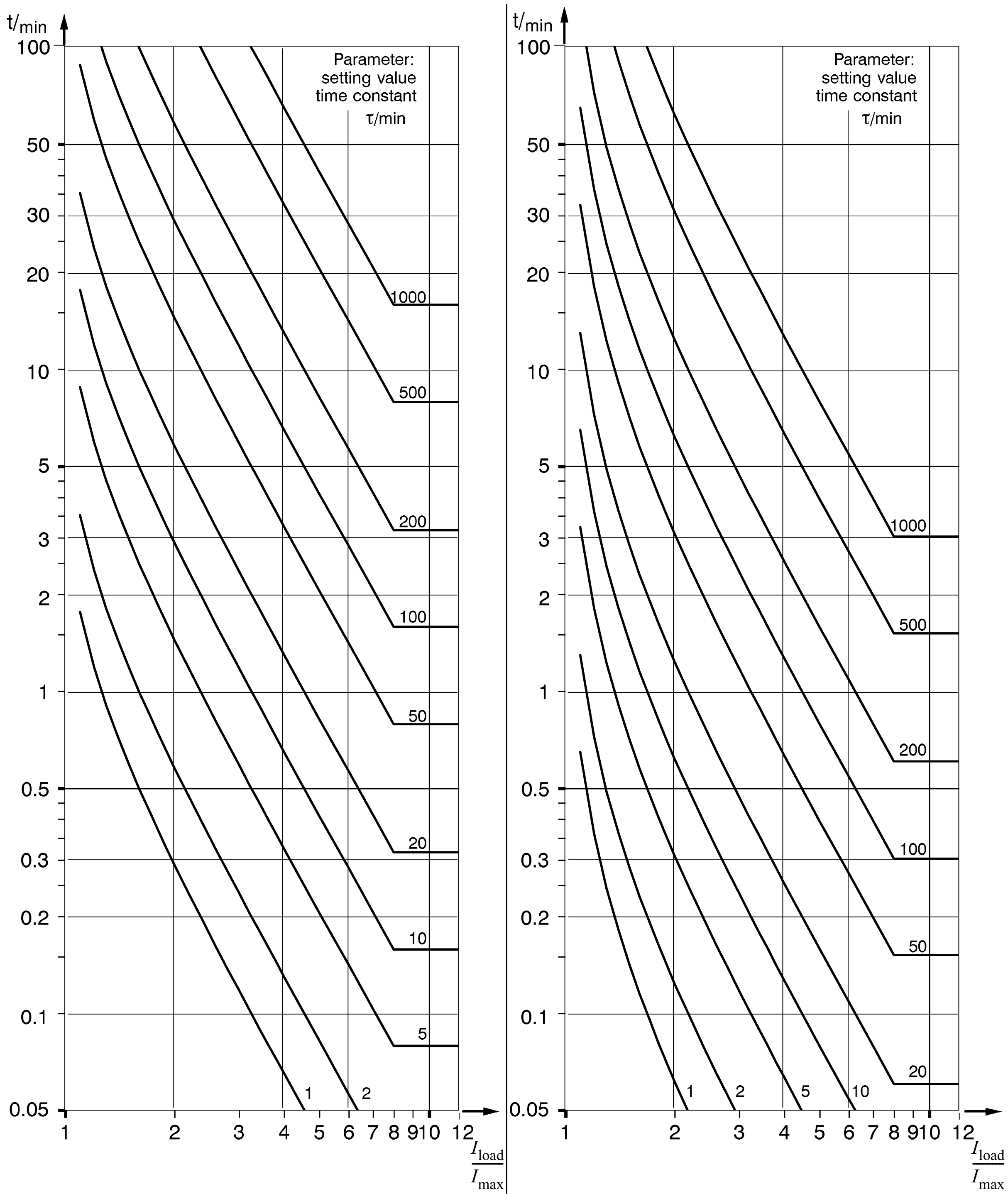
The warning based on the overload current occurs when the measured current reaches a specified multiple of the rated current:

2405 ALRM1 **2505 ALRM2** Warning-level continuous thermal current, specified as a multiple or fraction of I_N.
Range: 0.10 – 4.00 I/I_n Default: 1.10 I_n

9.3.4 Temperature Rise Calculation Method

The calculated temperature rise may be different for each phase of the protected winding. Address 2406 (or 2506) specifies whether to use as the value of Q the maximum of the three temperature values (one for each phase current), the mean temperature value, or the temperature rise calculated based on the largest phase current.

2406 TEMP METH1 **2506 TEMP METH2** Method for calculation of instantaneous temperature Θ.	
Option	**Description**
Θ max	Calculate the temperature for each phase current, then use the maximum (default).
Average Θ	Calculate the temperature for each phase current, then use the average.
Θ at Imax	Identify the largest phase current, then calculate and use its temperature.



$$t = \tau \times \ln\left(\frac{(I_{load}/I_{max})^2}{(I_{load}/I_{max})^2 - 1}\right)$$

0% Preload

$$t = \tau \times \ln\left(\frac{(I_{load}/I_{max})^2 - (0.90)^2}{(I_{load}/I_{max})^2 - 1}\right)$$

90% Preload

Figure 9.1 *Overload Time Characteristic with a 0% Preload and 90% Preload*

9.4 Logical Events and Actions

Table describes the events that control and are generated by the 49-1 and 49-2functions. They are listed in the order that they are likely to occur, which is roughly in numerical order by their event identification number (shown in the “Event” column). The text in the “LCD Abbreviation” column is the corresponding text that will appear when viewing logs on the front panel LCD display. In the “Oper” column, a letter “C” or “G” indicates that the “Coming” and/or “Going” events are logged in the Operational Log, while if in the “Fault” column they indicate that the events are logged in the open fault log. A letter in the “In/Out” column indicates that the event can be controlled by a binary-signal input (“I”), control an LED and/or signal contact (“S”), and/or control a trip (command) contact (“T”).

Thermal Overload Protection (49-1 and 49-2) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Change in Operational Status					
When the operational status of either 49 function changes, a going-event for the old status occurs followed by a coming-event for the new status. The normal operational status is set in Address 2401 or 2501.	>49 O/L1 OFF >49 O/L1 BLOCK >49 O/L1 ACTIV >49 O/L2 OFF >49 O/L2 BLOCK >49 O/L2 ACTIV	1561 1562 1563 1611 1612 1613	CG CG CG CG CG CG		S S S S S S
A binary input can temporarily change the operational status of either or both 49 functions (see Section 13.2 on page 126). Any outputs configured to these events will remain actuated for as long as the binary input remains actuated.	>49 O/L1 BLK >49 O/L1 EVNT >49 O/L1 BLK >49 O/L2 BLK >49 O/L2 EVNT >49 O/L2 BLK	1553 1554 1555 1603 1604 1605			I S I S I S I S I S I S
Warning Level					
Warning level does not initiate a fault log, and the element can remain in warning stage indefinitely.					
If the current exceeds a specified fraction of the thermal overload current (see Section 9.3.3 on page 109), the 49 element enters warning stage until the current drops below 99% of the warning level.	>49 O/L1 Warn1 >49 O/L2 Warn1	1565 1615	CG CG		S S
If the calculated temperature exceeds a specified fraction of the trip-level temperature, the 49 element enters warning stage until the calculated temperature drops below 99% of the warning level.	>49 O/L1 Warn Q >49 O/L2 Warn Q	1566 1616	CG CG		S S
Pickup (and Reset or Dropout)					
A 49 element will pick up when the measured current exceeds the maximum thermal current, OR when the calculated temperature reaches the trip-level temperature. If no fault log is already open, a new fault log is opened. The time delay timer starts with a time value determined by the measured current at the moment of the pickup. Until dropout or trip, full computing capacity is dedicated to the 49 and other protection algorithms. Overhead (metering, communication) programs move into a background mode. The corresponding “going” event will be either a trip or dropout of the protection. The protection will dropout if the thermal current drops below approximately 99% of the pickup value for two or more cycles before the time-delay expires.	>49 O/L1 PU Q >49 O/L2 PU Q	1567 1617	CG CG		S S

Thermal Overload Protection (49-1 and 49-2) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Trip					
The thermal overload protection will trip if and when ALL the following statements are true: • the corresponding 49 element has picked-up and it has not yet dropped out or already caused a trip, • the corresponding 49 time delay has expired, With the default marshalling, the occurrence of logical event 1571 or 1621 will light and latch LED 9 (49-1) or LED 10 (49-2), and (as for any trip event) LED 1.	>49 O/L1 TRIP >49 O/L2 TRIP	1571 1621		CG CG	S T S T
Configuration Error					
Configuration Error: One of the 49 functions has been assigned to winding 3 (Address 7824 or 7825), but the protected device (Address 7801) does not have a third winding (7UT513 only)	>49 O/L1 ErrS3 >49 O/L2 ErrS3	1576 1626	C C		S S

Table 9.1 *Events Related to Thermal Overload Protection (49-1 and 49-2)*

10 Tank Leakage Protection (64T)

A 7UT513 relay can ordered with a tank-leakage protection element (64T). The element can either measure the tank-leakage current in milliamperes, or as a fraction (or multiple) of the nominal rated current of the protected object.

Note: When protecting a 60Hz object, the relay can provide tank leakage protection if the protected object has one or two windings (or sides), but not three.

If desired, the tank leakage protection element can protect a separate, additional object instead of the main protected object.

10.1 Method of Operation

"*Tank leakage*" is current flowing from a phase-conductor (winding or bus bar) of the protected object to the frame of the protected object (or to a conducting tank surrounding the protected object). A fault causing tank leakage may be highly resistive.

The tank leakage current is measured by a CT attached to a conductor connecting the frame or tank to an earth ground (as shown in Figure 10.1). The frame or tank must otherwise be electrically isolated.

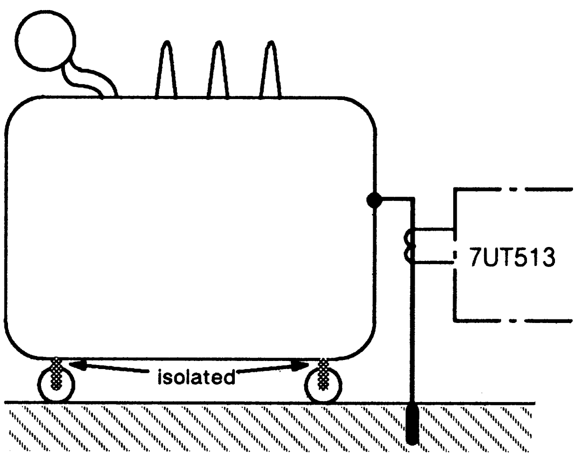


Figure 10.1 *Tank Leakage Protection*

Tank leakage protection (64T) operates like an overcurrent element using one of the following two method: If the element uses the less sensitive ground-current input (I_{Ga}), the pickup level is specified as a fraction (or multiple) of the rated nominal current of the protected object. If instead the element uses the relay's highly sensitive ground-current input (I_{Gb}), the pickup level is specified in milliamperes.

Address 2705 setting specifies whether the measured current includes only the fundamental component or the true rms current. The dropout level is specified in Address 2709 as a fraction of the pickup level. If desired, time delays can be set.

10.2 Normal Operational Status

The tank leakage element (64T) can be either NON-EXISTENT/DISABLED or the element can monitor the tank leakage current either as an absolute current or as a multiple of the rated nominal current of the protected object. The choice is made in Address 7827.

7827 TANK PROT. Existence and type of tank leakage protection. The relay must be a 7UT513 that was ordered with the tank leakage option.	
Option	**Description**
NON-EXISTENT/ DISABLED	Tank leakage element exists (default).
SENSITIVE CT B	Tank leakage element exists and monitors the absolute tank-leakage current. (Connect the tank-leakage CT to the I_{Gb} current input.)
INSENSITIVE CT A	Tank leakage element exists and compares the tank-leakage current to the rated nominal current of the protected object. (Connect the tank-leakage CT to the I_{Ga} current input.)

Once the tank-leakage element exists, it can be configured. Its normal operational status is set in Address 2701.

2701 TANK Normal operational status of tank-leakage protection element.	
Option	**Description**
OFF	64T element is inactive (default).
ON	64T element is active.
BLOCK TRIP REL	64T element is active except that trip contacts and signal contacts will not respond to 64T trip events.

10.3 Pickup and Dropout Levels

Depending on the type selected in Address 7827, the pickup level is specified as either a fraction (or multiple) of the rated nominal current of the protected object (Address 2703), or as an absolute tank-leakage current (Address 2704)

2703 I> TANK Pickup level for sensitive (type A) tank leakage protection, specified as a fraction or multiple of the rated nominal current of the protected object. (Address 7827 must be set to “INSENSITIVE CT A.”)
Range: 0.10 – 10.00 I_n Default: 0.50 I_n Operating Tolerance: 5% of setting value

2704 I> TANK Pickup level for highly sensitive (type B) tank leakage protection, specified as a absolute current in milliamperes. (Address 7827 must be set to “SENSITIVE CT B.”)
Range: 10 – 1000 mA Default: 500 mA Operating Tolerance: 5% of setting value

The measured current value compared to the pickup level can be either the true rms current, or only the fundamental component.

2705 RMS FORMAT Choice of whether to calculate the true r.m.s tank leakage current (including harmonics) or just use the fundamental component.	
Option	**Description**
WITHOUT HARMON.	Fundamental component only (default)
WITH HARMONICS	True rms current, including harmonics

The dropout level of the tank leakage element is specified as a fraction of the pickup level. Avoid a high level since arc faults within the tank can produce considerable current fluctuations.

2709 D.OFF TNK Dropout level as a fraction of the pickup level. This value is also used as the reset level.
Range: 0.25 – 0.95 (unitless) Default: 0.50 Operating Tolerance: 5% of setting value

10.4 Time Delays

If a 64T pickup occurs, the element will immediately trip unless a time delay has been set in Address 2725.

2725 T-DELAY Time delay between pickup and trip for tank leakage protection (in addition to the inherent operating time of the relay).
Range: 0.00 – 60.00 s (or ∞ for no trip) Default: 0.00 s Operating Tolerance: 1% of setting value or 10 ms

If a trip occurs, the contacts and LEDs marshalled to the event will remain activated until the measured tank-leakage current drops below the dropout level set in Address 2709. If desired, the trip-state can be prolonged by a reset time delay that is set in Address 2727.

2727 T-RESET Additional time to remain in trip state after dropout of the 64T element (in addition to the inherent reset time of the relay).
Range: 0.00 – 60.00 s Default: 0.10 s Operating Tolerance: 1% of setting value or 10 ms

10.5 Events and Actions

This table describes the events that control and are generated by the 64T function. They are listed in the order that they are likely to occur, which is roughly in numerical order by their event identification number (shown in the “Event” column). The text in the “LCD Abbreviation” column is the corresponding text that will appear when viewing logs on the front panel LCD display. In the “Oper” column, a letter “C” or “G” indicates that the “Coming” and/or “Going” events are logged in the Operational Log, while if in the “Fault” column they indicate that the events are logged in the open fault log. A letter in the “In/Out” column indicates that the event can be controlled by a binary-signal input (“I”), control an LED and/or signal contact (“S”), and/or control a trip (command) contact (“T”).

Tank Leakage Protection (64T) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Change in Operational Status					
When the operational status of the 64T function changes, a going-event for the old status occurs followed by a coming-event for the new status. The normal operational status is set in Address 2701.	Tank OFF Tank BLOCK Tank ACTIVE	5911 5912 5913	C G C G C G		S S S
A binary input can temporarily change the operational status of the function (see Section 13.2 on page 126). Any outputs marshalled to these events will remain actuated for as long as the binary input remains actuated.	>Tank BLOCK >TankBloTrip	5903 5905			I S I S
Pickup (and Reset or Dropout)					
If the tank leakage current rises above the pickup level (set in Address 2703 or 2704), event 5917:C will occur. The inherent pickup operating time (if the tank leakage current is twice the pickup level and without parallel operation of other protection elements) is approximately 25 to 35 ms (at 60Hz). If no fault log is already open, a new one will start. When the tank leakage current drops below the dropout level set in Address 2709, event 5917:G will occur. The inherent dropout operating time is approximately 35 ms (at 60Hz).	Tank Gen. Flt	5917		C G	S T

Tank Leakage Protection (64T) Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Time Delay Before Trip					
If a pickup occurs, the time delay (set in Address 2725) starts. If this setting is zero, this event never occurs. Any outputs marshalled to this event will remain energized until the time delay expires.	Tank T start	5916		C	S T
Trip					
If the element is still in pickup when the trip time delay (if any) ends, the element will trip. With the default marshalling, LED 1 and LED 8 will light and latch. Any outputs marshalled to this event will remain energized until the element resets (event 5917:G). If the operational status is “Block Tripping,” the trip event will occur, be logged, and affect any LEDs it is marshalled to, but it will not energize any output signal or trip (command) contacts.	Tank Gen.Trip	5921		C	S T
If a 64T trip occurs, the value of the tank leakage current (fundamental component) at the time of the trip is recorded in the open fault log.	Tank = *value*	5926		C	
Configuration Errors					
This event occurs if an attempt is made to save the settings with the tank leakage protection set to exist (Address 7827), but other settings make tank leakage protection unavailable (for example, the protected object has three windings or sides). Lights LED 14 on a 7UT513 with default marshalling.	Tank no exist	5928	C		S

Table 10.1 *Events Related to Tank Leakage Protection (64T)*

11 Protecting an Additional Device or Equipment

A 7UT513 relay has three sets of phase-current inputs that enable it to protect an object with three windings or branches. An alternative application is to use a 7UT513 relay to protect a two-winding (or two-branch) object, and use the relay's third set of phase-current inputs to protect a separate, additional device or equipment.

The relay's time overcurrent function, and/or either thermal overload element can protect this virtual object instead of the object being protected by the differential element. Likewise, the ground-current CT inputs of a 7UT513 can be used to provide tank leakage protection of a virtual object (providing that the tank leakage option was ordered). If this feature is used, the virtual object must be described using the settings described in this section.

1401 In VIRT OB Rated nominal current of the additional protected object.
Range: 1 – 100,000 A Default: 2,000

1402 In CT Rated nominal primary current of the CTs monitoring the phase currents of the additional protected object.
Range: 1 – 100,000 A Default: 2,000

1404 In CT STPT Rated nominal primary current of the CT monitoring the ground current of the additional protected object.
Range: 1 – 100,000 A Default: 2,000

1405 CT STARPT
Orientation of CTs monitoring the additional protected object.

Option	Description
SAME SIDE	The CT common points are on the same side of the additional protected object.
OPPOSITE SIDES	The CT common points are on the opposite sides of the additional protected object.

12 Protection Self-Monitoring

The relay has self-monitoring features that monitor the relay hardware, relay software, DC supply power, and the CT circuitry. If self-monitoring determines that the relay is not ready, until the condition is resolved (which may be accomplished by the relay itself), the following actions occur:

- All protection functions of the relay will be blocked.
- Relay status contact 6A1-6A2-6A3 of the relay will be *de-energized.*
- The “Blocked” LED on the front panel will be lit.

If the problem persists, an event reporting the particular problem is added to the Operational Log or open fault log (see Table 12.1 on page 122).

This chapter describes the details and settings of the self-monitoring features.

12.1 Self-Monitor Signal Contact

Signal contact 5 of the relay is dedicated to reporting the operational readiness of the relay. Event 51 (“**Relay OK**”) reports that the relay is operational with at least one protection function active; and it is always marshalled to relay status contact 6A1-6A2-6A3 (no other event can be marshalled to that signal contact). This contact is energized when the relay is ready to operate.

12.2 Internal Self-Monitoring

The relay monitors its own internal components (hardware and software).

12.2.1 Reset of LEDs

If the LED’s are reset, Event 5 is recorded in the operational log. This does not affect the readiness of the relay.

12.2.2 Change of Parameter Set

When changing which parameter set is active, or when changes to the active set are being made effective. For a brief time no set is active.

12.2.3 Software-Hardware Mismatch

If on start-up the relay detects that its internal software does not correspond to its hardware, event 100 and/or 101 will occur. The relay will not be ready.

12.2.4 Data Buffer Invalid or Overflowing

If a data recording buffer becomes full and more data is required to be written to the buffer, or if the relay detects that the data in the buffer has been corrupted, a corresponding event (115C) is reported in the operational log or open fault log (depending on the event). These events do not affect the readiness of the relay.

12.2.5 Memory Monitoring (Checksum)

A cyclic checksum is formed for the program memory (EPROM), the parameter assignment memory (EEPROM), and the working memory (RAM); then compared to the stored checksum. If the checksum does not match, event 135C occurs, and the relay will not be ready until a subsequent cyclical checksum does match, and event 135G occurs.

After settings to a parameter set are entered, the relay performs a checksum of the parameter set. If the checksum fails, the corresponding event (136C, 137C, 138C, or 139C) occurs. The corresponding going event occurs when the same parameter set is entered and no checksum error occurs. These events do not affect the readiness of the relay unless the parameter set in question (A, B, C, or D) is the active set.

12.2.6 Processor

For continuous monitoring of the program sequences, a watchdog timer is provided which will reset the processor in the event of processor failure or if a program falls out of step. Further, internal plausibility checks ensure that any fault in processing of the programs, caused by interference, will be recognized. Such faults lead to reset and restart of the processor.

If such a fault is not eliminated by restarting, further restarts are initiated. If the fault is still present after three restart attempts the problem is considered persistent and the relay places itself out of service.

12.2.7 Internal Power Supplies

The relay monitors the internal voltage supplies used to power internal components of the relay. These include voltages for the multiplexer and offset and reference voltages for the ADC (analog/digital converter). Between the corresponding coming and going events, the relay is not ready.

Failure or switch-off of the auxiliary voltage automatically puts the system out of operation. This status is indicated by a fail-safe contact and announced in events 141, 142, and 143.

12.2.8 Analog/Digital Converters

If the relay detects a problem of the analog/digital (A/D) converters, event 145C occurs and the relay is not ready.

12.2.9 Trip Circuits

The functioning of the trip contacts of the relay are monitored by internal software.

The trip contacts are controlled by two command channels and one additional release channel. If discontinuities or short circuits in the circuits controlling the trip contacts are detected, the relay is not ready.

12.3 Monitoring of Supply Power

Failure or switch-off of the DC supply voltage will de-energize the Self-Monitor signal contact (which is normally energized, see Section 12.2 on page 119). No events or other actions occur, and, of course, the relay is no longer providing any protection functions. Transient dips in the DC supply voltage for less than 50 ms (for VDC $\geq$ 110V) will not disturb the functioning of the relay.

12.4 Monitoring of CT Circuits

The relay can detect interruptions or short circuits in the current transformer (CT) circuits by monitoring the plausibility of the measured current values. The values are checked at cyclic intervals, so long as no protection function is in pickup.

Note that implausible measured current values detected while commissioning the relay may indicate incorrect connection of the CT's to the relay's current-input terminals.

The sensitivity of the measured values monitoring can be changed in Address Block 2900. The factory settings should be adequate in most cases. When using the 7UT51 as protection for a single-phase transformer, both parameters should be set to the highest value since otherwise an alarm could be given continuously.

12.4.1 Current Symmetry

During healthy operation, it can be expected that the three phase currents for each protected winding (or bus branch) will be approximately symmetrical. Specifically, if I_{min} is the smallest of the three phase currents and I_{max} is the largest, the ratio of their magnitudes will be unity when the currents are exactly symmetrical.

The relay detects non-symmetric currents if the ratio of the magnitude of I_{min} to the magnitude of I_{max} is smaller than a setting value, “SYM. Fact. I” (setting 2904):

$$\frac{|I_{min}|}{|I_{max}|} < \text{SYM.Fact.I} \qquad (12.1)$$

When all the phase currents are small, they may be non-symmetrical for reasons other than a faulty CT circuit. Hence, no action is taken unless the value of I_{max} is greater than a sensitivity threshold value, “SYM.Ithres” (setting 2903):

$$|I_{max}| > \text{SYM.Ithres} \qquad (12.2)$$

If the ratio of I_{min} to I_{max} is in the BLOCK area of Figure 12.1, the relay will report that the currents are non-symmetric for that particular winding (or bus branch).

2903 SYM.Ithres Current threshold above which at least one phase current of the winding (or bus branch) must be before current-symmetry monitoring will react (see Figure 12.1).
Range: 0.10 – 1.00 *In* Default: 0.50

2904 SYM.Fact.I Ratio of minimum measured current to maximum measured current below which current symmetry monitoring will react (see Figure 12.1).
Range: 0.00 – 0.95 Default: 0.50

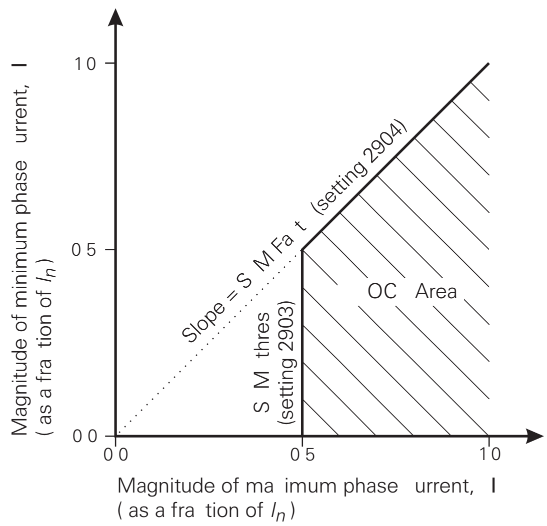


Figure 12.1 *Current Symmetry Monitoring*

12.4.2 Current Summation

If the relay is protecting a bus, an additional protection self-monitoring feature is available. If the differential current of any phase has a magnitude corresponding to a load current, the relay assumes that a CT circuit is faulty and blocks the differential protection. The details and settings for this feature are described in Section 6.6 on page 86.

12.5 Events and Actions

This table describes the events that control and are generated by the self-monitoring features of the relay. They are listed in numerical order by their event identification number (shown in the “Event” column). The text in the “LCD Abbreviation” column is the corresponding text that will appear when viewing logs on the front panel LCD display. In the “Oper” column, a letter “C” or “G” indicates that the “Coming” and/or “Going” events are logged in the Operational Log, while if in the “Fault” column they indicate that the events are logged in the open fault log. A letter in the “In/Out” column indicates that the event can control an LED and/or signal contact (“S”), and/or control a trip (command) contact (“T”).

Protection Self-Monitoring Occurrence	LCD Abbreviation	Event	Oper	Fault	In/Out
Internal Self-Monitoring (see Section 12.2 on page 119)					
Relay is operational and at least one protection function is active. (This event is always marshalled to signal contact 5, and can be marshalled to other contacts as well.)	Relay OK	0051	CG		S
LEDs have been reset	LED Reset	0005	C		
Parameters are being set	SetChg inProg	0095	CG		S
Wrong version of internal software	Wrong SW-vers	0100	C		
Wrong internal device identification	Wrong dev. ID	0101	C		
Annunciations lost (Operational Log buffer overflow)	Annunc. lost	0110	C		
Annunciations for PC lost	Annu. PC lost	0111	C		
Fault annunciations lost (buffer overflow of a Fault Log)	Flt.Buff.Over	0115		C	
Operational annunciations invalid	Oper.Ann.Inva	0120	CG		
Fault annunciations invalid	Flt.Ann.Inval	0121	CG		
LED annunciations buffer invalid	LED Buff.Inva	0124	CG		
VDEW state invalid	VDEW-StateInv	0129	CG		
Checksum error in memory	Chksum Error	0135	CG		
Checksum error in parameter set A	ChksumA Error	0136	CG		
Checksum error in parameter set B	ChksumB Error	0137	CG		
Checksum error in parameter set C	ChksumC Error	0138	CG		
Checksum error in parameter set D	ChksumD Error	0139	CG		
Failure of 24VDC internal power supply circuit	24 V Failure	0141	CG		S
Failure of 15VDC internal power supply circuit	15 V Failure	0143	CG		S
Failure of 5VDC internal power supply circuit	5 V Failure	0144	CG		S
Analog/digital converters (offset failure)	Offset Fail	0145	CG		S
Failure of I/O Module 1 (ZEA)	I/O 1 Failure	0151	CG		S
Failure of I/O Module 2 (ZEA, 7UT513 only)	I/O 2 Failure	0152	CG		S
Failure of RKA Module	RKA Failure	0154	CG		
LSA (data communication interface) disrupted	LSA disrupted	0159	CG		
Monitoring of Supply Power (Section 12.3 on page 120)					
Failure of the supply power de-energizes the Self-Monitor signal relay.					
Monitoring of CT Circuits (Section 12.4 on page 120)					
Failure of current summation monitoring (only available when the protected object is a bus)	I Supervision	0161			S
Failure of current symmetry for at least one winding (or branch)	Failure Isymm	0163	CG		S
Failure of current symmetry for Winding 1 (or branch 1)	Fail. Isym 1	0571	CG		S
Failure of current symmetry for winding 2 (or branch 2)	Fail. Isym 2	0572	CG		S
Failure of current symmetry for winding 3 (or branch 3) (7UT513 only)	Fail. Isym 3	0573	CG		S

Table 12.1 *Events Related to Protection Self-Monitoring*

13 Binary-Signal Inputs, Signal Contacts, Trip Contacts, and LED Indicators

This chapter describes how to program (marshal) the relay to communicate with other devices that are part of the protection scheme, including the binary inputs, signal-output contacts, and trip contacts and also to the user.

13.1 Overview

The 7UT51 can be programmed (or mashalled) to allow external signal contact inputs to function within the relay, and to cause internal functions to activate signal contact outputs and fault contact outputs. These functions can control the functioning of the relay in many ways.

The functions of the contact inputs, contact outputs, and LED indicators are preset at the factory and can be changed either by using the keypad on the front panel or by using a PC with WinDIGSI software.

Input of a password is required for configuring the control logic. The factory set password is “000000.” Without entering the password, the settings can be read but not changed. If you change any of the control logic settings, the relay microprocessor will automatically reset, momentarily placing the relay out of service.

The logical annunciation functions can be used in multiple. For example, one annunciation function can trigger several signal relays, several trip relays, additionally be indicated by LEDs, and be controlled by a binary input unit. The restriction is that the total of all physical input/output units (binary inputs plus signal relays plus LEDs plus trip relays) which are to be associated with one logical function, must not exceed a number of ten (10). If this number is exceeded, the display will show a corresponding message.

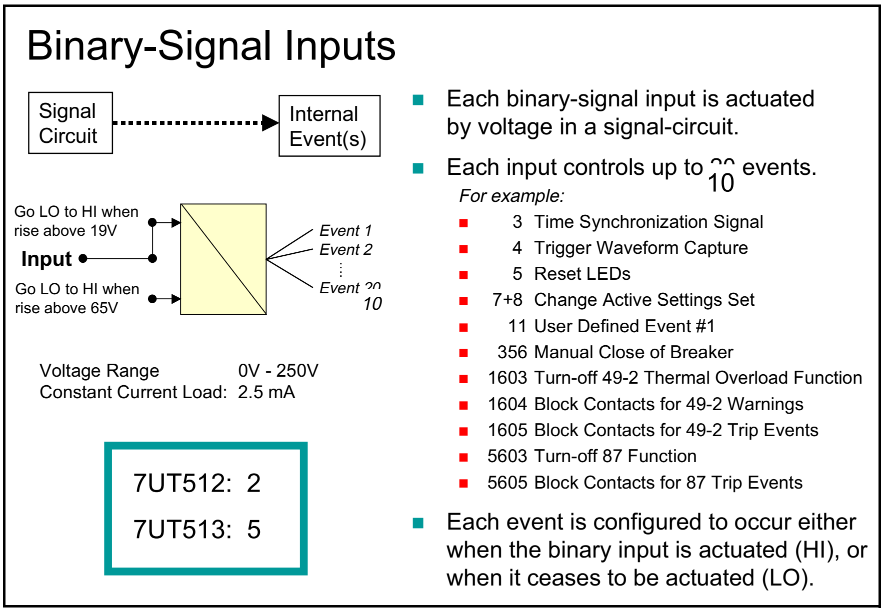
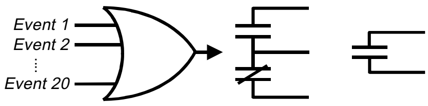


Figure 13.1 *Binary-Signal Inputs*

Signal Contacts

- Each signal contact is controlled by up to 20 events.
  For example:
  - 0141 Failure of internal 24V power supply
  - 0511 General trip of the relay
  - 1566 49-Thermal O/L prot.1: Thermal warn.
  - 1571 49-Trip by thermal O/L protection 1
  - 5671 87-Diff protection: General Trip
  - 5821 Restricted Ground Fault: General Trip
  - 5921 Transformer tank prot: General trip
- Use to...
  - Sound alarms for operators
  - Signal other protection devices



Configurable		
7UT512:	4	0
7UT513:	5	5

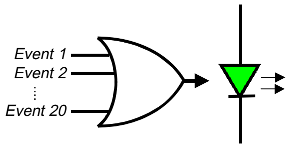
Self-Test Alarm: 1

Make Capacity:	20 W/VA
Break Capacity:	20 W/VA
Switching Voltage:	250 V
Permissible Current:	1 A

Figure 13.2 *Signal Contacts*

LED Targets

- Each LED is controlled by up to 20 events.
  For example:
  - 95 Parameters are Being Set
  - 163 Failure: Current Symmetry Supervision
  - 501 General Fault Detection
  - 1566 Thermal Overload 1 Warning Stage
  - 1571 Trip by Thermal Overload Protection 1
  - 4533 External Trip 1 is Active
  - 5616 87 Function is Blocked
  - 5621 87 Time Delay Started
  - 5641 87 Function Blocked by Harmonics
  - 5651 87 Blocked by Saturation on Phase A
  - 5817 87N Time Delay Started
- Each event can either latch (“memorized”), or not latch (“not memorized”) an LED.
- Latched LEDs can be reset using a key on the front panel, a binary-signal input, or an attached PC running WinDIGSI.



Power:	1
Blocked:	1
Configurable	
7UT512:	6
7UT513:	14

Figure 13.3 *LED Targets*

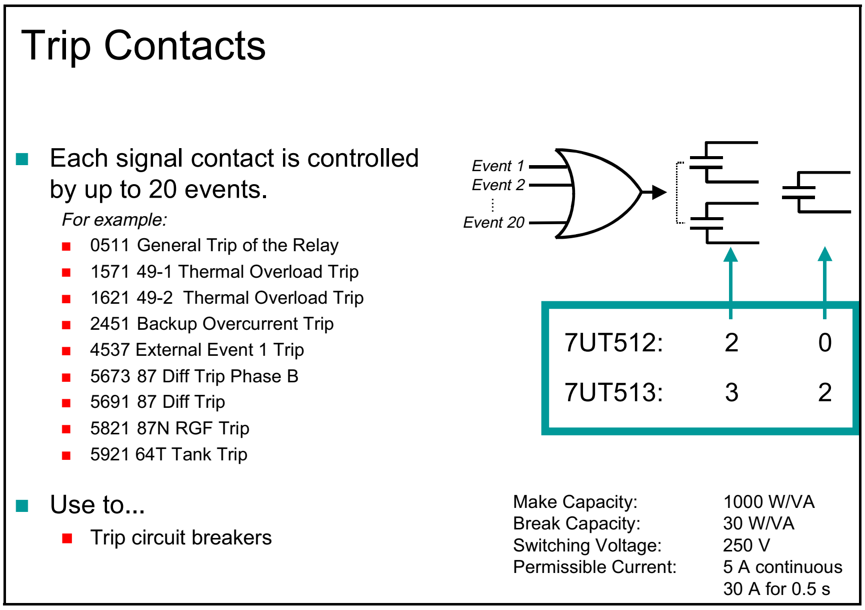


Figure 13.4 *Trip Contacts*

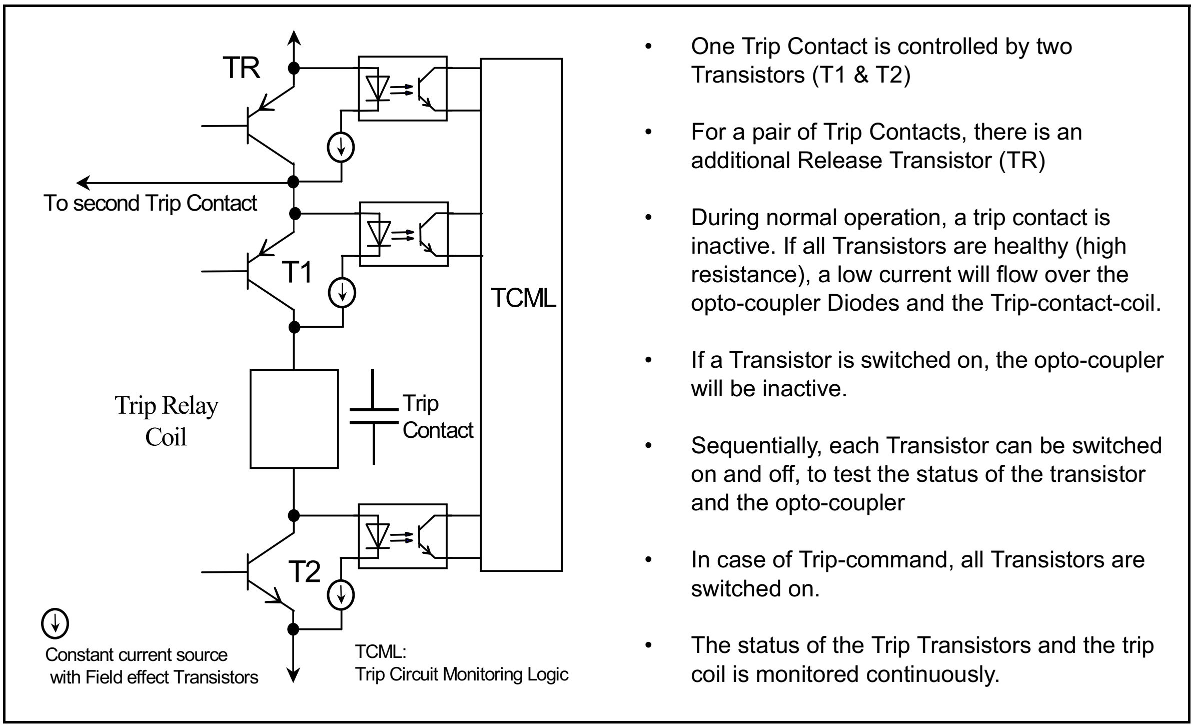


Figure 13.5 *Trip Contact Monitoring Circuit*

13.2 Binary-Signal Inputs

Binary-signal inputs (also called discrete inputs, input contacts, or binary inputs) enable the relay to respond to signals communicated by applying (or removing) a voltage across a pair of signal-input terminals. A 7UT512 relay has two binary-signal inputs, while a 7UT513 has five. Each binary signal input contact can control up to ten events, with each event independently configured to be active when voltage is applied to the terminals (HI) or when voltage is removed from the terminals (LO).

The input functions will have no effect if the corresponding protection function is not ENABLED in the relay or has been set to OFF.

Binary input can also perform the following functions:

- Change the settings set (see Section 14.4.2 on page 143)
- Synchronize the internal clock (Event 3)
- Reset the front panel LEDs (Event 5)
- Trigger a waveform capture (see Section 14.7 on page 147)

6101 BINARY INPUT 1 [default is 5 >Reset LEDs HI]
6102 BINARY INPUT 2 [default is 2306 >BU50HS BLK HI]
6103 BINARY INPUT 3 (7UT513 only) [default is 11 >UsrDefEvent1 HI]
6104 BINARY INPUT 4 (7UT513 only) [default is 391 >Buchh. Warn HI]
6105 BINARY INPUT 5 (7UT513 only) [default is 392 >Buchh. Trip HI]

Each discrete input can be associated with up to ten (10) functions that will be activated when the corresponding discrete input is active. Each function can be independently configured to be active when the input is active (HI) or active when the signal is inactive (LO).

LCD Abbreviation	Event	Effect of Input Signal
not allocated	1	If the input is associated with less than ten functions, the unused slots are “not allocated”.
>Time Synch	3	Synchronize internal real time clock when input signal goes HI (or LO).
>Trig. wave	4	Start waveform recording when input signal goes HI (or LO).
>Reset LEDs	5	Reset front panel LED indicators when input signal goes HI (or LO).
>ParamSelect.1 >ParamSelect.2	7 8	Change the **active parameter set** (must be used with a pair of binary inputs, see Table 14.1) when input becomes active.
>UsrDefEvent1 >UsrDefEvent2 >UsrDefEvent3 >UsrDefEvent4	11 12 13 14	The four user defined events have no effect on relay operation, but can be mapped to LEDs (to display) and signal relay outputs (to pass along to another device).
>Manual Close	356	Circuit breaker has been manually closed (signal from discrepancy switch)
>Buchh. Warn >Buchh. Trip >Buchh. Tank	391 392 393	No effect on relay operation. Status of **Buchholz** protection (warning, trip, or tank pickup) can be mapped to LED and signal relay outputs.
>49 O/L1 BLK >49 O/L1 EVNT >49 O/L1 BLK	1553 1554 1555	If thermal overload protection **49-1** is enabled, it will be blocked (1553), will only generate alarms (1554), or will be blocked from issuing a trip command (1555) as long as the signal input is active
>49 O/L2 BLK >49 O/L2 EVNT >49 O/L2 BLK	1603 1604 1605	If thermal overload protection **49-2** is enabled, it will be blocked (1603), will only generate alarms (1604), or will be blocked from issuing a trip command (1605) as long as the signal input is active.
>BU BLOCK >BU BLK Trip	2303 2304	Backup overcurrent protection will be blocked (2303) or will be blocked from issuing a trip command (2304).

LCD Abbreviation	Event	Effect of Input Signal
>BU50HS BLK >BU50/51 BLK	2306 2307	Block 50HS stage of backup O/C Block 50/51 stage of backup O/C
>Ext1 BLOCK >Ext1 blkTRIP >Ext1 TRIP	4523 4525 4526	External Trip 1 signal (received through another signal input) will be blocked, will be blocked from causing a trip ( ), or will be issued by a signal to this discrete input ( ).
>Ext2 BLOCK >Ext2 blkTRIP >Ext2 TRIP	4543 4545 4546	BLOCK external trip 2 BLOCK trip signal of external trip 2 External trip 2
>87Diff BLOCK >87DiffBlkTrip	5603 5605	BLOCK differential protection BLK differential prot. trip signal
>RGF BLOCK >RGF blk Trip	5803 5805	Block restricted ground-fault protect Block trip of restricted ground-fault
>Tank BLOCK >Tank blkTrip	5903 5905	Block transformer tank protect Block transformer tank protect trip signal

13.3 Signal Output Contacts

13.3.1 Programmable Signal Contacts

Signal contact outputs enable the relay to send signals to other devices by closing (or opening) the connection between a pair of terminals. Each signal contact output is controlled by up to twenty functions selected from Table 6.x. The 7UT512 relay has four contact outputs and the 7UT513 relay has ten contact outputs. If desired, a function can activate more than one signal contact relay.

Alarm functions have effect only when the corresponding protection function is enabled and active. Functions with a “>” sign prefix can be assigned to both signal contact inputs and signal contact outputs to pass a signal through the relay independent of the relay’s protective functions (of course, the relay must be operational).

6201 SIGNAL CONTACT 1
6202 SIGNAL CONTACT 2
6203 SIGNAL CONTACT 3
6204 SIGNAL CONTACT 4
6205 SIGNAL CONTACT 5

7UT513 Only
6206 SIGNAL CONTACT 6
6207 SIGNAL CONTACT 7
6208 SIGNAL CONTACT 8
6209 SIGNAL CONTACT 9
6210 SIGNAL CONTACT 10
6211 SIGNAL CONTACT 11

Each signal relay can be independently activated by up to twenty (20) functions (chosen from the list in section Table 13.1). The default configuration is listed below:

Relay	Code	Function(s)	Description
Relay 1	511	Device Trip	General trip signal
Relay 2	5671	Diff Gen Trip	Trip of differential protection
Relay 3	2451	Back Gen Trip	Trip of backup overcurrent time protection

Relay	Code	Function(s)	Description
Relay 4	141 143 144 145 151 152	Failure 24V Failure 15V Failure 5V Failure 0V Failure I/O 1 Failure I/O 1	Relay failure
Relay 5	51	Device Operative	
Relay 6	1571 1621	O/L 1 Trip O/L 2 Trip	Thermal overload protection
Relay 7	1566 1616	O/L 1 warn O/L 2 warn	Thermal overload protection
Relay 8	5821	RGF Gen. Trip	Trip of restricted ground-fault protection
Relay 9	5921	Tank Gen. Trip	Trip of tank leakage protection
Relay 10	391	Buchh. Warn	Buchholz warning
Relay 11	392	Buchh. Trip	Buchholz trip

13.4 LED Targets

The LED targets on the front panel of the relay can be controlled by the functions in section Table 13.1. One LED indicates that the relay has power, while another indicates when the relay is blocked. The other LEDs can be configured. An LED lights when one of its functions becomes active, and can be configured to remain lit until reset (memorized, m) or only until the function becomes inactive (not memorized, nm). The 7UT512 relay has six programmable LEDs, while the 7UT513 relay has 14.

Alarm functions have effect only when the corresponding protection function is enabled and active. Functions with a “>” sign prefix can be assigned to both signal contact inputs and signal contact outputs to pass a signal through the relay independent of the relay’s protective functions (of course, the relay must be operational).

6301 LED1
6302 LED 2
6303 LED 3
6304 LED 4
6305 LED 5
6306 LED 6
6307 LED 7 (7UT513 only)
6308 LED 8 (7UT513 only)
6309 LED 9 (7UT513 only)
6310 LED 10 (7UT513 only)
6311 LED 11 (7UT513 only)
6312 LED 12 (7UT513 only)
6313 LED 13 (7UT513 only)
6314 LED 14 (7UT513 only)

Each LED can be independently lit by up to twenty functions (chosen from the list in Table 13.1). Each function can cause the LED to remain lit until deliberately reset (memorized, m) or go out once the function is no longer active (not memorized, nm) unless, of course, another function lighting the LED is still active. The default configuration is listed below:

LED	Code	Function(s)	Description
LED 1	511	Device Trip m	General trip signal
LED 2	5691	87-Trip	87 Trip of differential protection
LED 3	5692	87HS Trip	87HS Trip of differential protection
LED 4	2451	BU Gen. Trip	General Trip of backup overcurrent protection

LED	Code	Function(s)	Description
LED 5	141 143 144 145 151 152	24V Failure 15V Failure 5V Failure Offset Fail I/O 1 Failure i/O 2 Failure	Relay failure
LED 6	95	SetChg in Prog	Setting change in progress
LED 7	5821	RGF Gen Trip	Restricted ground-fault: General Trip
LED 8	5921	Tank Gen. Trip	Transformer tank prot.: General TRIP
LED 9	1571	49 O/L 1 Trip	49-Trip by thermal O/L protection 1
LED 10	1621	49 O/L 2 Trip	49-Trip by thermal O/L protection 2
LED 11	391	>Buchh. Warn	Buchholz warning
LED 12	392	>Buchh. Trip	Buchholz trip
LED 13	11	>UsrDefEvent3	User Defined Event #1
LED 14	5711 5712 1576 1626 2457 5828 5829 5830 5831 5834 5928	Err 2 CT star Err no CTStar 49O/L1 ErrS3 49O/L2ErrS3 BU Error W3 RGF Err S3 RGFErr2CTsta RGFErr0CTsta RGF ErrVirObj RGF no exist Tank Err S3	Diff prot err:2 starpt CT for Wnd 1 Diff prot err:No strpt CT connctd 49-Therm O/L prot.1 err:No side3 49-Therm O/L prot.2 err:No side3 Backup O/C err: Wnd 3 No exist Restricted gnd fualt err: No Side 3 Restricted gnd flt err: 2 starpt CT Restricted gnd flt err: No starptCT RGF Error: Use only virtual obj. Restricted gnd fault err: Non-exist Transfrmr tank prot. err: Nonexist

13.5 Trip (Command) Contacts

The relay sends trip signals to circuit breakers by closing trip (command) contact relays, each of which can be activated by up to twenty trip functions, including two external trip functions. The 7UT512 relay has two trip contacts and the 7UT513 relay has five trip contacts. The differential current trip commands are preassigned to all of the trip contacts.

6401 TRIP CONTACT 1
6402 TRIP CONTACT 2
6403 TRIP CONTACT 3 (7UT513 only)
6404 TRIP CONTACT 4 (7UT513 only)
6405 TRIP CONTACT 5 (7UT513 only)

Each Address holds up to twenty functions, any one of which will activate the corresponding trip relay. For a function to trip the relay, it must be both assigned to a trip contact AND the protection function must be enabled and active. Each has the same seven default functions: 1571, 1621, 2451, 5691, 5692, 5821, and 5921.

LCD Message	Code	Event that will activate the trip relay
not allocated	1	No function assigned
>UsrDefEvent1 >UsrDefEvent2 >UsrDefEvent3 >UsrDefEvent4	11 12 13 14	>User defined event 1 >User defined event 2 >User defined event 3 >User defined event 4

LCD Message	Code	Event that will activate the trip relay
>Buchh. Trip	392	>Tripping stage from Buchholz protection
>Buchh. Tank	393	>Tank supervision from Buchholz protection
Relay Pick-up	501	Relay Pick-up
Trip	511	General trip of the relay
49 O/L1 TRIP	1571	49-TRIP by thermal O/L protection 1
49 O/L2 TRIP	1621	49-TRIP by thermal O/L protection 2
Back Gen. Flt	2411	Back-up O/C+G/F: General fault detected
BU Tdly 50HS	2441	BU 50HS -Highest O/C time expired
BU Tdly 50/51	2442	BU 50/51 -Overcurrent timer expired
BU Gen.Trip	**2451**	BU Overcurrent+G/F: General Trip
Ext1 Gen.Flt	4536	External trip 1: General fault detect
Ext1 Gen.TRIP	4537	External trip 1: General TRIP
Ext 2 Gen.Flt	4556	External trip 2: General fault detect
Ext 2 Gen.TRIP	4557	External trip 2: General TRIP
87Diff Pickup	5621	87 -Differential unit picked-up
87Diff HS PU	5622	87 -HS Diff prot unit picked-up
87Diff GenFlt	5631	87 -Diff prot: General fault detection
87DiffGenTrip	5671	87 -Diff protection: General trip
87DiffTripPhA	5672	87 -Diff protection: Trip PhA
87DiffTripPhB	5673	87 -Diff protection: Trip PhB
87DiffTripPhC	5674	87 -Diff protection: Trip PhC
87 Trip	**5691**	87 -Diff protection: Trip
87HS Trip	**5692**	87HS -Diff protection: Trip
RGF Pick-up	5816	Restricted ground-fault: Pick-up
RGF Gen. Flt	5817	Restricted ground-fault: General fault detection
RGF Gen. TRIP	**5821**	Restricted ground-fault: General TRIP
Tank PU	5916	Transformer tank prot.: Pick-up
TankGen FAULT	5917	Transformer tank prot: General FAULT detect
Tank Gen.TRIP	**5921**	Transformer tank prot.: General TRIP

13.6 Processing External Trip Commands

Up to two desired trip signals from external protection or supervision units can be incorporated into the processing of 7UT51. the signals are coupled as “External signals” via binary-signal inputs. Like the internal protection and supervision signals, they can be annunciated as “External trip”, time delayed and transmitted to the trip matrix. A precondition is that they are configured to **Existent/Enabled**.

The settings for processing external trip commands are contained in Address Block 3000.

13.6.1 Normal Operational Status

Each external trip function can be set either to exist or not exist (addresses 7830 and 7831).

7830 EXT TRIP 1 **7831 EXT TRIP 2** Choice of whether the corresponding external trip function exists.	
Option	**Description**
EXISTENT/ ENABLED	Corresponding external trip function exists.
NONEXISTENT/ DISABLED	Corresponding external trip function does not exist (default).

An external trip function exists, it can be configured. The normal status of each is set in Address 1601.

3001 EXT1 STATUS **3101 EXT1 STATUS** Normal operational status of transformer differential protection (87T and 87HS).	
Option	**Description**
OFF	Corresponding external trip function is inactive (default).
ON	Corresponding external trip function is active.
BLOCK TRIPPING	Corresponding external trip function is active except that trip contacts and signal contacts will not respond to its events.

13.6.2 Time Delays

If a pickup occurs, the function will immediately trip unless a time delay has been set in Address 3002 or 3102.

3002 T-DELAY **3102 T-DELAY** Time delay between energization of a binary-signal input marshalled to an external trip function event and the trip of the external trip function (in addition to the inherent operating time of the relay).
Range: 0.00 – 60.00 s, or ∞ Default: 0.00 s

If a trip occurs, the contacts and LEDs marshalled to the event will remain activated until the binary-signal input controlling the corresponding external trip function is no longer energized. To ensure that the trip state lasts long enough for the circuit breaker to operate, the trip state of each function can be prolonged by a corresponding reset time delay set in Address 3003 or 3103.

3003 T-RESET **3103 T-RESET** Additional time to remain in trip state after the binary-signal input that caused a trip becomes de-energized (in addition to the inherent reset time of the relay).
Range: 0.00 – 60.00 s Default: 0.10 s

13.7 Numerical Listing of User Definable Trip and Signal Functions

The events listed below are the marshalling possibilities for signal contact inputs, signal contact outputs, trip contact outputs, and LEDs. Some events are for transformer protection only and some are for the 7UT513 only.

Note: Annunciations with a leading “>” sign are identical with those for binary inputs and signal or trip outputs. They represent the direct confirmation of the binary input and are available as long as the corresponding binary input is energized.

Event	LCD Abbreviation	Description
1	not allocated	
3	>Time Synch	Clock-synchronizing binary-signal input actuated.
4	>Trig. wave	Trigger waveform capture
5	>Reset LEDs	Reset LEDs
7 8	>ParamSelec.1 >ParamSelec.2	Change the **active parameter set** (must be used with a pair of binary inputs, see Table 14.1 on page 144) when input becomes active.
11 12 13 14	>UsrDefEvent1 >UsrDefEvent2 >UsrDefEvent3 >UsrDefEvent4	>User defined event 1 >User defined event 2 >User defined event 3 >User defined event 4
51	Relay OK	Relay is operational and protecting (cannot be changed)
95 96 97 98 99	SetChg inProg Set Group A Set Group B Set Group C Set Group D	Setting change in progress Setting group A is active Setting group B is active Setting group C is active Setting group D is active
141 143 144 145	24V Failure 15V Failure 5V Failure Offset Fail	Failure of internal 24VDC power supply Failure of internal 15VDC power supply Failure of internal 5VDC power supply Offset failure (A/D converter)
151 152	I/O 1 Failure I/O 2 Failure	Failure in I/O module 1 Failure in I/O module 2
161 163	I Supervision Failure I symm	Failure: Current supervision Failure: Current symmetry supervision
356	>Manual Close	Manual Close command
391 392 393	>Buchh. Warn >Buchh. Trip >Buchh. Tank	Warning stage from Buchholz protection Tripping stage from Buchholz protection Tank Supervision from Buchholz protection
501 511	Relay Pick-up Trip	Relay Pick-up General trip of the relay
561	M/C Detect	Manual close command
571 572 573	Fail. I sym 1 Fail. I sym 2 Fail. I sym 3	Fail: Current symm. supervision Side 1 Fail: Current symm. supervision Side 2 Fail: Current symm. supervision Side 3

Event	LCD Abbreviation	Description
1553	>49 O/L1 BLK	49-Block thermal O/L protection 1
1554	>49 O/L1 EVNT	49-Event only from thermal O/L prot. 1
1555	>49 O/L1 BLK	49-Block trip of thermal O/L prot. 1
1561	49 O/L1 OFF	49-Thermal O/L protection 1 is switched OFF
1562	49 O/L1 BLOCK	49-Thermal O/L protection 1 is BLOCKED
1563	49 O/L1 ACTIV	49-Thermal O/L protection 1 is ACTIVE
1565	49 O/L1 Warn1	49-Thermal O/L protection 1: Current Warning
1566	49 O/L1 Warn q	49-Thermal O/L protection 1: Thermal Warning
1567	49 O/L1 PU q	49-Thermal O/L protection 1: Pick-up
1571	49 O/L1 TRIP	49-Trip by thermal O/L protection 1
1576	49 O/L1 ErrS3	49-Thermal O/L protection 1 error: No Side 3
1603	>49 O/L2 BLK	49-Block thermal O/L protection 2
1604	>49 O/L2 EVNT	49-Event only from thermal O/L prot. 2
1605	>49 O/L2 BLK	49-Block trip of thermal O/L prot. 2
1611	49 O/L2 OFF	49-Thermal O/L protection 2 is switched OFF
1612	49 O/L2 BLOCK	49-Thermal O/L protection 2 is BLOCKED
1613	49 O/L2 ACTIV	49-Thermal O/L protection 2 is ACTIVE
1615	49 O/L2 Warn1	49-Thermal O/L protection 2: Current Warning
1616	49 O/L2 Warn q	49-Thermal O/L protection 2: Thermal Warning
1617	49 O/L2 PU q	49-Thermal O/L protection 2: Pick-up
1621	49 O/L2 TRIP	49-Trip by thermal O/L protection 2
1626	49 O/L2ErrS3	49-Thermal O/L protection 2 error: No side
2303	>BU BLOCK	Block backup O/C time protection
2304	>BU BLK Trip	Block trip signal of backup O/C
2306	>BU50HS BLK	Block 50HS stage of backup O/C
2307	>BU50/51 BLK	Block 50/51 stage of backup O/C
2401	BU OFF	Back-up O/C protection is switched OFF
2402	BU BLOCK	Back-up O/C protection is BLOCKED
2403	BU ACTIVE	Back-up O/C protection is ACTIVE
2411	Back Gen. Flt	Back-up O/C + G/F: General fault detected
2412	BU Flt PhA	Back-up O/C: Fault detection PhA
2413	BU Flt PhB	Back-up O/C: Fault detection PhB
2414	BU Flt PhC	Back-up O/C: Fault detection PhC
2421	BU 50HS	BU 50HS-Phase highest OC fault det.
2422	BU 50/51	BU 50/51-Phase O/C fault det.
2441	BU Tdly 50HS	BU 50HS-Highest O/C time expired
2442	BU Tdly 50/51	BU 50/51 - Overcurrent timer expired
2451	BU Gen. Trip	BU Overcurrent & G/F: General trip
2457	BU Error W3	Back-up O/C error: Winging 3 no exist
4523	>Ext1 BLOCK	BLOCK external trip 1
4525	>Ext1 blkTRIP	BLOCK trip signal of external trip 1
4526	>Ext1 TRIP	External trip 1
4531	Ext1 OFF	External trip 1 is switched OFF
4532	Ext1 BLOCKED	External trip 1 is BLOCKED
4533	Ext1 ACTIVE	External trip 1 is ACTIVE
4536	Ext1 Gen.Flt	External trip 1: General fault detect
4537	Ext1 Gen.TRIP	External trip 1: General trip

Event	LCD Abbreviation	Description
4543	>Ext2 BLOCK	BLOCK external trip 2
4545	>Ext2 blkTRIP	BLOCK trip signal of external trip 2
4546	>Ext2 TRIP	External trip 2
4551	Ext2 OFF	External trip 2 is switched OFF
4552	Ext2 BLOCKED	External trip 2 is BLOCKED
4553	Ext2 ACTIVE	External trip 2 is ACTIVE
4556	Ext2 Gen.Flt	External trip 2: General fault detect
4557	Ext2 Gen.TRIP	External trip 2: General trip
5603	>87Diff BLOCK	BLOCK differential protection
5605	>87DiffBlkTrip	BLK differential prot. trip signal
5615	87Diff OFF	Differential protect switched OFF
5616	87Diff BLOCK	Differential protect switched BLOCKED
5617	87Diff ACTIVE	Differential protect switched ACTIVE
5621	87Diff Pickup	Differential unit pickup
5622	87Diff HS PU	HS Diff prote. unit picked up
5631	87Diff GenFlt	Diff prot: General Fault detection
5641	87Blk HarmPhA[1]	Diff prot: BLOCKED by harmonics PhA
5642	87Blk HarmPhB[1]	Diff prot: BLOCKED by harmonics PhB
5643	87Blk HarmPhC[1]	Diff prot: BLOCKED by harmonics PhC
5651	87Blk SatPhA	Diff prot: BLOCKED by external fault PhA
5652	87Blk SatPhB	Diff prot: BLOCKED by external fault PhB
5653	87Blk SatPhC	Diff prot: BLOCKED by external fault PhC
5671	87Diff GenTrip	Diff protection: General trip
5672	87Diff TripPhA	Diff protection: Trip PhA
5673	87Diff TripPhB	Diff protection: Trip PhB
5674	87Diff TripPhC	Diff protection: Trip PhC
5681	87Diff PhA	Diff protection: Trip PhA (w/o Time dly)
5682	87Diff PhB	Diff protection: Trip PhB (w/o Time dly)
5683	87Diff PhC	Diff protection: Trip PhC (w/o Time dly)
5684	87HS PhA[3]	HS-Diff protection: Trip PhA
5685	87HS PhB[3]	HS-Diff protection: Trip PhB
5686	87HS PhC[3]	HS-Diff protection: Trip PhC
5691	87 Trip	87-Diff protection: Trip
5692	87HS Trip	87HS-Diff protection: Trip
5711	Err 2 CT star	Diff prot error: 2 Star-point CT for Wnd 1
5711	Err no CTstar	Diff prot error: No star-point CT connected
5803	RGF BLOCK	Block restricted ground-fault protect
5805	RGF blk Trip	Block trip of restricted ground-fault
5811	RGF OFF	Restricted ground-fault is switch OFF
5812	RGF BLOCKED	Restricted ground-fault is switch BLOCKED
5813	RGF ACTIVE	Restricted ground-fault is switch ACTIVE
5816	RGF Pick-up	Restricted gnd fault: Pick-up
5817	RGF Gen. Flt	Restricted gnd fault: Gen fault detection
5821	RGF Gen. Trip	Restricted ground-fault: General Trip
5828	RGF Err S3	Restricted gnd fault error: No Side 3
5829	RGF Err2CTsta	Restricted gnd fault error: 2 star-point CT
5830	RGF Err0CTsta	Restricted gnd fault error: No star-point CT
5831	RGF ErrVirObj	Restricted gnd fault error: Use only virtual obj
5834	RGF no exist	Restricted gnd fault error: Non-exist

Event	LCD Abbreviation	Description
5903	>Tank BLOCK	Block transformer tank protect
5905	>Tank blkTrip	Block transformer tank protect trip signal
5911	Tank OFF	Transformer tank protection switched OFF
5912	Tank BLOCKED	Transformer tank protection switched BLOCKED
5913	Tank ACTIVE	Transformer tank protection switched ACTIVE
5916	Tank PU	Transformer tank prot.: Pick-up
5917	TankGen FAULT	Transformer tank prot: General FAULT detect
5921	Tank Gen.TRIP	Transformer tank prot.: General TRIP
5928	Tank Err S3	Transformer tank protection error: NONEXIST

Table 13.1 *Numerical Listing of User Definable Trip and Signal Functions*

14 Operation Using the Front Panel Controls

This chapter describes how to operate the relay using the front panel controls. The relay can also be operated remotely by connecting the relay to a PC running WinDIGSI software provided by Siemens (see Chapter 15).

Operating the relay and configuring its settings is done by viewing and changing values stored in memory locations, each of which is identified by a four-digit address.

The addresses are grouped into Address blocks. All of the addresses in a block have the same first two digits (e.g., 1000, 1100, 7800).

Some addresses contain numeric values, while others contain a selection from a menu of options. A few addresses contain two-level menus, in which each top-level menu choice contains a selection from a sub-menu.

The relay can be in one of two modes. *Display mode* (the normal mode) enables you to view existing settings, as well as data acquired by the relay. *Password mode* enables you to change settings and clear stored data. The relay remains in-service while in either mode. However, changing some settings will cause the relay's microprocessor to reset, momentarily removing the relay from service.

14.1 Front Panel Components

Before configuring and operating the relay, you need to be familiar with the integral keypad and other features of the front panel. Figure 14.1 and Figure 14.2 illustrate the features of the front panel for the 7UT512 and 7UT513 relay models, respectively.

14.1.1 Display

The two-line by sixteen-character liquid crystal display (LCD) allows the viewing of settings, measured data, fault logs, and the event log. One message can be displayed during normal operation, while another is displayed after a fault. Each message is displayed until superseded by another pickup, a trip message, a target reset, or a request by the operator to display other information.

The LCD is not capable of displaying subscript characters. As a result, lowercase characters are used for the subscripts in the display. For example, I_N becomes In. In this manual, most of the specific references to the LCD text show the symbols as they appear in the display. Otherwise, symbols with correct case and subscripts are used.

14.1.2 Keypad

The keys on the front panel keypad have four basic functions: data entry, navigation, control, and confirmation. The numeric keys are used specifically for data entry or Address selection. The navigation, control, and confirmation keys are described in Figure 14.3.

The keypad has 28 keys with numbers, Yes and No and control functions.

Three of the keys, somewhat separated from the rest of the keys, can be accessed when the front cover is closed. The arrow keys enable incrementing in the forward direction. Thus all setting values and event data can be displayed with the front cover closed.

Stored LED indications on the front can be erased via the RESET key without opening the front cover. During reset operation all LEDs on the front will be illuminated thus performing a LED test. Also, with this reset, the fault event indications in the display on the front panel of the device are acknowledged; the display then shows the operational values of the quiescent state. The display is switched over to operating mode as soon as one of the keys is pressed.

14.1.3 On/Off Switch

The On/Off switch controls the operational state of the relay. When the switch is in the "Off" position, the microprocessor is reset and processing stops. Secondary (DC) power output from the power supply module is switched off, so the relay is effectively disabled or blocked in this state. This switch should stay in the On position after the relay has been properly installed, programmed, and commissioned. The relay is switched off for certain maintenance and testing procedures.

14.1.4 Relay Nameplate

The relay nameplate identifies specific data about your relay such as rated current, DC supply voltage, relay model number, and serial number.

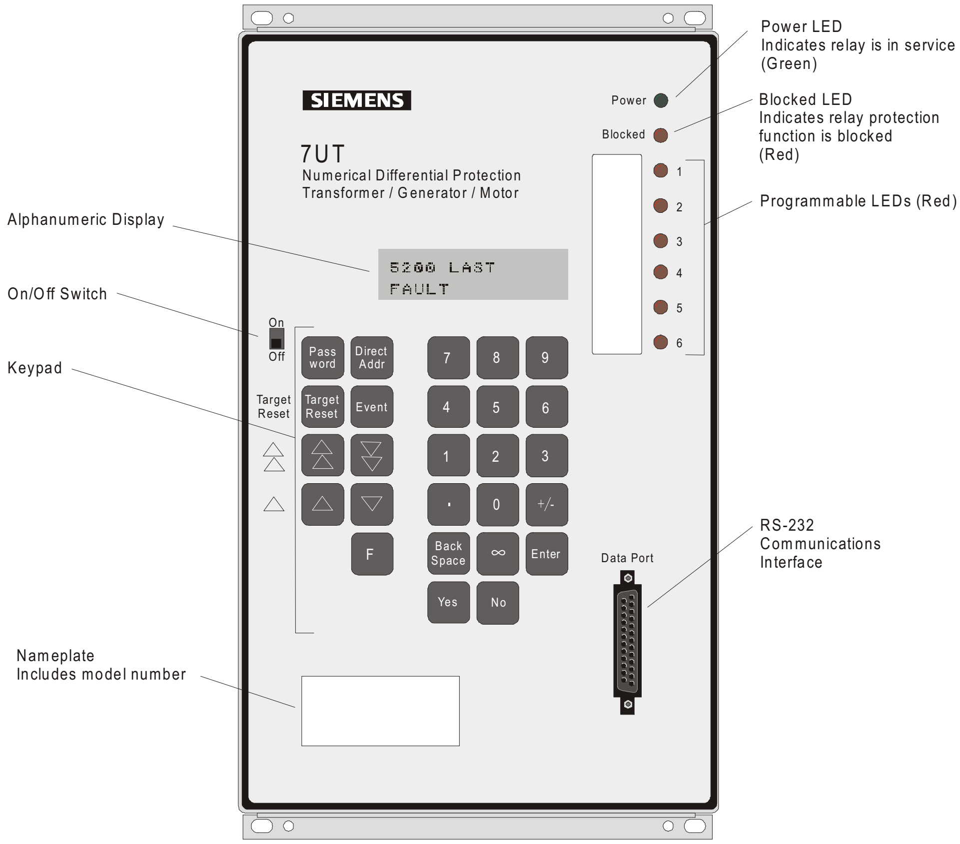


Figure 14.1 *7UT512 Front Panel*

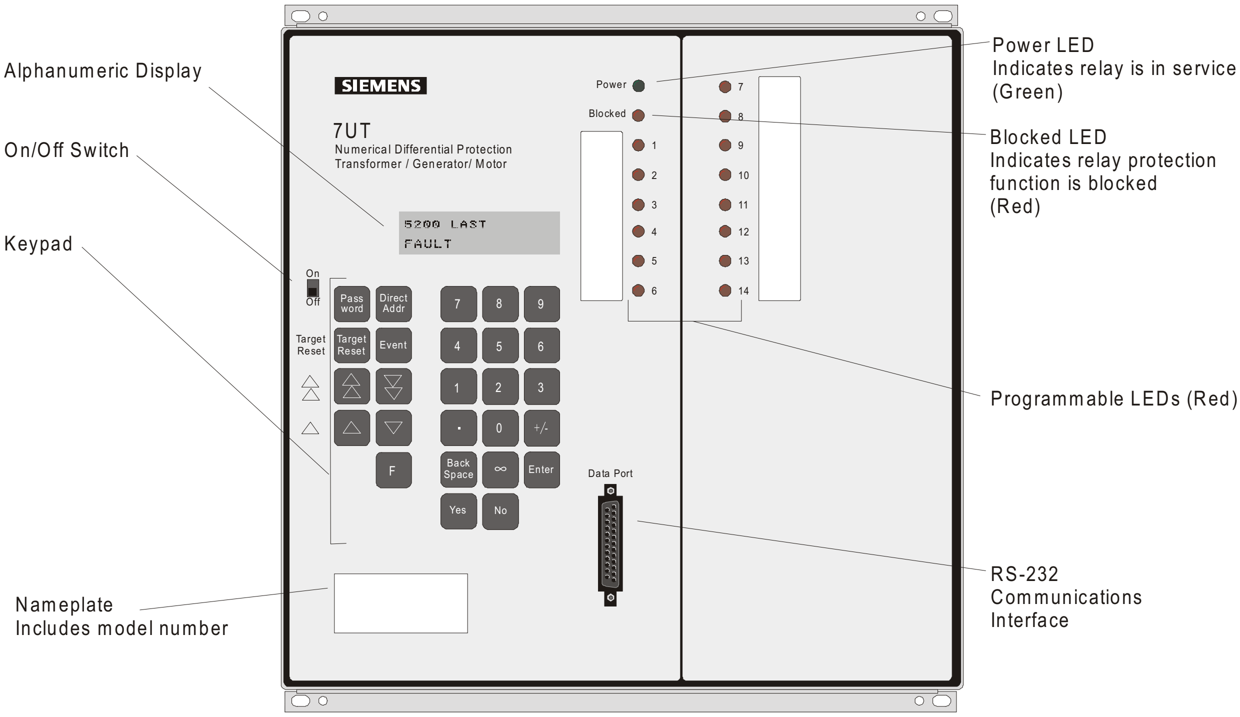


Figure 14.2 *7UT513 Front Panel*

14.1.5 LED Indicators

The 7UT512 relay has eight LEDs, six of which can be configured by the user. The 7UT513 relay has 16 LEDs, 14 of which can be configured by the user.

Each configurable LED can indicate up to ten events of conditions chosen from a long list. See Section 13.4 on page 128 of this manual for more information.

The LEDs that cannot be changed for either relay model are as follows:

Power – Lights up GREEN to indicate the relay powered on and is working properly. Normally, this indicator will remain on. It will be off if the On/Off switch is in the "**Off**" position or if power to the relay is interrupted. It also will be off if any of the internal failure monitoring functions detect a device failure.

Blocked – Lights up RED to indicate that the relay has detected an internal problem and has blocked itself from operation. This LED also will light briefly during initial power-up and after the protected system setting, system frequency setting, or input/output function assignments are changed and saved.

The remaining LEDs (1 through 6 for the 7UT512 or 1 through 14 for the 7UT513) will light up RED to indicate that the annunciation assigned to this LED indicator during the configuration process has occurred. These indicators will remain on until reset, and the relay will retain this data even if power is lost. Whether or not the indications are retained in the nonvolatile memory is a configuration option. If the indications are not retained, they will be reset when the fault condition is removed. If they are retained, they can be reset locally by the Target Reset key on the front panel, through a serial port, through a binary input. If another fault occurs before the LEDs are reset, the relay will automatically reset the LEDs and light the LEDs appropriate for the new fault.

To reset the LEDs, press **Target Reset** on the front panel, or go to **Address 8201 RESET LED?** and press **Yes**.

14.1.6 Custom LED Labels

Each relay provides you space to label its LEDs based on how you program them. Labels for the preset annunciations are provided with the relay. The slip of paper with the labels printed on it slides into the top of the front panel, which is accessible with the relay partially pulled forward out of its housing.

14.1.7 Data Communications Port

This serial data port allows you to connect a personal computer (PC) directly to the relay. This port conforms to the EIA RS-232 standard. This feature is typically used in conjunction with WinDIGSI software to view event logs and target logs, to monitor measured values, to program the settings, and to analyze captured waveforms.

14.2 Viewing a Setting

There are two ways to select a specific memory Address to view or change its contents. One is to go directly to an Address by entering its number as described below. The other is to scroll through the addresses until you reach the one you want.

14.2.1 Entering an Address Directly

If you know the Address you want to view or change, the fastest way to get to it is by direct addressing. Do the following:

1. Press **Direct Addr**. key, the LCD will prompt you to enter an address:

```
DIRECT ADDRESS
```

2. Enter the four-digit Address number.

3. Press **Enter**. The Address number, description, and the present setting will appear on the LCD display.

Key	Description
Pass word	**Password** Accesses the relay password function.
Direct Addr	**Direct Address** Directly accesses an address — enter the address number after pressing this key.
Event	**Event** Directly accesses address 5000 (Annunciations).
Target Reset	**Target Reset** Tests and resets the LEDs.
△△ / ▽▽	**Double Arrow** Navigation keys scroll through address blocks.
△ / ▽	**Single Arrow** Navigation keys scroll through addresses or through a list of logical functions.
F	**Function** Used in combination with numeric keys to select certain functions.
0 / 9	**Numeric Keys (0-9)** Enters numeric data (addresses, values, etc.).
.	**Decimal Point** Indicates a decimal point in numeric data.
+/-	**Plus-Minus** Toggles between positive and negative values.
Back Space	**Backspace** Deletes one character to the left.
∞	**Infinity** Enters the setting value of infinity.
Enter	**Enter** (1) Confirms the address or value that has been keyed in or selected, or (2) clears error or operational messages from the LCD.
Yes	**Yes** (1) Accepts the displayed setting, or (2) responds "Yes" to the displayed question.
No	**No** (1) Rejects the displayed setting, or (2) responds "No" to the displayed question.

Figure 14.3 *Keypad Key Descriptions*

14.2.2 Scrolling to an Address

If you are not sure of the number of the Address you want to view or change, or if you want to scroll to another address, you can select an Address with the navigation keys. Two keys (double arrows keys) change the Address block, while two (single arrow keys) move up and down within an Address block. As each key is pressed, the LCD identifies the newly selected block or address.

- Press ⇑ to scroll to the next higher block.
- Press △ to scroll to the next higher Address in a block.
- Press ▽ to scroll to the next lower Address in a block.
- Press ⇓ to scroll to the next lower block.

14.3 Changing a Setting

To change the content of a memory address, the Address must be selected and the relay must be placed in password mode. How you then change the address's content depends on whether the Address content is an entered value, an option chosen from a menu, or an option chosen from a two-level menu. These procedures are described in this section.

If relay configuration settings have been changed the processor system will reset when the settings are saved. During reset the device is not operational.

The relay stores the changed information in volatile memory until you explicitly save it, as described in the procedures in this section. Note that saving a setting change may be required before the relay will allow further parameter changes related to that setting. This will also require a re-entry of the password.

14.3.1 Entering Password Mode

To prevent inadvertent changes to the relay configuration or loss of recorded data, any keypad inputs that would affect the operation of the relay must be preceded by the entry of a password that places the relay in password mode. You do not need to be in password mode to examine the present settings, look at event and fault logs, or look at measured values.

Normally the relay is in Display mode when powered up. The display has a solid rectangle on the first line of the front panel display that does not blink when the relay is in Display mode. In password mode, the display shows the solid rectangle blinking on the first line of the display.

Note: The factory-set password is six zeros (000000) and cannot be changed. The relay remains in password mode until you save the settings as discussed below.

You can enter the password *before* or *after* selecting an address, but you must enter it before you can change the content of the address.

To place the relay in Password mode, do the following:

1. Press the **Password** key. The password prompt will appear:.

```
ENTER PASSWORD
```

2. Enter the relay's password (000000) using the number keys from the keypad. The LCD displays each digit entered as an @ symbol:

```
ENTER PASSWORD
@@@@@@
```

3. Press the **Enter** key after you complete the entry.

4. If a correct password has been entered, the LCD displays a confirmation message that the password has been accepted:

```
ENTER PASSWORD
PW ACCEPTED
```

If the wrong password has been entered, the dialog box displays the following message:

```
ENTER PASSWORD
INVALID PASSWORD
```

Begin again with Step 2.

5. When the confirmation message appears, press the **Enter** key. The display returns to the Address where you were before you pressed the **Password** key.

If you change a value or choice stored in an Address and then press ⇑ or ⇓ to scroll out of the Address block, the LCD may ask if you want to exit Password mode. Press **No** to continue selecting addresses and perhaps make other changes, or press **Yes** if you are done making changes. If you press **Yes**, the LCD will ask if you want to save the change(s) you have made. Press **Yes** to save the change(s), or press **No** to abandon the change(s). In either case, you exit Password mode and will have to re-enter the password before making further changes.

14.3.2 Changing an Entered Value

To change the content of an Address which contains an entered value, do the following:

1. If the relay is not already in password mode, enter the password.

2. Enter or select the Address whose content you want to change. The existing value will be displayed.

3. Use the number keys to enter the new value, then press the **Enter** key. (The backspace key enables you to move to the left and re-enter a digit.)

   The new value will be displayed. If the value you entered is outside the allowed range for that address's content, a "**Value Too Small**" or "**Number Too Big**" message will appear. Re-enter an allowed value, or press **Enter** to cancel the change and keep the existing value.

4. If you wish, change other values or choices in other addresses.

5. When done, press the **F** key, then the **Enter** key. The LCD will ask if you want to save the changes. Press **Yes** to save the change(s), or press **No** to abandon the change(s). In either case, you exit password mode and will have to re-enter the password before making further changes.

14.3.3 Changing a Setting Selected from a List

To change the content of an Address that contains a selection from a list of options, do the following:

1. If the relay is not already in password mode, enter the password.

2. Enter or select the Address whose content you want to change. The existing selected option will be displayed.

3. To change the existing selection, press **No** until the option you want is displayed, then press **Yes**.

4. If you wish, change other values or options in other addresses.

5. When done, press **F**, then **Enter**. The LCD will ask if you want to save the changes. Press **Yes** to save the change(s), or press **No** to abandon the change(s). In either case, you exit password mode and will have to re-enter the password before making further changes.

14.3.4 Changing a Control Configuration Option

To change a control configuration option or an LED configuration, do the following:

1. If the relay is not already in password mode, enter the password.

2. Enter or select the Address whose content you want to change.

3. Press **F** and △ to get to the submenu of possible options.

4. To change the existing option, press the **No** key until the option you want is displayed.

5. Press **F** and △ to exit the submenu.

6. Exit password mode and re-enter the password before making further changes.

14.4 Using Multiple Settings Groups

Up to four sets of protection settings can be stored in memory to enable rapid switching between stored configuration. Note that not all Address are duplicated in each set; only the protective settings (Address blocks 1000 to 4000). The sets are named A, B, C, and D.

An example application where more than one group of settings would be practical would be a facility that had seasonal weather changes and one group of settings was relevant for one season and another group of settings could be switched to for another season.

14.4.1 Selecting Which Group to Configure

Follow these steps to change which set you are **configuring** without changing which set is **in use**:

- Set A – press **F**, press **1**, then press **Enter**
- Set B – press **F**, press **2**, then press **Enter**
- Set C – press **F**, press **3**, then press **Enter**
- Set D – press **F**, press **4**, then press **Enter**

14.4.2 Changing the Group in Use by the Relay

To change which group is in use by the relay, do the following:

1. If the relay is not already in Password mode, enter the password.

2. Select Address 8503, then choose which group to use:

8501 ACTIVE GRP
8503 SELECT GRP
Address 8501 contains the selection of which group to use, while Address 8503 contains the selection of which group you want to make active.

Option	Description
SET A	Settings Group A
SET B	Settings Group B
SET C	Settings Group C
SET D	Settings Group D
SET BY BIN.INPUT	Settings group will be controlled by a signal contact input.
SET BY LSA CONTR	Settings group will be controlled by an LSA controller.

3. Press **Enter**.

   The contents of Address 8501 will be replaced by the option you selected in Address 8503, making it the active group.

Change-over of the Active Parameter Set via Binary Inputs

If change-over of parameter sets is intended to be carried out via binary inputs, the following should be followed:

- Activation must be switched to **Set By Bin Inputs**
- Two logical binary inputs are available for control of the 4 parameter sets. These binary inputs are designated of “ParamSelec. 1” (Event 7) and “ParamSelec. 2”, (Events 8).
- The logical binary inputs must be allocated to two physical input modules in order to allow control. An input is treated as not energized when it is not assigned to any physical input.
- The control input signals must be continuously present as long as the selected parameter set is active.

The active parameter sets are assigned to the logical binary inputs as shown in Table 14.1

Binary Input		
>ParamSelec. 1	**>ParamSelec. 2**	**Causes Active Set**
no	no	Set A
yes	no	Set B
no	yes	Set C
yes	yes	Set D

Table 14.1 *Parameter Set Change Via Binary Input*

14.4.3 Copying a Group’s Contents

Since you often will have settings groups that are similar, the relay provides a way to copy the contents of one setting group into another.

To copy the contents of one set into another, do the following:

1. If the relay is not already in password mode, enter the password.
2. Select one of the following addresses:

8510 COPY ORIG.SET ->SET A **8511 COPY ORIG.SET ->SET B** **8512 COPY ORIG.SET ->SET C** **8513 COPY ORIG.SET ->SET D** **8514 COPY SET A -> SET B** **8515 COPY SET A -> SET C** **8516 COPY SET A -> SET D** **8517 COPY SET B -> SET A** **8518 COPY SET B -> SET C** **8519 COPY SET B -> SET D** **8520 COPY SET C -> SET A** **8521 COPY SET C -> SET B** **8522 COPY SET C -> SET D** **8523 COPY SET D -> SET A** **8524 COPY SET D -> SET B** **8525 COPY SET D -> SET C**
Select one of these addresses and press Yes to perform the corresponding copying of a settings group’s contents.

3. Press **Yes.**

The message IN PROGESS will appear, followed by the word **Successful**.

14.5 Operational/Event Log and Fault Logs

The relay records in internal logs messages describing events. The **Event Log** includes the 50 most recent events of all types, including pickup and dropout of active protection functions, activation and deactivation of contact inputs, signal contact outputs, trips, relay diagnostics, and other relay operational information. Three (3) additional logs, the **Fault Logs**, each record up to 80 fault-related events that occur from the pickup to the dropout of any active protection function.

If a log becomes full and another event occurs, the oldest message in the log is discarded to make room in memory for the new event message. If a pickup occurs (starting a new fault log), the oldest fault log will be discarded if necessary to make room for the new fault log.

You can manually clear a log, and you can export its contents through the serial ports on the relay. The WinDIGSI software running on a PC connected to the relay can store as many event-messages as you wish to save.

Each event message has three parts:

- The date and time of the event (to the nearest millisecond)
- A description of the event
- An indication of whether the condition that triggered the event was starting (**C**, for "*coming*") or ending (**G**, for "*going*"). For example, a pickup will generate two events, one at the time of pickup and one at the time of dropout. Events which have no duration are always marked as "coming".

Only the three most recent fault logs can be displayed on the front panel LCD; however, as many fault logs as required and be store on a PC using WinDIGSI software.

For each event, the data and time of the event are displayed on the top line, while the event type and coming/going code is displayed on the bottom line. For example:

```
04/12/96  08:32:52??
LED Buff.Inva:G
```

Unused memory locations of a log contain the message "empty."

To set the date and time, see Section 14.12 on page 152.

Remember that a protection function must be enabled and active to generate events.

The first trip log entry message displays the fault number as recorded since the relay memory was last cleared. Subsequent display messages indicate all relay events that occur after initial detection of the fault until drop-out. "Table overflow" is displayed in the last message slot when messages are lost due to memory overflow, and "Table superseded" is displayed when a new fault has occurred while displaying the fault data.

14.5.1 Viewing a Log

To view the Event Log on the front-panel LCD, press the **Event** key, then scroll through it using the up-arrow and down-arrow keys. To view a fault, go to its address, then scroll.:

5100 Operational Annunciations Contains the 50 most recent event messages, both operational and fault messages, with older messages overwritten by newer messages.
Possible messages are listed in Table 13.1.

5200 LAST FAULT **5300 2nd TO LAST FAULT** **5400 3rd TO LAST FAULT** Each fault log contains up to 80 fault-related event messages beginning with the pickup of any active protection function and ending with the dropout of that function. If necessary to make room, the oldest fault log and/or oldest event messages within a log may be overwritten.
Possible messages are listed in Table 13.1.

14.5.2 Clearing a Log

Follow these steps to reset the Event Log and/or Fault Logs:

1. Enter the password (000000).
2. Go to Address 8202 to reset the Event/ Operational Log, or Address 8203 to reset the fault logs.
3. Press the **YES** key.

In a moment, the message “**SUCCESSFUL**” will appear.

14.6 Measured Values

Metered values are system data collected and calculated by the relay. The relay can display metered values on the front panel LCD, or export them to a device connected to the relay through a serial port. The display of metered values is updated every 1 to 5 seconds. The ability to check the relay’s metered values is helpful during commissioning, normal operation, and troubleshooting.

5700 Operational Metered Values
5900 Thermal Overload Protection Calculated Values
Metered values are stored in these address. They are updated every 1 – 5 seconds.

LCD Abbreviation	Address	Description
W1 Ia[%]= W1 Ib[%]= W1 Ic[%]=	5701 5702 5703	Current in winding (or side) 1 for phases A, B, and C as a percentage of the rated current.
W2 Ia[%]= W2 Ib[%]= W2 Ic[%]=	5704 5705 5706	Current in winding (or side) 2 for phases A, B, and C as a percentage of the rated current.
W3 Ia[%]= W3 Ib[%]= W3 Ic[%]=	5707 5708 5709	Current in winding (or side) 3 for phases A, B, and C as a percentage of the rated current (7UT513 only).
IA[%]= IB[%]=	5710 5711	Additional current inputs when used and assigned (7UT513 only).
W1 Ia= W1 Ib= W1 Ic=	5721 5722 5723	Current in winding (or side) 1 for phases A, B, and C in amps.
W2 Ia= W2 Ib= W2 Ic=	5724 5725 5726	Current in winding (or side) 2 for phases A, B, and C in amps.
W3 Ia= W3 Ib= W3 Ic=	5727 5728 5729	Current in winding (or side) 3 for phases A, B, and C in amps (7UT513 only).
IA= IB=	5730 5731	Additional current inputs when used and assigned in amps or milliamps, depending on how configured (7UT513 only).
Θ1/Θtrp Θ1/ΘtrpA Θ1/ΘtrpB Θ1/ΘtrpC	5911 5912 5913 5914	Temperature rise of 49-1 protection function for all phases, and separately for phases A, B, and C.
Θ2/Θtrp Θ2/ΘtrpA Θ2/ΘtrpB Θ2/ΘtrpC	5921 5922 5923 5924	Temperature rise of 49-2 protection function for all phases, and separately for phases A, B, and C.

14.7 Capturing Waveform Data

5700 Operational Metered Values
5900 Thermal Overload Protection Calculated Values
Metered values are stored in these address. They are updated every 1 – 5 seconds.

LCD Abbreviation	Address	Description
W1 Ia[%]= W1 Ib[%]= W1 Ic[%]=	5701 5702 5703	Current in winding (or side) 1 for phases A, B, and C as a percentage of the rated current.
W2 Ia[%]= W2 Ib[%]= W2 Ic[%]=	5704 5705 5706	Current in winding (or side) 2 for phases A, B, and C as a percentage of the rated current.
W3 Ia[%]= W3 Ib[%]= W3 Ic[%]=	5707 5708 5709	Current in winding (or side) 3 for phases A, B, and C as a percentage of the rated current (7UT513 only).
IA[%]= IB[%]=	5710 5711	Additional current inputs when used and assigned (7UT513 only).
W1 Ia= W1 Ib= W1 Ic=	5721 5722 5723	Current in winding (or side) 1 for phases A, B, and C in amps.
W2 Ia= W2 Ib= W2 Ic=	5724 5725 5726	Current in winding (or side) 2 for phases A, B, and C in amps.
W3 Ia= W3 Ib= W3 Ic=	5727 5728 5729	Current in winding (or side) 3 for phases A, B, and C in amps (7UT513 only).
IA= IB=	5730 5731	Additional current inputs when used and assigned in amps or milliamps, depending on how configured (7UT513 only).
Θ1/Θtrp Θ1/ΘtrpA Θ1/ΘtrpB Θ1/ΘtrpC	5911 5912 5913 5914	Temperature rise of 49-1 protection function for all phases, and separately for phases A, B, and C.
Θ2/Θtrp Θ2/ΘtrpA Θ2/ΘtrpB Θ2/ΘtrpC	5921 5922 5923 5924	Temperature rise of 49-2 protection function for all phases, and separately for phases A, B, and C.

The relay can record waveform data for the time just before, during, and just after a fault. While this data cannot be viewed on the front panel LCD, it can be exported to a PC for analysis and viewing. The sampling rate is 12 samples per power cycle. Data for up to 3 faults is stored.

The storage of waveform data can be initiated in four ways: (1) by the pickup of any active protection function, (2) by the trip of any active protection function, (3) by an external signal-contact input, or (4) by a manual command using the front panel keypad.

The waveform recording-time period is divided into three parts: the **pre-time**, the **middle-time**, and the **post-time**. The middle-time period begins when an event initiates a fault log (a pickup, trip, contact-input, or keypad-input). The middle-time ends with the dropout of the protection function (for internally initiated recordings), after a specified time period (for recordings initiated by a signal-contact or a keypad-input), or the external signal-input ends (an option for recordings initiated by a signal-contact input).

Waveform data can be included for a specified pre-time and post-time before and after the middle-time. The total recording-time period is limited by a specified maximum time.

To configure waveform recording, specify the following:

1. Specify when an enabled and active protection function will initiate waveform recording:

7402 INITIATION Kind of protection-function event (any pickup or any trip) that will initiate storage of a waveform recording, and which event starts the middle-time.	
STORAGE BY FD	pickup initiates storage; middle-time begins when pickup occurs
STORAGE BY TRIP	trip initiates storage; middle-time begins when pickup occurs
START WITH TRIP	trip initiates storage; middle-time begins when trip occurs

2. Specify the maximum recording-time (pre-time + active-time + post-time) for recording events:

7410 T-MAX Maximum duration for waveform recording. The maximum duration is dependent on the frequency chosen. For 50 Hz or 16 2/3, the maximum time is 5 seconds. For 60Hz, the maximum time is 4 seconds.	
1.00 s	0.30 – 4.00 seconds

3. Specify the length of the pre-time to include in the recording-time before the middle-time:

7411 T-PRE Length of pre-time during which to include waveform data.	
0.10 s	0.05 – 0.50 seconds

4. Specify the length of the post-time to include in the recording-time after the middle-time:

7412 T-POST Length of time to continue recording waveform data after the end of the middle-time. Note that the maximum recording-time (Address 7410) takes precedence over this setting.	
0.10 s	0.05 – 0.50 seconds

5. If the relay's configuration includes having a signal-contact input directly initiate a waveform recording (see Section 13.2 on page 126), specify the middle-time period of the resulting fault log:

7431 T-BINARY-IN Length of middle-time when waveform recording is initiated by a signal-contact input. A setting of ∞ will extend the middle time until the signal-contact becomes inactive. Note that the maximum recording-time (Address 7410) takes precedence over this setting.	
0.50 s	0.10 – 4.00 seconds, or ∞

6. If waveform recordings will be initiated manually using the front panel keypad, specify the middle-time period of the resulting fault log:

7432 T-KEYBOARD Length of middle-time when waveform recording is initiated by a manual input using the front panel keypad. Note that the maximum recording-time setting (Address 7410) may end recording sooner.	
0.50 s	0.10 to 4.00 seconds

7. The following setting can be ignored when waveform data is exported using the VDEW protocol:

7490 SYS LENGTH Specification of length each fault record exported out either of the relay's serial ports. This setting only applies to older data communication networks using the Siemens LSA protocol, and has no effect on networks using the VDEW/ZVEI protocol.	
660 VALUES FIX	fixed length of 660 values
<=3000 VAL. VAR.	variable length of up to 3000 values

14.8 Address Blocks

Each relay setting is assigned to an Address number that must be accessed to display or to change the setting. Address numbers are grouped into blocks according to their function. The main Address blocks are listed below.

Block	Function (LCD Text)	Description
1000	PARAMETERS	Protection and system settings (1100-3900)
1100	TRANSFORMER DATA	Transformer setup information, such as the number of windings, used in transformer differential protection (87T) determined from the relay configuration and cannot be changed
1200	MOTOR OR GENERATOR DATA	Motor or generator setup information, such as the position of the commons of the CTs relative to one another, used in differential protection for either motor (87M) or generator (87G)
1300	TIE-POINT DATA	Bus setup information, used in bus differential protection (87B)
1400	VIRTUAL OBJECT DATA	Virtual object (user assigned object) setup information used in differential protection of another assigned object other than the transformer or bus or motor/ generator.
1600	87 TRANS DIFF PROT. DATA	Transformer differential protection (87T) settings and specify whether on, blocked, or off
1700	87 MOTOR/GEN DIFF PROT	Motor (87M) or generator (87G) differential protection settings and specify whether on, blocked, or off
1800	87TIE PT DIFF PROT	Bus differential protection (87B) settings and specify whether on, blocked, or off
1900	RSTRICTED GND FAULT PROT	Optional restricted ground-fault protection (87N) settings and specify whether on, blocked, or off (in 7UT513 only)
2100	BACKUP OVERCURRENT TIME	Optional time overcurrent protection (50,51) settings and specify whether on, blocked, or off
2400	49 THERMAL OVERLOAD PRT. 1	Optional thermal overload protection (49-1) settings for first of two windings and specify whether on, blocked, or off
2500	49 THERMAL OVERLOAD PRT. 2	Optional thermal overload protection (49-2) settings for second of two windings and specify whether on, blocked, or off
2700	TRANSFORM. TANK PROTECTION	Optional transformer tank protection (64T) settings and specify whether on, blocked, or off (in 7UT513 only)
2900	MEAS. VALUE SUPERVISION	Settings for optional supervision of metered values
3000	EXTERNAL TRIP FUNCTION 1	Settings for an external trip function, including whether on, blocked, or off, delay time before trip, and reset time
3100	EXTERNAL TRIP FUNCTION 2	Settings for a second external trip function, including whether on, blocked, or off, delay time before trip, and reset time
4000	TESTS	Test Settings for Tests (4100-4900)
4100	COMMISSION TESTS	Settings for commissioning tests
4800	END TEST	Used to end the test and take it out of test mode
4900	WAVEFORM CAPTURE TEST	Settings for testing the waveform capture function

Block	Function (LCD Text)	Description
5000	EVENT DATA	Data available about events (faults) (5100-5900)
5100	EVENT LOG	Event (fault) log
5200	LAST FAULT	Data of the most recent event (fault) including time stamp and applicable alarms
5300	2nd TO LAST FAULT	Data of the2nd most recent event (fault) including time stamp and applicable alarms
5400	3rd TO LAST FAULT	Data of the 3rd most recent event (fault) including time stamp and applicable alarms
5700	METERING	Data from metering functions
5900	MEASURED OVERLOAD VALUE	Data from predefined overload values.
6000	CONFIGURATION	Matrix settings connecting inputs to outputs (6100-6900)
6100	CONFIGURING DISCRETE INPUTS	Settings for the contact inputs
6200	CONFIGURING SIGNAL RELAYS	Settings for the output contacts
6300	CONFIGURING LEDs	Settings for the LEDs on the front panel
6400	CONFIGURING TRIP CONTACTS	Settings for the trip contacts
7000	DEVICES CONFIGURATION	Settings for the relay and interfaces to other systems (7100-7900)
7100	LOCAL USER INTERFACE	Settings for the front panel display
7200	SERIAL COMM CONFIGURATION	Settings for serial communication (RS-232) at the front port
7400	WAVEFORM CAPTURE	Data from the waveform capture function
7800	DEVICE OPTIONS	Settings for the relay
8000	OTHER OPTIONS	Optional settings for the relay (8100-8900)
8100	DATE AND TIME	Date and time for the relay
8200	RESETTING STORED DATA	How and when to reset stored data in the relay
8300	REAR FORMAT	Settings for the rear port for network communications
8500	SETTING GROUP OPTIONS	Optional settings for a group of protection settings

14.9 General Configuration

Operating the relay and configuring its settings is done by viewing and changing the values stored in memory addresses. This can be done using the front panel operator interface or using software running on a PC connected to the relay. This section describes configuration settings that apply to all applications of the relay.

14.10 Front-Panel Display Options

Address Block 7100 contains addresses that specify the appearance and content of the LCD display on the front panel of the relay, and what kind of an event will update the LCD display and LED states.

7101 LANGUAGE Language used in LCD display	
Option	**Description**
German	(default)
English	
US-English	

7102 DATE FORMAT Date format	
Option	**Description**
DD.MM.YYYY	European (default)
MM/DD/YYYY	American

7105 LINE1 NORML **7106 LINE2 NORML** Information shown on line 1 (top line) and line 2 (bottom line) of LCD during normal operation.	
Option	**Description**
value	Any measured current value (see Address Block 5700); any measured thermal rise value (see Address Block 5900) [defaults Line 1: Winding 1PhA current in primary amps Line 2: Winding 2 PhA current in primary amps]

7107 LINE1 FAULT **7108 LINE2 FAULT** Information shown on line 1 (top line) and line 2 (bottom line) of LCD after a network disturbance until a reset
fault type trip type protective function that picked up protective function that tripped time from detection to drop-off time from detection to trip backup overcurrent (9 options) differential protection (8 options) [defaults Line 1: Protection function(s) pickup Line 2: Protection Trip]

7110 NEW TARGETS Type of event that will update the LCD information and LED states	
Option	**Description**
WITH PICKUP	with pick up [any fault event] (default)
WITH TRIP	with trip [only when a trip occurs]

14.11 Use of Multiple Parameter Sets

If you want to use multiple settings groups, enable this capability:

7885 SEL.SET.GRP Capability to use multiple settings groups (change-over)	
Option	**Description**
NONEXISTENT	(default)
EXISTENT	

14.12 Setting Date & Time

The date and time can be set as long as the real-time clock is operational. This is done by changing the setting in Address 8100. The password is required to change the setting. Each modification must be confirmed with **Enter**. The date and time are entered with dots as separator signs since the keypad does not have a colon or slash (for American date format).

The clock is synchronized at the moment when **Enter** is pressed following input of the complete time. The delta time facility (Address 8104) enables a more exact setting of the time since the difference can be calculated prior to the input, and the synchronization of the clock does not depend on the moment when **Enter** is pressed.

8100	**DATE AND TIME**	
Address	**Setting**	**Options**
8102	SET DATE	DD.MM.YYYY MM.DD.YYYY
8103	SET TIME	HH.MM.SS
8104	DELTA TIME	Enter amount of time by which to set clock forward or backward.

15 Operation Using a Personal Computer

15.1 Overview

All the settings and data of the 7UT51 relay are available to a PC connected to the communications port. At the computer, the data can be easily read on the screen, changed, saved to disk, or printed. To do this, Siemens provides Windows-based software, called WinDIGSI.

Personal Computer Interface

A front panel 25-pin RS-232 port is available for connection to a PC. This port is intended for the engineer or technician for connection locally at the substation, using the WinDIGSI software supplied with the relay to configure the relay as needed.

Remote Interface

An RS-232 port on the rear of the case provides remote interface for configuring the relay from another facility. This port is transient hardened. The protocol is based on the international IEC-870-5 standard.

This port may be configured in software for modem communication (10-bit) using WinDIGSI software standing alone, using WinDIGSI in concert with WinTerm, ProComm or other terminal emulation software for dial up, or using WinDIGSI with dial up software provided by third-party telephone port switching devices.

This port may also be software configured to include an 11th bit for added data security. This would allow a relay being used as an intelligent electronic device (IED) for substation automation and integration. For more information on protocol and data definition, consult Siemens.

Configuration & Analysis Software

Windows-based PC software supplied with the relay (WinDIGSI) provides access to settings, configuration, metering information, and event logs. Relays may be programmed off-line. Archiving, file management, and rapid loading and altering of programs are also supported. WinDIGSI provides an easy-to-use graphical user interface.

In addition, captured waveforms may be viewed with the inclusion of a Windows-based, full-function digital oscillographic analysis program (WinDIGRA).

WinDIGSI provides the ability to configure a relay or a whole system of relays from one personal computer. The Windows-based software allows the user to configure a relay for various types of protection. It also allows the user to retrieve and analyze event data. Displaying data including waveform captures is an integral part of the software.

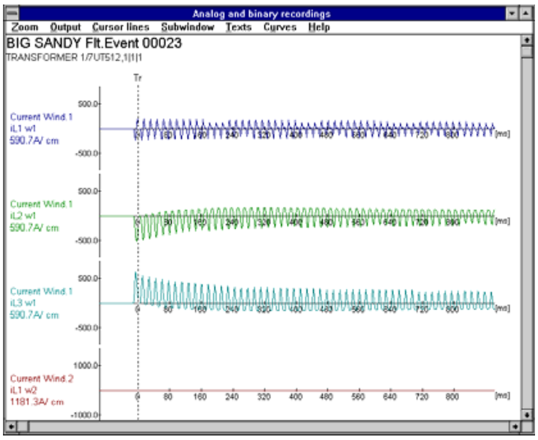


Figure 15.1 *Example WinDIGSI Waveform Capture*

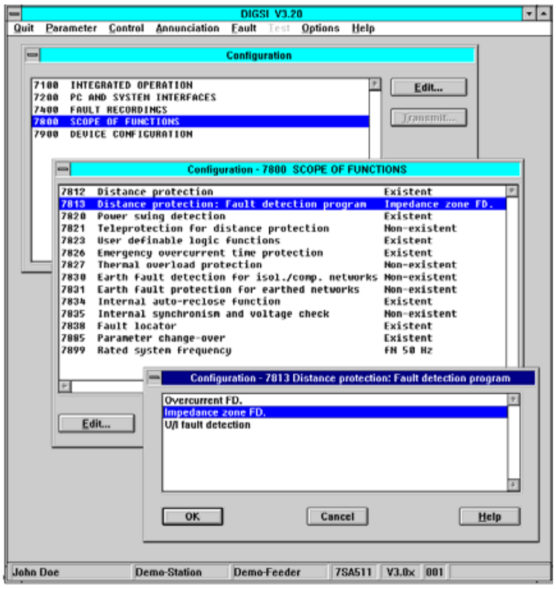


Figure 15.2 *Example WinDIGSI Screens*

15.2 Programming the Relay

Programming of the relay with a PC and WinDIGSI software is straight forward since it is Windows based; however, consult the Siemens *WinDIGSI User's Manual* for detailed instruction if necessary.

When using a PC to set the parameters, it is best to enter the data as you page through the screens rather than programming for particular functions. The following parameters must be entered to enable the relay to respond accurately with tripping, alarms, measurements, and event recording, etc. Use the completed Relay Setting Sheets (available in Chapter 19) to expedite with the programming process.

Before programming begins, the entry of the following information is required:

- Enter *User Name*
- Choose *NEW* Substation
- Enter the *Destination Directory*
- Enter the *Substation Address*
- Enter the *Feeder Name*
- Enter the *Device Name*
- Enter the *Device Address*
- Enter the *Ordering Code*
- Choose the menu option *DIALOG*
- Choose *with file or with protective device direct*

WinDIGSI then opens a new screen with the following menu options:

- Parameter (describe in detail in Section 15.3 on page 154)
  - Configuration Menu
  - Marshalling Menu
  - Settings Menu
- Control
- Annunciations
- Fault
- Options
  - Interface
  - Response Time
  - Delete device files
  - Transmit with/without saving
  - Modify baud rate
  - Command archive
  - Date/Time
  - Reset LEDs
  - Initiate fault record
- Help

15.3 Parameter Menu

The following Parameter menu choices are shown for a 7UT513 with restricted ground-fault option and with isolated serial interface option. Menu options will change depending on the model selected and the device **Enabled** and set to **On**. If you are not certain about the proper parameter settings to use, it is best to keep it at the factory setting.

15.3.1 Configuration Menu

Local User Interface (Address Block 7100)

- Address 7101 – Language
- Address 7102 – Date Format
- Address 7105 – Top Line of Display Under Normal Conditions
- Address 7106 – Bottom Line of Display Under Normal Conditions
- Address 7107 – Top Line of Display After Fault
- Address 7108 – Bottom Line of Display After Fault
- Address 7110 – Update LEDs/display (with pickup or with trip.

Configuration of Communications Port (Address Block 7200)

The device provides one or two serial interfaces: one PC interface in the front for operation by means of a PC and depending on the model ordered, another system interface for connection of a central control and storage unit, for example Siemens LSA 678. Communication via these interfaces requires some configured settings: identification of the relay, transmission format, and transmission speed.

- 7209 DEVICE. TYPE
  - Identifies the device type of the relay to Siemens LSA systems and to WinDIGSI software. Usually this setting should not be changed.
- 7211 FRONT PORT
  - Data format for communication via the front-panel data port.
- 7215 FRONT BAUD
  - Data transmission rate for front-panel data port.
- 7216 FRT. PARITY
  - Data parity setting for front-panel data port.
- 7221 REAR PORT
  - Data format for communication of Operational Log and fault logs via the rear data port (on the back of the relay case).
- 7222 REAR FORMAT
  - Data format for communication of measured values via the rear data port (on the back of the relay case).
- 7225 REAR BAUD
  - Data transmission rate for rear data port (on the back of the relay case).
- 7226 REAR PARITY
  - Data parity setting for rear data port (on back of the relay case).
- 7235 PROGviaREAR
  - Choice of whether relay will allow configuration via the rear data port (on the back of the relay case).

Wave Capture (Address Block 7400)

- Address 7402 – Trigger for waveform capture
- Address 7410 – Max length of a waveform capture record
- Address 7411 – Amount of captured waveform prior to trigger
- Address 7412 – Amount of captured waveform after trigger
- Address 7431 – Discrete input initiated waveform capture time
- Address 7432 – Keyboard initiated waveform capture duration
- Address 7490 – Length of fault log (for previous LSA)

Device Options (Address Block 7800)

- Address 7801 – Selection of the protected object
- Address 7806 – Selection of transformer A star point
- Address 7807 – Selection of transformer B star point
- Address 7816 – 87-State of the differential protection
- Address 7819 – Restricted ground-fault protection
- Address 7821 – Backup overcurrent protection
- Address 7824 – 49-Thermal overload protection 1
- Address 7825 – 49-Thermal overload protection 2
- Address 7830 – State of external trip function 1

- Address 7831 – State of external trip function 2
- Address 7885 – Select settings group
- Address 7899 – Rated Frequency

15.3.2 Marshalling Menu

The marshalling menu allows the users to program all of the relay inputs, outputs, and LED indicators.

Configuration of Discrete Inputs (Address Block 6100)

- Address 6101 – Configuration of Discrete Input 1
- Address 6102 – Configuration of Discrete Input 2
- Address 6103 – Configuration of Discrete Input 3
- Address 6104 – Configuration of Discrete Input 4
- Address 6105 – Configuration of Discrete Input 5

Configuration of Signal Relays (Address Block 6200)

- Address 6201 – Configuration of signal relay 1
- Address 6202 – Configuration of signal relay 2
- Address 6203 – Configuration of signal relay 3
- Address 6204 – Configuration of signal relay 4
- Address 6205 – Configuration of signal relay 5
- Address 6206 – Configuration of signal relay 6
- Address 6207 – Configuration of signal relay 7
- Address 6208 – Configuration of signal relay 8
- Address 6209 – Configuration of signal relay 9
- Address 6210 – Configuration of signal relay 10
- Address 6211 – Configuration of signal relay 11

Configuration of LED Indicators (Address Block 6300)

- Address 6301 – Configuration of LED 1
- Address 6302 – Configuration of LED 2
- Address 6303 – Configuration of LED 3
- Address 6304 – Configuration of LED 4
- Address 6305 – Configuration of LED 5
- Address 6306 – Configuration of LED 6
- Address 6307 – Configuration of LED 7
- Address 6308 – Configuration of LED 8
- Address 6309 – Configuration of LED 9
- Address 6310 – Configuration of LED 10
- Address 6311 – Configuration of LED 11
- Address 6312 – Configuration of LED 12
- Address 6313 – Configuration of LED 13
- Address 6314 – Configuration of LED 14

Configuration of Trip Contacts (Address Block 6400)

- Address 6401 – Configuration of Trip Relay 1
- Address 6402 – Configuration of Trip Relay 2
- Address 6403 – Configuration of Trip Relay 3
- Address 6404 – Configuration of Trip Relay 4
- Address 6405 – Configuration of Trip Relay 5

15.3.3 Settings Menu Example for Transformer Protection

Transformer Data Example (Address Block 1100)

- Address 1102 – Rated voltage of transformer Winding 1
- Address 1103 – Rated apparent power (VA) of Winding 1
- Address 1104 – Rated primary current of Winding 1 CT
- Address 1105 – Star-point formation of Winding 1 CT
- Address 1106 – Processing of Winding 1 zero sequence current
- Address 1107 – Rated prim. current of Winding 1 star-point CT
- Address 1108 – Ground point formation of Winding 1 star-point CT
- Address 1121 – Vector group associated with winding 2
- Address 1122 – Rated voltage of transformer winding 2
- Address 1123 – Rated apparent power (VA) of winding 2

- Address 1124 – Rated primary current of Winding 2 CT
- Address 1125 – Star-point formation of Winding 2 CT
- Address 1126 – Processing of winding 2 zero sequence current
- Address 1127 – Rated prim. current of Winding 2 star-point CT
- Address 1128 – Ground point formation of Winding 2 star-point CT

Transformer Data (Address Block 1400)

- Address 1401 – Nominal current of virtual object
- Address 1402 – Rated primary current of CT
- Address 1404 – Rated primary current of star-point CT
- Address 1405 – Ground point of the CT currents

87-Transformer Diff Protection Data (Address Block 1600)

- Address 1601 – 87-State of differential protection
- Address 1603 – 87-Pick-Up value of differential protection
- Address 1604 – 87HS-Highset Pickup rms value of differential protection
- Address 1606 – 87-Slope 1 of operating characteristic
- Address 1607 – 87-Base point for slope 2 of operating characteristic
- Address 1608 – 87-Slope 2 of operating characteristic
- Address 1610 – 87-State of 2nd harmonic restraint
- Address 1611 – 87-2nd harmonic content in the differential current
- Address 1612 – 87-Time for cross-blocking with 2nd harmonic
- Address 1613 – 87-Choice a further (n-th) harmonic restraint
- Address 1614 – 87- nth harmonic content in the differential current
- Address 1615 – 87-Active time for cross-blocking w/ nth harmonic
- Address 1616 – 87-Limit IDIFFmax of nth harmonic restraint
- Address 1617 – 87-Max. blocking time at CT saturation
- Address 1618 – 87-Min. restraint current for blocking @CT saturation
- Address 1625 – 87-Trip time delay of differential current stage
- Address 1626 – 87-Operating time of high-set differential current stage
- Address 1627 – Reset delay after differential operation has been initiated

Measured Value Supervision (Address Block 2900)

- Address 2903 – Symmetry threshold for current monitoring
- Address 2904 – Symmetry factor for current monitoring

16 Bench Testing

⚠ WARNING

Hazardous voltage or current.

Can cause death, serious personal injury, or property damage.

Only qualified personnel should test or commission a relay. Read and understand this manual and the manuals for any test equipment before proceeding.

Before performing work on current transformer wiring, always short-circuit the secondary of the current transformers.

This chapter describes procedures for bench testing a 7UT51 relay, such as for acceptance tests or testing of applied settings. A 7UT51 has many protective elements and control features that can be used in a variety of ways. Testing all of the elements and control features, in the many different ways they can be used, is **not** recommended. Such testing would be time consuming. This chapter provides typical tests for protective functions likely to be used. Testing of all applied “in-service” settings and all required protective functions is recommended.

Sample typical applications are used to illustrate how to calculate test values. Actual test values for a specific application must be calculated from that application’s data.

The procedures take into account that the protection settings may vary, but they assume that the relay’s contact inputs, contact outputs, and LEDs are configured with their default values (unless otherwise specified). If they have been configured differently, the user must determine the expected behavior of the relay and compare it to the observed results of the procedure.

16.1 Required Test Equipment

This procedure *requires* the following test equipment:

- Power source matching the rating of the 7UT51
- Two variable current sources with the following capabilities:
  - Accuracy of +/- 2% or better over the entire output range
  - One source that can provide 20 amps (if 7UT51 rated for 5 amps)
  - One source that can provide 120 Hz, 180 Hz, 240 Hz, and 300 Hz current
  - Both sources can be individually or simultaneously turned on and off
- A timer that can be started when either a current source is turned **On** or **Off**, and stopped by either the opening or closing of a dry contact. The accuracy should be +/- 2% or better. A timer built-in to a test-set with one (or both) of the current sources is preferred.
- An ohmmeter, or other sensor for detecting a transition of a dry contact
- An on/off switch to apply DC voltage to discrete inputs of the 7UT51
- Calculator with the capability of performing sine, cosine, and natural log functions.

The following is not required, but highly recommended:

- A timer with +/- 2% accuracy or better, that can be started by the opening or closing of a dry contact, and stopped by the opening or closing of a dry contact.
- Computer with WinDIGSI software and cable

16.2 Important Notes for This Procedure

Note: Do **not** exceed the current limitations of the 7UT51

- Ensure that output contacts do not break currents greater than their rating.
- Ensure that any control power or test value applied to the relay does not exceed the corresponding input's limit.
- Exceeding the contact or voltage limits may damage the relay.

The current limitations (rms) of the CT inputs associated with the transformer winding (or protected object) and neutral CTs are:

7UT51 RATED CURRENT	CONTINUOUS CURRENT RATING	10 SECOND CURRENT RATING
5 AMPS	I ≤ 20 AMPS	20AMPS < I ≤ 100 AMPS
1 AMP	I ≤ 4 AMPS	4 AMPS < I ≤ 20 AMPS

Table 16.1 *Currents Limitations*

Note: The rated current is on the nameplate.

Be especially mindful of the current limitations when testing the high-set differential element, the upper slope of the differential characteristic, the required restraint current to activate the through-fault-CT-saturation restraint, the high-set element of the overcurrent backup protection, and the thermal overload elements.

The current limitations for the CT input associated with the highly sensitive tank leakage protection, terminals [1D1-1D2] are:

- Continuous Current Rating: I ≤ 15 AMPS
- 10 Second Current Rating: 15 AMPS < I ≤ 100 AMPS

16.2.1 Annunciations and Setting Examples

Event annunciations and setting options for the addresses mentioned are as they appear in the WinDIGSI software or the relay front panel. The titles can vary between the software and the front panel of the 7UT51.

After each test reset all targets and annunciations as described in Section 16.10 on page 177.

16.2.2 Verify Actual Programming of Trip Relays and Signal Relays

For each test, the user should always verify the operation of the relays and targets based on the settings for the particular 7UT51 being tested. Verification of the programming of trip relays and signals relays is especially important during installation testing. The user may have to add tests to the procedure to verify each output relay is operating as intended.

16.2.3 Control of Protective Elements by Discrete Inputs during Testing

The operational status of most of the protective elements can be controlled by discrete inputs. Before testing any element, determine if any such control is intended, and apply (or remove) the necessary input to allow testing.

16.3 Testing Transformer Differential Protection

Note: Do **not** exceed relay's current, voltage, and frequency capabilities when performing tests.

Testing a numerical relay with a test set is a quick method of determining if a relay is correctly connected and functioning as intended. The relay is tested by applying currents to its inputs that simulate field conditions, including the configuration (polarity and wiring) of the CTs.

For testing the differential protection, this function must have been configured as **Exist** (Address 7816) and the protected object (Address 7801) must be a 2WIND-TRANSF or a 3WIND-TRANSF (7UT513 only) or a 1PHASE-TRANSF. Additionally, it must be parameterized as operative, **On** in Address 1601.

Since differential protection is sensitive to single-ended currents, one can simultaneously test that the relay does not trip for through current. If backup overcurrent protection is used in the relay, ensure that the through current applied does not exceed the pickup of the overcurrent function.

The following test procedure is written for a standard delta-wye transformer connected as shown in Figure 16.1. Settings for this example are shown in Table 16.2. If your application varies, determine how current typically flows for the simplest fault in your system and trace the currents through the CTs to the relay inputs (similarly to the method shown in this example). For instance, if the transformer is a wye-wye or delta-delta with no phase shift, the differential relay can be tested by applying only one phase current to each “side” of the relay (the correct polarity and magnitudes must also be considered) that is, to phase A primary and phase a secondary.

Address	Description	Value
1103, 1123	Trans. Winding 1 & 2, kVA	45,000
1102	$kV_{L-L, W1}$	138
1122	$kV_{L-L, W2}$	24.5
1142	$kV_{L-L, W3}$	24.5
1121	Vector Group	d1
1141	Vector Group	d1
1104	In CT Winding 1, amps	300 (CT 300/5)
1124	In CT Winding 2, amps	1200 (CT 1200/5)
1144	In CT Winding 3, amps	1200 (CT 1200/5)
1147	In CT STP3, amps	600 (CT 600/5)

Note: All other parameters remain at default settings unless otherwise noted in individual test instructions. Some addresses may not be available until its protective function is enabled.

Table 16.2 *Example Settings*

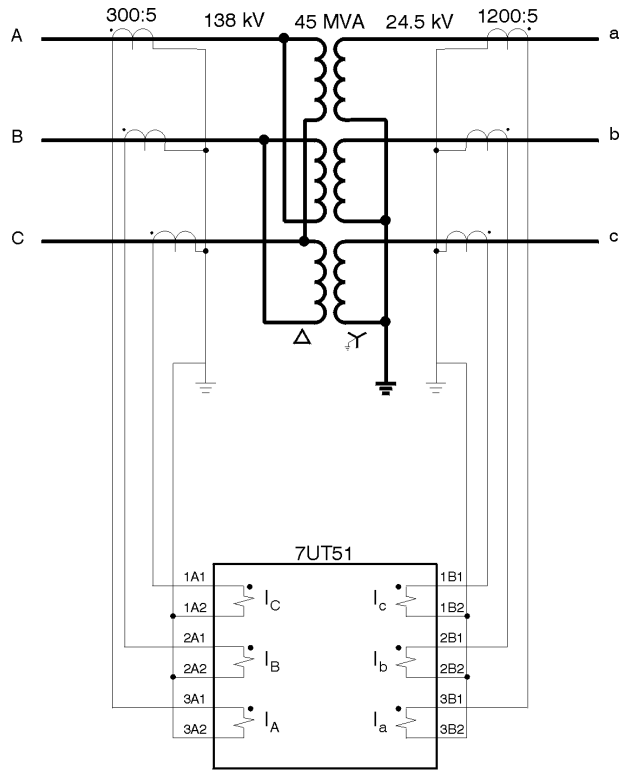


Figure 16.1 *Sample Three-Phase Connection Diagram*

When performing testing other than three-phase testing for the 7UT51 relay and protecting a transformer with a 30 degrees phase shift, keep in mind the underlying physical principles. For instance, if a single-phase to ground-fault on phase ‘a’ occurs on the wye side of an ANSI connected transformer, current will flow as shown in Figure 16.2. The relay would see current in phases A and C (180 degrees apart) on the delta side of the transformer. This is typical for any delta connection.

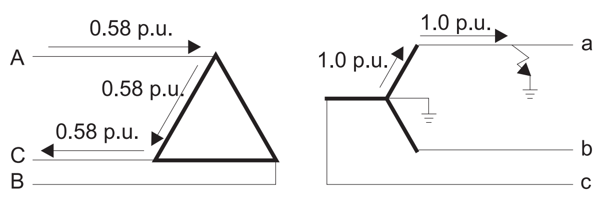


Figure 16.2 *Single-Phase Fault on Wye Side of Delta-Wye Transformer*

16.3.1 Ideal Through-Fault Test

When performing two-source testing, the sources can be set to create an ideal through-fault condition, in which case *no differential current is expected.* The easiest way to test this is to apply the calculated nominal current (I_{Nsec}) on the wye side of the transformer and 0.58 times calculated nominal current on the delta side of the transformer as shown in Figure 16.3, Figure 16.4, and Figure 16.5. These test currents replicate a perfect through current.

I_{NsecW1} is the CT secondary, nominal (per unit base) current of the delta side of the transformer, while I_{NsecW2} is the CT secondary, nominal (per unit base) current of the wye side of the transformer:

$$I_{\text{NsecW1}} = \frac{\text{kVA Rating of Transformer}}{\sqrt{3} \times V_{\text{L-L,W1}} \times \text{CTR}_{\text{W1}}}$$

$$I_{\text{NsecW2}} = \frac{\text{kVA Rating of Transformer}}{\sqrt{3} \times V_{\text{L-L,W2}} \times \text{CTR}_{\text{W2}}}$$

where

V_{L-L} =Line-to-Line Voltage in kV
CTR =CT Ratio
$W1$ =Data Associated with Winding 1 (Delta-side in this example)
$W2$ =Data Associated with Winding 2 (Wye-side in this example)

Note: The values to use for the above equation are found or entered in Address Block 1100. Be aware that CT ratios are not entered in this Address Block if the CTs have a secondary rating of 5 amps. Instead, the primary current ratings of the CTs, for the set ratios, are entered in Addresses 1104, 1124, and 1144. For CTs with a rating of 5 amps, these addresses must be divided by 5 amps to obtain the ratios to use in this equation.

Connect Test Equipment

Connect the test equipment and the relay as shown in Figure 16.3. The currents I_1 and I_2 must be 180° apart (±1°) to simulate a through-fault condition.

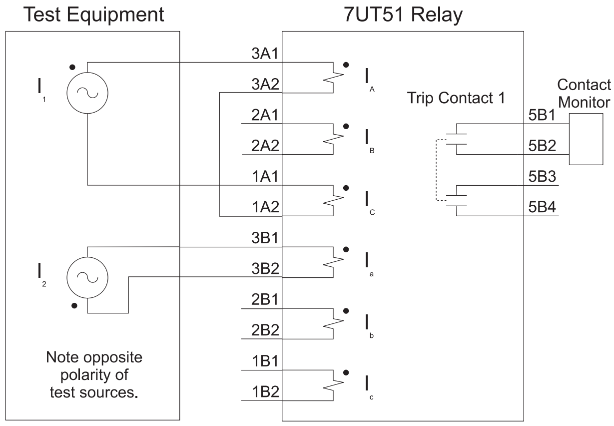


Figure 16.3 *Two-Source Through-Fault Test for Phase A-Gnd Fault on Wye Side*

Apply Currents

Calculate and apply currents I_1 and I_2, as shown in Figure 16.3:

$$I_1 = \frac{1}{\sqrt{3}} I_{\text{NsecW1}}$$

$$I_2 = I_{\text{NsecW2}}$$

Using the example values from Table 16.2:

$$I_1 = \frac{1}{\sqrt{3}} \times \frac{45{,}000 \text{ kVA}}{\sqrt{3} \times 138 \text{ kV} \times (300/5)} = 1.81 \text{ A}$$

$$I_2 = \frac{45{,}000 \text{ kVA}}{\sqrt{3} \times 24.5 \text{ kV} \times (1200/5)} = 4.42 \text{ A}$$

Expected Result

If applied accurately, the above currents will result in a differential of less than 2%. If overcurrent elements are being used and the overcurrent pickup levels will be exceeded by one of the test currents, reduce both source currents proportionally or temporarily turn the overcurrent off. The same should be considered for the restricted ground-fault function.

The applied test currents should not cause the relay to trip or pickup. Confirm that this is true.

16.3.2 Validate Metering

Testing the metering of numerical relays is the quickest method of determining if a relay is no longer functioning or that it is incorrectly connected. If the relay cannot correctly determine what is being applied to its inputs, it can no longer protect by default.

Next, check the differential current metering of the relay (taking into account phase relationships and CT settings). These values can be read directly from the front display of the relay or remotely (on a PC) using WinDIGSI software.

To read these values directly from the front panel display:

1. Press **Dir Addr** and enter 4101. The display should now read “4101 Test Diff - Measuring?”.

2. Press the **Yes** key. The display will report ”I1 PhA= xxx”, where xxx is the PhA current on primary as a percentage of 5 A. The value should be the current you are injecting into I_1 PhA divided by 5 A.

3. Press the **No** key to page through the metering of the rest of the inputs. For the test shown in Figure 16.3 “I1 PhA” and “I1 PhC” should read approximately 36.2% and I2 PhA should read approximately 88.4%

4. Next display the differential current, which the relay calculates. Press **Dir Addr** and enter 4161. The display should now read “4161 TEST DIF/ST - INDICATE RESULT?”.

5. Press the **Yes** key. The display will report ”IaDiff = xxx”, where xxx is the PhA differential current calculated by the relay. It should measure from 1.0 to 2.0% of the differential current, if the test sources being used are accurate.

6. Press the **No** key to page to “IbDiff” and “IcDiff”. These should also read under 2.0% differential current. If this accuracy cannot be achieved, verify the phase angles and magnitudes of the applied signals.

7. Press **Dir Addr** and enter 4801. The display should now read “4801 STOP TEST - FINISH?”

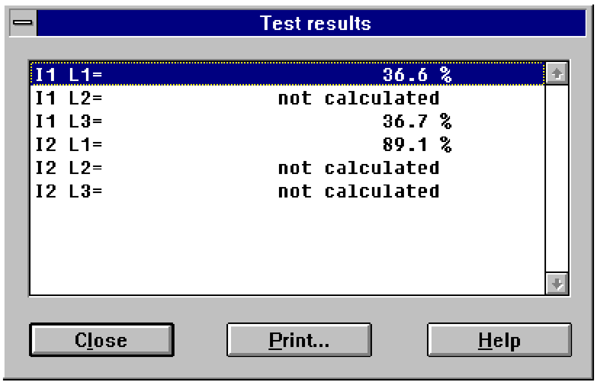
8. Press the **Yes** key to end the differential current tests.

To read these values using WinDIGSI, begin communication with the relay, then:

1. Click **Test** in the menu bar.

2. Select “**Commissioning Tests**.”

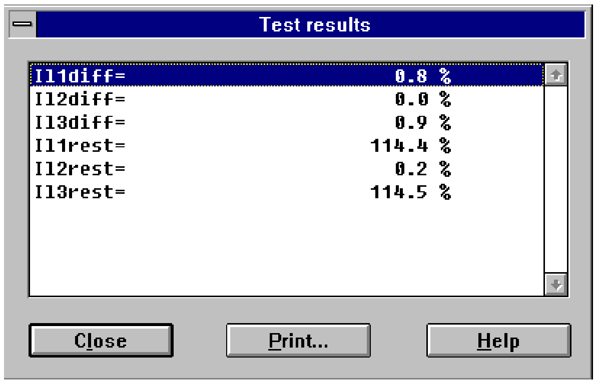
3. Select the function “**4101 Measuring and indication of current values**”, then click **Yes**. The following dialog box will appear in WinDIGSI:



The displayed current values are percentages of 5A. “Ix Ly” is an abbreviation for the Winding ‘x’ Phase ‘y’ current. The currents should correspond to your test configuration.

4. Click **Close**. The Commissioning Tests dialog box will become active again.

5. Select “**4161 Indication of diff. and restr. current values**”, the click **Yes**. The following dialog box will be appear in WinDIGSI or each value can be read out on the LCD:



If the test sources being used are accurate, IL1diff”, IL2diff” and IL3diff” should all measure less than 2.0%

6. Click **Close** to close the Test Results dialog box.
7. Click **Close** to close the **Commissioning Tests** window.
8. Select “**4800 Commissioning Tests Stop**”.
9. Select “**4801 Stop the Commission Tests**” and click **Yes**.

Validate for Other Phases

Connect the test sources to the relay as shown in Figure 16.4 and Figure 16.5. In each case, re-apply the test currents and check the metering as described in the previous procedure.

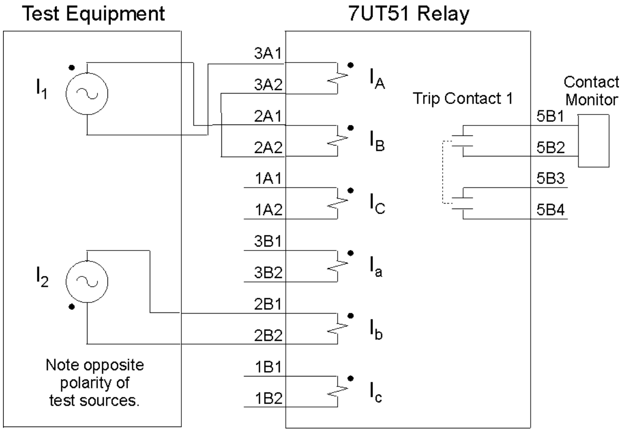


Figure 16.4 *Two-Source Through Fault Testing for Phase B-Gnd Fault on Wye Side*

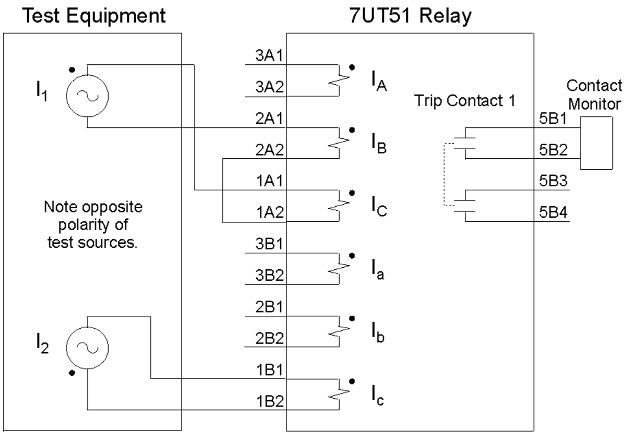


Figure 16.5 *Two-Source Through Fault Testing for Phase C-Gnd Fault on Wye Side*

16.3.3 Three-Winding Transformer Differential Protection (7UT513 Only)

A 7UT513 relay, protecting three winding transformers, can be adequately tested by considering two windings at a time, and testing them like a two-winding transformer. Test the reference winding and Winding 2. Then test the reference winding and Winding 3. Testing Winding 2 and Winding 3 is not necessary.

To test tertiary transformer differential protection, do the following:

1. For testing the three-winding transformer differential protection, this function must be configured as EXIST (Address 7816) and the protected object (Address 7801) must be a 3WIND-TRANSF (7UT513 only). Additionally, it must be parameterized as operative, **On** in Address 1601.
2. Connect the relay as shown in Figure 16.6. (assuming the tertiary winding is connected in a wye configuration.)

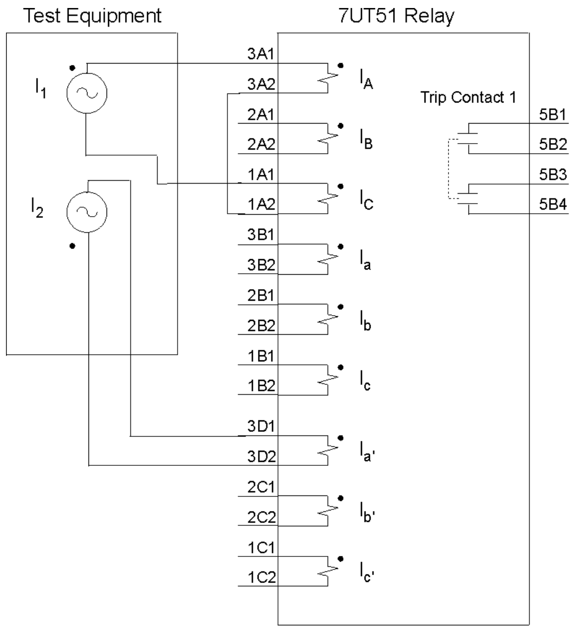


Figure 16.6 *Two Source Through-Fault Testing for Delta-Wye 3 Winding Transformer Protection*

3. Follow the same procedure as described earlier in this section, but use the configuration of the tertiary winding in place of the secondary winding.

16.3.4 Testing the Differential Element 87T

Connect your current source to IA primary (as seen in Figure 16.7).

Note: Any CT input may be used.

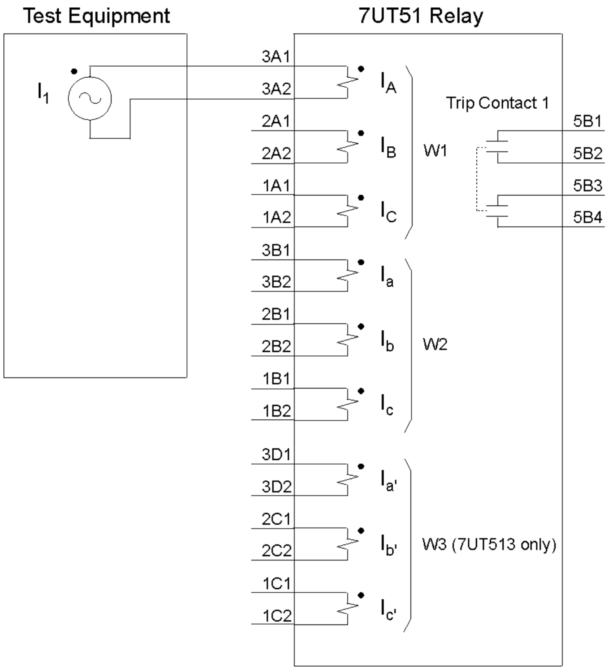


Figure 16.7 *Differential Setpoint Testing*

When testing with the operational parameters, it should be noted that the setting value 87T refers to the rated current of the transformer. The pickup values can change with single and two-phase testing depending on the vector group of the protected transformer; this corresponds to conventional circuitry, when currents are applied via matching current transformers. Table 16.3 shows these changes as a correction factor CF depending on the vector group and the type of fault, for three-phase transformers.

To obtain the trip value, the setting value 87T (Address 1603) must be multiplied by the CF as follows:

$$I_{trip} = I_{\text{NsecW1}} \times |CF| \times \textit{Diff-Setting}$$

where

I_{NsecW1} =Nominal current (secondary) of Winding 1

CF =Correction Factor (from Table 16.3)

Ramp up the single-phase current (60 Hz) slowly from 0 A and stop when Trip Contact 1 closes. Ramp the single-phase current down slowly, from the trip value, and stop when Trip Contact 1 opens.

Type of Fault	Winding 1 (A, B, C) Voltage (high-side)	Secondary (a, b, c) or Tertiary (a', b', c') Even Num Vector Grp	Secondary (a, b, c) or Tertiary (a', b', c') Odd Num Vector Grp
3-Phase	1.0	1.0	1.0
2-Phase	1.0	1.0	~0.866
1-Phase[1] **with** I_0-Elim.	1.5	1.5	~1.73
1-Phase[2] without I_0-Elim.	1.0	1.0	~1.73

[1] I_0-Process is I_0 ELIMINATION, at Address 1106, 1126, or 1146.
[2] I_0-Process is either I_0 CORRECTION or WITHOUT, at Address 1106, 1126, or 1146.
I_0 is Zero Sequence Current

Table 16.3 *Operating Current Correction Factor*

Expected Results

The relay should trip and LEDs 1 and 2 should light within +/- 5% of the operating current level, $I_{trip.}$ Note that the 87 delay setting is 0 seconds (the default setting)

For the example values in Table 16.2:

$$I_{\text{trip}} = \frac{45{,}000\text{ kVA}}{\sqrt{3} \times 138\text{ kV} \times (300/5)} \times 1 \times 0.2 = 0.63\text{ A}$$

The reset value should be approximately 70% of the pickup test current.

Contacts, LEDs, and LCD

For the default settings, all trip contacts should close, Signal Relays 1 and 2 should operate, and LEDs 1 and 2 should light when 87 trips. At dropout, the contacts should reset but the LEDs should remain lit because they are set to latch. When the current is turned off, the LCD should display “87Diff GenFlt” and “87DiffGenTrip.”1.

Testing of Other Phases

If testing of the High Set differential element is desired, follow the 87HS testing instructions before continuing with this step.

Move the test source to another phase inputs on Secondary or Tertiary and repeat the above test.

Remember to calculate the new pickup current dependent upon the Voltage level, CT primary rating, and correction factor for that winding. The new pickup current will most likely not be the same for each winding (W1, W2, or W3).

Note: The functionality of all CT-inputs is verified during the Through-Fault Testing procedure. Hence, it is not necessary to test all phase inputs during this procedure.

16.3.5 Testing Differential Setting of High-Set Element 87HS

⚠ WARNING

Do not exceed the limits as indicated in the Relay Specifications section!

See Section 2.5 on page 18 or Table 16.1 on page 160.

⚠ CAUTION

Never leave high currents on the relay for an extended period of time.

Thermal damage to the input could result.

1. Set 87 Delay, Address 1625, to **infinite** seconds. With the current source still connected to the CT input, switch the single-phase current from 0 A to 120% of I_{HS}, calculated from the following equation:

$$I_{\mathrm{HS}} = I_{\mathrm{NsecW1}} \times |CF| \times \text{HS-Setting}$$

where

I_{NsecW1} =Nominal current (secondary) of Winding 1

CF =Correction Factor (from Table 16.3)

HS-Setting=Setting in relay Address 1604

Note: If a sufficient current source is not available, the setting must be lowered to facilitate testing.

2. Change the 87HS setting (Address 1604) to 1.

3. Perform the test as described above.

4. Change the 87HS setting back to its original value.

Expected Results

The pickup current at contact closure should be within +/- 5% of the calculated 87HS calculated trip value.

Contacts, LEDs, and LCD

All trip contacts should close, Signal Relays 1 and 2 should operate, and LEDs 1, and 3 will light when 87HS trips. When the current is turned off, the contacts should open, the LEDs should remain latched, and the LCD should display "**87Diff GenFlt**" and "**87DiffGenTrip**".

16.3.6 Testing Harmonic Restraint

Connect the relay as shown in Figure 16.8.

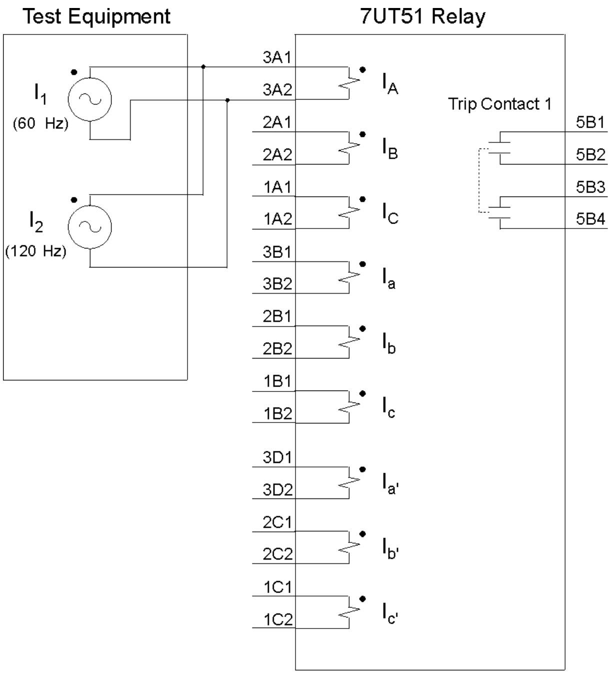


Figure 16.8 *Differential Testing with Harmonic Restraint*

For testing the harmonic restraint, it must be:

1. Parameterized as operative, **On** in Address 1610.
2. Set the Source 1, @ 60Hz to 1.2 x 87-I_{trip} (as calculated in Section 16.3.4 on page 165). To minimize current requirements, choose a phase of the winding that has the lowest 87-I_{trip} setting. This is typically a phase of Winding 1 (high voltage side of the transformer). Avoid operation of 87HS or exceeding the continuous current rating of the 7UT51.
3. Set the harmonic source to:

$$..2 \times \frac{\text{address 1611, 2nd Harmonic Res.}}{100} \times \text{Source 1 current}$$

4. Remember to set the harmonic source to the correct frequency (that is, 120 Hz for second harmonic).
5. First apply only Source 1 current to verify 87 tripping.
6. Turn **Off** Source 1. Reset targets.
7. Enable both sources simultaneously. The relay should restrain.
8. Turn **Off** both sources.
9. Slightly adjusting the Source 2 current magnitude while the currents are off, until the minimum Source 2 current magnitude for restraint is found.
10. Reset all targets and annunciations.
11. Complete steps 1 through 9 for the nth harmonic. This test need only be done to one input.

Expected Results

The percent of second harmonic current required for restraint is:

$$\%2\text{nd Harmonic Restraint} = \frac{\text{Source 2, 120Hz current}}{\text{Source 1, 60Hz current}} \times 100$$

The result should be within +/- 5% of Address 1611.

When 87 tripping occurs, the operations of the contacts, LEDs, and LCD should be consistent with 87T testing in Section 16.3.4 on page 165.

For the harmonic restraint, LEDs and contacts programmed to operate for 87 tripping should not operate. After current is turned off, an LCD message may appear. For the default settings, the message should be “**87DiffGenFlt**.”

16.4 Testing Restricted Ground Fault Protection (7UT513 Only)

The tests in this section will be based upon the application shown in Figure 16.9. Adjust the following test procedure to match the specifics of your application as necessary.

Note: This test can only be performed if the 7UT513 is ordered with the restricted ground-fault protection option, 87N.

The protection is operational when configured other than **Nonexistent** and set to **ON**.

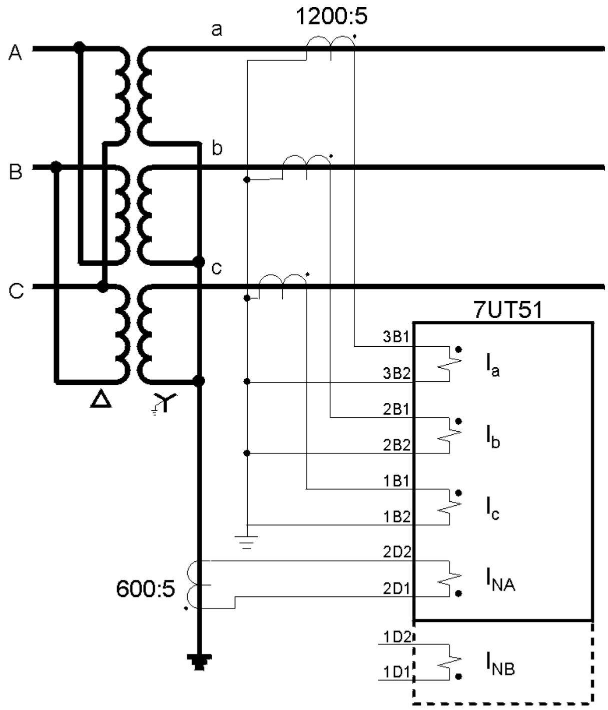


Figure 16.9 *Standard Application of Restricted Ground-Fault Protection*

Metering Test

Testing the metering of numerical relays is the quickest method of determining if a relay is no longer functioning or that it is incorrectly connected. If the relay cannot correctly determine what is being applied to its inputs, it can no longer protect by default.

Since the restricted ground-fault function is sensitive to unbalanced zero sequence currents between the phase and ground inputs, temporarily turn **Off** the RGF function in Address 1901 (OFF is the default setting).

Connect the test set to the 7UT51 as shown in Figure 16.10

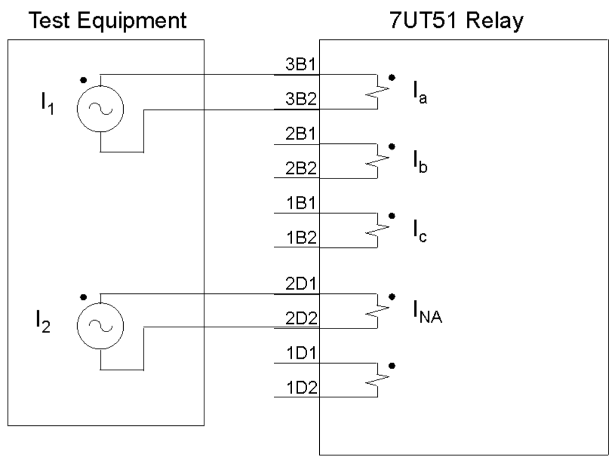


Figure 16.10 *Testing Restricted Ground-Fault on Secondary*

Apply 1.0A to the ground input being used for the RGF function using test source I_2 (*since 1/5 = .20*).

Read the Metered current for that ground input using the relay's MMI (front display) or WinDIGSI

To read the value from the front panel of the relay:

1. Go to Address 4101.
   "**4101 Test Diff - Measuring?**".
2. Press the **Yes** key.
3. "**I1 PhA= xxx**" will be displayed.
4. Press the **No** key to page through to the "IA" current (or "IB" if you are using the second ground current input.)
5. The display should approximately read: "IA= 20.0%" for the 1.0A current injected.
6. Go to Address "**4801 STOP TEST - FINISH?**"
7. Press the **Yes** key to end the Commissioning Tests.
8. Reset all targets and annunciations.

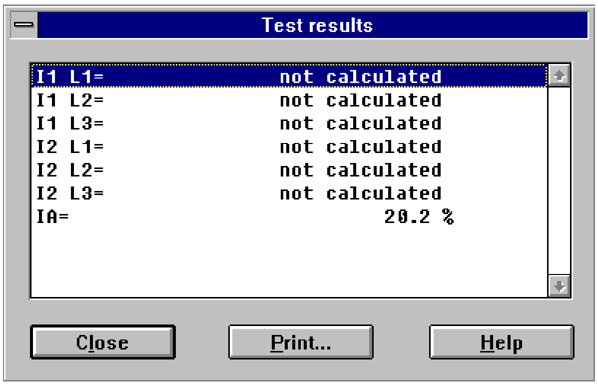
To read these values on a PC using WinDIGSI, begin communication with the relay, then:

1. Select "**Test**" from the menu bar.
2. Display "**Commissioning Tests**".

3. Execute the function “4101 Measuring and indication of current values”.

4. Confirm your selection by clicking the **Yes** key.

   The following screen will be displayed:



   This displays all currents in percentage of 5A. “Ix Ly” is an abbreviation for the Winding ‘x’ Phase ‘y’ current. The “IA” (or “IB” if used) current should read approximately 20.0%.

This metering test validates the current inputs to which current is being applied.

Close up the test:

1. Close the “**Test Results**” window.

2. Close the “**Commissioning Tests**” window.

3. Display “**4800 Commissioning Tests Stop.**”

4. Execute “**4801 Stop the Commissioning Tests**.”

5. Confirm by pressing the **Yes** key.

6. Reset all targets and annunciations.

RGF Functional Test

The restricted ground-fault (RGF) protective function must be parameterized as operative, **On** in Address 1901.

To avoid misinterpretations, the trip signal of the 87 phase differential protection should be blocked. Yhis can be done by setting the Address of 1601 to “**Block Tripping**.”

RGF protection is based on detecting a zero sequence source (such as a ground-fault or insulation degrading to a ground-fault) in the zone defined by the location of the phase CTs and the CT on the neutral of the transformer. For instance, if a phase “a” to Gnd fault in the winding happens on the wye side of a transformer, current flows as shown in Figure 16.11. If the currents in all the relay phase inputs were vectorially added to the current at the ground input, the resultant would not add up to 0. This situation indicates to the relay a ground-fault is located between the phase CTs and the ground CT.

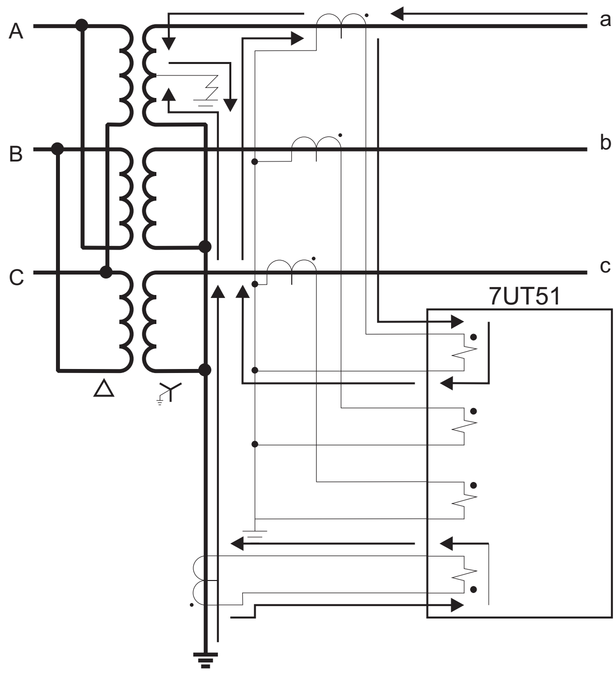


Figure 16.11 *Current Flow for Restricted Ground Fault Inside of Protected Zone*

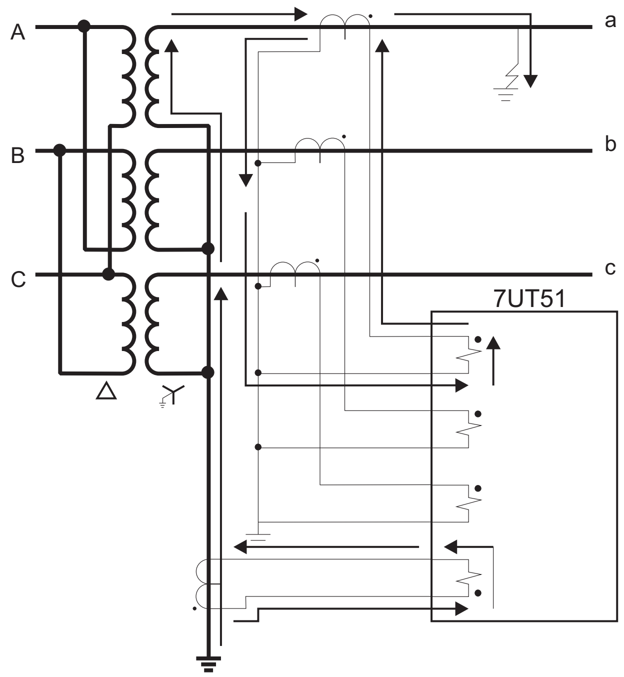


Figure 16.12 *Current Flow for Restricted Ground Fault Outside of Protected Zone*

The sum of the currents for an ‘external’ ground-fault (as shown in Figure 16.12) add to 0, indicating no ground-fault in the RGF zone.

External Fault Test

Using the test configuration as shown in Figure 16.10, apply currents as follows to emulate the condition shown in Figure 16.12, Restricted Ground Fault Outside of Protected Zone. Note the polarity of I_2.:

$I_1 = 1.81A \angle 0°$

$I_2 = I_1 \times CT_{W2} / CT_{STP3} = 1.81A \times 1200 / 600$

$= 3.62A \angle 180°$

The relay should not trip.

To view the values of the RGF test results, use either the front display of the relay or WinDIGSI software on a PC.

To read these values from the relay front display:

1. Go to Address “**4181 Test RGF - Measuring?**”
2. Press the **Yes** key.

   ”**IPhA= xxx**” will be displayed. This is PhA current on the winding assigned to RGF protection in percentage of 5A.

   It should display the current you are injecting into PhA of the RGF winding divided by 5A.

   Press the **No** key to page through the metering until you reach “**Diff =**”.

   If the test sources are accurate, the relay should measure a ground Diff of less than 2.0%. This indicates that the relay is configured properly.

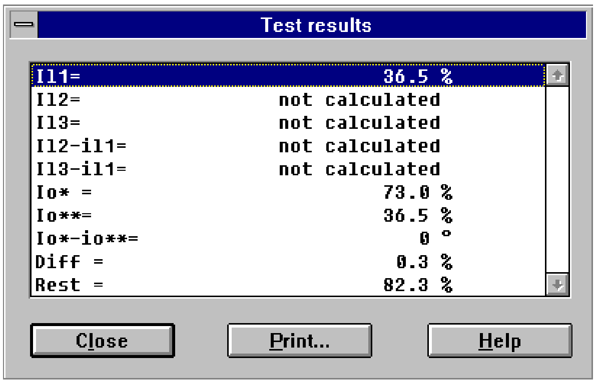
   Go to Address “**4801 STOP TEST - FINISH?**”

   Press the **Yes** key to end the Commissioning Tests.

To read these values on a PC using WinDIGSI, begin communication with the relay, then:

1. Select “**Test**” from the menu bar.
2. Display “**Commissioning Tests.**”
3. Execute the function “**4181 Meas./ind. of current-/ angle values of REF**”.
4. Confirm your selection by clicking the **Yes** key.

   The following screen will be displayed:



“ILx=” displays currents on the RGF winding in percentage of 5A.

IL1 should display the current you are applying to the relay's phase A input in % of 5 A.

"Io*-Io**=" displays the angle between the calculated 3Io (sum of phases) and the 3Io input.

Io*-Io** should be 0 degrees. If it is 180 degrees, there is a polarity / wiring error to the relay or the test is set up improperly or the polarity setting for the ground CT is set wrong (Address 1108 or 1128).

"Diff =" displays the % of differential current the relay recognizes between the calculated 3Io (sum of phase currents) and the current measured at the ground input.

If the test sources being used are accurate, "Diff" should measure less than 2.0%

Internal Fault Test

Change I2 to 3.62 A $\angle 0°$ to emulate the condition shown in Figure 16.11, Restricted Ground Fault Inside of Protected Zone.

The relay should trip and LEDs 1 and 7 should light.

Re-enable the differential protection under Address 1601.

Reset all targets and annunciations.

This validates the configuration of the relay as connected to your system.

Close Test

1. Close the "**Test Results**" window.
2. Close the "**Commissioning Tests**" window.
3. Display "**4800 Commissioning Tests Stop**".
4. Execute "**4801 Stop the CommissioningTests.**"
5. Confirm by pressing the **Yes** key.

16.5 Branch Point Differential Protection Testing

For testing the differential protection, this function must have been configured as EXIST/ENABLED in Address 7816 and the protected object in Address 7801 must be a @ENDS-BRANCH POINT or a 3ENDS-BRANCH POINT (7UT513 only). Additionally, it must be parameterized as operative in Address 1801.

The trip value of the differential protection can be checked by means of a secondary test set. The test current can be applied separately for each branch point terminal, that is, in each case a fault with single-ended infeed is simulated.

The preset parameter for 87T applies.

Checking the trip value is performed by slowly increasing the test current. Trip occurs when the trip value, converted using the matching factor (see Section 1.2 on page 11), is reached. When the test current falls below approximately 0.7 times the trip value, the relay drops off.

16.6 Backup Overcurrent Time Protection Testing

For testing the backup overcurrent time protection, this function must be assigned to one side of the protected object or to the virtual object (Address 7821). Additionally, this function must be switched **On** or BLOCK TRIP REL in Address 2101.

16.6.1 Testing the High-Set Overcurrent Stage

Testing can be performed with single-phase, two-phase or three-phase test current. When assessing the currents, it must be considered that the current that is evaluated by the relay is referred to the rated current of the protected object or transformer winding.

⚠ CAUTION

Test currents larger than four (4) times In or 15A (Sensitive input) may overload and damage the relay if applied continuously.

Observe a cooling down period!

For testing the 50HS stages, therefore, measurement shall be performed dynamically. It should be noted that the relay picks up at 1.1 times the setting value and does not at 0.9 times setting value.

When the test current is injected, the pickup indication of the 50HS stage, annunciation “**Backup 50HS**”, appears. After expiration of the time delay, trip signal is given (LED 4 at deliver and annunciation “**Back Gen. Trip**”). If the protection is switched **On**, the assigned trip contacts close.

It must be noted that the set times are pure delay times, operating times of the measurement functions are not included.

16.6.2 Testing the Definite Time Overcurrent Stage

For the test, the **Definite Time** mode must be selected in Address 2111.

The rated object current is to be considered.

When the set value for 50T (Address 2112) is exceeded, the pickup indication “**Backup I>/Ip**” appears.

After the expiration of the time delay in Address 2113, trip signal is given (LED 4 and annunciation “Back Gen. Trip”). If the protection is switched **On**, then the assigned trip contacts close.

It must be noted that the set times are pure delay times, operating times of the measurement functions are not included.

16.6.3 Testing the Inverse Time Overcurrent Stage

For these tests, one of the **Inverse Time** modes must be selected in Address 2111.

The rated object current is to be considered.

⚠ CAUTION

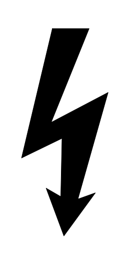
Test currents larger than four (4) time In or 15A (Sensitive input) may overload and damage the relay if applied continuously.

Observe a cooling down period!

When the test current is increased above 1.1 times the set value 51PU (Address 2114), pickup indication appears (“**Backup I>/Ip**”).

The time delay depends on which characteristic has been selected in Address 2111 and the set time multiplier in Address 2115. The expected time delays can be calculated or read from the characteristic curves. *Be certain to consider current matching factors.*

16.7 Thermal Overload Protection Testing



⚠ CAUTION

Test currents larger than four (4) time In or 15A (Sensitive input) may overload and damage the relay if applied continuously.

Observe a cooling down period!

Two thermal overload protection functions are available, each of which can be assigned to any desired side of the protected object or to the virtual object. The relay is programmed with the side of the protected object of the first overload protection (Address 7824) and the second overload protection (Address 7825). Each overload protection must be parameterized as operative, **On**, in addresses 2401 and 2501.

Testing of 49-1 and 49-2 may cause operations of 87, 87HS, 50/51, and 50HS. If this occurs, set to **Off** to disable the differential elements and backup overcurrent elements.

Note: After testing 49-1 and 49-2, these addresses must be reset to the desired values.

The basis current for the detection of overload is the rated current of the protected object.

For use as transformer protection, the basis current is the rated current of the protected transformer winding. If the windings have different MVA ratings, then the overload function always refers to the rated current of the respective winding. It is assumed that the transformer data for each winding have been correctly parameterized.

For use as generator or motor protection, overload protection is based on the rated current of the protected machine which is derived from the data entered in Address Block 1200.

For use as branch protection, overload protection is based on the rated current of the branch point entered in Address Block 1300.

If the overload protection is used for a virtual object, overload is based on the rated current of the virtual object entered in Address Block 1400.

Address 2406 is important for testing 49-1. If Address 2406 = Average Θ, this procedure requires that a single current source be connected to inject current in all three phases associated with the winding or object. If Address 2406 = [Θ MAX] or [Θ @ Imax], then current injection into any one phase is sufficient.

The same comments for Address 2406 apply to Address 2506, which is associated with 49-2.

The same 7UT51 connections can be used for all of the 49 tests. Figure 16.13 shows the connections for the following example. Element 49-1 is protecting Winding 1 using either the maximum calculated temperature for each phase current (Address 2406 = Θ MAX) or the calculated temperature based on the highest phase current (Address 2406 = Θ @ Imax). Element 49-2 is protecting Winding 2 using the average of the calculated temperatures of the phases.

For the example, this procedure requires current be injected in all three phases of Winding 2 to test 49-2. Current injection for Winding 1 can be either single-phase or include all three phases (single-phase is shown for simplicity).

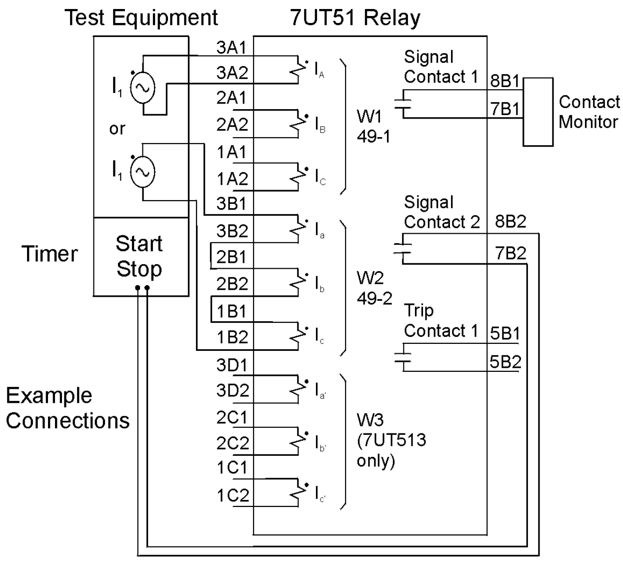


Figure 16.13 *Test Connections for Testing 49-1 and 49-2*

First identify the applicable winding for current injection. Then, based on Address 2406 or Address 2506, connect the winding phases for either single-phase or three phase current injection.

Settings for Trip Relays, Signal Relays, and LEDs – All 49 Tests

Apply the following setting. If only one 49 is being tested, the events for the other element are not needed.

- LED 2 = nm 1571 49-TRIP by thermal O/L protection 1 (nm means no memory)

  = nm 1621 49-TRIP by thermal O/L protection 2 (nm means no memory)

- LED 3 = nm 1566 49-Thermal O/L prot.1: Thermal warning

  = nm 1616 49-Thermal O/L prot.2: Thermal warning

- LED 4 = nm 1565 49-Thermal O/L prot.1: Current warning

  = nm 1615 49-Thermal O/L prot.2: Current warning

- Signal Relay 1 = 1565 49-Thermal O/L prot.1: Current warning

  = 1615 49-Thermal O/L prot.2: Current warning

- Signal Relay 2 = 1566 49-Thermal O/L prot.1: Thermal warning

  = 1616 49-Thermal O/L prot.2: Thermal warning

- Trip Relay 1 = 1571 49-TRIP by thermal O/L protection 1

  = 1621 49-TRIP by thermal O/L protection 2

16.7.1 Warning, Overload Current: Address 2405 (49-1) and 2505 (49-2)

Connect the 7UT51 using the example and the accompanying Figure 16.13. The timer is not needed for this test.

49-1 Current Warning:

1. The alarm should occur near

   [I ALRM1, Address 2405 X I_{NsecWx}]

   or

   [I ALRM2, Address 2405 X I_{Objsec}].

   Slowly increase the current until LED 4 lights and the contact of Signal Relay 1 closes. Record the current.

2. Slowly decrease the current until LED 4 goes out and the Signal Relay 1 contact opens. Record the current.

3. Turn off the current, note the LCD display, and reset the targets.

49-2 Current Warning: Follow steps 1-3 using Address 2505 in step 1.

Expected Results

The 49-1 current warning should occur within +/- 3% of [Address 2405 X I_{NsecWx}] or [Address 2405 X I_{Objsec}]. This applies for 49-2 also, using Address 2505.

The 49 warning should dropout at a current between [95% and 99%] of the actual current at pickup.

For the default settings and the changes made, LED 4 should light and the contact of Signal Relay 1 should close when the 49 current warning occurs. At dropout, the LED should go out and the contact open. The LCD should not give an indication of the event.

Notes about 49 Trip Times and Alarm Times

The tests below require there be no preload before 49 temperature warnings and 49 tripping are tested. Without preload, the trip time of 49 is calculated:

Let $a_1 = \frac{\text{49k factor, Address 2402 X } I_{NsecWx}}{I1}$

or

Let $a_1 = \frac{\text{49k factor, Address 2402 X } I_{Objsec}}{I1}$ (for 49-1)

Let $a_2 = \frac{\text{49k factor, Address 2502 X } I_{NsecWx}}{I1}$

or

Let a_2 = $\frac{\text{49k factor, Address 2502 X } I_{Objsec}}{I1}$ (for 49-2)

where I1 is the test current Figure 16.13:

a1 and **a2** must be less than 1 (I1 > Address X I rated)

49 Tcont, Address 2403 and 2503 are in minutes.

The time for a 49 warning based on temperature rise is calculated as such (no preload):

49-1 $T_{warn} \approx$ 49-1 T_{trip} X 49 ALRMΘ, Address 2404 in decimal format

49-2 $T_{warn} \approx$ 49-2 T_{trip} X 49 ALRMΘ, Address 2504 in decimal format

For any group of 49 settings, the trip time decreases as the test current increases. The maximum test current for the tests below is 20 amps (4 amps for a 7UT51 rated for 1 amp). Using this current, calculate 49 T_{trip} now. Also estimate 49 $T_{warn.}$

Testing the 49 elements with the desired, in-service settings is strongly recommended. However, if those settings would result in unpractical warning and trip times, decrease Address 2403 or 2503. The recommended minimum 49 warning time – if setting changes are made – is about 2 minutes, giving a trip time of [2-3] minutes. If the *desired* settings result in warning times faster than 2 minutes, do not change the settings.

The 7UT51 continually calculates the temperature rise of the winding or object. Therefore, prior testing or loading of the 7UT51 will make the test results below unpredictable unless the temperature rise is forced to zero. Changing Address 2401 (2501) to OFF, waiting at least one minute, and then resetting Address 2401 (2501) to the desired setting accomplish this.

Note: These steps must be done *before*, and in-*between*, *all* tests for 49 warning times and 49 trip times.

16.7.2 Warning, Temperature: Addresses 2404, 2403 and 2402 (49-1) ; Addresses 2504, 2503, and 2502 (49-2)

Connect the 7UT51 using the example and the accompanying Figure 16.13. The timer is used with the Signal Relay 2 contact in this test.

49-1 Temperature Warning

1. Set Address 2401 = OFF. Wait at least one minute with this setting. Set up the test during the wait.
2. Any Source 1 current magnitude between {[1.2 X Address 2402 X I_{NsecWx}] or [1.2 X Address 2402 X I_{Objsec}]} and 20 amps (4 amps) can be used. The alarm time decreases as the current increases. The following is recommended. If 49-1T_{warn} < 2 minutes for a current of 20 amps (4 amps), lower the current to get a warning time of about 2 minutes. Otherwise, use a current magnitude of 20 amps (4 amps).
3. Set the timer to start on the application of current, and stop on the closure of the Signal Relay 2 contact.
4. Set Address 2401 for the desired setting.
5. Apply the current.
6. Observe the LEDs and the Signal Relay 1 contact during the tests.
7. Turn off the current after the alarm but before the trip. If the trip occurs, there is no problem. Turning off the current before the trip saves time in reading the LCD.
8. Record the value from the timer.
9. Record the LEDs and LCD, and reset.
10. Follow step 1 if any other testing is done.

49-2 Temperature Warning

Follow steps 1-10 for 49-1, except use Address 2501 in steps 1 and 4, Address 2502 in step 2, and 49-2 T_{warn} in step 2.

Expected Results:

The warning alarm should occur within the larger of +/- 12% or +/- 2 seconds of the calculated 49 T_{warn}.

With the default settings and the changes made, LED 4 should light and the contact of Signal Relay 1 should close several seconds after the application of current (the actual time is not important). When the temperature warning occurs, LED 3 and Signal Relay 2 should operate. If 49 does not trip, no other target or contact operations should occur. The LCD should show "49 O/L1 PU Θ" or "49 O/L2 PU Θ". LED 3 and Signal Relay 2 should not reset immediately after the current is off. The 7UT51 will calculate the temperature as still being above the alarm point, until a cool-down period occurs.

16.7.3 49 Tripping: Addresses 2402 and 2403 (49-1), 2502 and 2503 (49-2)

Perform this test for 49-1 only if Address 2401 = **On**.

Perform this test for 49-2 only if Address 2501 = **On**.

Connect the 7UT51 using the example and the accompanying Figure 16.13. Connect the contact of Trip Relay 1 to the timer.

49-1 Tripping

1. Set Address 2401 = OFF. Wait at least one minute with this setting. Set up the test during the wait.
2. If Section 16.7.2 on page 175 was done, use the same Source 1 current. Otherwise, any Source 1 current magnitude between {[1.2 X Address 2402 X I_{NsecWx}] or [1.2 X Address 2402 X I_{Objsec}]} and 20 amps (4 amps) can be used. The trip time decreases as current increases. The following is recommended. If 49-1 T_{trip} < 2 minutes for a current of 20 amps (4 amps), lower the current to get a trip time of about 2 minutes. If 49-1 T_{trip} > 2 minutes for a current of 20 amps (4 amps), use this maximum current.
3. Set the timer to start on the application of current, and stop on the closure of the Trip Relay 1 contact.
4. Set Address 2401 = **On**.
5. Apply the current.
6. Observe the LEDs and the Signal Relay 1 contact during the test.
7. Turn OFF the current, after a trip, as soon as practical. This will save time in reading the LCD.
8. Record the value from the timer.
9. Record the LEDs. Wait for the LCD and record. Reset.
10. Follow step 1 if any other testing is done.

49-2 Tripping

Follow steps 1-10 for 49-1 tripping except use Address 2501 in steps 1 and 4, Address 2502 in step 2, and 49-2 T_{trip} in step 2.

Expected Results

The trip time should occur within the larger of +/- 12% or +/- 2 seconds of the calculated 49-1 T_{trip} or 49-2 T_{trip}.

After several seconds of the current application (the actual time is not important), LED 4 should light and the contact of Signal Relay 1 should close. The warning should occur at about the same time as in Section 16.7.2 on page 175 if the same test current is used. LED 3 and Signal Relay 2 should operate. At tripping, with the default settings and the changes made, all of the trip contacts should close, contacts of Signal Relays 1, 2, 6 and 7 should be toggled, and LEDs 1, 2, 3, 4, and 9 (49-1) or 10 (49-2) should be lit. When the current is turned off, the contact of Signal Relay 1 should open and LED 4 should go out. After some time – perhaps minutes – the trip contacts should open, Signal Relay 6 should reset, and LED 2 should go out (the 7UT51 is still calculating temperature with the current off). Later, LED 3 should go out and Signal Relays 2 and 7 should reset. The other LEDs have memory. The LCD should display "**49 O/L1 PU Θ**" and "**49 O/L1 TRIP**", or "**49 O/L2 PU Θ**" and "**49 O/L2 TRIP**", after LED 2 goes out (49 trip resets).

Reset Relay

Reset 7UT51 for desired settings. Program Trip Relay 1, Signal Relays 1 and 2, and LED 2,3, and 4 for the desired settings. If 49 warning or trip times were decreased for testing purposes, reset addresses 2403 and 2503 to the original settings. Be sure addresses 2401 and 2501 have the proper settings. Reset any other addresses changed for testing purposes.

16.8 Tank Leakage Protection Testing (if Available)

One of the additional measured current input IA or IB can be allocated to the tank leakage protection, Address 2827. Depending on the input used, the pickup value of the protection is set under Address 2703 (Insensitive CT A), setting range 0.10 to 10 times rated relay current, or Address 2704 (Sensitive CT B), setting range 10mA to 1,000mA (independent of the rated current).

For testing the tank leakage protection, this function must be parameterized as operative, **On** or **Block Trip Rel** in Address 2701.

Apply test current to the current input which is assigned to the tank leakage protection.

⚠ CAUTION

Test currents larger than four (4) times In or 15A (Sensitive input) may overload and damage the relay if applied continuously.

Observe a cooling down period!

Testing with higher currents should be performed dynamically. It should be confirmed that the relay picks up at 1.1 times setting value and does not pickup at 0.9 times setting value.

When the set pickup value is exceeded, pickup indication "**Tank Gen. Flt**" occurs (must be marshalled/programmed, see Chapter 13).

After the set time delay in Address 2725 (default = 0 sec.), a trip signal is issued and the annunciation "**Tank Gen. Trip**", LED 8 (must be marshalled/ programmed, see Chapter 13).

16.9 External Trip Function Coupling Testing

Two desired signal from external protection or supervisory units can be connected into the processing of the 7UT51 via binary inputs. Like the internal signals, they can be annunciated, delayed and transmitted to the trip matrix.

The external signals can be checked when they have been configured as EXISTENT/ENABLED under addresses 7830 and/or 7831 and parameterized as operative in addresses 3001 and/or 3101, respectively. Additionally, binary inputs must be allocated to these functions.

After the binary input of the tested external trip function has been activated, annunciation **>Ext. Trip *** is given. Annunciation "**Ext. * Gen. Flt"** is the actual fault event annunciation.

After T-DELAY (addresses 3002 and 3102) annunciation "**Ext. * Gen. Trip**" will occur.

For the input of annunciations of the Buchholz protection (when the relay is used as transformer protection), three binary inputs are reserved. When these are allocated to physical inputs, their correct function can be tested also.

16.10 Putting The Relay Into Operation

All setting values should be checked and returned to the required settings. Particularly check that all desired protection functions have been programmed in the configuration parameters (Address Block 7800) and that all desired protection functions have been switched **On**.

Reset and clear all annunciation logs and LEDs in Address Block 8200, using front panel:

- For LEDs:
  - Address 8201, Reset LED?
  - Press **Yes** during erasure of the logs (which may take some time) the display shows **Task in Progress**. After erasure the relay acknowledges "**Successful**". During reset the LEDs on the front will light up (except the "**Blocked**" LED); thus, a LED test is performed at the same time.
- For Operational/Event Annunciations:
  - Address 8202, Reset Operat. Annunc.?
  - Press **Yes** during erasure of the logs (which may take some time) the display shows **Task in Progress.** After erasure the relay acknowledges "**Successful.**"
- For Fault Annunciations:
  - Address 8203, Reset Fault Annunc.?
  - Press **Yes** during erasure of the logs (which may take some time) the display shows **Task in Progress**. After erasure the relay acknowledges "**Successful.**"

Reset and clear all annunciation logs and LEDs in Address Block 8200, using a PC and WinDIGSI software:

- For LEDs, enter the **Options** menu, choose Reset LEDs.
- For Operational and Fault Log - enter Control menu, choose Resetting Stored Data -> 8202 - Reset Event Log or 8203 - Reset Trip Log.
  - Press **Target Reset** on the front panel of relay.

If relay is ready for installation, check that the module is properly inserted. The cover must be in place. The green LED must be lit (**On**) on the front panel: the red LED must not be lit (**On**).

17 Installation and Servicing

This chapter describes the procedure for installing a 7UT51 relay. The procedure includes:

- Transporting and Storing the Relay
- Unpacking
- Mounting the Relay Case
- Inserting the Back-up Battery
- Attaching the Connections

7UT51 relays are completely tested at the factory prior to shipment and are designed so that no special testing, calibration, or maintenance is required.

To install a 7UT51 relay, you must be familiar with all applicable safety regulations from ANSI, IEC, NEC, and other pertinent standards.

If you wish to perform acceptance test prior to installing the relay, see Chapter 16].

17.1 Transport and Storage

Transport the relay in its original packaging material to protect it from mechanical shock (the factory packaging meets the IEC 255-21 impact-resistance guideline).

Store the relay in a dry, clean room with temperature in the range -13°F to +131°F (-25°C to +55°C) and relative humidity controlled so that neither condensation nor frost forms. (Unpacking the relay and applying DC supply power can help prevent condensation.)

If the relay is de-energized and stored for an extended time period, unpack and apply DC supply voltage to the relay for one or two days prior to placing the relay into service.

17.2 Unpacking and Repacking

Figure 17.1 shows an exploded view of the relay packaging material. Do not use the relay if it appears to have been damaged during transport.

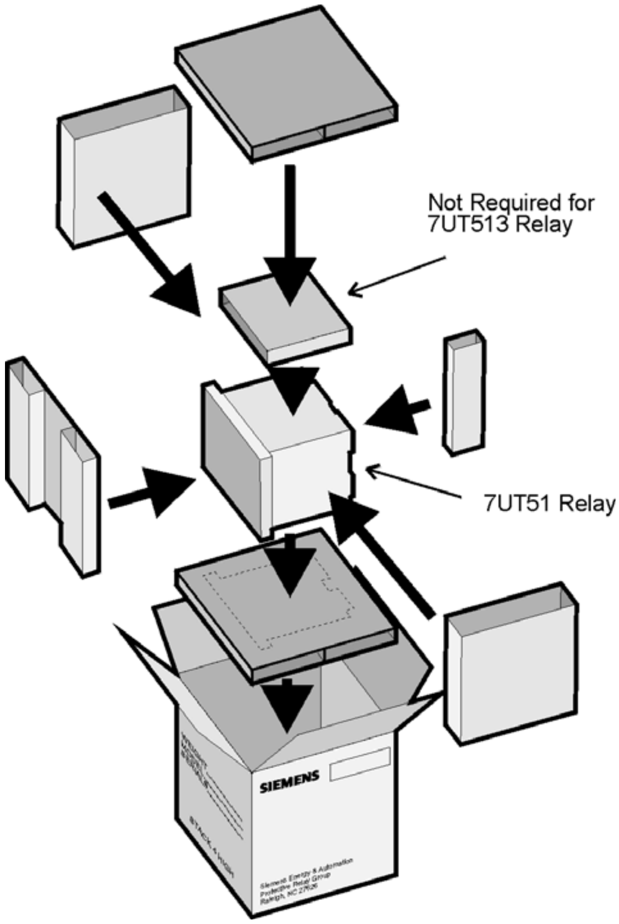


Figure 17.1 *7UT51 Packing Material Diagram*

17.3 Removing and Inserting the Relay Modules

A 7UT512 relay consists of a relay module that is inserted into the relay case and secured by the relay cover (see Figure 17.2). A 7UT513 has a larger case that holds two modules: a main module and a smaller auxiliary module.

The wiring connections are made to the terminal blocks on the back of the case. When the module is inserted into the case, the module is automatically connected to the terminals.

The relay module(s) can be removed to make the case easier to handle during installation, and must be removed to perform any hardware modifications and some maintenance procedures. This section describes how to remove the module(s).

1. Remove the front cover from the relay: Open the horizontal, hinged panels at the top and bottom of the front cover and loosen the four screws that hold the front cover to the relay's case (see Figure 17.3).

2. Pull the releasing levers at the top and bottom edges of the front panel to unplug the relay from the connectors inside the back of the case, as shown in Figure 17.4. Carefully pull the relay out of the case and place it on a conducting surface.

⚠ WARNING

Hazardous voltage or current. Loss of system protection.

Can cause death, serious personal injury, or property damage.

Only qualified personnel should install or perform maintenance on a relay. Read and understand this manual before proceeding.

Ensure that backup protection of the protected equipment is operational before removing the relay from service.

De-energize and ground the devices and/or equipment to be protected before installing the relay.

Before performing work on current transformer wiring, always short circuit the secondary of all the current transformers.

When the relay module is out of the case, protect it from electrostatic discharges by touching a grounded surface before touching the module.

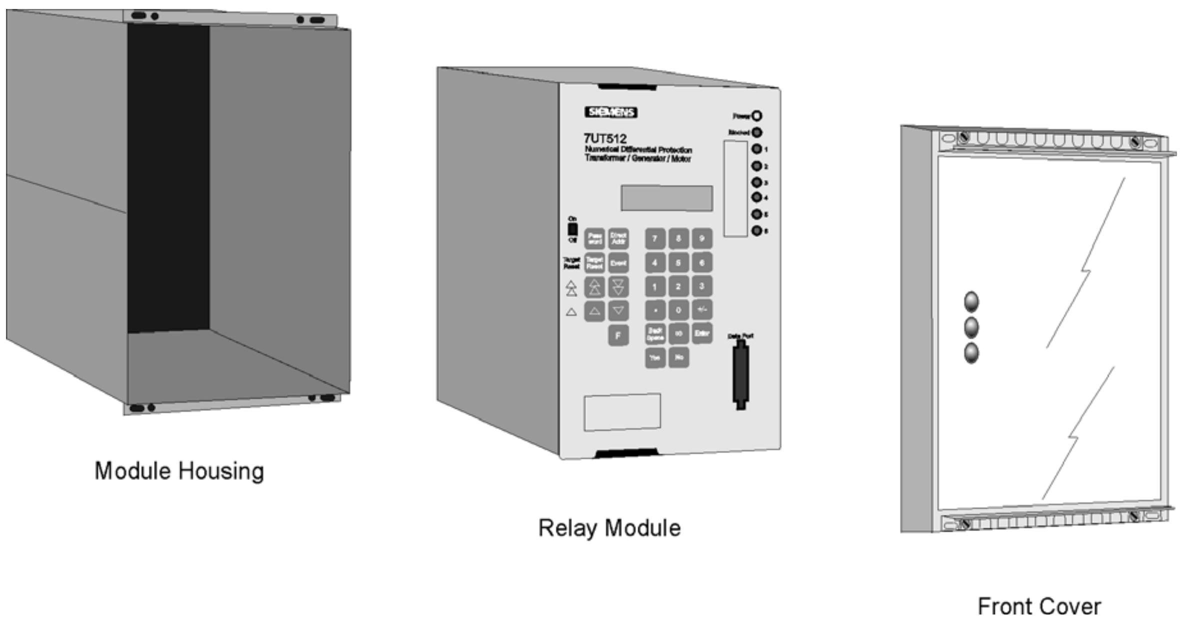


Figure 17.2 *Components of a 7UT512 Relay*

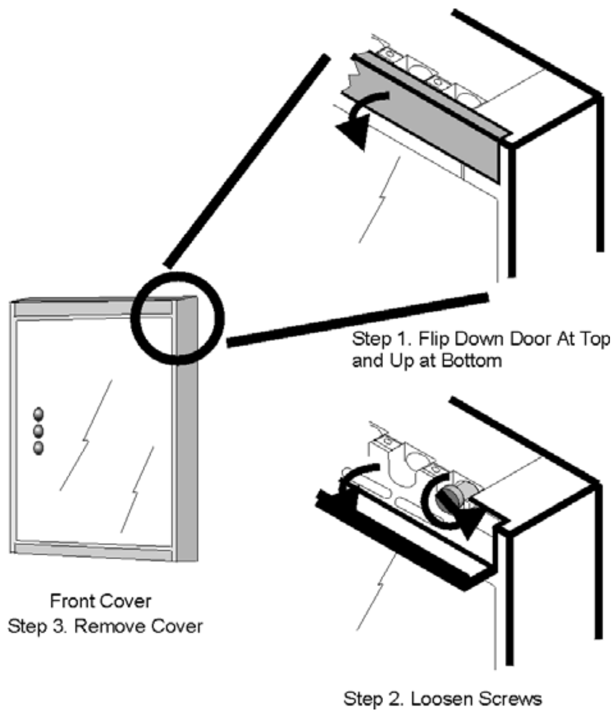


Figure 17.3 *Front Cover Removal*

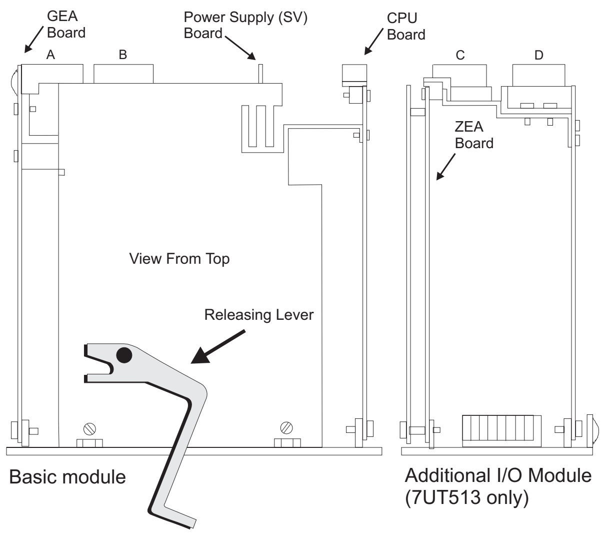


Figure 17.4 *Release Lever Operation*

17.4 Mounting the Relay Case

The procedure for mounting the relay case is as follows:

1. Cut and drill the mounting panel to the dimensions shown in Figure 17.6 (for the 7UT512 relay) or Figure 17.7 (for the 7UT513 relay).

2. To make the case lighter and thus easier to handle, remove the relay module(s) from the case.

3. Insert the relay case into the panel from the front, so that the case's mounting flange is on the outside of the panel. Make sure that the case is right-side up (the letters and numbers of the labels on the back of the case should be right-side up). Secure the case to the panel with four screws or bolts.

4. Connect a braided ground strap to either of the grounding screws on the back of the case (see Figure 17.5).

5. Insert the relay module(s) back into the case and re-attach the front panel.

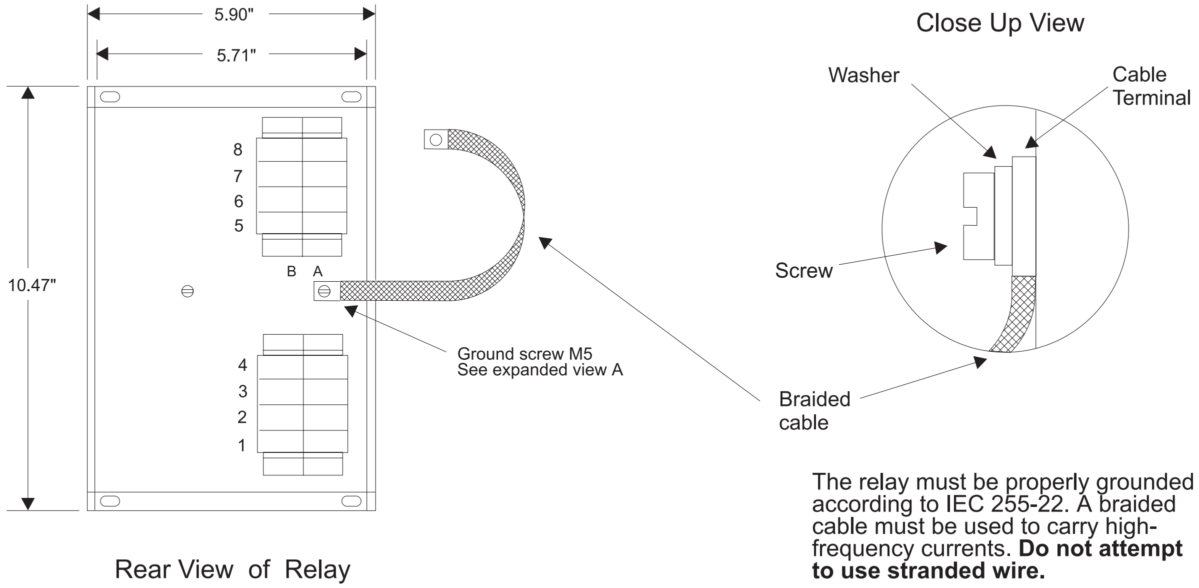


Figure 17.5 *Connecting the Ground Strap*

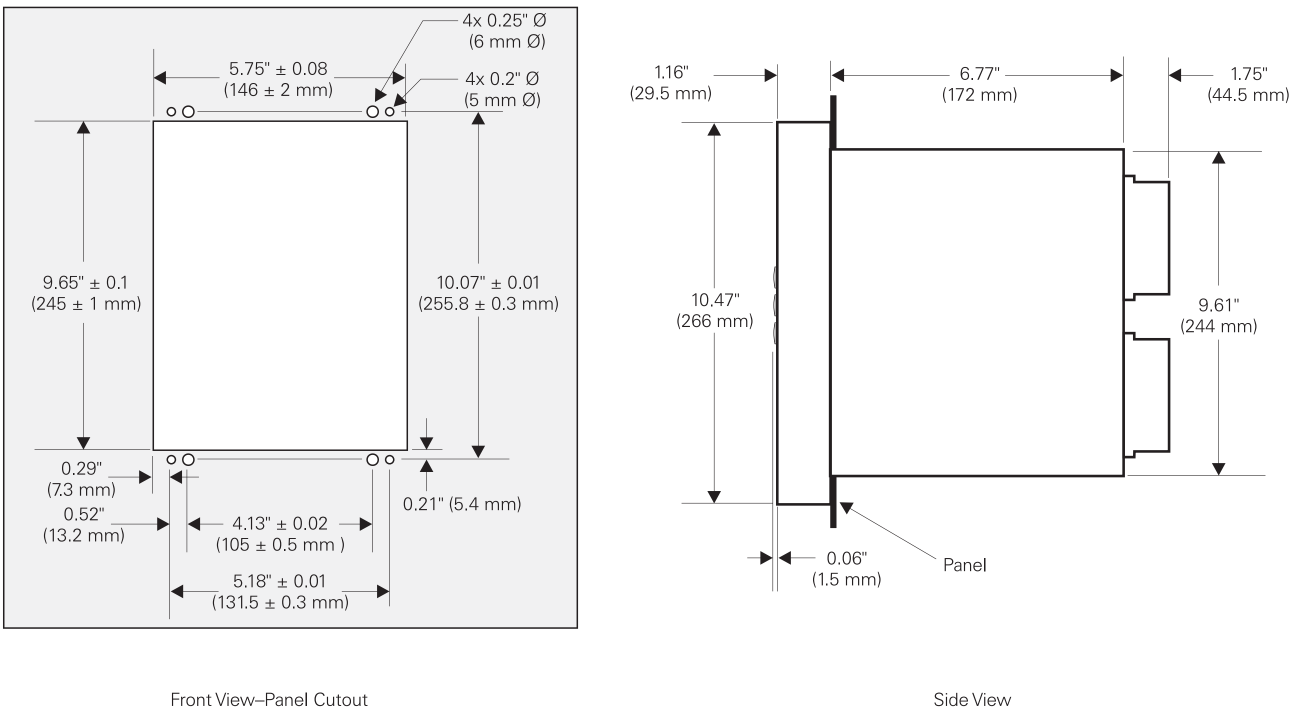


Figure 17.6 *Dimensions of Case and Panel Cutout for a 7UT512 Relay*

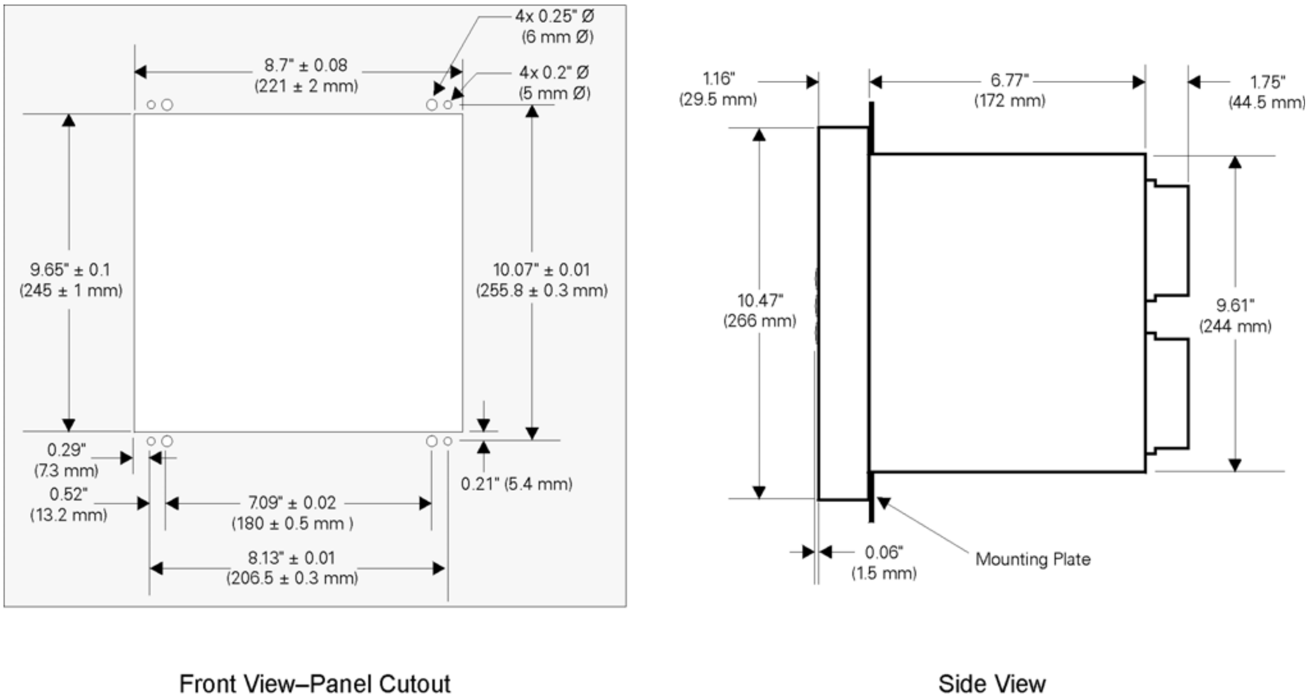


Figure 17.7 *Dimensions of Case and Panel Cutout for a 7UT513 Relay*

17.5 Wiring

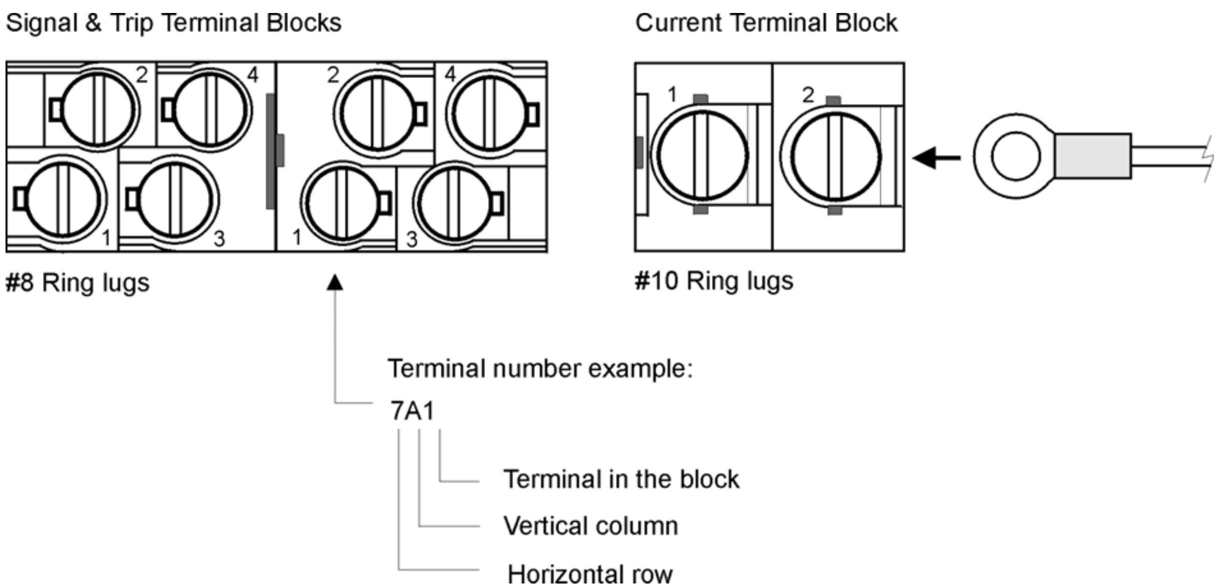


Figure 17.8 *Screw Terminals & Ring Lugs Terminal Block Detail*

17.5.1 Connection Diagrams

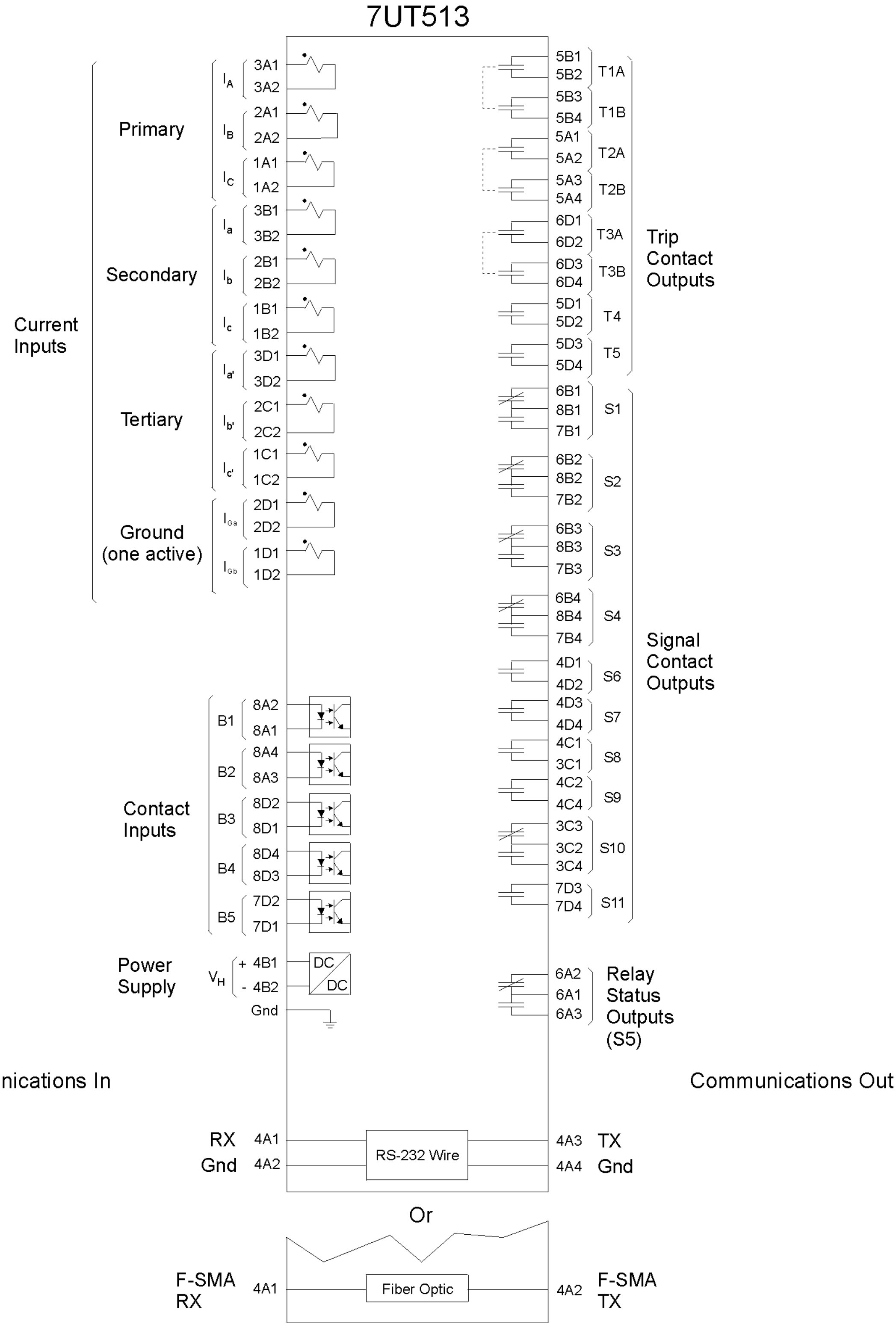


Figure 17.9 *Connection Diagram for 7UT513*

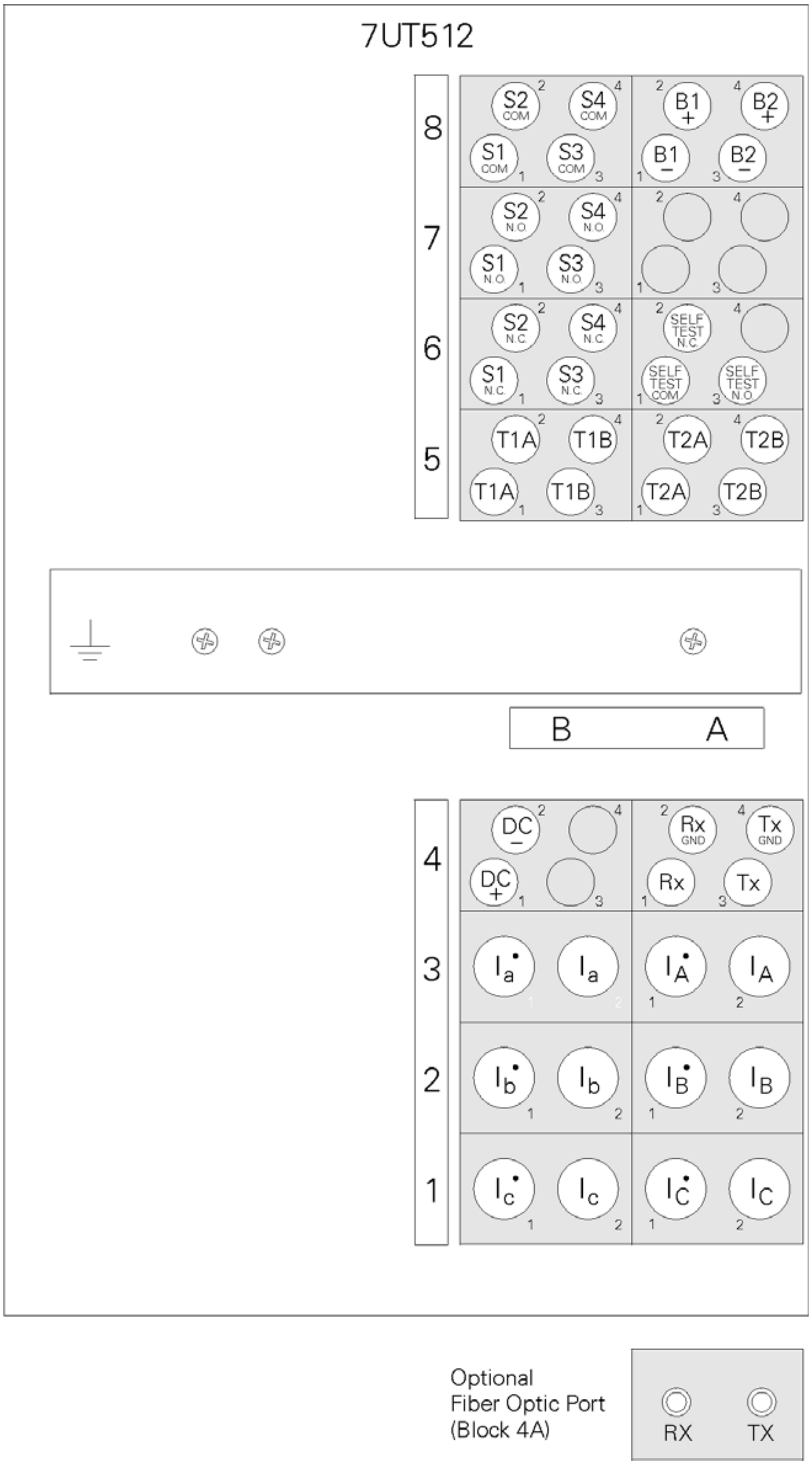


Figure 17.10 *Terminal Locations for 7UT512*

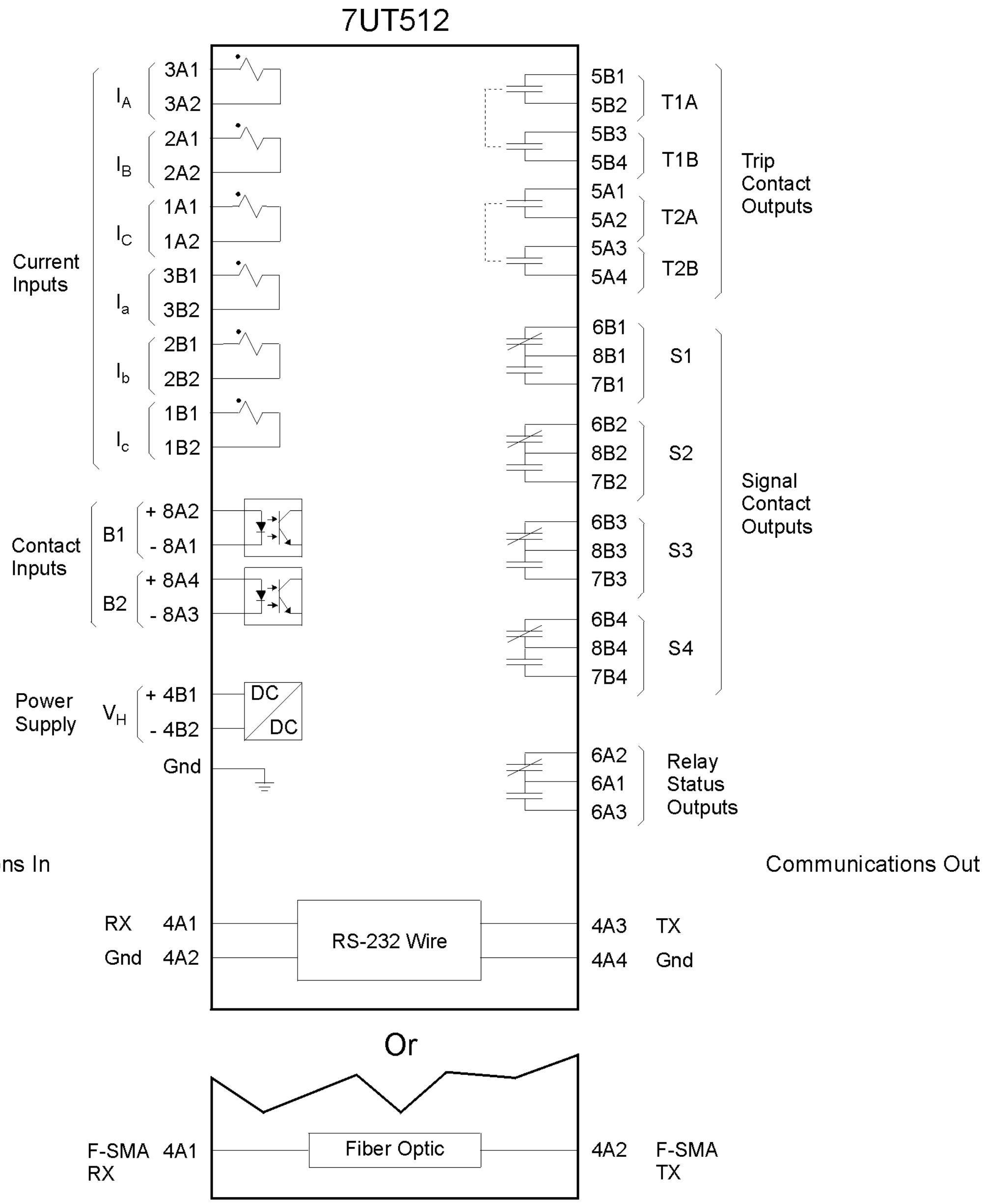


Figure 17.11 *Connection Diagram for 7UT512*

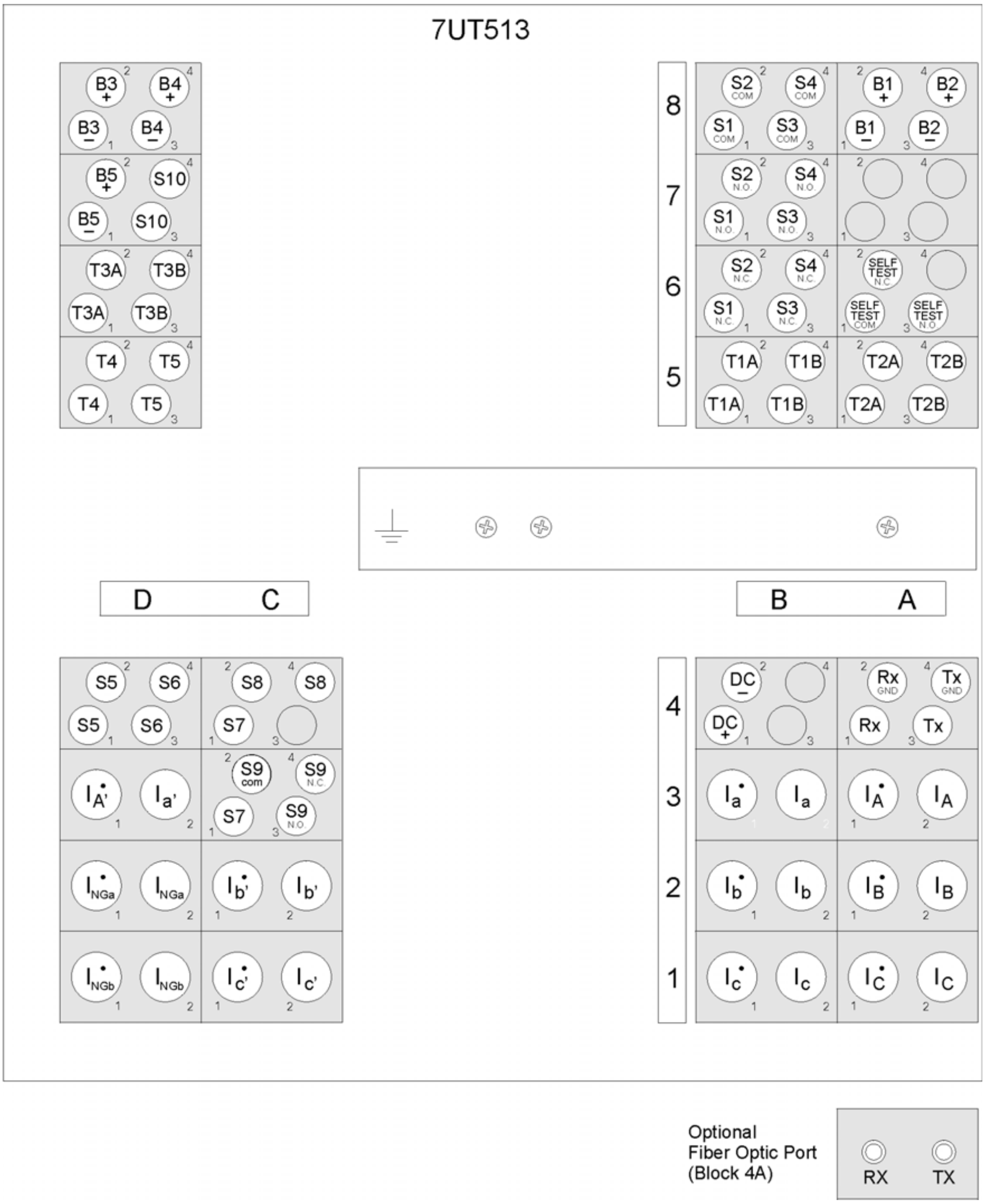


Figure 17.12 *Terminal Locations on Back of 7UT513*

17.6 Checking Connections

Make sure the circuit breaker for the DC supply is open.

Check the continuity of all the current transformer circuits against the plant and connection diagrams:

- Are the current transformers correctly grounded?
- Are the polarities of the current transformer connections consistent?
- Is the phase relationship of the current transformers correct?
- Is the assignment of the additional current transformers IA and IB correct (if used)?
- Are the current transformers IA and IB correctly grounded (if used)?
- Are the polarities of the current transformers IA and IB correct (if used)?

If test switches have been fitted in the secondary circuits, check their function, particularly that in the “test” position the current transformer secondary circuits are automatically short-circuited.

Fit a DC ammeter in the auxiliary voltage lead; range approximately. 1.5 A to 3.0 A.

Check that the relay power switch is in the off position.

Close the battery supply circuit breaker; check polarity and magnitude of voltage at the terminals or connector modules.

The measured current consumption should be insignificant. Transient movement of the ammeter pointer only indicates the charging current of the storage capacitors.

Put the miniature slide switch of the front plate in the “**On**” position. The unit starts up and, on completion of the run-up period, the green LED on the front comes on, the red LED gets off after at most 7 seconds.

Open the circuit breaker for the DC power supply.

Remove DC ammeter; reconnect the auxiliary voltage leads.

Check through the tripping circuits to the circuit breakers.

Check through the control wiring to and from other devices.

Check the signal circuits.

Reclose the DC supply circuit breaker.

17.7 Replacing the Internal Fuse

1. Select a replacement fuse 5 – 20 mm. Ensure that the rated value, time lag (medium slow) and code letters are correct.
2. Prepare area of work: Provide conductive surface for the basic module.
3. Open cover.
4. Loosen the basic module using the pulling aids provided at the top and bottom.
5. Pull out basic module and place onto the conductive surface.
6. Remove blown fuse from the holder.
7. Fit new fuse into the holder.
8. Insert basic module into the housing; ensure that the releasing lever is pushed fully to the left before the module is pressed in.
9. Firmly push in the module using the releasing lever.
10. Close cover.
11. Switch on the device again. If a power supply failure is still signalled, a fault or short-circuit is present in the internal power supply. The device should be returned to the factory.

17.8 Installing or Replacing the Battery

While the relay's settings are stored in non-volatile RAM memory, the event logs and captured waveform data are not. In addition, the internal clock requires continuous power. To provide power during any power failure, the relay has a backup battery. When shipped from the factory, the relay's battery is not installed (to keep it from running down).

⚠ CAUTION

This procedure interrupts the protection provided by the relay!

To install the backup battery, do the following:

1. Prepare the battery by cutting and bending the leads as shown in **Figure 17.13**.

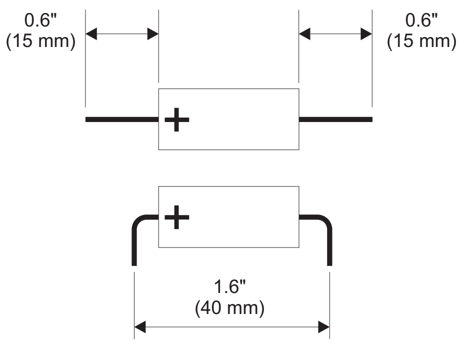


Figure 17.13 *Battery Leads Length and Shape*

2. Remove the main module from the relay case and place it on its side (see Section 17.3 on page 180).

3. Insert the battery leads into the terminals shown in **Figure 17.14** and tighten the terminal screws.

Figure 17.14 *Battery Location*

4. Insert the module back into the relay case and re-attach the front cover (see Section 17.3 on page 180).

17.9 Changing the Rated Nominal Current of the Current Inputs

When shipped from the factory. The rated nominal current of all the relay's current inputs is either 1A or 5A, depending on which was ordered. The rated nominal current for the current inputs monitoring each winding (or bus branch), and for the two ground-current inputs (on a 7UT513) can be changed by making a hardware modification. All three phase-current inputs for a particular winding (or bus branch) must have the same rated nominal current. To make the modification, do the following:

1. Remove the module(s) from the relay case as described in Section XREF.

2. If the last two characters of the relay's serial number are JH or alphabetically earlier, use a soldering iron, connect or disconnect the wire jumpers as shown in Figure 17.17.

   or

   If the last two characters of the relay's serial number are KK or alphabetically later, position the plug jumpers and shown in Figure 17.18 and Figure 17.19.

3. Return the module(s) to the relay case, as described in Section XREF.

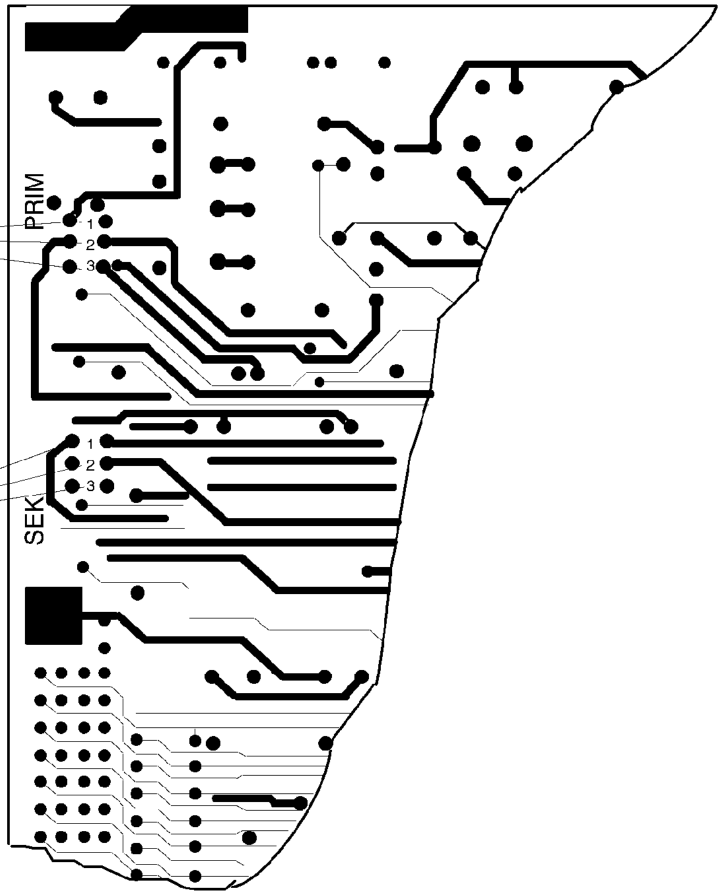
Main Module (7UT512 and 7UT513):

Setting for the first terminal
of protected object (primary)
I_N = 5 A ac: bridges in place
I_N = 1 A ac: bridges removed

All three bridges must be in the same position!

Setting for the second terminal
of the protected object (secondary)
I_N = 5 A ac: bridges in place
I_N = 1 A ac: bridges removed

All three bridges must be in the same position!



Auxiliary Module:

Only for 7UT513:

Setting for additional current input I_B
I_N = 5 A ac: bridge in place
I_N = 1 A ac: bridge removed
(models 7UT513*–*****–1***)

Note: Bridge 5 has no influence in case I_B is the highly sensitive current input (models 7UT513*–*****–**2*****)

Setting for additional current input I_A
I_N = 5 A ac: bridge in place
I_N = 1 A ac: bridge removed
(models 7UT513*–*****–1***)

Setting for the third terminal
of the protected object (tertiary)
I_N = 5 A ac: bridges in place
I_N = 1 A ac: bridges removed

All three bridges must be in the same position!

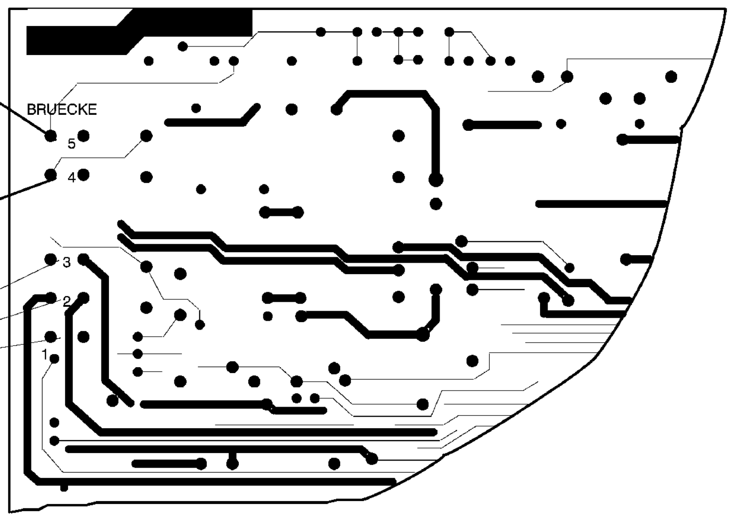
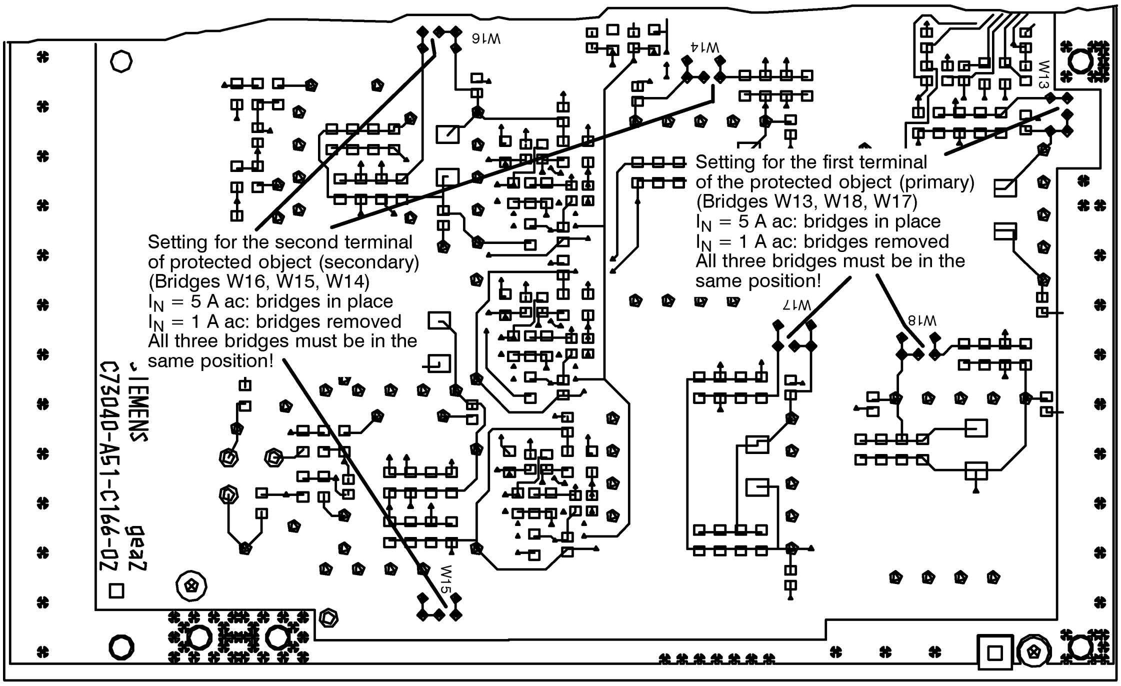


Figure 17.15 *Locations of Jumpers for Setting Rated Nominal Current of Current Inputs (Production Series /JH or Earlier).*

Main Module (7UT512 and 7UT513):



Solder side left p.c.b.

Auxiliary Module (7UT513 only):

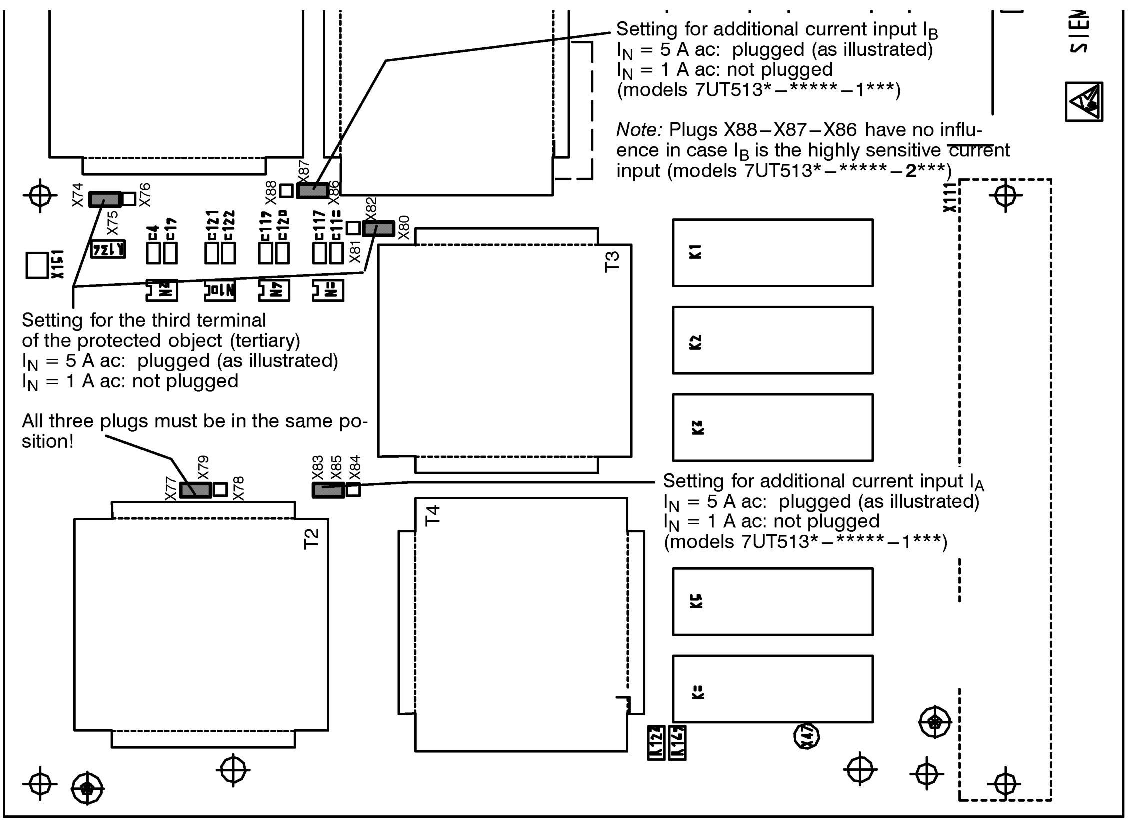


Figure 17.16 *Locations of Jumpers for Setting Rated Nominal Current of Current Inputs (Production Series /KK or Later).*

17.10 Changing the Rated Voltage of the Binary-Signal Inputs

A binary-signal input is actuated by applying a control voltage across its two terminals. When delivered from the factory, the voltage required to actuate the binary input is the same as the relay's DC supply power voltage, which is specified when the relay is ordered. If appropriate, the actuating-voltage for each binary-signal input can be independently changed to a different voltage. The change requires a hardware modification.

1. Remove the module(s) from the relay case as described in Section XREF.
2. If the last two characters of the relay's serial number are JH or alphabetically earlier, use a soldering iron, connect or disconnect the wire jumpers as shown in Figure 17.17.

   or

   If the last two characters of the relay's serial number are KK or alphabetically later, position the plug jumpers and shown in Figure 17.18 and Figure 17.19.
3. Return the module(s) to the relay case, as described in Section XREF.

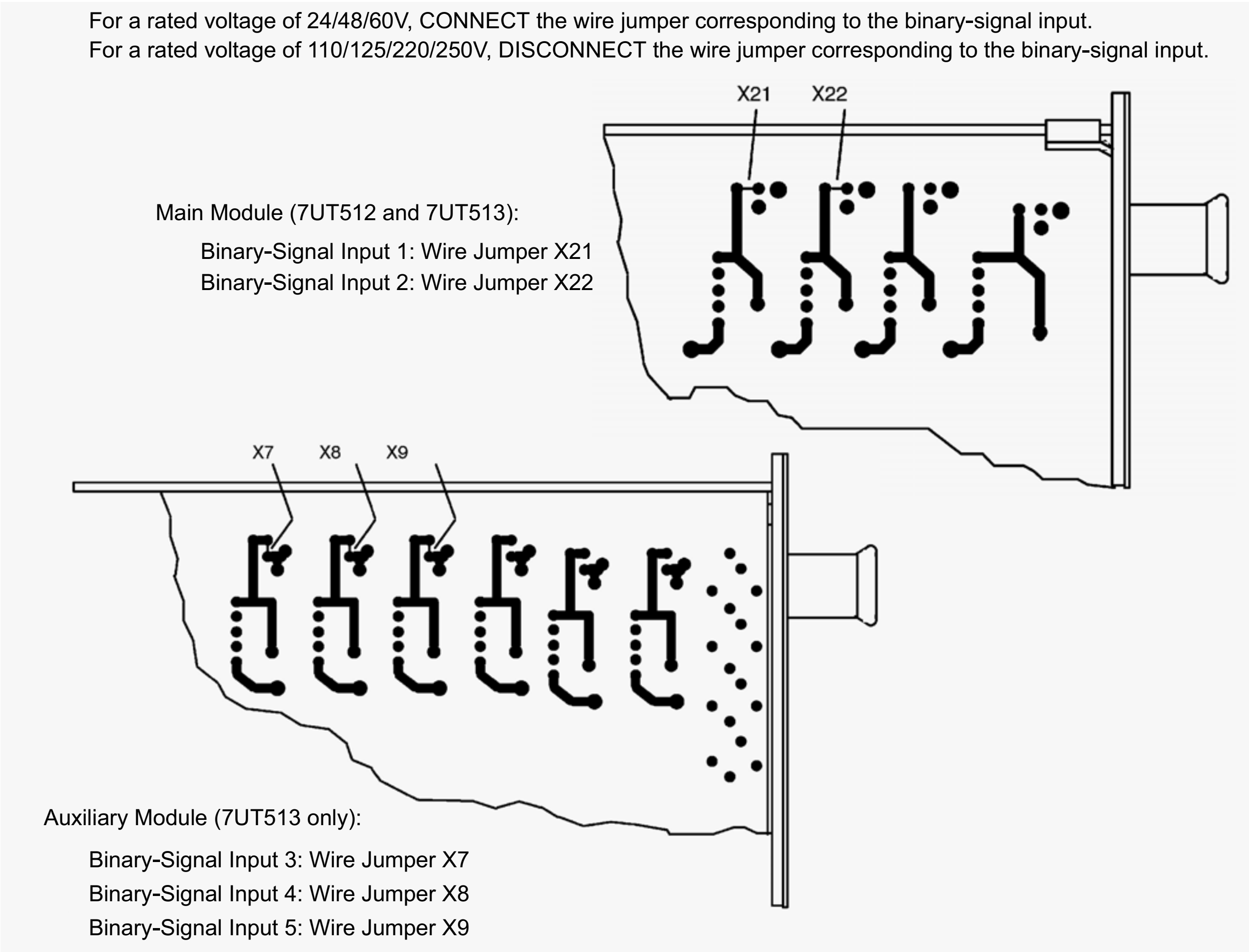


Figure 17.17 *Locations of Jumpers for Setting Rated Voltage of Binary-Signal Inputs (for Production Series /JH or Earlier).*

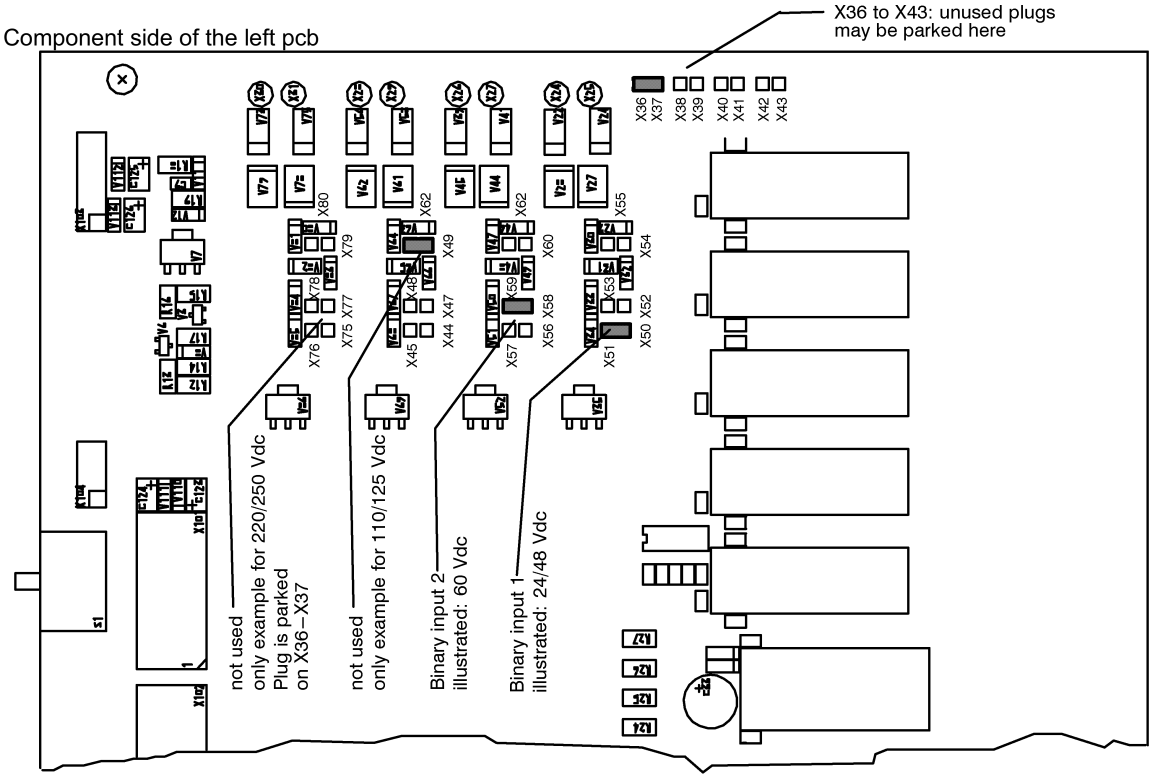


Figure 17.18 *Jumper Locations for Setting Rated Voltage of Binary-Signal Inputs 1 and 2 (Production Series /KK or Later)*

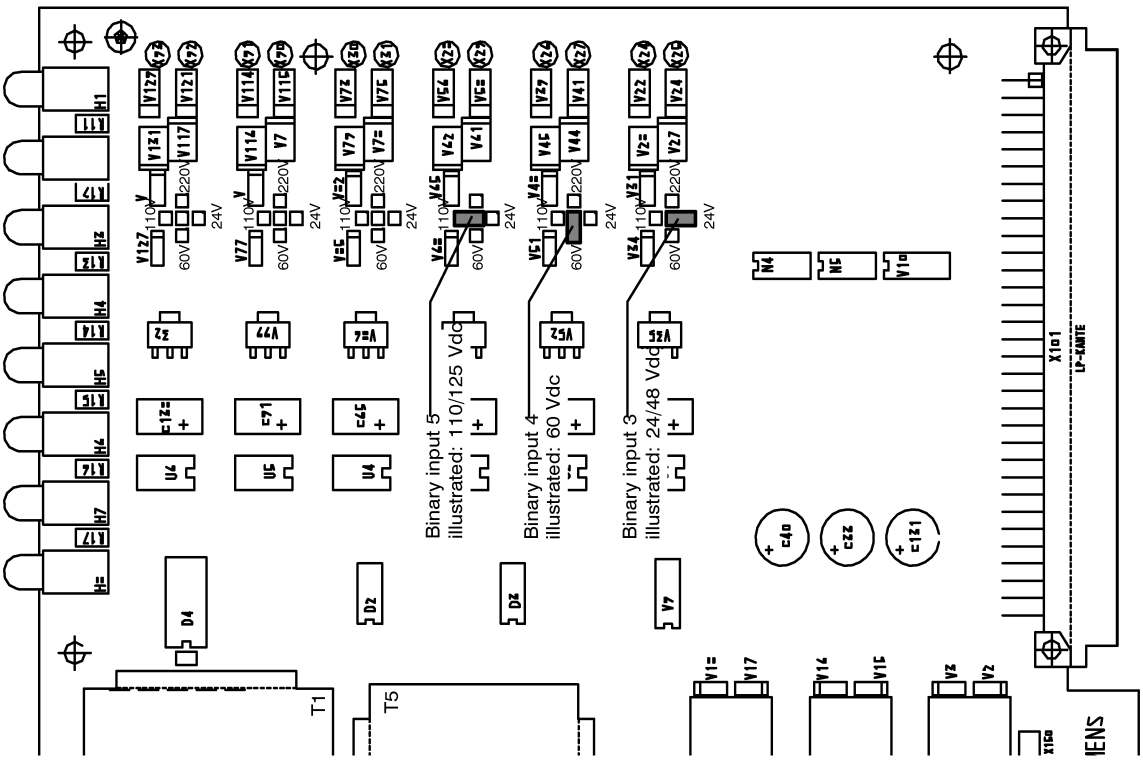


Figure 17.19 *Jumper Locations for Setting Rated Voltage of Binary-Signal Inputs 3, 4, and 5 (Production Series /KK or Later)*

17.11 Changing the Normal Signal Position of the Fiberoptic Data Port

If the relay was ordered with a fiberoptic rear data port, the normal signal position is factory preset to be "**Light Off**." This can be changed by repositioning plug-jumper X239, which is located in the rear area of the power supply board (the center board of the main module). The procedure is as follows:

1. Remove the main module from the relay case as described in section XREF.
2. Change the jumper location to the appropriate position, as shown in Figure 17.20.
3. Return the module to the relay case, as described in Section XREF.

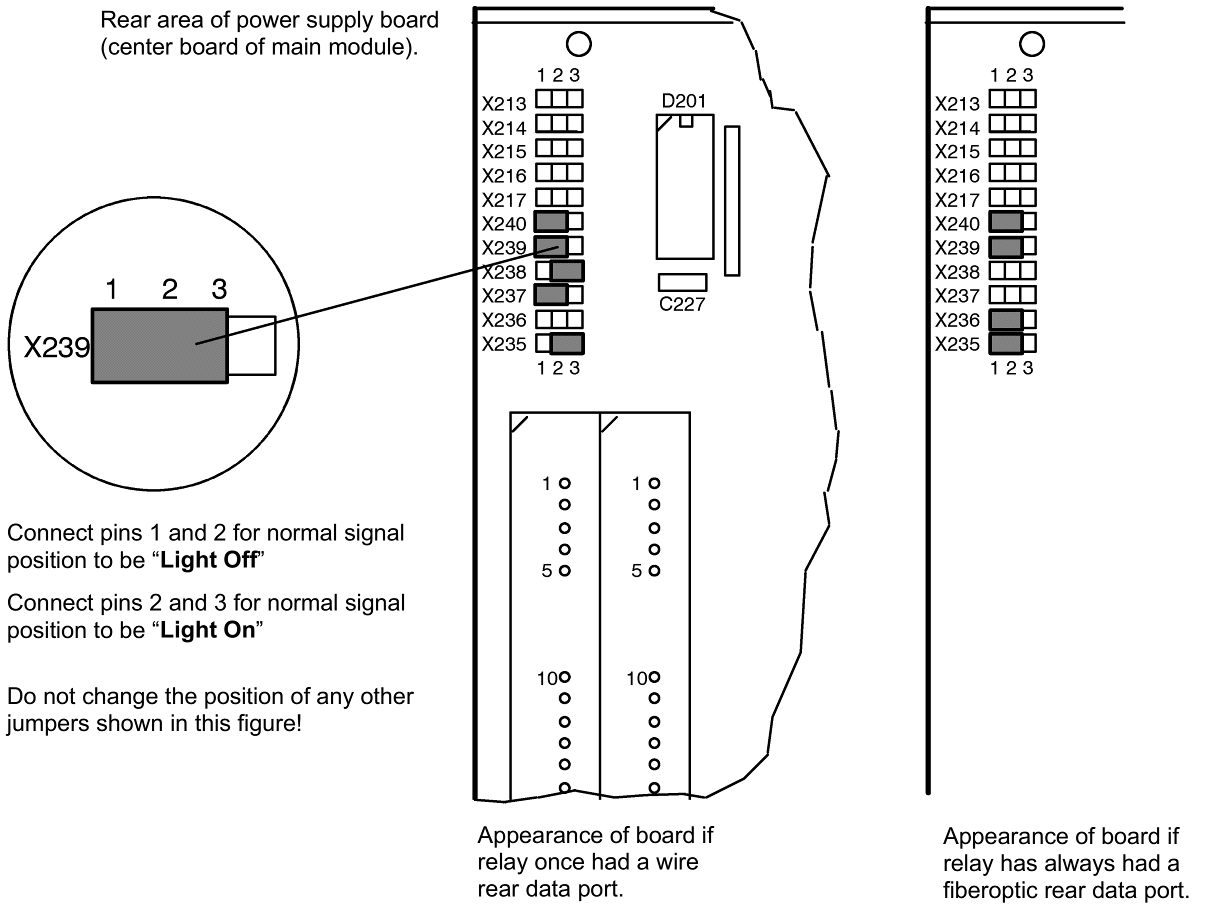


Figure 17.20 *Jumper Location for Setting Normal-Signal Position of Fiberoptic Data Port*

18 Field Testing and Commissioning

⚠ WARNING

Hazardous voltage or current.

Can cause death, serious personal injury, or property damage.

Only qualified personnel should test or commission a relay. Read and understand this manual and the manuals for any test equipment before proceeding.

Before performing work on CT wiring, always short circuit the secondary of all the CTs.

To avoid damage to the relay, ensure that output contacts do not break currents greater than their rating.

To avoid damage to the relay, ensure that any control power or test value applied to the relay does not exceed the corresponding input's limit.

This chapter describes commissioning a 7UT51 relay, including procedures to verify correct operation and configuration.

The procedures in this chapter test functions of both the 7UT512 and 7UT513 models. When testing a 7UT512, simply skip sections that apply only to a 7UT513. Likewise, any functions not used in a particular application need not be tested.

Complete testing of all required protective functions, discrete inputs, signal contacts, and trip contacts is recommended prior to installation.

The procedures take into account that the protection settings may vary, but they assume that the relay's contact inputs, contact outputs, and LEDs are configured with their default values (unless otherwise noted). If they have been configured differently, the user must determine the expected behavior of the relay and compare it to the observed results of the procedure.

Note: All secondary testing sets and equipment must be removed. All current circuits should be connected to the relay.

18.1 Preparation

18.1.1 Physical Inspection

Check all wiring from the relay to all substation components such as CTs, breaker trip coils, status contacts, etc. Inspect all cables, junction boxes, circuit breakers, etc., for proper wiring, shorting type terminal blocks at proper locations, tight connections (screw heads must be tight against wire). Check that shorting screws are removed from CT blocks that will be in service. Inspect boxes, switches, relays, etc., for any material such as wires, screws, lugs, tags, etc., that could short or ground the circuit. Visually wire check all current circuits.

Check auxiliary switches for connections, wipe, and adjustment per manufacturer's instructions, particularly the operating relation with respect to main blade make and break.

Ensure that current inputs are wired with an A-B-C phase rotation. Ensure that settings match those prepared by a qualified protective relaying engineer.

Check the connections to the relay:

- Ensure that inputs to the relay are connected with the correct polarity.
- Ensure that trip circuits are disconnected from the relay trip contacts and are left open-circuited. Also, disconnect from external breaker failure devices any of the relay outputs that are being tested.

Once acceptance tests have been completed (see Chapter 16) and the relay is installed with the in-service settings applied and tested, and the above physical inspections made, the commissioning tests and checks can be performed.

18.1.2 Energizing the Relay

Before energizing the relay, it must be installed for at least two hours to ensure temperature equalization and to avoid condensation.

1. Switch off the DC supply and the potential transformer circuit.
2. Verify that the miniature slide switch on the front panel is in the “**Off**” position.
3. Fit a DC ammeter in series with the auxiliary power circuit using a range of 1.5 to 3 amperes.
4. Close the DC supply circuit breaker; check polarity and magnitude of voltage at the terminals of the unit or at the connector module.
5. Steady-state current consumption should be insignificant. Any initial transient current is due to charging of the storage capacitors.
6. Slide the switch on the front panel to the “**On**” position. On completion of the start-up/warm-up period, the green LED on the front comes on in 0.5 seconds and the red LED goes off after 5 seconds.
7. Slide the switch on the front panel to the “**Off**” position.
8. Open the DC power supply circuit breaker.
9. Remove DC ammeter; reconnect the auxiliary voltage leads.
10. Slide the switch on the front panel back to the “**On**” position.
11. Check the direction of phase rotation at the relay terminals (clockwise).
12. Ensure that trip circuits are disconnected from the relay trip contacts and are left open-circuited. Also, disconnect from external breaker failure devices any of the relay outputs that are being tested.

    Note: All setting values should be checked again, in case they were altered during previous testing. Particularly check that all desired protection functions have been **Enabled** and that all desired protection functions have been switched **On** in the corresponding Settings menu.

Stored indications on the front plate should be reset by pressing the “**Target Reset**” on the front so that from then on, only real faults are indicated. From that moment, the measured values of the quiescent state are displayed. While pressing the RESET button, the LEDs on the front will light up (except the “**Blocked**” LED); thus, an LED test is performed at the same time.

Delete stored annunciations and counters go to Address Block 8200:

1. Enter the password (000000).
2. 8201 Resets LED memory. Using WinDIGSI, the LED reset is found under: **Options \ Device \ Reset LEDS**.
3. 8202 Deletes the operational buffer storage. Using WinDIGSI, deleting the operational buffer is found under: **Control/ Resetting Stored Data / 8202** - **Reset event log** or **8203 – Reset Trip Log**.
4. 8203 Deletes the fault annunciation buffer storage. Using WinDIGSI, deleting the operational buffer is founder under **Control/ Resetting Stored Data / 8202** - **Reset event log**, or **8203 – Reset Trip Log**.
5. Press the **Target Reset** on front panel
6. Push the **Event** key on the front of relay. The display shows the beginning of the annunciation blocks. Thus, it is possible that the measured values for the quiescent state of the relay can be displayed. These values had been chosen during configuration under the Addresses 7105 and 7106.
7. Close the housing cover.

    Note: Housing cover must be on relay for proper operation.

18.1.3 Check Matching Factors

Since external matching transformers have been eliminated and since the digital protection unit 7UT51 offers a number of commissioning aids, commissioning can be performed quickly and without external instruments.

Before performance of the actual primary tests, it is advisable to recheck that the matching factors for the rated currents of the protected object are correct. These factors are presented in the operational annunciation each time the parameterizing process has been terminated.

Select the operational annunciations either by direct addressing 5100 or using the PC and WinDIGSI.

The following factors are available:

$$k\ CT\ 1 = \frac{\text{current processed by 7UT51}}{\text{current through the relay terminals}}$$

for Side 1 of the protected object and similar for the other sides:

- k CT2 =
- k CT3 = (only 7UT513)
- ksCT 1 = (only 7UT513)
- ksCT 2 = (only 7UT513)
- ksCT 3 = (only 7UT513)

where ksCT are the factors for inputs from the CT in the star-point connection of a grounded transformer winding (if used).

When 7UT513 is used, check that LED 14 does not light. This LED indicates (by default) that combinations of configuration or function parameters are not consistent. If this LED is illuminated, look up the cause of this inconsistence in the operational event log. A listing of the types of error messages can be found in Table 13.1.

18.2 Preparation of Primary Tests

At first commissioning, current checks must be performed before the protected object is energized for the first time. This ensures that the differential protection is operative as a short-circuit protection during the first excitation of the protected object with voltage. If current tests are only possible with the protected object under voltage, it is imperative that a backup short-circuit protection be available. The trip circuits of other protection devices such as the Buchholz protection must remain operative as backup protection.

The test arrangement varies depending on the application.

On network power transformers or asynchronous machines, a low voltage test equipment is preferably used. A low-voltage current source is used to energize the protected object, which is completely disconnected from the network (see Figure 18.1). A short-circuit bridge, that is capable to carry the test current, is installed outside of the protected zone and allows the symmetrical test current to flow.

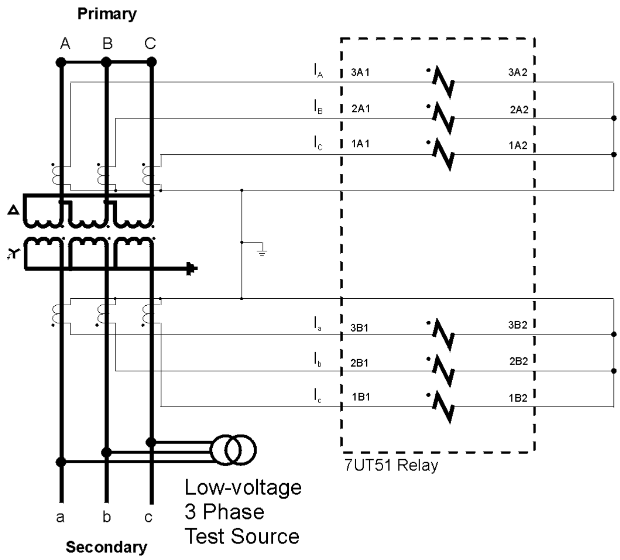


Figure 18.1 *Primary Current Tests Arrangement Example for a Two-Winding Transformer with Low-Voltage Source*

On power station unit transformers and synchronous machines, the checks are performed during the current tests. The generator itself forms the test current source. The current is produced by a three-pole short-circuit bridge that is installed outside of the protected zone and is capable of carrying rated current for a short time. The machine is started but not yet excited. Check that no current transformer is open or short-circuited. In order to achieve this, read out the operational measured values (Address Block 5700). Even when the currents and the measurement accuracy is still very small, errors can be detected.

On branch points, a low-voltage test source can be used. Alternatively, load current test is possible. Backup protection must be in service if current tests are only possible under voltage.

The test current must be at least 2% of the rated relay current.

When the 7UT513 is used on a protected object with three terminals (three-winding transformers, three-terminal branch points) or when a virtual object is included, the test currents are always fed over two sides: first Side 1 to Side 2, then Side 1 to Side 3. Current tests are initiated by a measurement request by the operator. The measured test values are stored but not continuously actualized to ensure comparable results. If the test arrangement is changed, a new measurement request will be necessary.

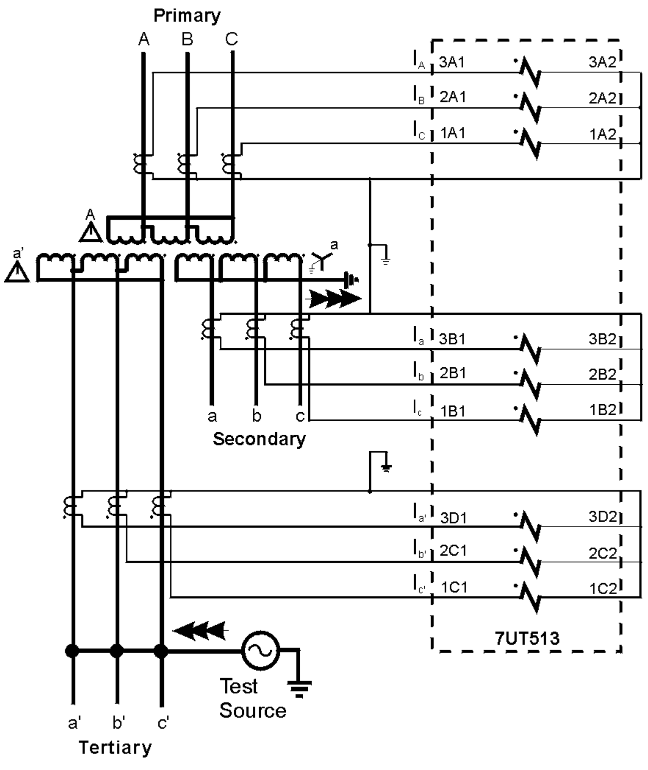


Figure 18.2 *Primary Current Test Arrangement Example for a Three-Winding Transformer*

During test operation, the differential protection or restricted earth fault protection is not operational even when they are switched **On**. When no activities are carried out during more than 60 minutes such as no measurement request or any change in the Address Block 4100, the relay terminates the test operation automatically. Of course, it is possible to terminate test operation at any time.

18.3 Symmetrical Current Tests, Address Block 4100

The test can be initiated directly from the relay panel or via WinDIGSI. These tests are located in Address Block 4000. The commissioning measurements for the differential protection in Address Block 4100.

All measurement values are stored immediately after the operator has started measurement request and are available for readout. They are not actualized in order to ensure comparable results. When the test conditions have been changed, a new measurement request must be started. For starting a measurement request via the relay panel, the password is required.

The following tests refer to the relay front panel; however, the same tests are easily performed using WinDIGSI. To initiate this test with WinDIGSI, go to the Test menu, choose **Commissioning Test**, and then choose the required measurement. See Figure 18.3 for the WinDIGSI measured current test screen.

Go to Address Block 4000 and page to Address 4101 to test the differential current:

Address	Test
4000	Tests
4100	Commission Test
4101	Test Diff? Enter Yes. Measurement is processed

The relay measures all currents and phase angle of this test Address 4101. As soon as the first measured value appears in the display, the test current can be switched off. The values can be read out be repeatedly depressing the No key, the Back Space key allows reads the preceding value.

After start, the relay first checks whether measurement can be carried out. If a protection function has picked up before, measurement is rejected. When the measured quantities are too small, a corresponding message is given. In these cases, Address 4101 must be left (by going back to 4100) and the test arrangement must be rechecked. Increase the test current if necessary. Finally go back to Address 4101 and repeat the procedure.

The symbols for the side or winding of the protected object are W1, W2, W3*, WA*, WB* or I1, I2, I3, IA, IB. The symbols for the phase reference are Ia, Ib, Ic or L1, L2, L3 or PhA, PhB, PhC.

Compare the displayed currents with the test currents. If deviations occur that cannot be explained by tolerances, either the connection or the test arrangement is wrong.

- Disconnect the protected object (shut down the generator) and ground.
- Check connections and test arrangement
- repeat test

18.3.1 Tests Related to All Applications

Connect the test equipment such that the test current will flow from Side 1 to Side 2 of the protected object. Side 3 (if applicable) must be isolated. Since the test current is flowing from Side 1 to Side 2, all results that concern Side 3 will have the message "****".

Address	Test Messages
4101	Test Diff I1 L1=12.3 (e.g.) This is the measured current of Side 1, phase 1 referred to the rated relay current
	Test Diff *Invalid* - Error message after measurement request, invalid result (e.g. because of network fault)
	Test Diff *Current Too Small* - All currents are too small for evaluation
	Test Diff *I1 L1 = ****** - current for an individual measurement is too small or no current. Further currents can be read by using the No key (on the front panel).

If the current magnitudes are consistent, page on to Address 4121. The phase angle relations are displayed. It is not necessary to request a new measurement. The phase angle differences are displayed in 30° increments; therefore small deviations (up to +/- 10°) are tolerated. When the measured angle is outside of this tolerance range, the display shows "inval" The angle differences are defined for clockwise phase rotation. The angle differences of the three currents of Side 1and 2 will be as follows:

Address	Test Message
4121	Test Angle L Test? Confirm with the Yes key or abort with the No key.
4121	Test Angle L I1L2-I1L1=240° - display of phase angle between the currents of Side 1, phase L2 against phase L1, should be 240°
4121	Test Angle L I1L3-I1L1=120° - display of phase angle between the currents of Side 1, phase L3 against phase L1, should be 120°
4121	Test Angle L I2L2-I2L1=240° - display of phase angle between the currents of Side 1, phase L2 against phase L1, should be 240°
4121	Test Angle L I2L3-I2L1=120° - display of phase angle between the currents of Side 1, phase L3 against phase L1, should be 120°.

If the values are not correct, wrong polarity or phase interchange at side (or winding) 1 or 2 is the cause:

- Disconnect the protected object (shut down generator) and ground.
- Check connections and test arrangement
- Repeat test by renewed measurement request

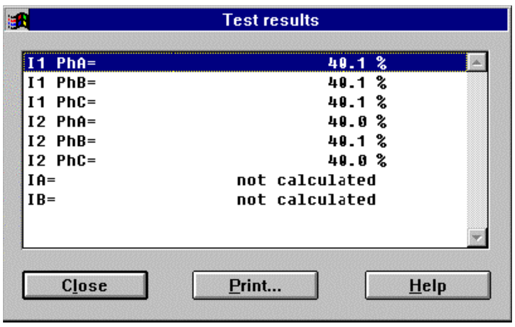


Figure 18.3 *WinDIGSI Screen Example of Measured Current Test for Each Phase on Each Side*

The polarities of the through flowing currents are defined to be equal. When currents of equal phase flow through the protected object, the angle difference is 0°, provided the connections are correct. The theoretical angle value depends on the protected object, the transformers, and the connection group entered into the relay (see Table 4.1 and Table 4.2). The measured angles must be equal for all three phases. If not, individual phases are interchanged.

The polarity of the current connections and the parameterized polarity are taken into consideration when the angles are displayed. Thus, if all three angles differ by 180° from the theoretical value, the polarity of one complete current transformer set is wrong. This can be corrected by checking and changing the corresponding plant parameters:

- Address 1105 for the primary winding of a transformer
- Address 1125 for the secondary winding of a transformer
- Address 1206 for generators or motors
- Address 1303 for Side 1 of a branch point
- Address 1305 for Side 2 of a branch point

Note: The connection group of power transformers is defined from the higher voltage side to the lower voltage side. The angle (vector group * 30°) is valid only when measurement is carried out in this way. That is, the test source is on the higher voltage side and the short-circuit bridges are on the lower voltage side. If measurement is carried out from the lower voltage side, the angle must be: 360° - vector group*30°.

Address	Test Message
4121	Test Angle L I1L1-I2L1=0° - display of phase angle between the currents of Side 1, phase L1 against Side 2, phase L1, refer to Table 4.1 and Table 4.2
4121	Test Angle L I1L2-I2L2=0° - display of phase angle between the currents of Side 1, phase L2 against Side 2, phase L2, should be 120° refer to Table 4.1 and Table 4.2
4121	Test Angle L I1L3-I2L3=0° - display of phase angle between the currents of Side 1, phase L3 against Side 2, phase L3, should be 120° refer to Table 4.1 and Table 4.2

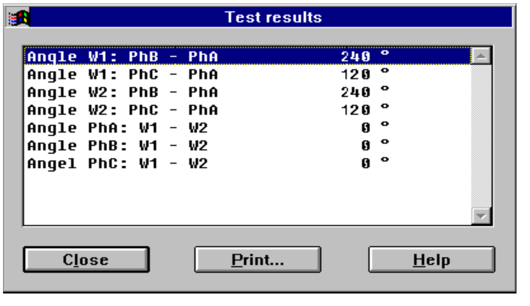


Figure 18.4 *WinDIGSI Screen example of the angle measurement of the line currents.*

Before the tests with symmetrical currents are terminated, the differential and stabilizing currents are checked. Even though the previous tests should have detected all connection errors, nevertheless, errors are possible concerning current matching and the assignment of the connection group. Page to Address 4161. In this Address, the calculated values can be read out by scrolling through the display with the **No** key or **Backspace** key. Note that the differential and stabilizing values are referred to the rated current of the protected object.

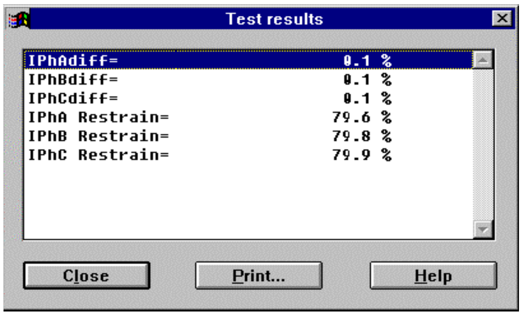


Figure 18.5 *WinDIGSI Example of Differential and Restraint Current Side 1Test*

If considerable differential currents occur, recheck the concerned parameters:

- For transformer protection,addresses 1102 to 1104 (matching of transformer Winding 1), addresses 1121 to 1124 (matching of transformer winding 2).
- For generator or motor protection, addresses 1202 and 1203 (matching of the rated machine values).
- For branch point protection, addresses 1301 and 1302 (matching of Side 1) and 1304 (matching of Side 2).

Address	Test Messages
4161	Test Dif/ST Test? Display of the results of calculation of the differential and stabilizing currents? Confirm with the Yes key or abort with the No key
	Test Dif/ST IL1,IL2, and IL3 diff = 0.4% (e.g.) - displays the differential current of measuring system L1,L2, and L3 referred to the rated current of the protected object, e.g. 0.4%. The value should be negligible against the magnitude of the line currents.
	Test Dif/ST IL1, IL2, and IL3 rest = 24.4 (e.g.) - Display of the stabilizing (restraint) current of measuring system L1, L2, and L3 referred to the rated current of the protected object, e.g. 24.4%. The value should be approximately twice the test current.

If the 7UT51 is configured for a protected object with two sides, the symmetrical current tests are thus completed. Disconnect the protected object (shut down the generator) and ground, disconnect test arrangement and skip the next test.

18.3.2 Tests Related to Protected Objects with Three Terminals

Modify the test arrangement such that the test current will flow from Side 1 to Side 3 of the protected object. Side 2 must be isolated: the short-circuit bridges at Side 2 must be removed and inserted at Side 3.

After the test current has been switched on, measurement request is initiated. Leave Address 4161 by paging back to Address 4101 and perform the measurement request as instructed in Sections 18.3.1.

As soon as the first measured value appears in the display, the test current can be switched off.

Since the test current is now flowing from Side 1 to Side 3, all results that concerned Side 2 have the message “****”.

If the current magnitudes are consistent, page on to Address 4121 to test the phase angle relations. It is not necessary to request for a new measurement. The results should follow Sections 18.3.1.

The polarity of the current connections and the parameterized polarity are taken into consideration when the angles are displayed. Thus, if all three angles differ by 180^{o} from the theoretical value, the polarity of one complete current transformer set is wrong. This can be corrected by checking and changing the corresponding plant parameters:

- Address 1105 for the primary winding of a transformer; this should have already been verified during the tests according to Section 18.3.1 on page 199. If this parameter is changed, the complete tests concerning Winding 1 against winding 2 would have to be repeated.
- Address 1145 for the tertiary winding of a transformer
- Address 1303 for Side 1 of a branch point: this should have already been verified during the tests according to Section 18.3.1 on page 199. If this parameter is changed, the complete tests concerning Side 1 against Side 2 would have to be repeated.
- Address 1307 for Side 3 or a branch point.

If the phase angles are correct, the differential and stabilizing currents can be checked in Address 4161. If considerable differential currents occur, recheck the concerned parameters as is Sections 18.3.1. If these parameters are changed now, the complete tests with Side 1 against Side 2 would need to be repeated.

The symmetrical current tests are now complete. Disconnect the protected object and ground, disconnect the test arrangement.

18.4 Preparation for Zero Sequence Current Tests

The zero sequence tests are necessary with 7UT513, if:

- zero sequence current correction by means of one of the additional measured current inputs IA or IB is carried out with transformer differential protection, i.e. addresses 7806 and/or 7807 are assigned to a transformer winding, which is parameterized to Io-Correction (addresses 1106 or 1126 or 1146),

  or

- the restricted earth fault protection is used, i.e. addresses 7806 and/or 7807 are assigned to a side of the protected object or virtual object, which is also assigned to the restricted earth fault protection.

Besides this, the neutral of the respective winding must be grounded and a current transformer must be installed in the ground lead of that winding.

Zero sequence current measurement is always performed from the side of the protected object where the transformer is grounded. The transformer must have a delta winding. The sides not included in the test can remain open as the delta winding ensures that the zero sequence current path is low impedance circuited. See Figure 18.2 for example test arrangements.

18.4.1 Zero Sequence Tests – Address Block 4100

Inititation of test is again made via the relay front panel or PC. If the test arrangement is changed, a new measurement is necessary.

As soon as the first measured value appears in the display the test current can be switched off.

Since the results of the symmetrical current tests have already been checked, only the results of the zero sequence current tests are relevant now. The remaining results can be bypassed by pressing the **No** key. The displayed currents are referred to the rated current of the relay.

Go to Address 4101 to initiate the differential test. After confirmation is carried out. The relay measures all currents and phase angles of this test address. If wrong values occur for the additional currents IA and/ or IB, the test arrangement must be rechecked. Additionally, recheck and correct the relevant configuration parameters in Address 7806 for measured current IA, and Address 7807 for measured current IB.

The test differential current value of IA and/or IB should be approximately three times the line currents. If not connected “****” will be displayed.

Continue on to the angle measurement test in Address 4141. The phase angle relation of the phase current need not be checked. The phase angles of all phase currents of the winding under test against each other are zero, those against different windings are not defined because of missing current. Therefore, page on to Address 4141. The phase angles, between the star-point current connected to input IA or IB against the phase current, are displayed. Numerical values are to be expected only for those current inputs which are included in the test current path, for the remaining currents, “****” is displayed.

If an additional current input is not assigned to any side of the protected object (addresses 7806 and/or 7807), the associated measured values do not appear at all.

If considerable deviations occur, recheck the corresponding parameters and correct them where necessary:

- Address 1108, when the additional current input is assigned to Winding 1 of a transformer
- Address 1128, when the additional current input is assigned to winding 2 of a transformer
- Address 1148, when the additional current input is assigned to winding 3 of a transformer
- Address 1405, when the additional current input is assigned to a virtual object.

Display of the phase angle between the star-point current connected to input IA against the phase current of Side 1, phase L1, L2, and L3 should be 0^{o}, when tested for IA-I1L1, IA-I1L2, and IA-I1L3, respectively.

If installed on the winding of a transformer, and the zero sequence current correction is used, the differential and stabilizing currents of the differential protection must be checked.

Page to Address 4161 to perform the differential and stabilizing test. These values are referred to rated current of the protected object.

Display of the differential current of the measuring system L1, L2, and L3, referred to the rated current of the protected object, should be negligible against the magnitude of the line currents.

Display of the stabilizing (restraint) current of the measuring system L1, L2, and L3, referred to the rated current of the protected object, should be negligible against the magnitude of the line currents.

If considerable differential currents occur, recheck the concerned parameters for zero sequence current processing and the matching factors:

- Addresses 1106 to 1108 when the zero sequence current is associated with Winding 1
- Addresses 1126 to 1128 when the zero sequence current is associated with winding 2
- Addresses 1146 to 1188 when the zero sequence current is associated with winding 3.

If the differential current corresponds to 1/3 of the test current, the star-point current correction is not effective. If the differential current corresponds to 2/3 of the test current, the star-point current has wrong polarity.

If the restricted ground-fault protection is not available or not used, the zero sequence current tests are complete. Disconnect the protected object and ground, disconnect test arrangement and skip the next test.

18.4.2 Current Test for Restricted Ground Fault Protection, Address Block 41

If the relay is equipped with restricted ground-fault protection and is required in the application, a further zero sequence current test must be carried out.

A renewed measurement of request of the operator is necessary. The measured values are then stored but not continuously actualized to ensure comparable results. If this test arrangement is changed, a new measurement request is necessary.

As soon as the first measured value appears in the display, the test current can be switched off.

Go to Address 4100 and page to Address 4181 to test the restricted ground-fault protection. Confirm with the **Yes** key to begin measurement of all currents and phase angles of this test.

Measurement of the Phase Current Relationship

During zero sequence current test, the three phase currents must be approximately equal and without phase difference. Otherwise wrong polarities are present in the current transformer connections.

If one angle is 180^{o} instead of 0^{o}, wrong polarity is present:

- Disconnect the protected object and ground
- Check connections and test arrangement
- Repeat test

Measured Values of the Restricted Ground Fault Protection

The current Io* and Io** are referred to the rated relay current and correspond to the values Io' and Io" which are relevant for the actual protection function.

Io* is the current that flows through the star-point current transformer. Io** is the sum of the phase currents. When the rated primary currents of all these CTs are equal, the Io* and Io** are almost equal.

If the display shows undefined values, such as "****", the test arrangement must be checked as well as the assignment of the additional measured current inputs IA and IB (addresses 7806 and 7807).

The display of the measured current of the star-point in Address 4181, referred to the relay current, should be approximately the star-point current.

The display of the sum of the phase currents, referred to rated relay current, should be approximately three times the phase current.

The phase angle between Io* and Io** must be 0^{o}. If it is 180^{o}, the star-point CT has wrong polarity. Recheck and correct the related parameters:

- Address 1108, when Winding 1 is assigned to the restricted ground-fault protection, i.e., Address 7806 on SIDE 1 for current input IA or Address 7807 on SIDE 1 for current input IB.

- Address 1128, when winding 2 is assigned to the restricted earth fault protection, i.e., Address 7806 on SIDE 2 for current input IA or Address 7807 of SIDE 2 for current input IB.

- Address 1148, when winding 3 is assigned to the restricted earth fault protection, i.e., Address 7806 on SIDE 3/V. OBJ for current input IA or Address 7807 on SIDE 3/V. OBJ for current input IB.

- Address 1405, when a virtual object is assigned to the restricted earth fault protection, i.e., Address 7806 on SIDE 3/V. OBJ for current input IA or Address 7807 on SIDE 3/V. OBJ for current input IB.

Before the tests are terminated, the differential and stabilizing currents are checked. When assessing the currents, note that the differential and stabilizing values are referred to the rated current of the protected object. If considerable differential currents occur, recheck the concerned parameters:

- Address 1107, when Winding 1 is assigned to the restricted ground-fault protection, i.e., Address 7806 on SIDE 1 for current input IA or Address 7807 on SIDE 1 for current input IB.

- Address 1127, when winding 2 is assigned to the restricted ground-fault protection, i.e., Address 7806 on SIDE 2 for current input IA or Address 7807 on SIDE 2 for current input IB.

- Address 1147, when winding 3 is assigned to the restricted ground-fault protection, i.e., Address 7806 on SIDE 3/V. OBJ for current input IA or Address 7807 on SIDE 3/V. OBJ for current input IB.

- Address 1404, when virtual object is assigned to the restricted ground-fault protection, i.e., Address 7806 on SIDE 3/V. OBJ for current input IA or Address 7807 on SIDE 3/V. OBJ for current input IB.

The display of the differential current in Address 4181, referred to the rated current of the protected object, should correspond approximately to the star-point current.

The display of the stabilizing (restraint) current, referred to the rated current of the protected object, should correspond approximately to twice the star-point current.

The zero sequence current tests are now complete. Disconnect the protected object and ground. Remove the test arrangement.

18.5 Leaving Test Operation, Address Block 4800

When the relay is in test mode, the differential protection and the restricted ground-fault protection are not effective, even when they are switched **On**. When no activities are carried out during more than 60 minutes, the relay terminates the test operation automatically. All protection functions that are switched **On** are then operational again. It is nevertheless recommended that the test mode be definitely finished after the tests have been completed.

- Access Address 4800 – **COMMISSIONING TEST STOP**
- Page to Address 4801 – **TEST STOP?**
- Enter **YES** key

18.6 Checking The Coupling of External Trip Signals

If the coupling of external functions for alarm and/or trip processing is used in 7UT51, then one or more of these functions must be configured as EXISTENT in addresses 7803 and/or 7831. Additionally, the respective function must be switched to **Block Trip Rel** in Address 3001 and/or **3101 Ext. Trip***.

The operation of the coupling is to be checked for each function one after another. For this check, the source object of the coupled signal is operated and the effect is checked.

Finally, the required functions are parameterized to **On** in the associated addresses 3001 and/or 3101.

If further annunciations such as Buchholz protection signals or user definable annunciations are used, these, must be checked. The origin of each annunciation is operated and the reaction of the relay is checked.

18.7 Operational Checks

Operational checks are performed after wire checking is complete and primary current tests are performed.

First, the differential protection is switched to **Block Trip Rel** or the trip commands to the circuit breakers are interrupted.

If trip test switches are installed in the circuit, these initial checks are performed with the trip test switches in the open position. If no trip test switches are installed, disable/block relay trip output.

Verify that all relay and lockouts are reset.

Once the current circuits and relay operations are verified, the major equipment such as circuit breakers and air break switches can be checked for proper operation. With the 86 relay in the trip position, close each test blade separately. When the test blade is closed, its corresponding piece of equipment will trip.

Once tripped, check and verify all interlocks for correct operation.

After verifying all tripping from the lockout (86) through the test blades, all external tripping of the 86 relay is performed.

An overall operational test should be performed to give a final system check. No part of the control scheme should be assumed correct. Test every input, output and function to verify that it operates independently and also in conjunction with the total scheme.

Once all checks are complete, check for zero (0) voltage across the relay trip test switches with a DC voltmeter.

18.8 Energizing the Protected Object

Place test switch in the operating position.

Prior to energizing the protected object, all relay protection is placed in service. All secondary test sets and equipment must be removed; all required CTs connected.

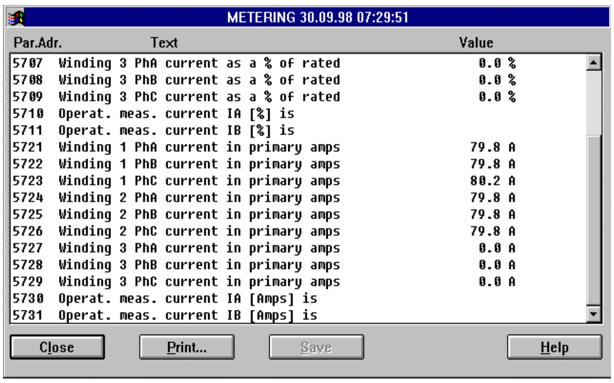
18.8.1 In-Service Readings

In-service readings are taken to ensure system reliability and security after the protected object is energized and loaded.

1. Read and record the current magnitude and phase angles in all leads and windings.
2. Check balance with meter. Trace any abnormalities.
3. Verify all measurable quantities (inputs) through the relay.

18.8.2 Operational Measured Values

Check the steady state rms operating values to verify that the relay is functioning properly. This information is accessed directly in Address Blocks 5700 and 5900 and compared with actual known values. Compare the known current values with the displayed test currents.



METERING 30.09.98 07:29:51

Par.Adr.	Text	Value
5707	Winding 3 PhA current as a % of rated	0.0 %
5708	Winding 3 PhB current as a % of rated	0.0 %
5709	Winding 3 PhC current as a % of rated	0.0 %
5710	Operat. meas. current IA [%] is	
5711	Operat. meas. current IB [%] is	
5721	Winding 1 PhA current in primary amps	79.8 A
5722	Winding 1 PhB current in primary amps	79.8 A
5723	Winding 1 PhC current in primary amps	80.2 A
5724	Winding 2 PhA current in primary amps	79.8 A
5725	Winding 2 PhB current in primary amps	79.8 A
5726	Winding 2 PhC current in primary amps	79.8 A
5727	Winding 3 PhA current in primary amps	0.0 A
5728	Winding 3 PhB current in primary amps	0.0 A
5729	Winding 3 PhC current in primary amps	0.0 A
5730	Operat. meas. current IA [Amps] is	
5731	Operat. meas. current IB [Amps] is	

Close Print... Save Help

Figure 18.6 *WinDIGSI Metering Data Screen*

18.8.3 Measured Current Tests – Address Block 4100

All current circuits were checked in the previous tests; however the use may want to perform the measured current test again under normal operating conditions.

Note: The differential protection and restricted ground-fault protection are not effective during the test. Backup protection must be present.

The relay measurement of all currents and phase angles can be read through test Address Block 4100:

See Section 18.1 on page 195 through Section 18.6 on page 205 for detailed information related to the measured current tests that follow.

Differential Current Test

Verify that the measured currents in each phase on each side of the protected object, displayed in Address 4101, are accurate. Note that the current is referred to the rated current of the protected object.

Line Phase Angle Relations

Verify that the angle differences of the three currents of Side 1, 2, and 3 are correct.

Differential and Stabilizing Current Check

Verify that the values in Address 4161 for the line current differential, and the restraining currents are accurate. The differential value should be negligible against the magnitude of the line currents. The stabilizing (restraint) value should be approximately twice the line or test current value. Note that the differential and stabilizing values are referred to the rated current of the protected object.

Stop Test Operation- Address Block 4800

1. Access Address 4800 – COMMISSION TEST STOP
2. Page to **Address 4801 – Test Stop?**
3. Enter the **YES** key

18.8.4 Waveform Capture during Test Fault Record – Address 4900

Recording a test fault record is especially important for use on protected objects where large inrush currents can be produced by transient saturation of the transformer iron. Since a large inrush current may have the same effect as a single ended infeed fault, energizing the protected object several times checks the effectiveness of the inrush stabilization.

Since the pick up signal of the relay is not stabilized, the inrush current will start fault recording automatically, provided that Address 7402 WAVE TRIG is set to **Trig with Pickup**. Otherwise a fault record is only stored if the relay has tripped. A fault record can always be triggered via a discrete input, provided this is allocated. A manual start of the waveform capture record (for analysis of the steady state rms current or test current) can also be performed in Address Block 4900.

The data can then be downloaded to a PC for analysis, and verification that the relay is processing all inputs as required by the application.

The effectiveness of the inrush stabilization can be determined from the recording of the differential currents and the harmonic contents. If necessary, the inrush current stabilization effect can be increased in Address 1611, when trip occurs, or when the recorded data show that the second harmonic content does not safely exceed the set stabilizing threshold set in Address 1611. A further method to increase inrush stability is to set the cross block function (Address 1612) effective or to increase the duration of the cross block function.

The relay can simultaneously capture data for all current inputs and up to four user-defined functions that report the status of discrete-signal inputs. The data must be downloaded to a PC for analysis and storage.

The data storage parameters can be programmed in Address Block 7400. Data storage can also be initiated via a discrete input or by the operator via the front panel of the relay or a PC. The configuration parameters required for this function to operate are as follows:

- Address 7402 – Initiates the waveform capture with pickup or trip.
- Address 7410 – Determines the max. length of time for the waveform capture.
- Address 7411 – Sets the pre-trigger time.
- Address 7412 – Sets amount of captured waveform after trigger.
- Address 7431 – Storage time for triggering via discrete (binary) input
- Address 7432 – Storage time for triggering via the keyboard.

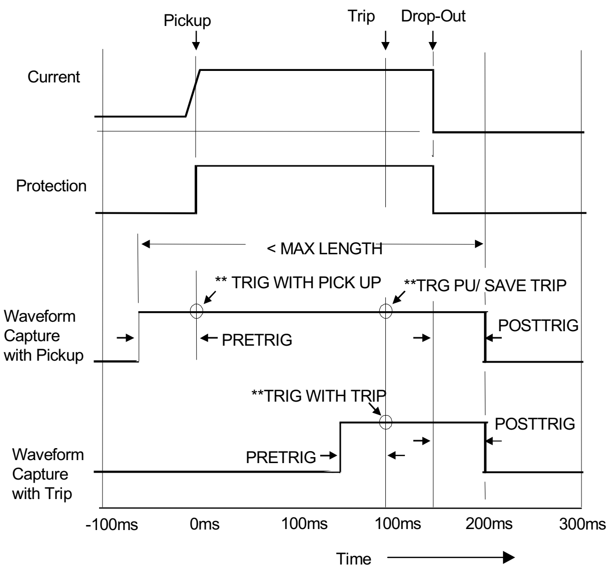
Manual starting of the record can be carried out in Address Block 4900. The message will read: FAULT REC. START? Confirm with YES key. The relay will acknowledge successful completion of the test recording.

To initiate manual starting of a fault via WinDIGSI:

1. Go to the Options Menu.
2. Choose Device.
3. Choose Initiate Fault Record.

To access the waveform data using WinDIGSI and DIGRA, choose the following menu items:

- Fault /
- Fault Record- *Select fault instance/*
- Options /Type of Graph - (Prim., Sec., or Normalized)
- DIGRA/
- Display Analog Curves -From this point, several choices are given to display and analyze the data.



** - Time point where decision to store waveform data is made.
Shown for each of the three trigger options.

Figure 18.7 *Waveform Capture*

18.9 Installation of 7UT51 Relay in Existing Circuit

The installation of the Siemens 7UT51 relay in an energized circuit can be perform without disturbing the existing system.

The following must be completed before the relay can be fully functional in the circuit:

- Settings applied
- Acceptance / Installation Tested (out of circuit)

Once all of the necessary and applicable testing has been performed on the relay, the relay can be prepared for installation and testing.

Ensure that trip circuits are disconnected from the relay trip contacts and are left open-circuited. Do not connect any of the relay outputs to any external breaker failure devices.

If test switches are available, place all related switches in the test position.

Read and record magnitude and phase angle readings in all leads and windings.

Perform Section 18.8 on page 206

Perform a manual Waveform capture through Address Block 4900 and verify the primary and secondary waveforms using WinDIGSI and DIGRA.

Verify all measurable quantities (inputs) through the relay.

Compare the known current values with the displayed test currents. If deviations occur that cannot be explained by tolerances, recheck connections and test arrangement and repeat.

When assessing the currents, note that the differential and stabilizing values are referred to the rated current of the protected object.

18.9.1 Output Connections

With test switches in the test position, proceed with making all trip and signal output connections.

Note: Since the relay is installed in an energized circuit, operational checks of each output cannot be performed; however, all outputs from the relay are checked prior to installation and all control circuitry is checked upon installation or subsequent outages. *A complete functional check for all trip and signal outputs should be performed during the next available outage.*

18.10 Testing for In-Service Setting Changes

Perform only the tests in the procedure that are applicable to the change.

18.11 Putting the Relay into Operation

All setting values should be checked again, in case they were altered during the tests. Particularly check that all desired protection functions have been **Enabled** in the Address Block 7800 and that all desired protection functions have been switched **On** in the corresponding settings menu.

Stored indications on the front plate should be reset by pressing the "**Target Reset**" on the front so that from then on, only real faults are indicated. From that moment, the measured values of the quiescent state are displayed. While pressing the **Reset** button, the LEDs on the front will light up (except the "**Blocked**" LED); thus, an LED test is performed at the same time.

Delete stored annunciations and counters go to Address Block 8200:

1. Enter the password (000000)

    - 8201 Resets LED memory - using WinDIGSI, the LED reset is found under:

      Options \ Device \ Reset LEDS

    - 8202 Deletes the operational buffer storage - using WinDIGSI, deleting the operational buffer is found under:

      Control/ Resetting Stored Data / 8202 - Reset event log / *or* / 8203 – Reset Trip Log

    - 8203 Deletes the fault annunciation buffer storage -using WinDIGSI, deleting the operational buffer is found under:

      Control/ Resetting Stored Data / 8202 - Reset event log / *or* / 8203 – Reset Trip Log

2. Press the **Target Reset** on front panel

3. Push the **Event** key on the front of relay. The display shows the beginning of the annunciation blocks. Thus, it is possible that the measured values for the quiescent state of the relay can be displayed. These values had been chosen during configuration under the Addresses 7105 and 7106.

   All terminal screws, even those not in use, should be tightened.

   Check that all modules are properly inserted. The green LED should be illuminated and the red LED should not be illuminated.

4. Close housing cover.

   Note: Housing cover must be on relay for proper operation.

5. Place test switch in the operating position.

   After all readings are taken and found to be correct, the relays are placed in service.

6. Check that all protection is in service and that all indicating lights, targets, and equipment are reset and normal before leaving.

19 Maintenance and Servicing

The 7UT51 relays has measurement and signal processing circuits that are fully solid state and, therefore, completely maintenance-free. However, there are basic maintenance procedures that can help solve problems if the performance of the relay is suspect. These procedures assume that the relay is operating in its intended environment and has been correctly set and configured.

If the device is equipped with a backup battery for saving of stored events and the internal time clock, the battery should be replaced after at least five years of operation. This recommendation is valid independent on whether the battery has been discharged by occasional supply voltage failures or not.

As the protection is almost completely self-monitored, from the measuring inputs to the trip contact outputs, hardware and software faults are automatically alarmed. This ensures the high availability of the relay and allows a more corrective rather than preventive maintenance strategy. With detected hardware faults the relay blocks itself; drop-off of the availability relay signals “equipment fault”. If there is a fault detected in the external measuring circuits, generally an alarm is given only.

Recognized software faults cause the processor to reset and restart. If such a fault is not eliminated by restarting, further restarts are initiated. If the fault is still present after three restart attempts the protective system will switch itself out of service and indicate this condition by the red LED “**Blocked**” on the front plate. Drop-off of the availability relay signals “equipment fault”.

The reaction to defects and indications given by the relay can be individually and in chronological sequence read off as operational alarms (Address 5100) for defect diagnosis. The relay’s event log and target log data may be useful for maintenance. The event log is under Address Block 5100, and the target logs for the last three faults are under Address blocks 5200, 5300, and 5400, respectively.

If the relay is connected to a local substation automation system (LSA), defect indications will also be transferred via the serial interface to the central control system.

19.1 Troubleshooting Tips

If the relay indicates a defect but none of the programmable LEDs on the operator panel are lit, then perform the following checks:

- Are the modules pushed in and locked properly?
- Is the **On/Off** switch on the operator panel in the “**On**” position?
- Does the input power have correct polarity and voltage?
- Is the input power connected to the proper relay terminals?
- Has the minifuse in the power supply section blown?
- Is the relay correctly set and configured?

If the red Blocked LED is lit and the green Power LED is not lit, the device has recognized an internal fault. To reinitialize the unit, turn the DC auxiliary voltage off then back on using the operator panel **On/Off** switch. When the DC auxiliary voltage is off, the relay will lose any event log data, target log data, and configuration settings that have not been saved.

19.2 Routine Checks

Routine checks of characteristics or pickup values are not necessary as they form part of the continuously supervised firmware programs. The planned maintenance intervals for checking and maintenance of the plant can be used to perform operational testing of the protection equipment. This maintenance serves mainly for checking the interfaces of the unit, that is the coupling with the plant. The following procedure is recommended:

- Readout of operational values (Address Block 5700) and comparison with the actual values for checking the analog interfaces.

Simulation of an internal short-circuit with 4 x IN for checking the analog input at high currents.

If the protective device indicates a defect, the following procedure is suggested:

If none of the LEDs on the front plate of the module is on:

1. Have the modules been properly pushed-in and locked?

2. Is the **On/off** switch on the front plate in the **On** position?

3. Is the auxiliary voltage available with the correct polarity and of adequate magnitude, connected to the correct terminals (*General Diagrams* in Appendix A)?

4. Has the mini-fuse in the power supply section blown? If appropriate, replace the fuse.

If the red fault indicator "**Blocked**" on the front is on and the green ready LED remains dark, the device has recognized an internal fault. Re-initialization of the protection system could be tried by switching the DC auxiliary voltage off and on again. This, however, results in loss of fault data and messages and, if a configuration has not yet been completed, the last settings are not stored.

19.3 When to Return a Relay

If you cannot correct a problem with the relay using the procedures described in this manual, then return the complete relay to the manufacturer in secure, appropriate packaging. If available, use the original packaging to avoid damaging the relay.

Repair of defective modules is not recommended at all because specially selected electronic components are used which must be handled in accordance with the procedures required for *Electrostatically Endangered Components* (EEC). Furthermore, special manufacturing techniques are necessary for any work on the printed circuit boards in order to do not damage the bath-soldered multilayer boards, the sensitive components and the protective finish.

If it is unavoidable to replace individual modules, it is imperative that the standards related to the handling of Electrostatically Endangered Components are observed. Should it become necessary to exchange any device or module, the complete setting assignment should be repeated.

20 Settings Record

This 7UT51 (version 3) settings worksheet enables easy recording of 7UT51 parameter settings when configuring the relay. The settings are listed in numerical sequence based on Address just as they appear on the LCD. Where applicable, value ranges are provided for easy reference. Only configurable settings are listed.

Before configuring the device, copy this form and enter the device identification number as well as the date of configuration. Then simply mark an X beside the desired options and enter numerical values in the blank spaces provided. The factory defaults appear in a column. Where different ranges and defaults apply for the 1 amp and 5 amp nominal relays, the 1 amp values are in parentheses below the 5 amp values.

After entering all data on this configuration form, take it to the device and enter the information into the relay. This form allows for the recording of all four setting groups. Be sure to file a copy of this worksheet for future reference.

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting Group A	Setting Group B	Setting Group C	Setting Group D
1100	**TRANSFORMER DATA** To configure 11xx settings, setting 7801 must first be set to one of the transformer types.						
1102	Vn WIND 1 Rated voltage of transformer Winding 1	0.4 - 800.0 kV	110.0				
1103	VA WIND 1 Rated apparent power (VA) of Winding 1	0.2 - 5000.0 MVA	38.1				
1104	In CT WND1 Rated primary current of Winding 1 CT	1 - 100000 A	200				
1105	CT1 STARPT Star-point formation of Winding 1 CT	Towards Transformer	X				
		Towards line/busbar					
1106	Io1PROCESS Processing of Winding 1 zero sequence current	Io-elimination	X				
		Io-correction					
		WITHOUT					
1107	In CT STP1 Rated prim. current of Winding 1 star-point CT	1 -100000 A	200				
1108	CT1 GND-PT Ground point formation of wind. 1 star-point CT	Towards transformer	X				
		Towards ground					
1121	VECTOR GR2 Vector group associated with winding 2	0 - 11	0				
1122	Vn WIND 2 Rated voltage of transformer winding 2	0.4 - 800.0 kV	11.0				
1123	VA WIND 2 Rated apparent power (VA) of winding 2	0.2 - 5000.0 MVA	38.1				
1124	In CT WND2 Rated primary current of winding 2 CT	1 - 100000 A	2000				
1125	CT2 STARPT Star-point formation of winding 2 CT	Towards transformer	X				
		Towards line/busbar					
1126	Io2PROCESS Processing of winding 2 zero sequence current	Io-elimination	X				
		Io-correction					
		WITHOUT					
1127	In CT STP2 Rated prim. current of winding 2 star-point CT	1 -100000 A	2000				

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting Group A	Setting Group B	Setting Group C	Setting Group D
1128	CT2 GND-PT Ground point formation of wind. 2 star-point CT	Towards transformer	X				
		Towards ground					
1141	VECTOR GR3 Vector group associated with winding 3	0 - 11	0				
1142	Vn WIND 3 Rated voltage of transformer winding 3	0.4 - 800.0 kV	11.0				
1143	VA WIND 3 Rated apparent power (VA) of winding 3	0.2 - 5000.0 MVA	10.0				
1144	In CT WND3 Rated primary current of winding 3 CT	1 - 100000 A	2000				
1145	CT3 STARPT Star-point formation of winding 3 CT	Towards transformer	X				
		Towards line/busbar					
1146	Io3PROCESS Processing of winding 3 zero sequence current	Io-elimination	X				
		Io-correction					
		WITHOUT					
1147	In CT STP3 Rated prim. current of winding 3 star-point CT	1 -100000 A	2000				
1148	CT3 GND-PT Ground point formation of wind. 3 star-point CT	Towards transformer	X				
		Towards ground					
1200	**MOTOR OR GENERATOR DATA** To configure 12xx settings, setting 7801 must first be set to “Motor/Generator.”						
1202	Vn M/G Rated voltage of motor / generator	0.4 - 800.0 kV	21.0				
1203	VA M/G Rated apparent power (VA) of motor / generator	0.2 - 5000.0 MVA	400.0				
1206	CT STARPT Indication of polarity of the CT currents	Same side	X				
		Opposite sides					
1207	In CT 1 Rated primary current of Side 1 CT	1 - 100000 A	11000				
1208	In CT 2 Rated primary current of Side 2 CT	1 - 100000 A	11000				
1300	**BUS DATA** To configure 13xx settings, setting 7801 must first be set to a two-branch or three-branch bus.						
1301	In TIE-PT Nominal rated current of the bus.	1 - 100000 A	2000				
1302	In CT 1 Rated primary current of Side 1 CT	1 - 100000 A	2000				
1303	CT1 STARPT Star-point formation of Side 1 CT	Zero Degrees	X				
		180 Degrees					
1304	In CT 2 Rated primary current of Side 2 CT	1 - 100000 A	2000				
1305	CT2 STARPT Star-point formation of Side 2 CT	Zero Degrees	X				
		180 Degrees					
1306	In CT 3 Rated primary current of Side 3 CT	1 - 100000 A	2000				
1307	CT3 STARPT Star-point formation of Side 3 CT	Zero Degrees	X				
		180 Degrees					

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting Group A	Setting Group B	Setting Group C	Setting Group D
1400	**ADDITIONAL PROTECTED OBJECT DATA**						
1401	In VIRT OB Nominal current of virtual object	1 - 100000 A	2000				
1402	In CT Rated primary current of CT	1 - 100000 A	2000				
1404	In CT STPT Rated primary current of star-point CT	1 - 100000 A	2000				
1405	CT STARPT Ground point of the CT currents	Same side	X				
		Opposite sides					
1600	**TRANSFORMER DIFFERENTIAL PROTECTION SETTINGS** To configure 16xx settings, setting 7816 must first be set to “Existent.”.						
1601	87 STATUS Normal operational status of transformer differential protection function (87 and 87HS).	OFF	X				
		ON					
		Block Tripping					
1603	87 PICKUP 87-Pick-Up value of diff protection	0.15 - 2.00 I/In	0.20				
1604	87HS RMS 87HS-Highset Pick-up RMS value of diff prot.	0.5 - 20.0 I/In	7.5				
1606	87SLOPE 1 87-Slope 1 of operating characteristic	0.10 - 0.50	0.25				
1607	87BASE PT2 87-Base point for slope 2 of operating char.	0.0 - 10.0 I/In	2.5				
1608	87SLOPE 2 87-Slope 2 of operating characteristic	0.25 - 0.95	0.50				
1610	HARMN RSTR 87-State of 2nd harmonic restraint	ON	X				
		OFF					
1611	%2nd HARMN 87-2nd harm content in the different. current	10 - 80 %	15				
1612	X-BLK 2HRM 87-Time for cross-blocking with 2nd harmonic	0 - 1000 cycles or ∞	0				
1613	n. HARMN 87-Choice a further (n-th) harmonic restr	5th harmonic	X				
		4th harmonic					
		3rd harmonic					
		OFF					
1614	%n. HARMN 87- n-th harmonic content in the diff. current	10 - 80 %	80				
1615	X-BLK nHM 87-Activ time for cross-blocking w/ n-th harm	0 - 1000 cycles or ∞	0				
1616	IDIFFmax n 87-Limit IDIFFmax of n-th harmonic restraint	0.5 - 20.0 I/In Trans	1.5				
1617	T-SAT-BLK 87-Max. blocking time at CT saturation	2 - 250 cycles or ∞	8				
1618	SAT-RESTR. 87-Min. restr. current for blocking @CT satur.	5.00 - 15.00 I/In Trans	7.00				
1625	87 DELAY 87-Trip time delay of diff. current stage	0.00 - 60.00 s or ∞	0.00				

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting Group A	Setting Group B	Setting Group C	Setting Group D
1626	87HS DELAY 87-Op time of high-set diff. curr stage	0.00 - 60.00 s or ∞	0.00				
1627	87 RESET 87-Reset dly after diff op has been initiated	0.00 - 60.00 s	0.10				
1700	**87-MOTOR/GENERATOR DIFF PROTECTION DATA** Password level = 2						
1701	87 STATUS 87-State of differential protection	OFF	X				
		ON					
		Block Tripping					
1703	87 PICKUP 87-Pick-up value of diff protection	0.05 - 2.00 I/In M/G	0.10				
1706	87SLOPE 1 87-Slope 1 of operating characteristic	0.10 - 0.50	0.12				
1707	87BASE PT2 87-Base point for slope 2 of oper charact.	0.0 - 10.0 I/In M/G	2.5				
1708	87SLOPE 2 87-Slope 2 of operating characteristic	0.25 - 0.95	0.50				
1717	T-SAT-BLK 87-Max. blocking time at CT saturation	2 - 250 cycles or ∞	8				
1718	SAT-RESTR. 87-Min. restr. current for block at CT satur.	5.00 - 15.00 I/In M/G	7.00				
1725	87 DELAY 87-Oper time delay of differential protection	0.00 - 60.00 s or ∞	0.00				
1727	87 RESET 87-Reset delay after trip has been initiated	0.00 - 60.00 s	0.10				
1800	**87-TIE POINT DIFFERENTIAL PROTECTION DATA** Password level = 2.						
1801	87 STATUS 87-State of differential protection	OFF	X				
		ON					
		Block Tripping					
1803	87 PICKUP 87-Pick-up value of diff protection	0.30 - 2.50 I/In Junct	1.00				
1806	87SLOPE 1 87-Slope 1 of operating characteristic	0.10 - 0.50	0.25				
1807	87BASE PT2 87-Base point for slope 2 of operating char	0.0 - 10.0 I/In Junct	2.5				
1808	87SLOPE 2 87-Slope 2 of operating characteristic	0.25 - 0.95	0.50				
1817	T-SAT-BLK Max. blocking time at CT saturation	2 - 250 cycles or ∞	8				
1818	SAT-RESTR. 87-Min. restr. current for blocking @CT satur.	5.00 - 15.00 I/In Junct	7.00				
1825	87-DELAY 87-Oper time delay of differential protection	0.00 - 60.00 s or ∞	0.00				
1827	87-RESET 87- Reset delay after trip has been initiated	0.00 - 60.00 s	0.10				
1831	87 MON PU 87-Pick-up value of diff. current monitoring	0.15 - 0.80 I/In Junct	0.20				
1832	87 MON DLY 87-Time delay of blocking by monitoring	1 - 10 s or ∞	2				

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting Group A	Setting Group B	Setting Group C	Setting Group D
1900	**RESTRICTED GROUND FAULT PROTECTION DATA** Password level = 2						
1901	RGF STATUS State of restricted ground-fault protection	OFF	X				
		ON					
		Block Tripping					
1903	RGF PU Pick-up value of restricted gnd fault prot	0.05 - 2.00 I/In	0.10				
1904	CRIT.ANGLE Critical angle of RGF charact. oper-curve	90					
		100					
		110	X				
		120					
		130					
1910	HARMN RSTR State of 2nd harmonic restraint	OFF	X				
		ON					
1911	%2nd HARMN 2nd harmonic content in the diff current	10 - 80 %	15				
1912	IRGF max 2 RGF-Upper limit of 2nd harmonic restraint curr	1.0 - 20.0 I/In	10.0				
1925	Tdly-RGF Oper time dly of restricted ground-fault prot	0.00 - 60.00 s or ∞	0.00				
1927	Trst-RGF Reset delay after RGF trip has been initiated	0.00 - 60.00 s	0.10				
2100	**OVERCURRENT PROTECTION (DTL/IDMTL)** Password level = 2 In = 1A or 5A						
2101	BACKUP O/C State of backup overcurrent protection	OFF	X				
		ON					
		Block Tripping					
2103	50HS PU 50HS-Phase highset (Def. Time) O/C pickup	0.10 - 30.00 I/In	4.00				
2104	50HS DELAY 50HS-Delay time for 50HS (Def. Time) funct	0.00 - 32.00 s or ∞	0.10				
2111	PH CHARACT PH O/C time characteristic	Definite Time	X				
		Moderately Inverse					
		Very Inverse					
		Extremely Inverse					
2112	50T PU 50T - Phase (Def. Time) overcurrent pickup	0.10 - 30.00 I/In	2.00				
2113	50T DELAY 50T - Delay time for 50T (Def Time) funct	0.00 - 32.00 s or ∞	0.30				
2114	51 PU 51 - Phase (Inv. Time) overcurrent pickup	0.10 - 20.00 I/In	2.00				
2115	51 T-DIAL 51 - Phase inverse overcurrent time dial	0.50 - 32.00 s or ∞	0.50				
2116	MEAS.FORM. Phase current measurement format	Without harmonics	X				
		With harmonics					
2118	TresetTRIP Reset delay after trip has been initiated	0.00 - 60.00 s	0.10				

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting Group A	Setting Group B	Setting Group C	Setting Group D
2121	M/C MODE P Phase overcurrent stage effective: Manual close	Inactive	X				
		50HS IOC w/o Delay					
		50 Inverse w/o Delay					
2400	**49-THERMAL OVERLOAD PROTECTION LEVEL 1** Password level = 2						
2401	49 Therml1 49-State of thermal O/L protection 1	OFF	X				
		ON					
		Block Tripping					
		Alarm Only					
2402	49 K-Fctr1 9- K-factor for thermal O/L protection 1	0.10 - 4.00	1.10				
2403	49 Tconst1 49-Time constant for thermal O/L prot 1	1.0 - 999.9 min	100.0				
2404	49 θ ALRM1 49-Thermal alarm stage 1	50 - 100 %	90				
2405	I ALRM 1 Current alarm stage 1	0.10 - 4.00 I/In	1.00				
2406	TEMP METH1 49-Calculation method for thermal stage 1	Theta MAX	X				
		Average \T					
		\T @ Imax					
2500	**49-THERMAL OVERLOAD PROTECTION LEVEL 2** Password level = 2						
2501	49 Therml2 49-State of thermal O/L protection 2	OFF	X				
		ON					
		Block Tripping					
		Alarm Only					
2502	49 K-Fctr2 9- K-factor for thermal O/L protection 2	0.10 - 4.00	1.10				
2503	49 Tconst2 49-Time constant for thermal O/L prot 2	1.0 - 999.9 min	100.0				
2504	49 θ ALRM2 49-Thermal alarm stage 2	50 - 100 %	90				
2505	I ALRM 2 Current alarm stage 2	0.10 - 4.00 I/In	1.00				
2506	TEMP METH2 49-Calculation method for thermal stage 2	Theta MAX	X				
		Average \T					
		\T @ Imax					
2700	**TRANSFORMER TANK PROTECTION** Password level = 2						
2701	TANK PROT State of transformer tank protection	OFF	X				
		ON					
		Block Tripping					
2703	TANK PU Pick-up value of transformer tank current (for Insensitive CT A)	0.10 - 10.00 I/In	0.50				
2704	TANK PU Pick-up value of transformer tank current (for Sensitive CT B)	10 - 1000 mA	500				
2705	MEAS.REPET Measurement repetition	Without Harmonics	X				
		With Harmonics					
2709	TANK PU/DO Drop-out to pickup ratio for tank current	0.25 - 0.95	0.50				

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting Group A	Setting Group B	Setting Group C	Setting Group D
2725	Tdly-TANK Operating time delay of tank protection	0.00 - 60.00 s or ∞	0.00				
2727	Trst-TANK Reset delay after trip has been initiated	0.00 - 60.00 s	0.10				
2900	**MEASURED VALUE SUPERVISION** Password level = 2						
2903	SYM.Ithres 60-Symmetry threshold for current monitoring [Unit /I/In or A???]	0.10 - 1.00 I/In	0.50				
2904	SYM.Fact.I 60-Symmetry factor for current monitoring	0.00 - 0.95	0.50				
3000	**INCLUSION OF AN EXTERNAL TRIP FUNCTION 1** Password level = 2						
3001	EXT.TRIP 1 State of external trip function 1	OFF	X				
		ON					
		Block Tripping					
3002	Tdly-EXT1 Time delay of external trip function 1	0.00 - 60.00 s or ∞	0.00				
3003	Trst-EXT1 Reset delay after trip 1 has been initiated	0.00 - 60.00 s	0.10				
3100	**EXTERNAL TRIP FUNCTION 2** Password level = 2						
3101	EXT.TRIP 2 State of external trip function 2	OFF	X				
		ON					
		Block Tripping					
3102	Tdly-EXT2 Time delay of external trip function 2	0.00 - 60.00 s or ∞	0.00				
3103	Trst-EXT2 Reset delay after trip 2 has been initiated	0.00 - 60.00 s	0.10				

Addr	LCD Line 1	Index	Setting	Index	Setting
6100	**DISCRETE INPUTS** Password level = 3				
6101	DISCRETE INPUT 1	001	0005 Reset LEDs HI	006	
		002		007	
		003		008	
		004		009	
		005		010	
6102	DISCRETE INPUT 2	001	2306 >Block 50HS stage of backup O/C HI	006	
		002		007	
		003		008	
		004		009	
		005		010	
6103	DISCRETE INPUT 3	001	0011 >User defined event 1 HI	006	
		002		007	
		003		008	
		004		009	
		005		010	

Addr	LCD Line 1	Index	Setting	Index	Setting
6104	DISCRETE INPUT 4	001	0391 >Warning stage from Buchholz prot. HI	006	
		002		007	
		003		008	
		004		009	
		005		010	
6105	DISCRETE INPUT 5	001	0392 >Tripping stage from Buchholz prot. HI	006	
		002		007	
		003		008	
		004		009	
		005		010	
6200	**SIGNAL RELAYS** Password level = 3 Up to 20 functions per signal relay.				
6201	SIGNAL RELAY 1	001	0511 General trip of the relay	006	
		002		007	
		003		008	
		004		009	
		005		010	
6202	SIGNAL RELAY 2	001	5671 87-Diff protection: General trip	006	
		002		007	
		003		008	
		004		009	
		005		010	
6203	SIGNAL RELAY 3	001	2451 BU Overcurrent+G/F : General Trip	006	
		002		007	
		003		008	
		004		009	
		005		010	
6204	SIGNAL RELAY 4	001	0141 Failure of internal 24VDC power supply	006	0152 Failure in I/O module 2
		002	0143 Failure of internal 15VDC power supply	007	
		003	0144 Failure of internal 50VDC power supply	008	
		004	0145 Offset failure (A/D converter)	009	
		005	0151 Failure in I/O module 1	010	
6205	SIGNAL RELAY 5	001	0051 Relay OK	006	
		002		007	
		003		008	
		004		009	
		005		010	
6206	SIGNAL RELAY 6	001	1571 49-TRIP by thermal O/L protection 1	006	
		002	1621 49-TRIP by thermal O/L protection 2	007	
		003		008	
		004		009	
		005		010	
6207	SIGNAL RELAY 7	001	1566 49-Thermal O/L prot.1: Thermal warning	006	
		002	1616 49-Thermal O/L prot.2: Thermal waning	007	
		003		008	
		004		009	
		005		010	

Addr	LCD Line 1	Index	Setting	Index	Setting
6208	SIGNAL RELAY 8	001	5821 Restricted ground-fault: General TRIP	006	
		002		007	
		003		008	
		004		009	
		005		010	
6209	SIGNAL RELAY 9	001	5921 Transformer tank prot.: General TRIP	006	
		002		007	
		003		008	
		004		009	
		005		010	
6210	SIGNAL RELAY 10	001	0391 Warning stage from Buchholz protection	006	
		002		007	
		003		008	
		004		009	
		005		010	
6211	SIGNAL RELAY 11	001	0392 Tripping stage from Buchholz protection	006	
		002		007	
		003		008	
		004		009	
		005		010	
6300	**LEDs** Password level = 3 Up to 20 functions to each LED.				
6301	LED 1	001	0511 General trip of the relay m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6302	LED 2	001	5691 87-Diff protection: Trip m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6303	LED 3	001	5692 87HS-Diff protection: Trip m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6304	LED 4	001	2451 BU Overcurrent+G/F : General Trip m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6305	LED 5	001	0141 Failure of internal 24VDC power supply nm	006	0153 Failure in I/O module 2 nm
		002	0143 Failure of internal 15VDC power supply nm	007	
		003	0144 Failure of internal 50VDC power supply nm	008	
		004	0145 Offset failure (A/D converter) nm	009	
		005	0151 Failure in I/O module 1 nm	010	

Addr	LCD Line 1	Index	Setting	Index	Setting
6306	LED 6	001	0095 Setting change in progress nm	006	
		002		007	
		003		008	
		004		009	
		005		010	
6307	LED 7	001	5821 Restricted ground-fault: General TRIP m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6308	LED 8	001	5921 Transformer tank prot.: General TRIP m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6309	LED 9	001	1571 49-TRIP by thermal O/L protection 1 m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6310	LED 10	001	1621 49-TRIP by thermal O/L protection 2 m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6311	LED 11	001	0391 >Warning stage from Buchholz prot. m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6312	LED 12	001	0392 >Tripping stage from Buchholz prot. m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6313	LED 13	001	0011 >User defined event 1 m	006	
		002		007	
		003		008	
		004		009	
		005		010	
6314	LED 14	001	5711 Diff prot error:2 Star-point CT for Wnd1 nm	007	5829 Restrictd gnd flt error: 2 star-point CT nm
		002	5712 Diff prot error:No star-point CT connctd nm	008	5830 Restrictd gnd flt error:No star-point CT nm
		003	1576 49-Thermal O/L prot.1 error: No Side 3 nm	009	5831 RGF Error: Use only virtual obj nm
		004	1626 49-Thermal O/L prot.2 error: No Side 3 nm	010	5834 Restricted gnd fault error: Non-exist nm
		005	2457 Back-up O/C error: Winding 3 no exist nm	011	5928 Transformer tank prot. error: Non exist nm
		006	5828 Restrictd gnd fault error: No Side 3 nm	012	

Addr	LCD Line 1	Index	Setting	Index	Setting
6400	**TRIP RELAYS** Password level = 3				
6401	TRIP RELAY 1	001	5691 87-Diff protection: Trip	006	1571 49-TRIP by thermal O/L protection 1
		002	5692 87HS-Diff protection: Trip	007	1621 49-TRIP by thermal O/L protection 2
		003	2451 BU Overcurrent+G/F: General Trip	008	
		004	5821 Restrictd ground-fault: General TRIP	009	
		005	5921 Transformer tank prot.: General TRIP	010	
6402	TRIP RELAY 2	001	5691 87-Diff protection: Trip	006	1571 49-TRIP by thermal O/L protection 1
		002	5692 87HS-Diff protection: Trip	007	1621 49-TRIP by thermal O/L protection 2
		003	2451 BU Overcurrent+G/F: General Trip	008	
		004	5821 Restrictd ground-fault: General TRIP	009	
		005	5921 Transformer tank prot.: General TRIP	010	
6403	TRIP RELAY 3	001	5691 87-Diff protection: Trip	006	1571 49-TRIP by thermal O/L protection 1
		002	5692 87HS-Diff protection: Trip	007	1621 49-TRIP by thermal O/L protection 2
		003	2451 BU Overcurrent+G/F: General Trip	008	
		004	5821 Restrictd ground-fault: General TRIP	009	
		005	5921 Transformer tank prot.: General TRIP	010	
6404	TRIP RELAY 4	001	5691 87-Diff protection: Trip	006	1571 49-TRIP by thermal O/L protection 1
		002	5692 87HS-Diff protection: Trip	007	1621 49-TRIP by thermal O/L protection 2
		003	2451 BU Overcurrent+G/F: General Trip	008	
		004	5821 Restrictd ground-fault: General TRIP	009	
		005	5921 Transformer tank prot.: General TRIP	010	
6405	TRIP RELAY 5	001	5691 87-Diff protection: Trip	006	1571 49-TRIP by thermal O/L protection 1
		002	5692 87HS-Diff protection: Trip	007	1621 49-TRIP by thermal O/L protection 2
		003	2451 BU Overcurrent+G/F: General Trip	008	
		004	5821 Restrictd ground-fault: General TRIP	009	
		005	5921 Transformer tank prot.: General TRIP	010	

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting
7100	**LOCAL USER INTERFACE** Password level = 3, except password level = 4 to set addresses 7151 to 7154			
7101	LANGUAGE Language	German	X	
		English		
		US-English		
7102	DATE FORMAT Date format	DD.MM.YY (Europe)	X	
		MM/DD/YY (US)		
7105	LINE 1 NORMAL Top line of display under normal conditions	See **Table 13.1**	0741	
7106	LINE 2 NORMAL Bottom line of display under normal conditions	See **Table 13.1**	0744	
7107	LINE 1 FAULT Top line of display after a fault	See **Table 13.1**	0543	
7108	LINE 2 FAULT Bottom line of display after a fault	See **Table 13.1**	0544	
7110	NEW TARGETS Update LEDs/display (with pickup or with trip)	WITH PICKUP	X	
		WITH TRIP		
7200	**CONFIGURATION OF COMM PORTS** Password level = 3			
7201	DEVICE ADD Device address	1 - 254	1	
7202	FEEDER ADD Feeder address	1 -254	1	
7203	STATION ADD Substation address	1 - 254	1	
7208	FUNCT. TYPE Function type (for the VDEW-protocol)	1 - 254	160	
7209	DEVICE TYPE Device Type	1-254	35	Do Not Change
7211	FRONT PORT Front port	WinDIGSI V3	X	
		ASCII		
7215	FRONT BAUD Baud rate for the front port	9600 BAUD	X	
		19200 BAUD		
		1200 BAUD		
		2400 BAUD		
		4800 BAUD		
7216	FRT. PARITY Parity and stop-bits for the front port	WinDIGSI V3	X	
		NO PARITY,2 STOP		
		NO PARITY,1 STOP		
7221	REAR PORT Data format (protocol) for rear port	VDEW COMPATIBLE	X	
		VDEW EXTENSION		
		WinDIGSI V3		
		LSA		
7222	REAR FORMAT Measured value format for the rear port	VDEW COMPATIBLE	X	
		VDEW EXTENSION		
7225	REAR BAUD Baud rate of the rear port	9600 BAUD	X	
		19200 BAUD		
		1200 BAUD		
		2400 BAUD		
		4800 BAUD		

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting
7226	REAR PARITY Parity and stop-bits for the rear port	VDEW/WinDIGSI/LSA	X	
		NO PARITY,2 STOP		
		NO PARITY,1 STOP		
7235	PROGviaREAR Programming via the rear port	NO	X	
		YES		
7400	**WAVEFORM CAPTURE** Password level = 3			
7402	WAVE TRIG. Trigger for waveform capture	TRIG WITH PICKUP	X	
		TRG PU/SAVE TRIP		
		TRIG WITH TRIP		
7410	MAX LENGTH Max length of a waveform capture record	0.30 - 5.00 s	1.00 s	
7411	PRETRIG. Amount of captured waveform prior to trigger	0.05 - 0.50 s	0.10 s	
7412	POSTTRIG. Amount of captured waveform after trigger	0.05 - 0.50 s	0.10 s	
7431	DI CaptTime Discrete input initiated waveform capture time	0.10 - 5.00 s or ∞	0.50 s	
7432	KeyCaptTime Keyboard initiated waveform capture duration	0.10 - 5.00 s	0.50 s	
7490	LSA LENGTH Length of fault log (for previous LSA)	Fixed 660 Samples	X	
		Varbl Wave<=3k samp.		
7800	**DEVICE OPTIONS** Password level = 3			
7801	PROT. OBJ. Selection of the protected object	2-winding trans	X	
		3-winding trans		
		Motor/Generator		
		Two line tie point		
		three line tie point		
		1ph-transformer		
7806	STAR-POINT A Selection of transformer A star point	No assignment	X	
		Side 1		
		Side 2		
		Side 3/Virt. obj.		
7807	STAR-POINT B Selection of transformer B star point	No assignment	X	
		Side 1		
		Side 2		
		Side 3/Virt. obj.		
7816	87 STATUS 87-State of the differential protection	EXISTENT	X	
		NONEXISTENT		
7819	RGF PROT. Restricted ground-fault protection	NONEXISTENT	X	
		Winding 1		
		Winding 2		
		Winding 3		
		Virtual object		
7821	BACK-UP O/C Backup overcurrent protection	NONEXISTENT	X	
		Reference Side 1		
		Reference Side 2		
		Reference Side 3		
		Virtual object		
7824	49 Therml1 49-Thermal overload protection 1	NONEXISTENT	X	
		Reference Side 1		
		Reference Side 2		
		Reference Side 3		
		Virtual object		

Addr	LCD Line 1 WinDIGSI Description	Options or Range and Unit	Default	Setting
7825	49 Therml2 49-Thermal overload protection 2	NONEXISTENT	X	
		Reference Side 1Side 2		
		Reference Side 2		
		Reference Side 3		
		Virtual object		
7827	TANK PROT. Transformer tank protection	NONEXISTENT	X	
		EXISTENT		
7830	EXT. TRIP 1 State of external trip function 1	NONEXISTENT	X	
		EXISTENT		
7831	EXT. TRIP 2 State of external trip function 2	NONEXISTENT	X	
		EXISTENT		
7885	SEL.SET.GRP Select settings group	NONEXISTENT	X	
		EXISTENT		
7899	FREQUENCY Rated Frequency	FREQ 50 Hz	X	
		FREQ 60 Hz		
		FREQ 16 2/3 Hz		
8300	**REAR FORMAT** Password level = 1			
8301	TESTviaREAR Testing via the rear port	OFF	X	
		ON		
8500	**SETTING GROUP OPTIONS** Password level = 3			
8503	SELECT Select settings group	SET A	X	
		SET B		
		SET C		
		SET D		
		SEL. VIA DI		
		SET BY LSA CNTRL		

A Address Reference

SIEMENS

Siemens Power Transmission & Distribution
Distribution Automation Division
PO Box 29503
Raleigh, NC 27626-0503
www.siemenstd.com

Manual No. PRIM-2330C
Printed in USA 0699 1K-HP