7PG2113/4/5/6

Feeder Protection

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Section 1: Common Functions

1.1 General

1.1.1 CE Conformity

CE This product is CE compliant to relevant EU directives.

1.1.2 Reference

This product complies with IEC 60255-3, IEC 60255-6, IEC60255-11, IEC 60255-12 and IEC61000-4-8.

1.1.2.1 Accuracy Reference Conditions

This product has been tested under the following conditions, unless specifically stated otherwise.

Parameter	Value
Auxiliary supply	nominal
Frequency	nominal
Ambient temperature	20 °C

1.1.3 Dimensions

Parameter		Value
Width	E10 case	260 mm
Height		177 mm
Depth behind panel (including clearance for wiring and fibre)		241.5 mm
Projection (from front of panel)		31 mm

See appropriate case outline and panel drilling drawing, as specified in Diagrams and Parameters of the Installation section, for complete dimensional specifications.

1.1.4 Weights

Parameter		Value
Net weight	7PG21113/4/5/6 E10 case	8.6kg

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1.2 Energising Quantities

1.2.1 Auxiliary Power Supply

IEC60255-11 & EATS 48-4

Nominal Operating Range		Absolute Range*	Comments
V_{aux}	24 to 60 VDC	18 to 72 VDC	Low voltage PSU suitable for 24VDC, 30VDC,48VDC and 60VDC systems
	80 to 250 VDC	64 to 300 VDC	High Voltage PSU suitable for 110VDC and 220VDC systems.

***No relay operation outside of this range is permissible or implied.**

1.2.1.1 Burden

Attribute		Value
24V DC	Minimum	3.9 W
	User Access (back light)	5.3 W
	Maximum	8.0W
60V DC	Minimum	3.9W
	User Access (back light)	5.2 W
	Maximum	7.3W
80V DC	Minimum	4.0W
	User Access (back light)	5.5W
	Maximum	6.5W
250V DC	Minimum	4.2W
	User Access (back light)	5.4W
	Maximum	7.5W

1.2.1.2 Operational Features

Attribute	Value	Comments
0% Dip Withstand Period	50ms	
Dip Immunity Acquisition Period	5minutes	Typical time after switch on to attain claimed immunity to dips

NOTE: Dips in supply that fall below the minimum voltage for a period greater than the 0% Dip With stand Period will invoke a relay reset.

During conditions of auxiliary input voltage variations which are not described (1) in section 1.4.3.1, the relay may enter a safety protection mode where a power supply shutdown occurs. This condition is designed to protect the power supply from damage as well as prevent internal relay faults from developing into dangerous situations.
Once the relay has entered this safety mode, it may be necessary to reduce the auxiliary input voltage to zero volts for up to 30 seconds before re-application of the auxiliary supply will cause the relay to power up and operate normally.

(1) Using fuses as on/off switches or allowing batteries to run at very low cell voltages for extended periods and then attempting to re-charge them are examples of such auxiliary supply conditions.

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1.2.2 AC Current

Nominal		**Measuring Range**
In	1 A or 5 A Phase, Earth models	80 x *In*
fn	50, 60Hz	47 to 52Hz, 57 to 62Hz

Note. 1A and 5A nominal rating must be specified at the point of ordering.

1.2.2.1 Burden

Attribute	**Value -**	
	R Mode	**Rf Mode**
AC Burden	1.2 VA	3 VA

1.2.2.2 Thermal Withstand

EATS48-5

Overload Period	**Overload Current**	
	Phase, Earth and SEF	
	1A	**5A**
Continuous	2.0 *xIn*	
10 minutes	3.5 *xIn*	
5 minutes	4.0 *xIn*	
3 minutes	5.0 *xIn*	
2 minutes	6.0 *xIn*	
3 seconds	57.7A	202A
2 seconds	70.7A	247A
1 second	100A	350A
1 cycle	700A	2500A

1.2.3 AC Voltage

Nominal		**Operating Range**
Vn	63.5V, 110 V	270 V
fn	50, 60Hz	47 to 52Hz, 57 to 62Hz

1.2.3.1 Burden

Attribute	**Value**
AC Burden	≤ 0.02 VA at 63.5 V , ≤ 0.06 VA at 110 V

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1.2.4 Binary (Digital) Outputs

Contact rating to IEC 60255-0-2

Attribute		**Value**
Carry continuously		5A AC or DC
Make and carry (L/R ≤ 40 ms and V ≤ 300 V)	for 0.5 s	20A AC or DC
	for 0.2 s	30A AC or DC
Break (≤ 5 A and ≤ 300 V)	AC resistive	1250 VA
	AC inductive	250 VA at p.f. ≤ 0.4
	DC resistive	75 W
	DC inductive	30 W at L/R ≤ 40ms 50 W at L/R ≤ 10ms
Contact Operate / Release Time		7ms / 3ms
Minimum number of operations		1000 at maximum load
Minimum recommended load		0.5 W at minimum of 10mA or 5V

1.2.5 Solkor Contactor NO Contacts

Contact Rating	Make and carry for 0.2s a burden of 6600VA with a maximum of 30A

1.2.6 Binary (Digital) Inputs

EATS48-4

Nominal		**Operating Range**
V_{BI}	19 VDC	17 to 320 VDC
	88 VDC	74 to 320 VDC

1.2.6.1 Performance

Attribute		**Value**
Maximum DC current for operation	V_{BI} = 19 V	1.5mA
	V_{BI} = 88 V	1.5mA
Reset/Operate voltage ratio		≥ 90 %
Response time		< 9ms
Response time when programmed to energise an output relay contact (i.e. includes output relay operation)		< 20ms

The binary inputs have a low minimum operate current and may be set for high speed operation. Where a binary input is both used to influence a control function (e.g. provide a tripping function) and it is considered to be susceptible to mal-operation due to capacitive currents, the external circuitry can be modified to provide immunity to such disturbances.

To comply with EATS 48-4, classes ESI 1 and ESI 2, external components / BI pick-up delays are required as shown in fig. 1-1.

To achieve immunity from AC interference, a BI pick-up delay of typically one-cycle can be applied.

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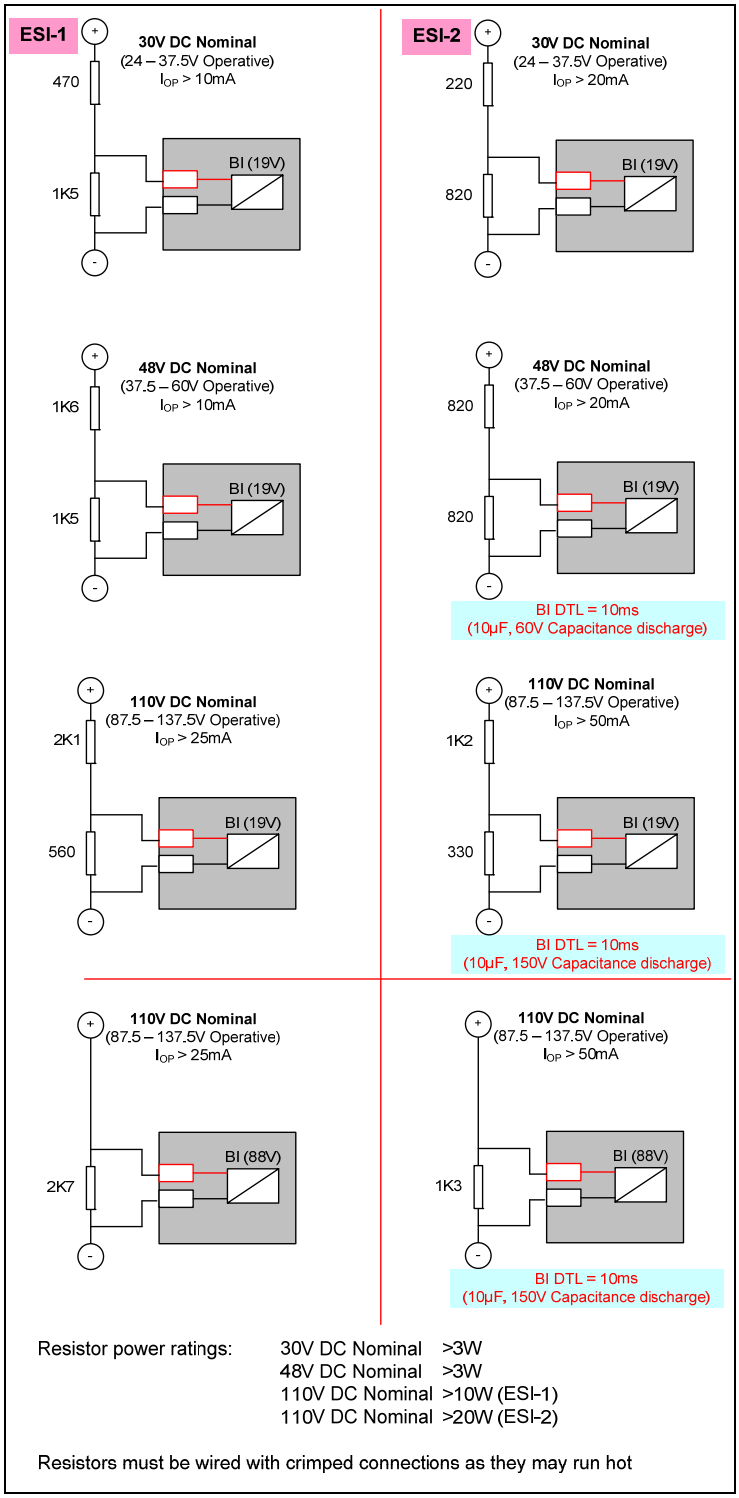

Figure 1.2-1 Binary Input Configurations Providing Compliance with EATS 48-4 Classes ESI 1 and ESI 2

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1.3 Functional performance

1.3.1 Instrumentation

	Instrument Value	Reference	Typical accuracy
I	Current	I ≥ 0.1 xIn	± 1 % In or ± 5 mA
V	Voltage	V ≥ 0.8 xVn	± 1 % Vn
W,Var, VA	Power, real and apparent	V = Vn, I ≥ 0.1 xIn, pf ≥ 0.8	± 3% Pn, where Pn = Vn x In
pf	Power factor	V = Vn, I ≥ 0.1 xIn, pf ≥ 0.8	± 0.05

1.3.2 USB 2.0 Data Communication Interface

Attribute	Value
Physical layer	Electrical
Connectors	USB-Type B

1.3.3 RS485 Data Communication Interface

Attribute	Value
Physical layer	Electrical
Connectors	4mm Ring Crimp

1.3.4 Real Time Clock

1.3.4.1 Internal Clock

The specification below applies only while no external synchronisation signal (e.g. 60870-5-103) is being received.

Attribute	Value
Accuracy (-10 to +55^{o}C)	± 3.5 p.p.m

1.4 Current Differential Application Limits

1.4.1 Pilot Cable connection

Number of Pilot cores required 2

Pilot Requirements

	R Mode	Rf Mode	Rf mode with 15kv Transf.		
			Tap 1	Tap 0.5	Tap 0.25
Max. Loop Resistance	1000 Ω	2000 Ω	1780 Ω	880 Ω	440 Ω
Max. Inter core Capacitance	2.5µF	0.8 µF	1 µF	2 µF	4 µF

Pilot Current and Voltage

	R Mode	Rf Mode	Rf mode with 15kv Transf.		
			Tap 1	Tap 0.5	Tap 0.25
Peak Voltage applied to pilots under fault conditions	300v	450v	450v	330v	225v
Maximum current carried by pilots under fault conditions	200mA	250mA	250mA	380mA	500mA

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1.4.2 Line Charging Current

Maximum Primary Line Capacitive Charging Current:
Solidly Earthed System, 1/3 times the most sensitive earth fault setting
Resistance Earthed System, 1/9 times the most sensitive earth fault setting

1.5 Environmental Performance

1.5.1 General

1.5.1.1 Temperature

IEC 60068-2-1/2

Type	**Level**
Operating range	-10 °C to +55 °C
Storage range	-25 °C to +70 °C

1.5.1.2 Humidity

IEC 60068-2-78

Type	**Level**
Operational test	56 days at 40 °C and 93 % relative humidity

1.5.1.3 Transient Overvoltage

IEC 60255-5

Type	**Level**
Between all terminals and earth, or between any two independent circuits	5.0 kV, 1.2/50 μs 0.5j

1.5.1.4 Insulation

IEC 60255-5

Type	**Level**
Between any terminal and earth	2.5 kV AC RMS for 1 min
Between independent circuits	
Across normally open contacts	1.0 kV AC RMS for 1 min
Between pilot circuit and all other independent circuits and earth	5.0 kV AC RMS for 1 min

1.5.1.5 IP Ratings

IEC60529

Type	**Level**
Installed with cover on	IP 5X, Category 2- Dust-protected
Installed with cover off	IP 4X, 1mm probe

Solkor R/Rf

Type	**Level**
Installed with cover on	IP 51
Installed with cover removed	IP 30

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1.5.2 Emissions

IEC 60255-25

1.5.2.1 Radiated Emissions: Enclosure

Type	**Limits at 10 m, Quasi-peak**
30 to 230 MHz	40 dB(μV/m)
230 to 1000 MHz	47 dB(μV/m)

1.5.2.2 Radiated Emissions: Conducted

Type	**Limits**	
	Quasi-peak	**Average**
0.15 to 0.5 MHz	79 dB(μV)	66 dB(μV)
0.5 to 30 MHz	73 dB(μV)	60 dB(μV)

1.5.3 Immunity

1.5.3.1 Auxiliary DC Supply Variation

IEC 60255-11

Type of Phenomena	Test Specifications	Duration	Declared Operation
Voltage Dips	0% RV	50ms (Claimed)	Normal Operation[1]
	40% RV	200ms	Normal operation[1] except where Dip falls below the relay minimum voltage then Relay Restart[2]
	70% RV	500ms	Normal operation[1] except where Dip falls below the relay minimum voltage then Relay Restart[2]
Voltage Interruptions	0% RV	5s	Relay Reset[2]
Alternating Component In DC (Ripple)	15% max and min RV	Continuous	Normal operation[1]
Gradual Shut-down/ Start-up	Max & min RV to 0V	60s	Relay Reset
	0V	5minutes	Relay Off
	0V to min & max RV	60s	Relay Restart[2]
Reversal of DC Power Supply polarity	Max reversed RV	1minute	Relay remains off After correcting polarity, Relay Restart[2]

Key:

RV = Residual Voltage Test Value. Two conditions: (a) range voltage low-20% and

(b) range voltage high +20%

[1] No effect on relay performance

[2] Restart with no mal-operation, loss of data or relay damage

1.5.3.2 High Frequency Disturbance

IEC 60255-22-1

Type	**Level**
Common (longitudinal) mode	2.5 kV
Series (transverse) mode	1.0 kV

1.5.3.3 Electrostatic Discharge

IEC 60255-22-2 Class 4

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Type	Level	Variation
Contact discharge	8.0 kV	≤ 5 %

1.5.3.4 Radiated Immunity

IEC 60255-22-3

Type		Level
80 MHz to 1000 MHz	Sweep	10 V/m
1.4GHz to 2.7GHz	Sweep	10V/m
80,160,380,450,900,1850,2150 MHz	Spot	10V/m

1.5.3.5 Fast Transients

IEC 60255-22-4 (2002) Class A

Type	Level
5/50 ns 2.5 kHz repetitive	4kV

1.5.3.6 Surge Immunity

IEC 60255-22-5

Type	Level
Between all terminals and earth	0.5, 1.0, 2.0, 4.0 kV
Between Line to Line	0.5, 1.0, 2.0 kV

1.5.3.7 Conducted Radio Frequency Interference

IEC 60255-22-6

Type	Level
0.15 to 80 MHz	10 V

1.5.3.8 Magnetic Field with Power Frequency

IEC 6100-4-8 Level 5

100A/m, (0.126mT) continuous	50Hz
1000A/m, (1.26mT) for 3s	

1.5.4 Mechanical

1.5.4.1 Vibration (Sinusoidal)

IEC 60255-21-1 Class I

Type	Level	Variation
Vibration response	0.5 gn	≤ 5 %
Vibration endurance	1.0 gn	

1.5.4.2 Shock and Bump

IEC 60255-21-2 Class I

Type	Level	Variation
Shock response	5 gn, 11 ms	≤ 5 %
Shock withstand	15 gn, 11 ms	
Bump test	10 gn, 16 ms	

1.5.4.3 Seismic

IEC 60255-21-3 Class I

Type	Level	Variation
Seismic response	X-plane - 3.5mm displacement below crossover freq (8-9Hz) 1.0gn above	≤ 5 %

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Type	Level	Variation
	Y-plane - 1.5mm displacement below crossover freq (8-9Hz) 0.5gn above	

1.5.4.4 Mechanical Classification

Type	Level
Durability	> 10^6 operations

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Section 2: Protection Functions

2.1 27/59 Under/over voltage

2.1.1 Reference

	Parameter	Value
V_s	Setting	5, 5.5…200V
hyst	Hysteresis setting	0, 0.1… 80.0%
t_d	Delay setting	0.00, 0.01…20.00, 20.50… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.1.2 Operate and Reset Level

	Attribute		Value
V_{op}	Operate level		100 % *Vs*, ± 1 % or ±0.25V
	Reset level	Overvoltage	= (100 % - *hyst*) x $V_{op,}$ ± 1 % ± 0.25V
		Undervoltage	= (100 % + *hyst*) x V_{op} ± 1 % ± 0.25V
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.1.3 Operate and Reset Time

	Attribute		Value
t_{basicE}	Element basic operate time	Overvoltage	0 to 1.1 x *Vs*: 73 ms ± 10ms
			0 to 2.0 x*Vs*: 63 ms ± 10ms
		Undervoltage	1.1 to 0.5 x*Vs*: 58 ms ± 10ms
t_{op}	Operate time following delay		t_{basic} + t_d, ± 1 % or ± 10ms
	Repeatability		± 1 % or ± 10ms
	Disengaging time		< 80 ms

2.2 37 Undercurrent

2.2.1 Reference

	Parameter	Value
Is	Setting	0.05, 0.10…5.0 *xIn*
t_d	Delay setting	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.2.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		100 % *Is*, ± 5 % or ± 1% *In*
	Reset level		≤ 105 % I_{op}
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

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2.2.3 Operate and Reset Time

	Attribute	Value
t_{basic}	Element basic operate time	1.1 to 0.5 x*Is*: 35 ms, ± 10ms
t_{op}	Operate time following delay	t_{basic} + t_d, ± 1 % or ± 10ms
	Repeatability	± 1 % or ± 10ms
	Overshoot time	< 40 ms
	Disengaging time	< 60 ms

2.3 46NPS Negative Phase Sequence Overcurrent

2.3.1 Reference (46DT)

	Parameter	Value
I_s	Setting	0.05, 0.06... 4.0x*In*
t_d	Delay setting	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.3.2 Operate and Reset Level (46DT)

	Attribute		Value
I_{op}	Operate level		100 % *Is*, ± 5 % or ± 1% *In*
	Reset level		≥ 95 % I_{op}
	Repeatability		± 1 %
	Transient overreach (X/R ≤ 100)		≤ -5 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.3.3 Operate and Reset Time (46DT)

	Attribute	Value
t_{basic}	Element basic operate time	0 to 2 x*Is*: 40 ms, ± 10ms
		0 to 5 x*Is*: 30 ms, ± 10ms
t_{op}	Operate time following delay	t_{basic} + t_d, ± 1 % or ± 10ms
	Repeatability	± 1 % or ± 10ms
	Overshoot time	<40 ms
	Disengaging time	< 60 ms

2.3.4 Reference (46IT)

	Parameter	Value
char	Characteristic setting	IEC-NI, -VI, -EI, -LTI; ANSI-MI, -VI, -EI; DTL
Tm	Time Multiplier setting	1.0
I_s	Setting	0.05, 0.06… 2.5x*In*
I	Applied Current (for operate time) IDMTL	2 to 20 x Is
t_d	Delay setting	0, 0.01… 20 s
t_{res}	Reset setting	ANSI DECAYING, 0, 1… 60 s

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2.3.5 Operate and Reset Level (46IT)

	Attribute		Value
I_{op}	Operate level		105 % *Is*, ± 4 % or ± 1% *In*
	Reset level		≥ 95 % I_{op}
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.3.6 Operate and Reset Time (46IT)

	Attribute		Value
	Starter operate time (≥ 2x*Is*)		35 ms, ± 10ms
t_{op}	Operate time	*char* = IEC-NI, IEC-VI, IEC-EI, IEC-LTI	$t_{op} = \frac{K}{\left[\frac{I}{Is}\right]^{\alpha} - 1} \times Tm$, ± 5 % absolute or ± 50 ms, for char = IEC-NI : K = 0.14, α = 0.02 IEC-VI : K = 13.5, α = 1.0 IEC-EI : K = 80.0, α = 2.0 IEC-LTI : K = 120.0, α = 1.0
		char = ANSI-MI, ANSI-VI, ANSI-EI	$t_{op} = \left[\frac{A}{\left[\frac{I}{Is}\right]^{P} - 1} + B\right] \times Tm$, ± 5 % absolute or ± 50 ms, for char = ANSI-MI : A = 0.0515, B = 0.114, P = 0.02 ANSI-VI : A = 19.61, B = 0.491, P = 2.0 ANSI-EI : A = 28.2, B = 0.1217, P = 2.0
		char = DTL	t_d, ± 1 % or ± 20ms
	Reset time	ANSI DECAYING	$t_{res} = \frac{R}{\left[\frac{I}{Is}\right]^{2} - 1} \times Tm$, ± 5 % absolute or ± 50 ms, for char = ANSI-MI : R = 4.85 ANSI-VI : R = 21.6 ANSI-EI : R = 29.1
		t_{res}	t_{res}, ± 1 % or ± 20ms
	Repeatability		± 1 % or ± 20ms
	Overshoot time		< 40 ms
	Disengaging time		< 60 ms

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2.4 47 Negative Phase Sequence Voltage

2.4.1 Reference (47)

	Parameter	Value
Vs	Setting	1, 1.5… 90V
Hyst.	Hysteresis	0, 0.1… 80%
t_d	Delay setting	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.4.2 Operate and Reset Level (47)

	Attribute		Value
V_{op}	Operate level		100 % *Vs*, ± 2 % or ± 0.5 V
	Reset level		(100%-Hyst.) x V_{op} ± 1% or ± 0.25V
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.4.3 Operate and Reset Time (47)

	Attribute	Value
t_{basic}	Element basic operate time	0V to 2.0 *xVs*, 80 ms, ± 20ms
		0V to 10 *xVs*, 70ms, ± 20ms
t_{op}	Operate time following delay	t_{basic} + t_d, ± 2 % or ± 20ms
	Repeatability	± 1 % or ± 20ms
	Overshoot time	< 40 ms
	Disengaging time	< 90 ms

2.5 49 Thermal Overload

2.5.1 Reference

	Parameter	Value
Is	Overload setting	1.0 x*In*
i	Applied Current (for operate time)	1.2 to 10 x Is
τ	Time constant setting	1, 10, 100, 1000 min

2.5.2 Operate and Reset Level

	Attribute		Value
I_{ol}	Overload level		100 % *Is*, ± 5 % or ± 1% *In*
	Reset level		≥ 95 % I_{ol}
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

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2.5.3 Operate and Reset Time

	Attribute	Value	
t_{op}	Overload trip operate time	$t = \tau \times \ln\left\{\frac{I^2 - I_p^2}{I^2 - (k \times I_B)^2}\right\}$ where I_P = prior current	, ± 5 % absolute or ± 100ms,
	Repeatability	± 100ms	
Note:- Fastest operate time is at 10 xIs			

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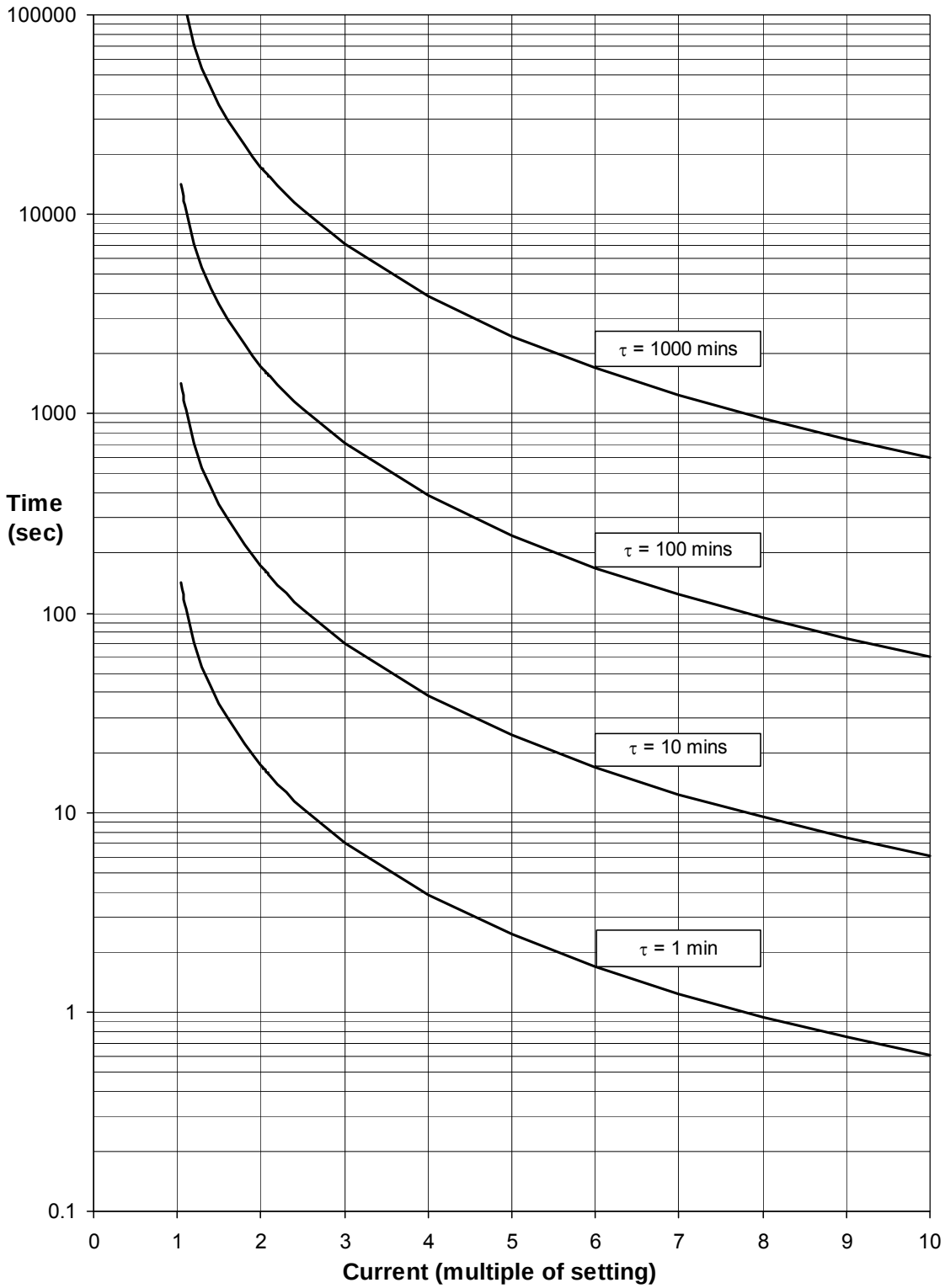

Figure 2.5-1 Thermal Overload Protection Curves

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2.6 50 Instantaneous Overcurrent

2.6.1 Reference

	Parameter	Value
Is	Setting	0.05, 0.06… 2.5, 2.55… 50 x*In*
t_d	Delay setting	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.6.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		100 % *Is*, ± 5 % or ± 1% *In*
	Reset level		≥ 95 % I_{op}
	Repeatability		± 1 %
	Transient overreach (X/R ≤ 100)		≤ -5 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.6.3 Operate and Reset Time

	Attribute	Value
t_{basic}	Element basic operate time	0 to 2 x*Is*: 35 ms, ± 10ms
		0 to 5 x*Is*: 25 ms, ± 10ms
t_{op}	Operate time following delay	t_{basic} + t_d, ± 1 % or ± 10ms
	Repeatability	± 1 % or ± 10ms
	Overshoot time	< 40 ms
	Disengaging time	< 50 ms

2.7 50G Instantaneous Measured Earth Fault

2.7.1 Reference

	Parameter	Value
Is	Setting	0.05, 0.06…2.5,2.55 …25.0,25.5…. 50 x*In*
t_d	Delay setting	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.7.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		100 % *Is*, ± 5 % or ± 1% *In*
	Reset level		≥ 95 % I_{op}
	Repeatability		± 1 %
	Transient overreach (X/R ≤ 100)		≤ -5 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

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2.7.3 Operate and Reset Time

	Attribute	Value
t_{basic}	Element basic operate time	0 to 2 x*Is*: 35 ms, ± 10ms
		0 to 5 x*Is*: 25 ms, ± 10ms
t_{op}	Operate time following delay	t_{basic} + t_d, ± 1 % or ± 10ms
	Repeatability	± 1 % or ± 10ms
	Overshoot time	< 40 ms
	Disengaging time	< 50 ms

2.8 50N Instantaneous Derived Earth Fault

2.8.1 Reference

	Parameter	Value
Is	Setting	0.05, 0.06…2.5,2.55 …25.0,25.5…. 50 x*In*
t_d	Delay setting	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.8.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		100 % *Is*, ± 5 % or ± 1% *In*
	Reset level		≥ 95 % I_{op}
	Repeatability		± 1 %
	Transient overreach (X/R ≤ 100)		≤ -5 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.8.3 Operate and Reset Time

	Attribute	Value
t_{basic}	Element basic operate time	0 to 2 x*Is*: 40 ms, ± 10ms
		0 to 5 x*Is*: 30 ms, ± 10ms
t_{op}	Operate time following delay	t_{basic} + t_d, ± 1 % or ± 10ms
	Repeatability	± 1 % or ± 10ms
	Overshoot time	< 40 ms
	Disengaging time	< 50 ms

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2.9 51 Time Delayed Overcurrent

2.9.1 Reference

	Parameter		Value
Is	Setting		0.05, 0.06… 2.5 *xIn*
char	Characteristic setting		IEC-NI, -VI, -EI, -LTI; ANSI-MI, -VI, -EI; DTL
Tm	Time Multiplier setting		1.0
t_d	Delay setting		0, 0.01… 20 s
t_{res}	Reset setting		ANSI DECAYING, 0, 1… 60 s
I	Applied Current (for operate time)	IDMTL	2 to 20 x Is
		DTL	5 x Is

2.9.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		105 % *Is*, ± 4 % or ± 1% *In*
	Reset level		≥ 95 % I_{op}
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.9.3 Operate and Reset Time

	Attribute		Value
	Starter operate time (≥ 2*xIs*)		20 ms, ± 20ms
t_{op}	Operate time	*char* = IEC-NI, IEC-VI, IEC-EI, IEC-LTI	$t_{op} = \frac{K}{\left[\frac{I}{Is}\right]^{\alpha} - 1} \times Tm$, ± 5 % absolute or ± 30 ms, for char = IEC-NI : K = 0.14, α = 0.02 IEC-VI : K = 13.5, α = 1.0 IEC-EI : K = 80.0, α = 2.0 IEC-LTI : K = 120.0, α = 1.0
		char = ANSI-MI, ANSI-VI, ANSI-EI	$t_{op} = \left[\frac{A}{\left[\frac{I}{Is}\right]^{P} - 1} + B\right] \times Tm$, ± 5 % absolute or ± 30 ms, for char = ANSI-MI : A = 0.0515, B = 0.114, P = 0.02 ANSI-VI : A = 19.61, B = 0.491, P = 2.0 ANSI-EI : A = 28.2, B = 0.1217, P = 2.0
		char = DTL	t_d, ± 1 % or ± 20ms
	Reset time	ANSI DECAYING	$t_{res} = \frac{R}{\left[\frac{I}{Is}\right]^{2} - 1} \times Tm$, ± 5 % absolute or ± 30 ms, for char = ANSI-MI : R = 4.85 ANSI-VI : R = 21.6 ANSI-EI : R = 29.1
		t_{res}	t_{res}, ± 1 % or ± 20ms
	Repeatability		± 1 % or ± 20ms
	Overshoot time		< 40 ms

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	Attribute	Value
	Disengaging time	< 50 ms

Figure 2.9-1 shows the operate times for the four IEC IDMTL curves with a time multiplier of 1.

Figure 2.9-2 and Figure 2.9-3 show the ANSI operate and reset curves. These operate times apply to non-directional characteristics. Where directional control is applied then the directional element operate time should be added to give total maximum operating time.

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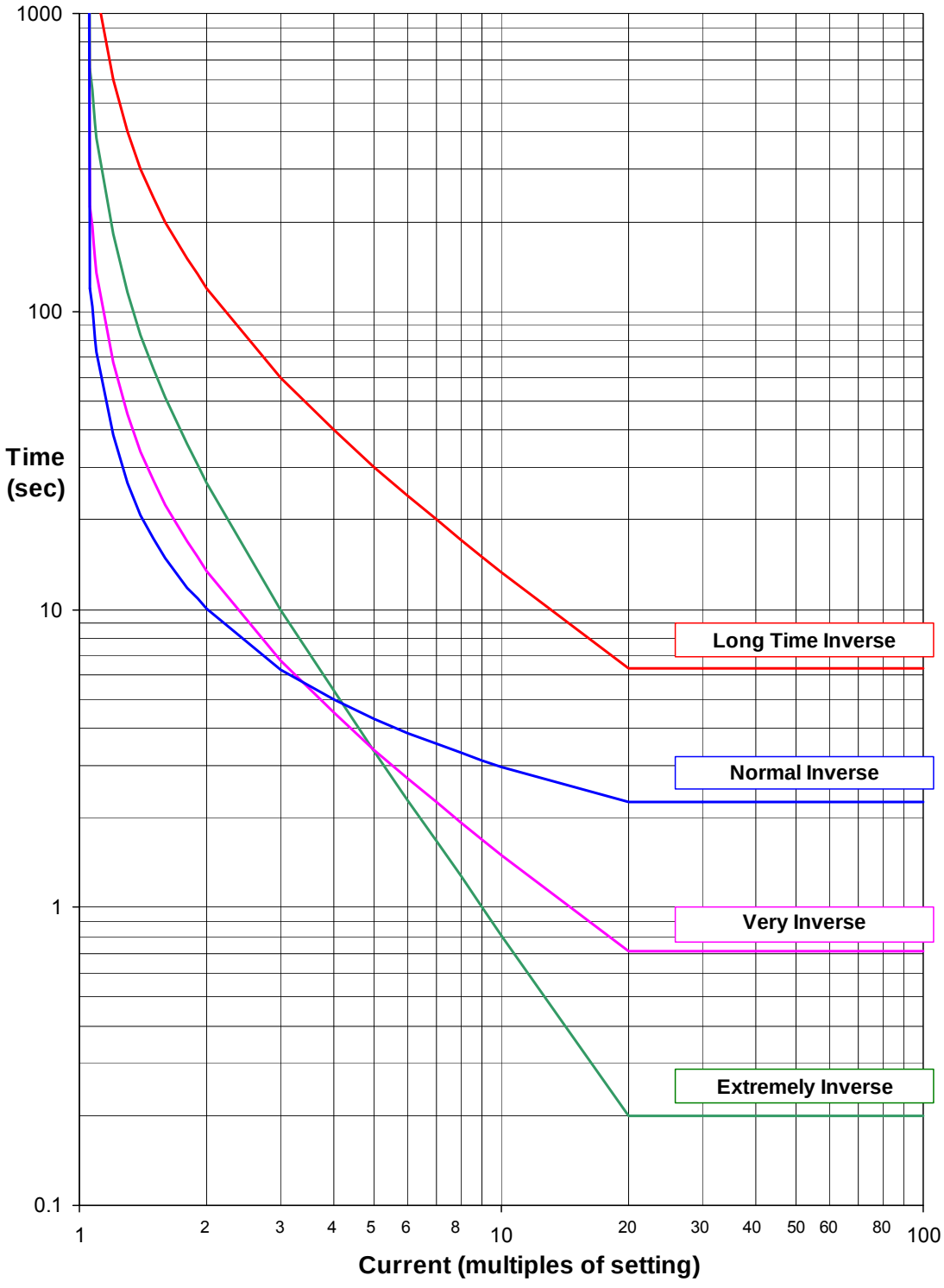

Figure 2.9-1 IEC IDMTL Curves (Time Multiplier=1)

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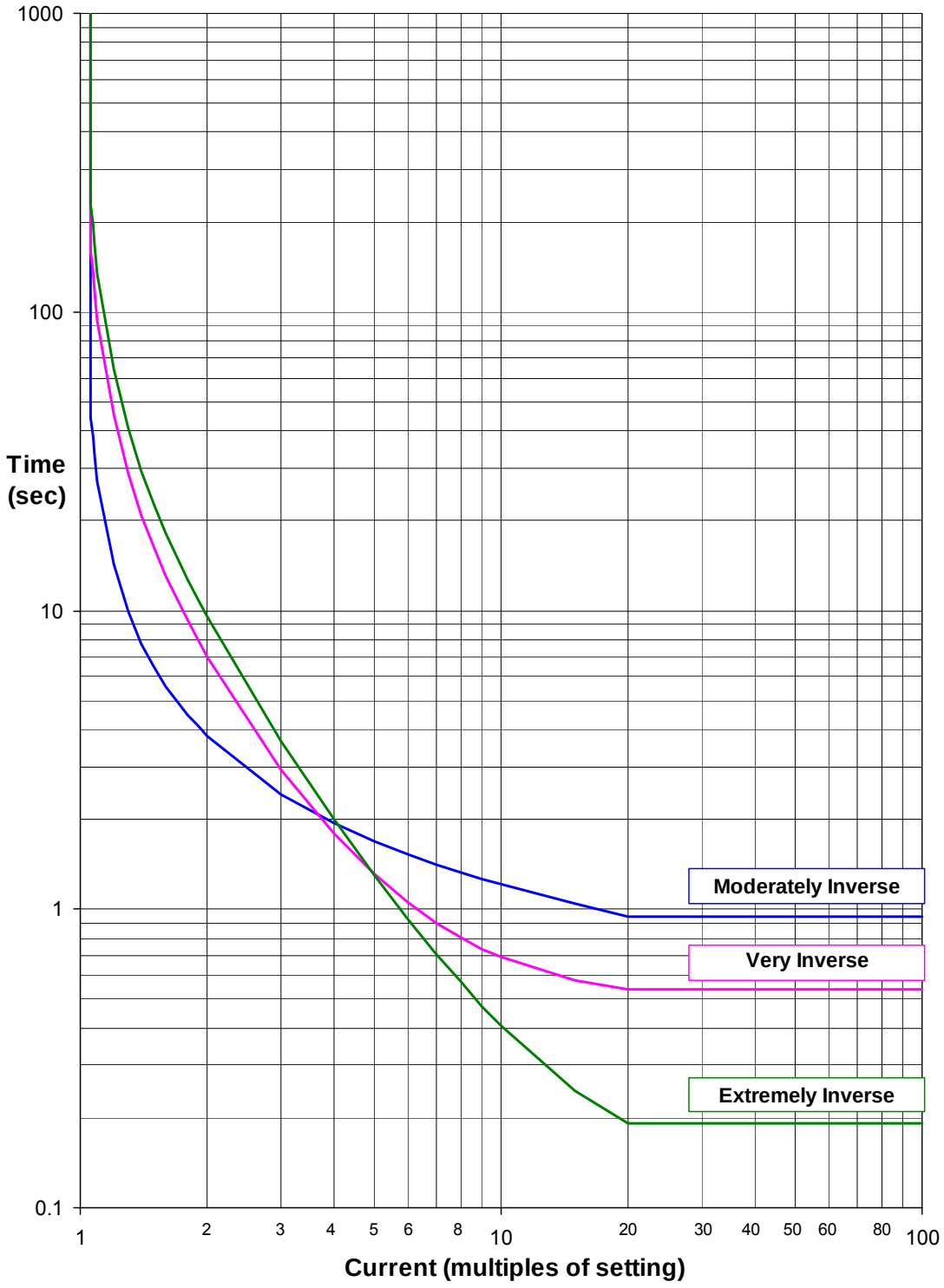

Figure 2.9-2 ANSI IDMTL Operate Curves (Time Multiplier=1)

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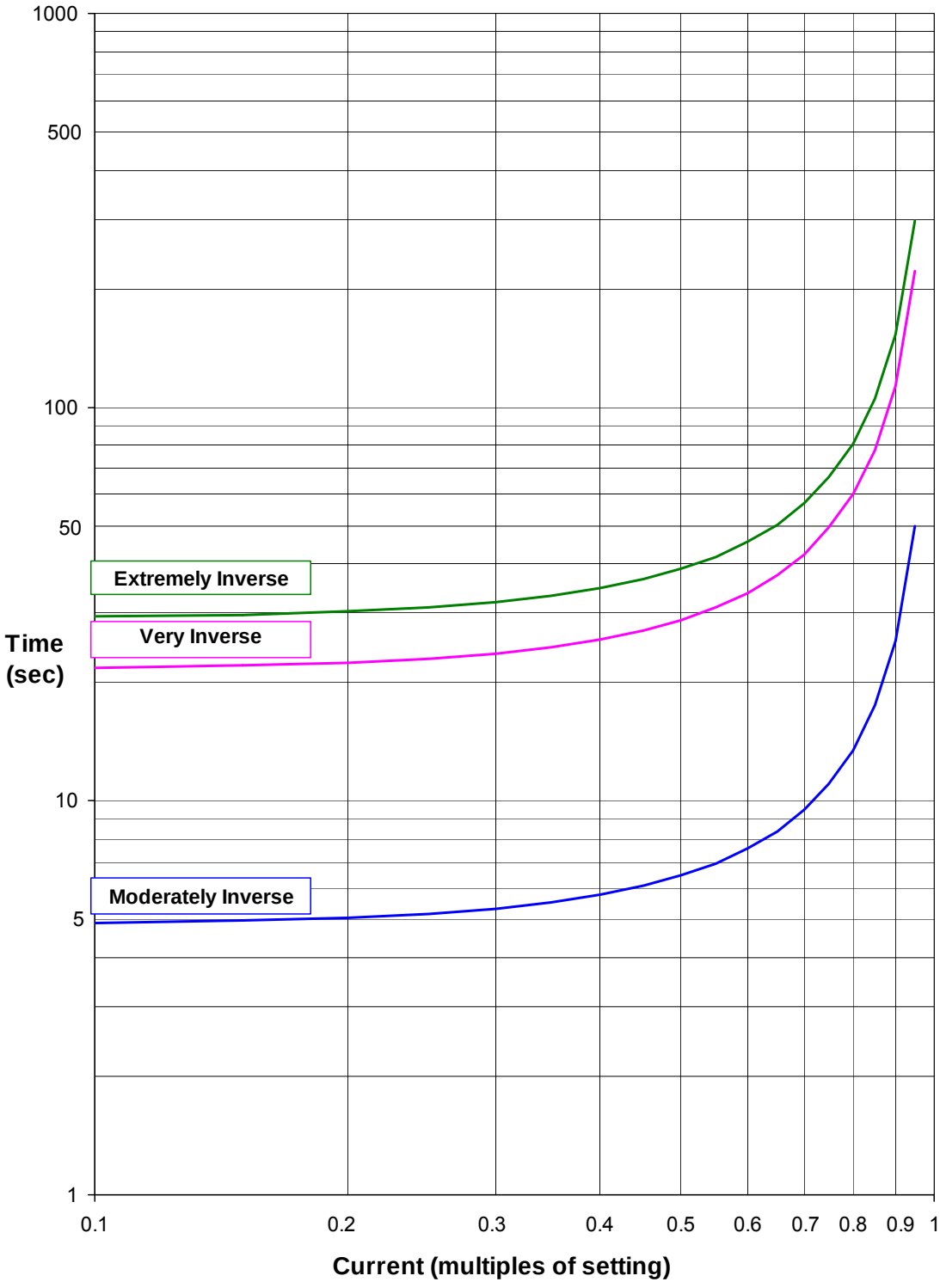

Figure 2.9-3 ANSI Reset Curves (Time Multiplier=1)

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2.10 51G Time Delayed Measured Earth Fault

2.10.1 Reference

	Parameter		Value
Is	Setting		0.05, 0.06… 2.5 *xIn*
Char	Characteristic setting		IEC-NI, -VI, -EI, -LTI; ANSI-MI, -VI, -EI; DTL
Tm	Time Multiplier setting		1.0
t_d	Delay setting (DTL)		0, 0.01… 20 s
t_{res}	Reset setting		ANSI DECAYING, 0, 1… 60 s
I	Applied current (for operate time)	IDMTL	2 to 20 x*Is*
		DTL	5 x*Is*

2.10.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		105 % *Is*, ± 4 % or ± 1% *In*
	Reset level		≥ 95 % I_{op}
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

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2.10.3 Operate and Reset Time

	Attribute		Value
	Starter operate time (≥ 2x*Is*)		20 ms, ± 20ms
t_{op}	Operate time	*char* = IEC-NI, IEC-VI, IEC-EI, IEC-LTI	$t_{op} = \frac{K}{\left[\frac{I}{Is}\right]^{\alpha} - 1} \times Tm$, ± 5 % absolute or ± 30 ms, for char = IEC-NI : K = 0.14, α = 0.02 IEC-VI : K = 13.5, α = 1.0 IEC-EI : K = 80.0, α = 2.0 IEC-LTI : K = 120.0, α = 1.0
		char = ANSI-MI, ANSI-VI, ANSI-EI	$t_{op} = \left[\frac{A}{\left[\frac{I}{Is}\right]^{P} - 1} + B\right] \times Tm$, ± 5 % absolute or ± 30 ms, for char = ANSI-MI : A = 0.0515, B = 0.114, P = 0.02 ANSI-VI : A = 19.61, B = 0.491, P = 2.0 ANSI-EI : A = 28.2, B = 0.1217, P = 2.0
		char = DTL	t_d, ± 1 % or ± 20ms
	Reset time	ANSI DECAYING	$t_{res} = \frac{R}{\left[\frac{I}{Is}\right]^{2} - 1} \times Tm$, ± 5 % absolute or ± 30 ms, for char = ANSI-MI : R = 4.85 ANSI-VI : R = 21.6 ANSI-EI : R = 29.1
		t_{res}	t_{res}, ± 1 % or ± 20ms
	Repeatability		± 1 % or ± 20ms
	Overshoot time		< 40 ms
	Disengaging time		< 50 ms

Figure shows the operate times for the four IEC IDMTL curves with a time multiplier of 1.

Figures 2.10-2 and 2.10-3 show the ANSI operate and reset curves. These operate times apply to non-directional characteristics. Where directional control is applied then the directional element operate time should be added to give total maximum operating time.

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2.11 51N Time Delayed Derived Earth Fault

2.11.1 Reference

	Parameter		Value
Is	Setting		0.05, 0.6… 2.5 *xIn*
char	Characteristic setting		IEC-NI, -VI, -EI, -LTI; ANSI-MI, -VI, -EI; DTL
Tm	Time Multiplier setting		1.0
t_d	Delay setting		0, 0.01… 20 s
t_{res}	Reset setting		ANSI DECAYING, 0, 1… 60 s
I	Applied Current (for operate time)	IDMTL	2 to 20 x Is
		DTL	5 x Is

2.11.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		105 % *Is*, ± 4 % or ± 1% *In*
	Reset level		≥ 95 % I_{op}
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

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2.11.3 Operate and Reset Time

	Attribute		Value
	Starter operate time (≥ 2x*Is*)		30 ms, ± 20ms
t_{op}	Operate time	*char* = IEC-NI, IEC-VI, IEC-EI, IEC-LTI	$t_{op} = \frac{K}{\left[\frac{I}{Is}\right]^{\alpha} - 1} \times Tm$, ± 5 % absolute or ± 30 ms, for char = IEC-NI : K = 0.14, α = 0.02 IEC-VI : K = 13.5, α = 1.0 IEC-EI : K = 80.0, α = 2.0 IEC-LTI : K = 120.0, α = 1.0
		char = ANSI-MI, ANSI-VI, ANSI-EI	$t_{op} = \left[\frac{A}{\left[\frac{I}{Is}\right]^{P} - 1} + B\right] \times Tm$, ± 5 % absolute or ± 30 ms, for char = ANSI-MI : A = 0.0515, B = 0.114, P = 0.02 ANSI-VI : A = 19.61, B = 0.491, P = 2.0 ANSI-EI : A = 28.2, B = 0.1217, P = 2.0
		char = DTL	t_d, ± 1 % or ± 20ms
	Reset time	ANSI DECAYING	$t_{res} = \frac{R}{\left[\frac{I}{Is}\right]^{2} - 1} \times Tm$, ± 5 % absolute or ± 30 ms, for char = ANSI-MI : R = 4.85 ANSI-VI : R = 21.6 ANSI-EI : R = 29.1
		t_{res}	t_{res}, ± 1 % or ± 20ms
	Repeatability		± 1 % or ± 20ms
	Overshoot time		< 40 ms
	Disengaging time		< 50 ms

Figure 2.10-1 shows the operate times for the four IEC IDMTL curves with a time multiplier of 1.

Figures 2.10-2 and 2.10-3 show the ANSI operate and reset curves. These operate times apply to non-directional characteristics. Where directional control is applied then the directional element operate time should be added to give total maximum operating time.

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2.12 51V Voltage Controlled Overcurrent

2.12.1 Reference

	Parameter	Value
Vs	Setting	60V
m	multiplier	0.5
Is	Setting	1xIn

2.12.2 Operate and Reset Level

	Attribute		Value
V_{op}	Operate level		100 % *Vs*, ± 1 % or ± 0.25V
	Reset level		≤ 105 % V_{op}
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz harmonics to f_{cutoff}	≤ 5 %

Operate and Reset Time

As per Phase Fault Shaped Characteristic Element (ANSI 51).

Where Pickup Level = Is for Voltage > Vs

Pickup Level = (Is x m) for Voltage < Vs

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2.13 59N Neutral Voltage Displacement

2.13.1 Reference (59NDT)

	Parameter	Value
Vs	Setting	0.1 x Vn
t_d	Delay setting	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.13.2 Operate and Reset Level (59NDT)

	Attribute		Value
V_{op}	Operate level		100 % *Vs*, ± 2 % or ± 0.5 V
	Reset level		≥ 95 % V_{op} or ± 0.5 V
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.13.3 Operate and Reset Time (59NDT)

	Attribute	Value
t_{basic}	Element basic operate time	0V to 1.5 *xVs*, 76 ms, ± 20ms
		0V to 10 *xVs*, 63 ms, ± 20ms
t_{op}	Operate time following delay	t_{basic} + t_d, ± 1 % or ± 20ms
	Repeatability	± 1 % or ± 20ms
	Overshoot time	< 40 ms
	Disengaging time	<100 ms

2.13.4 Reference (59NIT)

	Parameter	Value
M	Multiplier setting	1
Vs	Setting	1, 1.5… 100V
$3V_o$	Applied Current (for Operate-Time) IDMTL	2 x Vs
t_d	Delay setting	0, 0.01… 20 s
t_{res}	Reset setting	0, 1…60 s

2.13.5 Operate and Reset Level (59NIT)

	Attribute		Value
V_{op}	Operate level		105 % *Vs*, ± 2 % or ± 0.5 V
	Reset level		≥ 95 % V_{op} or ± 0.5 V
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

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2.13.6 Operate and Reset Time (59NIT)

	Attribute		Value
t_{basic}	Starter operate time		65 ms, ± 20ms
$3V_o$	Applied Current (for Operate-Time) DTL		10 x Vs
t_{op}	Operate time	char = IDMTL	$t_{op} = \frac{M}{\left[\frac{3V0}{Vs}\right] - 1}$, ± 5 % or ± 65 ms
		char = DTL	t_d, ± 1 % or ± 40ms
	Reset Time	char = IDMTL	t_{res}, ± 5 % or ± 65ms
		char = DTL	t_{res}, ± 1 % or ± 40ms
	Repeatability		± 1 % or ± 20ms
	Overshoot time		< 40 ms
	Disengaging time		< 100 ms

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2.14 64H Restricted Earth Fault Protection

2.14.1 Reference

	Parameter	Value
Is	Setting	0.05, 0.055.… 0.95 x*In*
t_d	Delay setting	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

2.14.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		100 % *Is*, ± 5 % or ±1% *xIn*
	Reset level		95 % I_{op}, ± 5 % or ±0.1% *xIn*
	Repeatability		± 1 %
	Transient overreach (X/R ≤ 100)		≤ -5 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

2.14.3 Operate and Reset Time

	Attribute	Value
t_{basic}	Element basic operate time	0 to 2 x*Is*, 45 ms, ± 10ms
		0 to 5 x*Is*, 35 ms, ± 10ms
t_{op}	Operate time following delay	t_{basic} + t_d, ± 1% or ± 10ms
	Repeatability	± 1% or ± 10ms
	Overshoot time	< 40 ms
	Disengaging time	< 50 ms

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2.15 67/67N Directional Overcurrent & Earth Fault

2.15.1 Reference

	Parameter	Value
θ_s	Angle setting	-95…+95 °
I	Applied current	*In*
V	Applied voltage	110 V phase-phase (63.5 V phase-earth)

2.15.2 Operate Angle

	Attribute		Value
CA	Characteristic angle (I with respect to V)		θ_s, ± 5 °
	Operating angle	forward	*CA* - 85 ° ± 5 ° to *CA* + 85° ± 5 °
		reverse	(*CA* - 180°) - 85° ± 5 ° to (*CA* - 180°) + 85° ± 5 °
	Variation in characteristic angle	10°C to +55°C	± 5 °
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	± 5 °

2.15.3 Operate Threshold

	Attribute		Value
	Minimum levels for operation	I (p/f)	> 5 % In
		I (e/f)	> 10 % In
		V (p/f)	> 1 V
		V (e/f)	> 1 V

2.15.4 Operate and Reset Time

	Attribute	Value
	Operate time	typically 32 < 40 ms at characteristic angle + element operate time
	Reset time	typically < 65 ms at characteristic angle

2.16 87L Pilot Wire Current Differential

2.16.1 Operate Level

The following sensitivities are shown as a percentage of rated current and are directly applicable to the local relay of a connected pair when subjected to current injection at the local end only. Settings are typically within +-15% of quoted sensitivity.

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Type of fault	Fault settings (% In)							
	Without isolating transformers				With isolating transformers			
	R Mode		Rf Mode		R Mode		Rf Mode	
	N1 tap	N tap	N1 tap	N tap	N1 tap	N tap	N1 tap	N tap
a-n	16	22	18	25	22	31	25	35
b-n	18	27.5	21	32	26	39	30	44
c-n	22	37	25	42	31	52	35	59
a-b	110		125		155		177	
b-c	110		125		155		177	
c-a	55		62		77.5		88.5	
a-b-c	63		72		89		101	

If Pilot Supervision is fitted, the settings will be increased by 20-50%.

In Rf mode the remote end relay will operate at a similar level to the local relay.

In R mode the remote end will typically operate at 2.5 times the local end setting.

2.16.2 Operate Time

	Attribute	**Mode**	**3x fault setting**	**5x fault setting**	**10x fault setting**
$t_{RfBasic}$	Element typical basic operate time	R Mode	60ms		45ms
		5kV Rf mode		45ms	
		15kV Rf mode		40ms	

2.16.3 Stability Level

	Parameter	**Value**
$I_{StabLimit}$	Maximum Through fault Stability Level	50x In

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Section 3: Supervision Functions

3.1 46BC Broken Conductor

3.1.1 Reference

	Parameter	**Value**
	NPS to PPS ratio	20,21…100%
t_f	Delay setting	0.03,04,20.0,20.1,100,101,1000,1010…..14400 s

3.1.2 Operate and Reset Level

	Attribute		**Value**
I_{curr}	Operate level		100 % I_{set} ± 5 %
	Reset level		90 % I_{curr}, ± 5 %
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz harmonics to f_{cutoff}	≤ 5 %

3.1.3 Operate and Reset Time

	Attribute		**Value**
t_{basic}	Basic operate time	1x In to 0 A	40 ms
	Operate time		$t_f + t_{basic}$, ± 1 % or ± *20ms*
	Repeatability		± 1 % or ± *20ms*
	Variation	f_{nom} - 3 Hz to f_{nom} + 2 Hz harmonics to f_{cutoff}	≤ 5 %

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3.2 50BF Circuit Breaker Fail

3.2.1 Reference

	Parameter	Value
Is	Setting	0.050, 0.055… 2.0 x*In*
I4	Setting	0.050, 0.055… 2.0 x*In*
t_{CBF1}	Stage 1 Delay setting	20, 25… 60000ms
t_{CBF2}	Stage 2 Delay setting	20, 25… 60000ms

3.2.2 Operate and Reset Level

	Attribute		Value
I_{op}	Operate level		100 % *Is*, ± 5 % or ± 1% *In*
I_{reset}	Reset level		<100 % I_{op}, ± 5 % or ± 1% *In*
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

3.2.3 Operate and Reset Time

	Attribute	Value
t_{op}	Stage 1	t_{CBF1}, ± 1 % or ± 20ms
	Stage 2	t_{CBF2}, ± 1 % or ± 20ms
	Repeatability	± 1 % or ± 20ms
	Overshoot	< 2 x 20ms
	Disengaging time	< 20ms

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3.3 60CTS Current Transformer Supervision

3.3.1 Reference

	Parameter		Value
I_{thresh}	Current Threshold		0.05, 0.1… 2 x*In*
I	Applied Current (for operate time)	Healthy CT Phases	5 x I_{thresh}
		Failed CT phase	0
t_d	Delay setting		0.3, 20.00, 20.50… 100, 101… 1000, 1010… 10000, 10100… 14400 s
Directional Relays have additional VT settings			
V_{thresh}	Voltage Threshold		7, 8… 110V

3.3.2 Current & Voltage Threshold

	Attribute		Value
I_{op}	CT failed current level		100 % I_{thresh}, ± 5% or ± 1% In
	Reset level		90 % $I_{op,}$ ± 5% or ± 1% In
V_{op}	CT failed voltage level		100 % V_{thresh}, ± 2% or ± 0.5V
	Reset level		110 % V_{op}, ± 2 % or ± 0.5V
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz harmonics to f_{cutoff}	≤ 5 %

3.3.3 Operate and Reset Time

	Attribute	Value
t_{basic}	Basic operate time	50 ms ± 20ms
	Operate time	t_d + t_{basic}, ± 1 % or ± 20ms
	Repeatability	± 1 % or ± 20ms

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3.4 60VTS Voltage Transformer Supervision

3.4.1 Reference

	Parameter	Value
V_{nps}	Vnps Level	7, 8 … 110V
I_{nps}	Inps Level	0.05, 0.1 … 1 x In
I_{pps}	Ipps Load Level	0.05, 0.1 … 1 x In
IF_{pps}	Ipps Fault Level	0.05, 0.1 … 20 x In
V_{pps}	Vpps Level	1, 2 … 110V
t_d	60VTS Delay	0.00, 0.01…20.00, 20.10… 100, 101… 1000, 1010… 10000, 10100… 14400 s

3.4.2 Operate and Reset Level

	Attribute		Value
V_{NPSop}	Voltage NPS operate level		100 % V_{nps}, ± 5 % *Vn*
	Voltage NPS reset level		90 % V_{NPSop}, ± 5 % *Vn*
V_{PPSop}	Voltage PPS operate level		100 % V_{pps}, ± 5 % *Vn*
	Voltage PPS reset level		110 % V_{PPSop}, ± 5 % *Vn*
I_{NPSblk}	Current NPS operate level		100 % I_{nps}, ± 5 % x*In*
	Current NPS reset level		90 % I_{NPSblk}, ± 5 % x*In*
I_{PPSblk}	Current PPS operate level		100 % IF_{pps}, ± 5 % x*In*
	Current PPS reset level		90 % I_{PPSblk}, ± 5 % x*In*
$I_{PPSload}$	Current PPS operate level		100 % I_{pps}, ± 5 % x*In*
	Current PPS reset level		90 % $I_{PPSload}$, ± 5 % x*In*
	Repeatability		± 1 %
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

3.4.3 Operate and Reset Time

	Attribute		Value
t_{basic}	Basic operate time	0V to 2 x *Vs*	32 ms ± 10ms
	Operate time		t_d + t_{basic} ± 1 % or ± 10ms
	Repeatability		± 1 % or ± 10ms

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3.5 74TCS & 74CCS Trip & Close Circuit Supervision

3.5.1 Reference

	Parameter	Value
t_d	Delay setting	0, 0.02…60 s

3.5.2 Operate and Reset Time

	Attribute		Value
t_{basic}	Element basic operate time		30ms ± 10ms
t_{op}	Operate time following delay		t_{basic} + t_d, ± 1 % or ± 10ms
	Repeatability		± 1 % or ± 10ms
	Variation	-10 °C to +55 °C	≤ 5 %
		f_{nom} - 3 Hz to f_{nom} + 2 Hz	≤ 5 %

3.6 81HBL2 Inrush Detector

3.6.1 Reference

	Parameter	Value
I	Setting (Ratio of 2nd Harmonic current to Fundamental component current)	0.10, 0.11... 0.5

3.6.2 Operate and Reset Time

	Attribute	Value
t_{basic}	Element basic operate time	Will pick-up before operation of any protection element due to magnetic inrush
	Reset Time	Will operate until drop-off of any protection element due to magnetic inrush

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