OPTIMHO

Distance Protection for Single Phase Electrified Railway Systems

ALSTOM

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Distance Protection for Single Phase Electrified Railway Systems

Figure 1:
Optimho (Type LFZP) relays

Features

- Full scheme distance relays with 3 measuring units
- Single or multiple zones
- Independent settings for reactance and resistive reach for each zone
- Typical operating time: one cycle
- Optional fault location with data recording for post fault analysis and instrumentation functions

Models Available

Two versions of the Optimho distance protection relay for single phase electrified railway systems are available:

LFZP141	50/60Hz
LFZP142	25Hz

Benefits

- Remote interrogation reduces need for site visits
- Precise fault type/location data reduces outage time
- Self diagnosis reduces maintenance costs
- Vertical case option eases retrofit problems
- Will interface with existing scheme logic
- Fulfils basic SCADA role at no extra cost

Application

LFZP141/2 is part of the Optimho model range originally developed for 3 phase protection. It is used as main protection to detect short circuits on the catenary and other single phase traction feeder equipment, including the feeder wire for autotransformer-fed systems.

Applications are:

– main protection of catenary and other feeder equipment

– time delayed back-up for faults in adjacent sections

– booster and autotransformer-fed system protection

Principles of Operation

Optimho is a full scheme distance relay which has a measuring element for each main zone of protection. Compared with the switched type of scheme, the full scheme system improves reliability by avoiding the need to rely on zone selection hardware or software, removing dependence on a single measuring unit. Full scheme distance relays are better able to copy with evolving faults.

The measuring element uses a micro-controller to produce a direct software equivalent of the hardware phase comparator used in Optimho's forerunners, Micromho and Quadramho. This phase comparator design is well tried, having accumulated nearly ten thousand relay years of successful operating experience over the last decade at locations throughout the world.

Many of the other hardware and software features of Quadramho have been retained and further enhanced in Optimho, ensuring the highest standards of reliability

Summary chart		
LFZP Model	**141**	**142**
Ground distance	*	*
Fault location	o	o
Railway	*	*
Operating frequency	50/60Hz	25Hz
No of distance elements	3	3
Independent zones	Z1	Z1
	Z2	Z2
	Z3	Z3
	Z1X	Z1X
	Z1Y	
No of output contacts	8	8
Schemes		
BASIC	*	*
Z1 EXTENSION	*	*
PUR	*	*
Distance characteristic		
Z1, Z1X, Z1Y, Z2 ground	q*	q*
Z3 ground	D*	D*
Overcurrent elements		
Inst.overcurrent element		*
Overcurrent backup elements		*
* = standard, o = optional, q = quadrilateral, D = offset quadrilateral		

Optimised Performance with Distorted Signals

The phase comparators and level detectors use logic processing to achieve immunity from maloperation due to noise, such as harmonic distortion, travelling wave effects and current transformer saturation. Operation of the phase comparators and level detectors can only occur if the input signals are dominated by power frequency components. Filters are used to ensure this dominance and to optimise operating times.

Hardware Structure

The hardware uses multiple micro-controllers to perform as comparators, level detectors, etc. A main micro-controller uses the digital bus to read outputs from the subsidiary micro-controllers, read signals from the outside world via optically coupled isolators, communicate with the user interface and perform scheme logic, serial communications, monitoring and output contact functions. Settings, indications and fault records are stored in a type of memory which is unaffected by loss of dc supply.

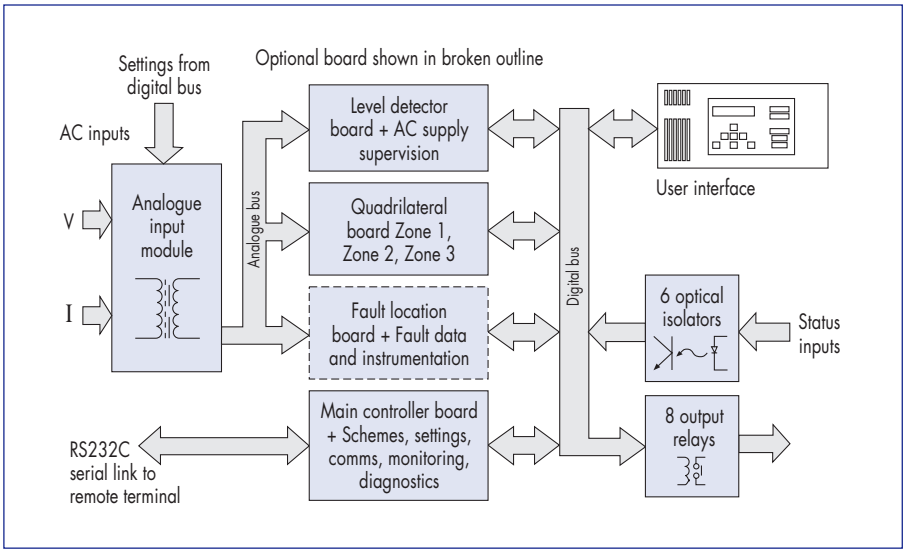


Figure 2:
Electrical structure

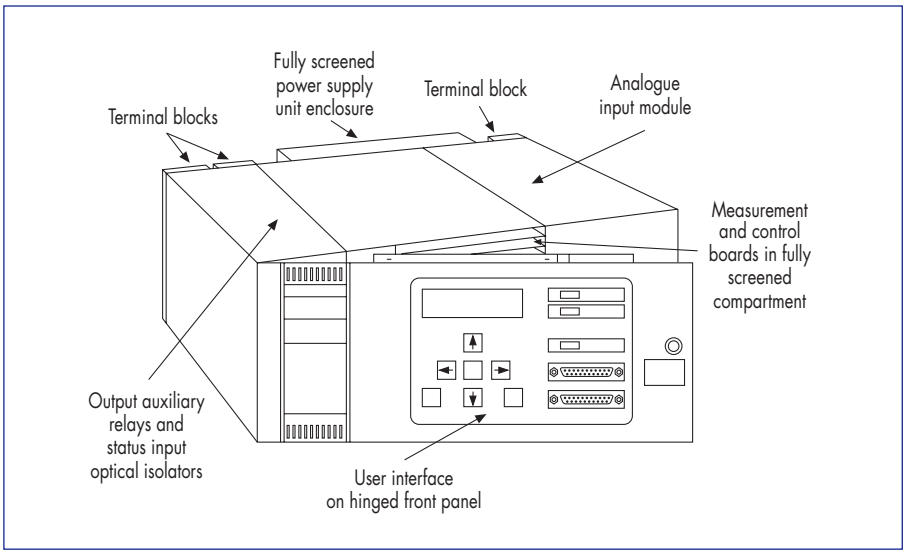


Figure 3:
Mechanical layout

The layout of the relay case follows the 'quiet region' arrangement introduced in Micromho and Quadramho, with measurement and control boards located in a screened compartment and fed with signals from the outside world via screened isolation devices and filters. See Figure 3.

A vertical aspect, panel mounted version can be used for replacing obsolescent distance relays in narrow panels, with the minimum of panel disturbance.

Integral User Interface

All relay settings and records are accessible from the integral user interface shown in Figure 4.

The liquid crystal display (LCD) indicates how the relay initiated the latest trip. The faulty zone is indicated for trips initiated by the distance elements. The latest alarm condition is also indicated.
If indications are present when the supply is lost, they are automatically reinstated when the supply is restored.

The date and time of the fault, location (if available), and more, are summoned by pressing READ. After the indications have been read, they can be cleared by pressing RESET and the READ key can then be used to step through all the relay settings displayed in sequence.

The cursor and SET keys, and the two test sockets, are only accessible after removing the transparent front cover. The keys are used to select from a menu of options displayed on the LCD in English, and to enter new settings into temporary memory. The menu has a simple structure, allowing rapid familiarisation.

The SET key is used to transfer temporary entries to the permanent memory which determines relay action. Accidental changes are prevented by allowing SET to be operative only at certain points in the menu after appropriate warnings have been displayed.

Menu Options

The menu holds an extensive range of options, including:

- viewing records of the LCD indications from the last four faults
- printing records or settings on a portable printer plugged into the PARALLEL test socket
- entering a relay identification code for use on printouts
- comprehensive test options such as:
  monitoring test points on the PARALLEL socket; blocking output contacts (the relay inoperative alarm contact closes when the output contacts are blocked); simplified on-load directional testing; and closing selected output contacts (for instance to carry out a circuit breaker test)
- setting up the baud rate and protocol for the serial communications

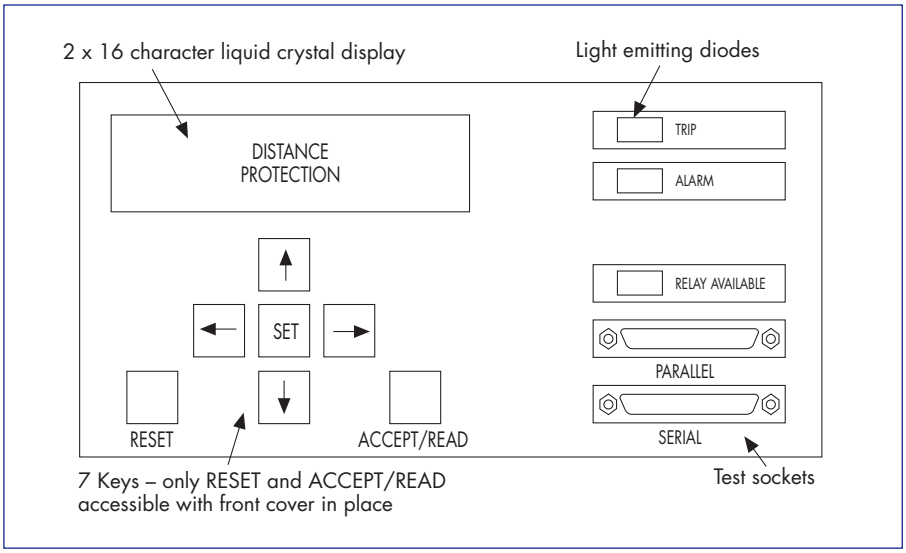


Figure 4:
User interface on front panel

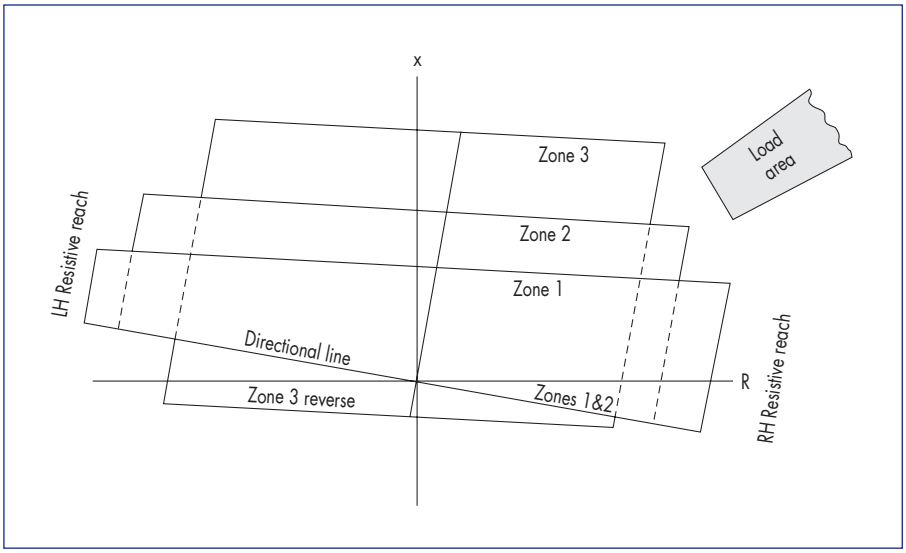


Figure 5:
Quadrilateral ground fault characteristics

Settings

The setting options allow the user to select functions to suit each application. They are:

- scheme type
- which distance zones are enabled (up to 5 zones)
- whether overcurrent elements (if fitted) are enabled
- whether START indications are required for remote faults which do not result in a trip
- eight independent groups of settings which are stored in the relay memory and are selectable from the menu.

The menu is adaptive; for example, if Zone 2 is not required and has been disabled, its time setting is automatically removed from the menu.

Schemes Available

The scheme selection includes basic distance with up to 3 independent zones available, designated Z1, Z2 and Z3. Additional zones 1X and 1Y (if available) are obtained, if required, by stepping the reach of the Zone 1 elements after time delays started by the Zone 2 and/or Zone 3 elements.

Zone 1 extension and permissive underreach schemes are provided to enable fast tripping for faults in the last 20% of the line if required.

Remote Communications

All the options available on the menu are also available from a local or remote terminal via an RS232C serial communications port. Sockets are provided on both the front and the rear of the relay for temporary or permanent connection respectively. The socket on the rear can also interface with a modem for communication over a suitable link, for instance a telephone line.

The facility to bulk transfer settings, event records and metering (if fault locator is fitted) is available using 'OPTICOM' software.

Distance Characteristics

The relay has quadrilateral characteristics with independent settings for reactance and resistive reach. The resistive reach setting of each principal zone is independent of that of the other zones and can therefore be set to provide the maximum possible resistance coverage without the encroachment of load impedance.

This overcomes many of the problems associated with circular mho characteristics. These required blinder elements of characteristic shaping to stabilise the relay under peak load impedance. In addition, the mho characteristic has restricted resistive coverage when applied to short feeders.

Polarising

The synchronous memory polarising signal is a square wave derived from a healthy phase reference and 16% of the amplitude of the prefault voltage. This wave is added to the faulty voltage and is for close-up fault conditions, to provide a clear directional reference during noise conditions.

Synchronous polarising is derived from prefault voltage and is available for 16 cycles after fault incidence to cover breaker failure protection time. Several cycles must elapse from system energisation before synchronous polarising is available, so switch-on-to-fault logic is arranged to provide protection for close-up faults during this initial period.

Overcurrent Elements

(Not available on all models)

The overcurrent protection has 3 tripping elements selectable via the user interface:

- single instantaneous extra high set level detector.
- a backup time delayed overcurrent element.
- time delayed tripping, either definite time or inverse definite minimum time using a selection of built-in IEC or USA curves. See Figure 9.

Fault Location, Fault Data Recording and Instrumentation

The fault locator, when fitted, works on the principle of calculating the reactance to the fault. Readout is in kilometres, miles or percent of line length, with reactive ohms, although these depend for their accuracy on the line reactance being linearly related to the distance to fault. This may not be true for all feeder arrangements.

The fault location board also computes prefault and fault voltages and currents. These values can be read out to allow analysis of the power system network as it was at the time of fault. The duration of the fault is also determined.

At any time under healthy live line conditions, the line voltage, current, watts and VArs can be calculated on demand. These values can be compared with other instrumentation for accuracy. As the fault location hardware is largely separate from that of the distance measuring elements, protection accuracy can be cross-checked with fault location accuracy during secondary injection tests.

All voltages and currents are given with phase angle relative to pre-fault voltage and rms amplitudes in primary or secondary terms.

Contact Arrangements

There are three pre-programmed output contact arrangements which can be selected via the menu. See Table 1.

Self-Monitoring and Voltage Transformer Fuse/MCB Supervision

Optimho has comprehensive continuous self-monitoring. If a failure occurs, an alarm is issued by closing the relay inoperative alarm contact and extinguishing the relay available LED. Diagnostic information is automatically displayed if the failure is such that it does not disable the main processor and LCD.

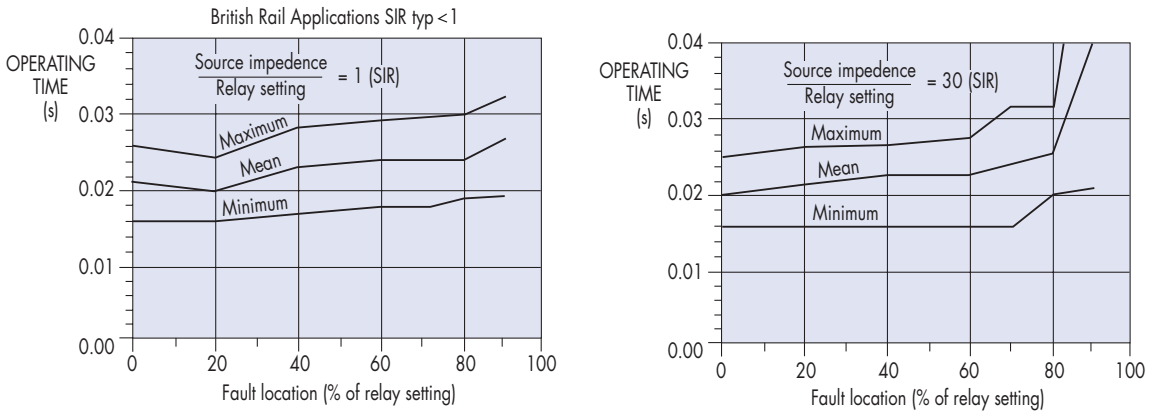


Figure 6:
50Hz typical operating times (quadrilateral characteristic)

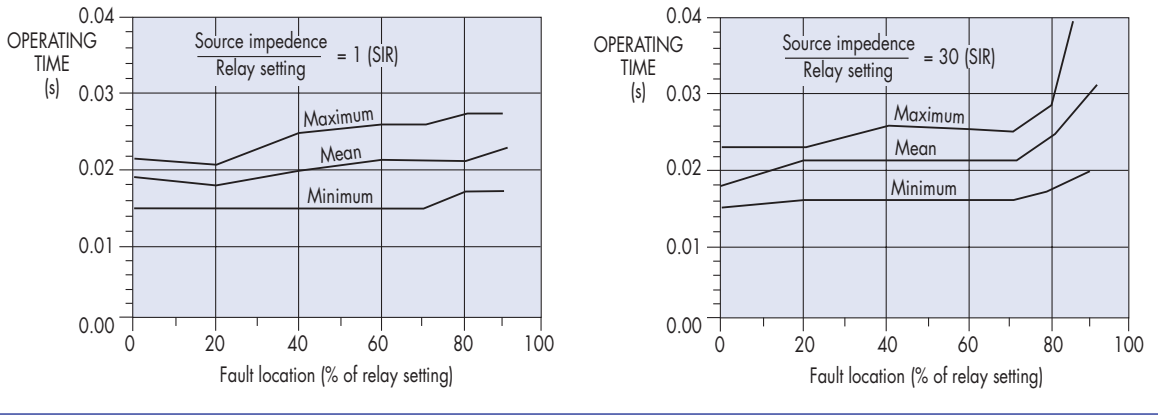


Figure 7:
60Hz operating times (quadrilateral characteristic)

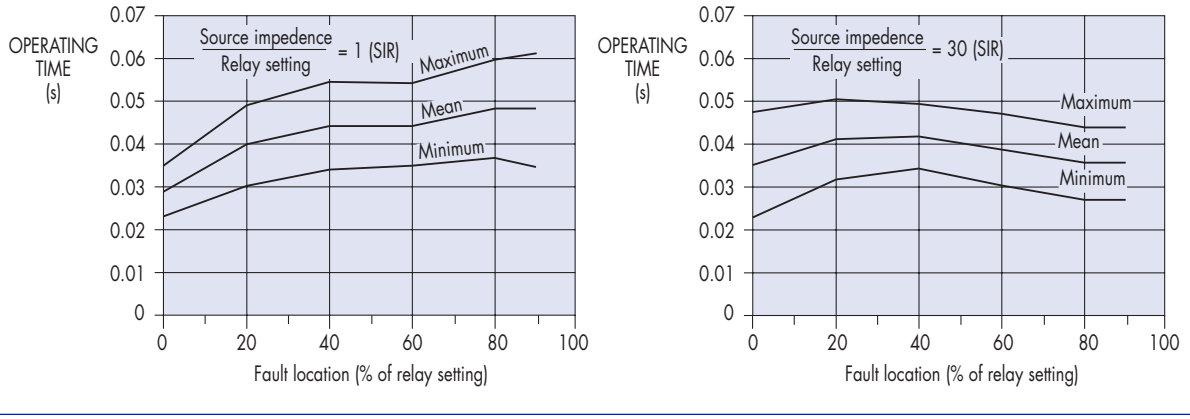


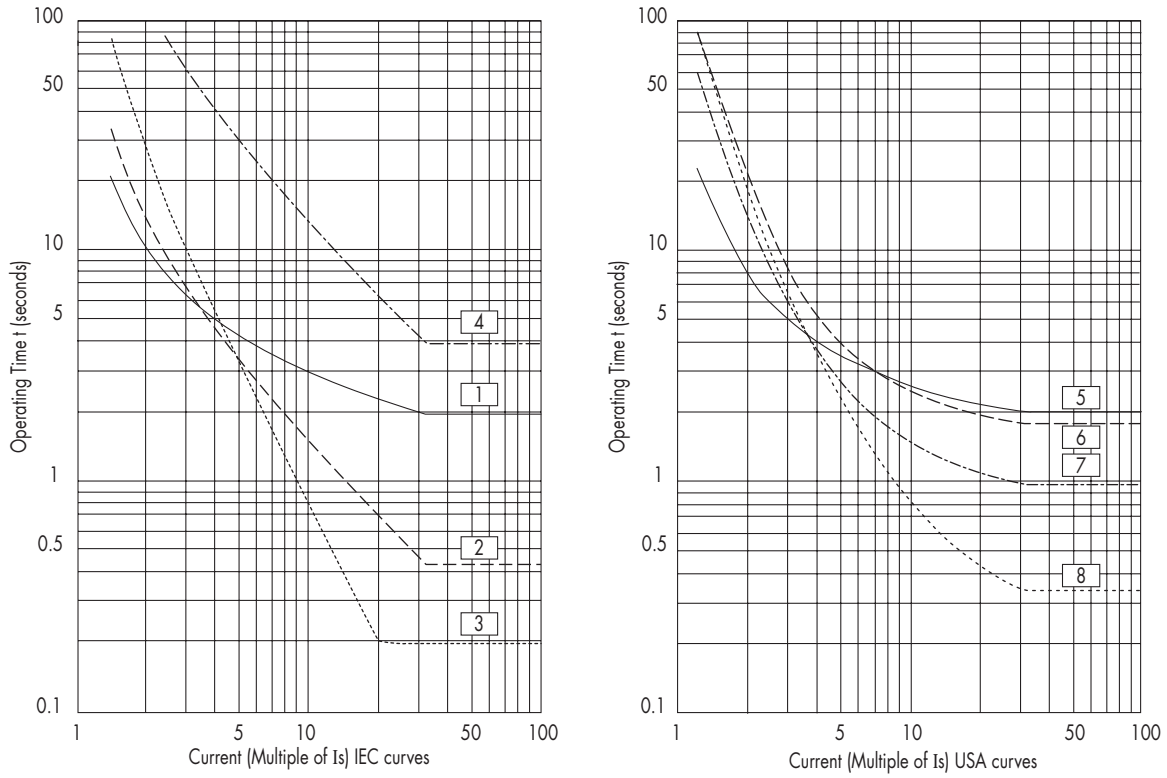
Figure 7:
25Hz operating times (quadrilateral characteristic)

Monitoring of the analogue circuits includes (i) the dc supply and all internal dc power supply rails, and (ii) the ac supplies and internal analogue voltage and current circuits.

The VT supervising logic can be set to block relay operation in the event of failure of a VT or fuse. The VT supervision logic can be selected via the menu, to self reset or to remain sealed-in until the reset push button is pressed.

An optically coupled isolator monitors the auxiliary contact of a miniature circuit breaker if the VT supplies are protected by an MCB instead of fuses. Energising the optical isolator blocks the relay operation.

Monitoring of the digital circuits includes (i) bus communications (ii) checking of RAM and EEPROM and (iii) watchdog circuits for every micro-controller. In the event of failure, trip signals originating from the affected part of the relay are blocked.



1 Standard inverse: $t = \frac{0.14}{I^{0.02}-1}$

2 Very inverse: $t = \frac{13.5}{I-1}$

3 Extremely inverse: $t = \frac{80}{I^{2}-1}$

4 Longtime earth fault: $t = \frac{120}{I-1}$

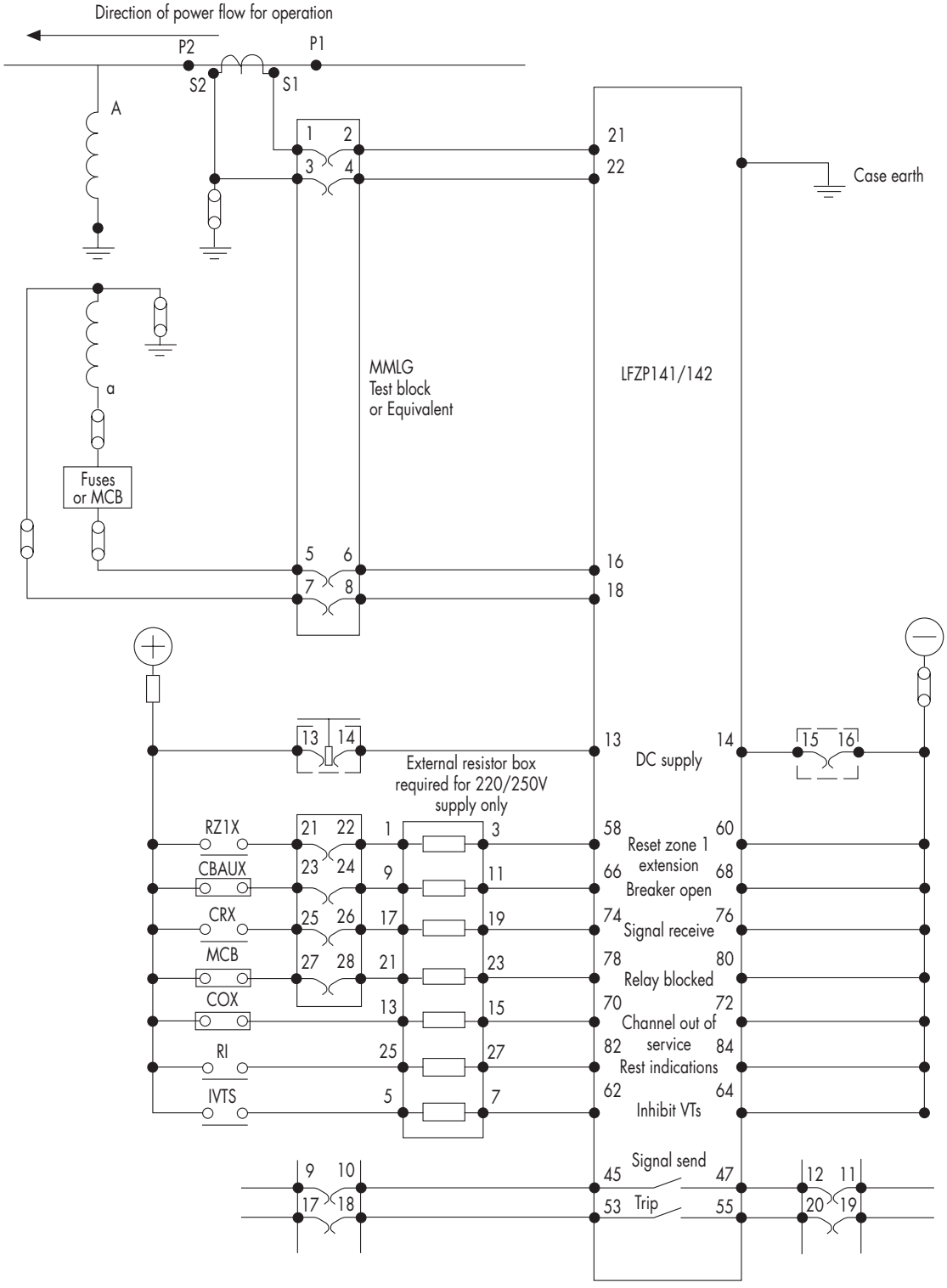
5 US moderate inverse

6 US standard inverse

7 US very inverse

8 US extremely inverse

Figure 9:
Overcurrent protection time delay trip times



Opto-isolator inputs when required

CRX	Open contact from signalling channel
COX	Closed contact from signalling channel
RZ1X	Open contact from auto-reclose relay
CBAUX	Closed circuit breaker contacts to indicate pole open. Required with busbar vt.
MCB	Closed contact from miniature circuit breaker required when no vt fuses are used.
RI	Open contact to reset visual indications
IVTS	Inhibit VTs

Figure 10:
Case connection diagram

Technical Data

Ratings

AC voltage Vn:	100 to 120V rms
AC current In:	1A or 5A rms
Frequency fn:	

The LFZP railway relay is available in two versions:

Relay type	Frequency fn	Operative frequency range
LFZP 141	50Hz	47 to 51Hz
	60HZ	56.4 to 61.2Hz
LFZP 142	25Hz	23.5 to 25.5Hz

For switched mode dc/ac/dc power supply unit, available in three versions:

Nominal (V)	Operative range (V)	Maximum withstand (V)
48/54	37.5 to 60	64.8
110/125	87.5 to 137.5	150
220/250	175 to 275	300

There is negligible change of accuracy with change of voltage within the operative range of the relay.

DC supply Vx(2):	For optically coupled isolators. Supply options are the same as Vx(1). External resistor box provided for 220/250V version (see Figure 12).

Maximum overload ratings

AC voltage:	1.2Vn for measuring accuracy 1.5Vn continuous withstand 2.5Vn withstand for 10s
AC current:	2.4In continuous withstand 100In withstand for 1s (In = 1A) 80In withstand for 1s (In = 5A)

Burdens

AC voltage circuits:	0.1VA per phase at Vn
AC current circuits:	0.08VA per phase (In = 1A) 0.5VA per phase (In = 5A)
DC supply (1):	8W under healthy live line conditions at Vx(1) 10W maximum
DC supply (2):	10mA per energised optically couples isolator at Vx(2)

Distance elements

Range of settings referred to line VT and CT secondaries:

All employed zones except reverse Zone 3:	LFZP 141	0.2 to 250Ω (In = 1A) 0.04 to 50Ω (In = 5A)
	LFZP 142	0.1 to 125Ω (In = 1A) 0.02 to 25Ω (In = 5A)

Reverse Zone 3:

LFZP 141 0.04 to 250Ω (In = 1A)
0.008 to 50Ω (In = 5A)

LFZP 142 0.02 to 125Ω (In = 1A)
0.004 to 25Ω (In = 5A)

In = 5A range is 0.008 to 50Ω

Reach setting method is by digitally controlled analogue attenuators. Attenuation factor KZPh operates on the current signal and is common to all zones. Attenuation factors KZ1, KZ1X, KZ1Y, KZ2, KZ3, and KZ3' operate on voltage signals and are specific to Zone 1, Zone 1X, Zone 1Y, Zone 2, Zone 3 and Zone 3 offset respectively.

The reach for Zone 1 is given by:

Zone 1 = KZ1. KZPh.5/In for LFZP 141

Zone 1 = KZ1. KZPh.5/2In for LFZP 142

Either KZ1 or KZPh is set to unity. To obtain the formula for each of the other zones employed, replace KZ1 by the appropriate attenuation factor for the zone.

Quadrilateral resistive reach settings:

Right-hand reach = KR.5/In

Left-hand reach = KR.5/In
where:

KR = KR1 for Zone 1
KR = KR2 for Zone 2
KR = KR3 for Zone 3

Range of factors:

KZPh 0.040 to 1.000 in steps of 0.001

KZ1, KZ1X, KZ1Y, KZ2, KZ3: 1.00 to 49.98 in steps of 0.02

KZ3' 0.2 to 49.9 in steps of 0.1

KR1, KR2, KR3: 1 to 30 in steps of 1

Characteristic angle settings:

θPh = arg Z_L to nearest available setting

θPh = 45° to 80° in 5° steps
LFZP141

θPh = 40° to 75° in 5° steps
LFZP142

Minimum operating values of the distance measuring elements for all types of fault:

Voltage: zero

Current: 0.05In/KZPh

Accuracy:

Reach: ±5% at 2In and 20°C

Dynamic range up to 25In for fault locator instrumentation and distance protection.

Characteristic angle: ±2°

Resetting ratio:

105%

Timer ranges:	Zone 1X timer Zone 1Y timer Zone 2 timer Zone 3 timer	each timer 0.10s to 9.98s in steps of 0.02s
	Timer accuracy	±1% of setting and ±3ms
Operating time	Typical relay operating times for Zone 1 are shown in Figures 6 – 8	
	Quadrilateral characteristic:	
LFZP 141	50Hz minimum:	16ms
	typical:	23ms
	60Hz minimum:	15ms
	typical:	20ms
LFZP 142	25Hz minimum:	23ms
	typical:	42ms
Reset time:	The trip contacts are sealed in for 60ms following the initial contact closure. Thereafter, the maximum reset time is 35ms	

Overcurrent elements (LFZP142)

Instantaneous trip LD1		
Setting range:	0.1In – 20In in steps of 0.05In	
Operating time:	min 6ms typical 10ms	
Accuracy:	±5% at fn, 20°C	
Time delayed trip LD2		
Current range:	0.1In – 20In in steps of 0.05In	
Timing range:	0.1s – 9.98s in steps of 0.05s	
Accuracy:	+30ms ±10ms LFZP 142	
Time delayed trip LD3		
Current range:	0.1In – 20In in steps of 0.05In	
Time curves:	Eight curves shown in Figure 10 and three definite time ranges	
Time multiplier:	*t= 0.025 to 1.000 in steps of 0.025 accuracy at fn, 20°C, *t=1	
Current:	+10% – 0%	
Operating time:	definite time	±3% 2Is to 31Is
	curves 1,2,4,5,6,7,8	±5% 2Is to 31Is
	curve 3	±7.5% 2Is to 20Is

Fault location and instrumentation (optional extra)

Fault location positive sequence settings referred to line VT and CT secondaries:

Range:	LFZP 141	0.2 to 200Ω (In = 1A) 0.04 to 40Ω (In = 5A)
	LFZP 142	0.1 to 100Ω (In = 1A) 0.02 to 20Ω (In = 5A)
Setting:		Zone F = KZF KZPh.5/In LFZP 141 Zone F = KZF KZPh.5/2In LFZP 142

KZPh is common to the distance measuring elements

KZF range: 1.00 to 40.00 in steps of 0.01

Line length setting (in miles, km, or %, with reactive ohms):

0.00 to 99.99 in steps of 0.01

100.0 to 999.9 in steps of 0.1

Accuracy ±2% at 2In, fn, 20°C

Settings to allow for transformer ratios for instrumentation functions:

CT ratio: 1:1 or 10 to 2000:1 in 10:1 steps

VT ratio: 1:1 or 10 to 5000:1 in 10:1 steps

Block or enable auto-reclose logic

A normally-open or normally-closed contact is supplied on most models to block or enable auto-reclose respectively

The menu allows the following choices of logic:

Auto-reclose blocked or enabled on:

Zone 1X and/or Zone 1Y (LFZP141) and/or Zone 2 time delayed trip

LFZP 142 only LD1 instantaneous and/or LD2 time delayed and/or LD3 time delayed

Channel out of service

Voltage transformer (fuse fail) supervision

The voltage transformer supervision (VTS) operates when the ac voltage fails. A 15s delay prevents a temporary depression of voltage giving an alarm, also the threshold level is such that traction load does not operate the alarm. The VTS does not limit the distance relay current sensitivity or operating times for line faults even when it is set to block relay tripping.

The blocking action of the VTS on distance comparators can be removed by menu selection via the user interface.

When the busbar supply is de-energised, alarms may be prevented by connecting the Inhibit VTS opto-isolator

Switch-on-to-fault logic

Menu choices allow instantaneous trip and alarm and indication for faults occurring on line energisation, whether busbar or line voltage transformers are used:

SOTF enabled either 0.2s or 110s after line de-energised
(110s prevents SOTF action on auto-reclosure)

SOTF trip via measuring elements SOTF trip via current and voltage level detectors

Output contacts

The available arrangements are shown in Table 1

Ratings:	Make and carry 7500VA for 0.2s, maxima 30A, 300V, ac or dc
	Carry continuously 5A ac or dc
Break	ac: 1250VA dc: 50W resistive 25W L/R = 0.04s } maxima 5A, 300V
Durability: Loaded contact Unloaded contact	 10,000 operations minimum 100,000 operations minimum.

Atmospheric environment

Temperature	
IEC 60255-6:1988	Storage and transit –25°C to +70°C Operating –25°C to +55°C
IEC 60068-2-1:1990	Cold
IEC 60068-2-2:1974	Dry Heat
Humidity IEC 60068-2-3:1969	 56 days at 93% RH and 40°C
Enclosure protection IEC 60529:1989	 IP50 (dust protected)

Mechanical environment

Vibration IEC 60255-21-1:1988	 Response Class 1

High voltage withstand

Dielectric withstand IEC 60255-5:1977	2kV rms for 1 minute between all case terminals connected together and the case earth terminal. 2kV rms for 1 minute between all terminals of independent circuits, with terminals on each independent circuit connected together. 1.5kV rms for 1 minute across normally open outgoing contact pairs.

High voltage impulse IEC 60255-5:1977	Three positive and three negative impulses of 5kV peak, 1.2/50µs, 0.5J between all terminals of the same circuit (except output contacts), independent circuits, and all terminals connected together and case earth.

Electrical environment

High frequency disturbance IEC 60255-22-1:1988 Class III	2.5kV peak between independent circuits and between independent circuits and case earth. 1.0kV peak across terminals of the same circuit (except metallic contacts).
Fast transient disturbance IEC 60255-22-4:1992 Class IV	4kV, 25kHz applied directly to auxiliary supply.
IEC 60801-4:1988 Level 4	4kV, 25kHz applied directly to all inputs.
Electrostatic discharge IEC 60255-22-2:1989 Class III	8kV discharge in air with cover in place.
IEC 801-2:1991 Level 3	8kV point contact discharge with cover removed.
EMC compliance 89/336/EEC	Compliance with the European Commission Directive on EMC is claimed via the Technical Construction File route.
EN 50081-2:1994 EN 50082-2:1995	Generic Standards were used to establish conformity.
CE Product Safety 73/23/EEC	Compliance with the European Commission low voltage directive
EN 61010-1:1993/A2:1995 EN 60950:1992/A3:1995	Compliance is demonstrated by reference to generic safety standards

Table 1. Standard output contact case terminal connections

	Contact configuration					
Terminal	01		02		03	
29–31	RIA	97Y	RIA	97Y	RIA	97Y
29–33	VTS	97X	VTS	97X	VTS	97X
29–35	Z1	Z1	Z1	Z1	Z1	Z1
37–39	Z2T	Z2(T)	Time delay TR	94T	Time delay TR	94T
41–43	SOTF	98	SOTF	98	SOTF	98
45–47	Z3T	Z3(T)	Signal send	85X	BAR	96
49–51	Any trip	94	Any trip	94	Any trip	94
53–55	Trip	94T	Trip	94T	Trip	94(T)

Key to contact functions

85X	Signal send	Z1	Zone 1 trip
94	Any trip	Z2(T)	Zone 2 time delay trip
94T	Trip	Z3(T)	Zone 3 time delay trip
96	Block auto–reclose		
97Y	Relay inoperative alarm		
97X	Voltage transformer supervision		
98	Switch on to fault trip		

Dimensions:

For outline drawings see Figure 11

Weight: 12kg

Information Required with Order

Whether fault location required

Nominal current rating In: 1A or 5A

Frequency fn:
25Hz, 50Hz or 60Hz

Voltage of dc supply Vx(1):
48/54V, 110/125V or 220/250V

Voltage of dc supply Vx(2)
48/54V, 110/125V or 220/250V

Mounting arrangements: rack, panel horizontal, panel vertical, semi projection

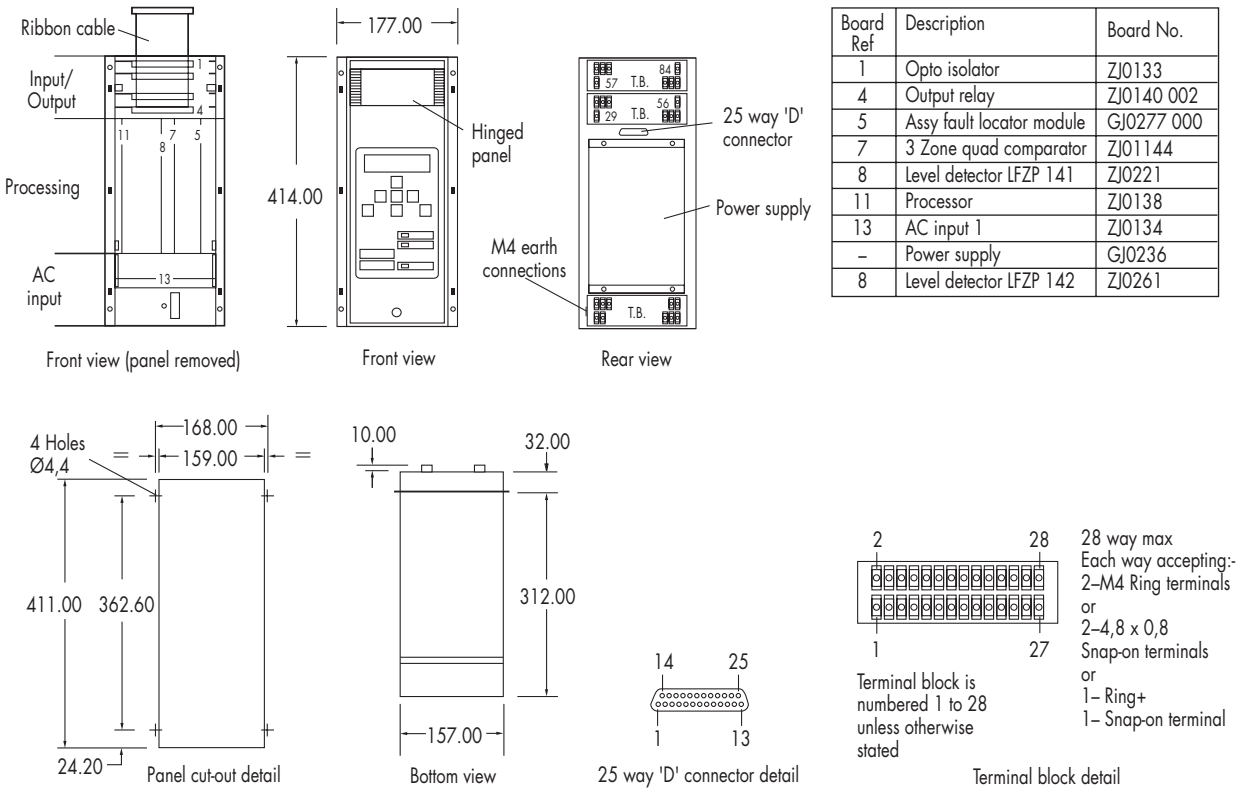
Whether the block auto-reclose contact 96 is to be a normally-open or normally-closed contact

Whether the signal send contact 85X is to be a normally-open or normally-closed contact

Advice is available when the information requested above is difficult to specify

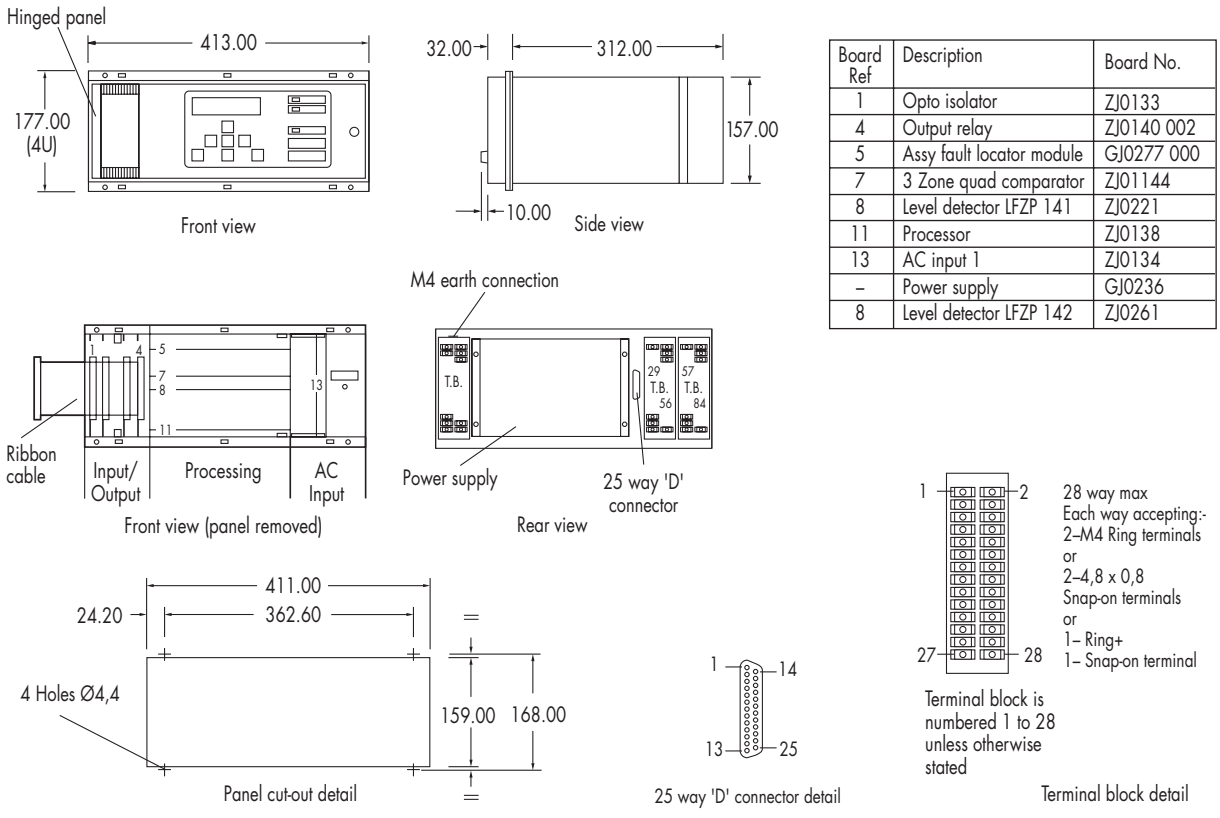
Requests for advice should include:

- current and voltage transformer ratios
- impedances of the protected feeder or full details of the feeder lengths and construction
- source impedances or fault levels for both minimum and maximum plant conditions



Board Ref	Description	Board No.
1	Opto isolator	ZJ0133
4	Output relay	ZJ0140 002
5	Assy fault locator module	GJ0277 000
7	3 Zone quad comparator	ZJ01144
8	Level detector LFZP 141	ZJ0221
11	Processor	ZJ0138
13	AC input 1	ZJ0134
–	Power supply	GJ0236
8	Level detector LFZP 142	ZJ0261

Figure 11a:
Arrangement and outline: Optimho panel mounting vertical



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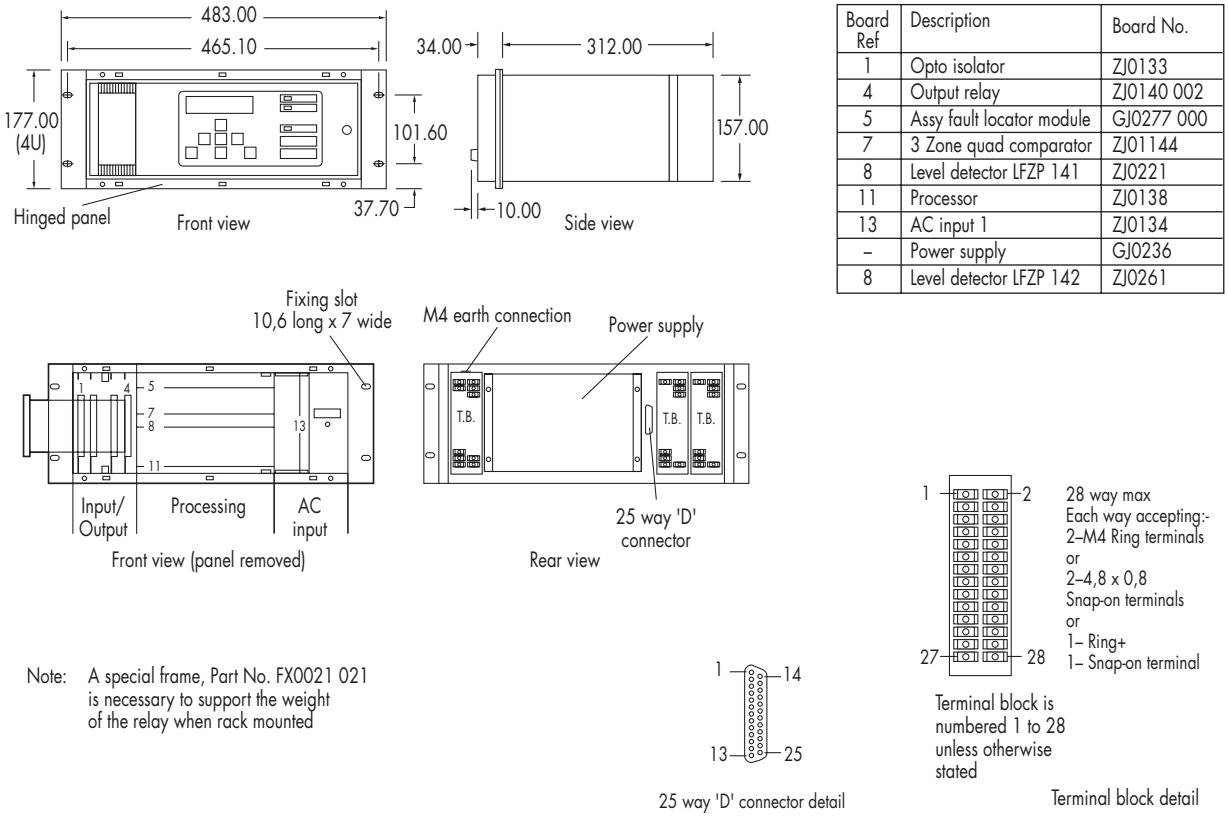
7	3 Zone quad comparator	ZJ01144
8	Level detector LFZP 141	ZJ0221
11	Processor	ZJ0138
13	AC input 1	ZJ0134
–	Power supply	GJ0236
8	Level detector LFZP 142	ZJ0261

Figure 11b:
Arrangement and outline: Optimho panel mounting horizontal



Board Ref	Description	Board No.
1	Opto isolator	ZJ0133
4	Output relay	ZJ0140 002
5	Assy fault locator module	GJ0277 000
7	3 Zone quad comparator	ZJ01144
8	Level detector LFZP 141	ZJ0221
11	Processor	ZJ0138
13	AC input 1	ZJ0134
–	Power supply	GJ0236
8	Level detector LFZP 142	ZJ0261

Figure 11c:
Arrangement and outline: Optimho rack mounting

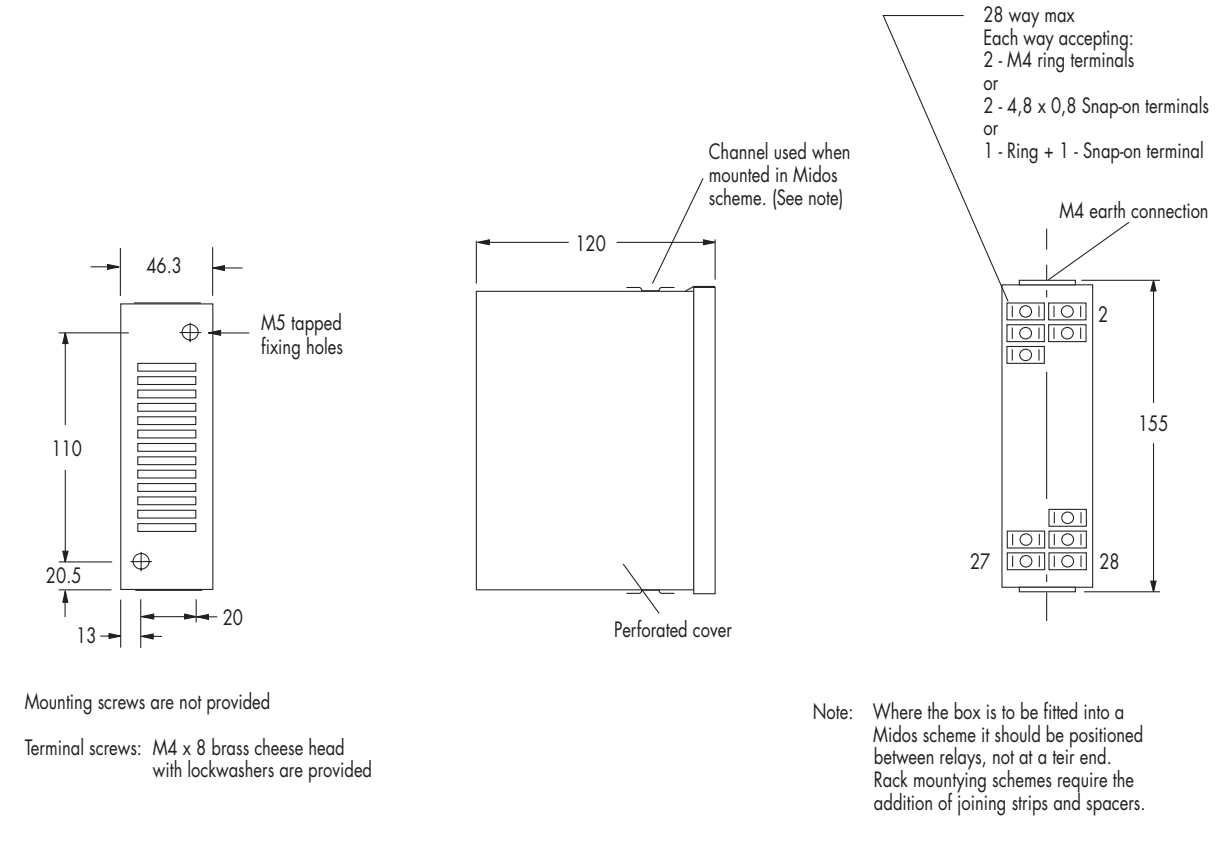


Figure 12:
External resistor box for 220/250V supplies

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