Type LFCB
Digital Current Differential Relay

ALSTOM

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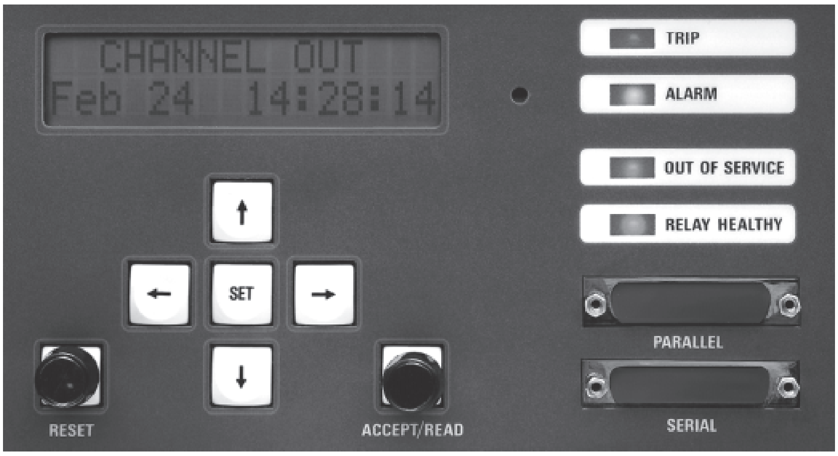


Figure 1: Operator interface

Features

- Unit protection for two and three terminal feeders
- Phase segregated differential current protection with high sensitivity
- Single and three pole tripping
- Suitable for use with dedicated optical fibre links or multiplexed systems
- Optional dual redundant communication channels for two terminal feeders
- Continuous channel propagation delay measurement and compensation
- 1 to $1^1/_2$ cycle operating time when used with a standard 56 or 64kb/s channel
- Power-on diagnostic and continuous self-monitoring
- Event recording, fault recording and intertripping
- Remote interrogation via RS232 serial link

Models Available

Three models are available:

LFCB102 – for two terminal applications

LFCB103 – for three terminal applications

LFCB202 – for two terminal applications, with dual redundant communication channels

Introduced in July 1993, there are three versions of the LFCB which have the facility to provide protection where the line is fed from two circuit breakers, as often found in $1^1/_2$ switch substations or mesh corner applications. This protection of the line between the Circuit Breakers (when closed) and Line Isolator (when open) ensures that only the local relay operates for faults in this area. Normal current differential protection is carried out when the Line Isolator is closed.

These versions are:

LFCB122 – for two terminal applications

LFCB123 – for three terminal applications

LFCB222 – for two terminal applications, with dual redundant communication channels

A range of communication interfaces is available to allow the LFCB to work with different types of dedicated or multiplexed communications links.

Application

Current differential protection requires a comparison of the currents entering and leaving a protected zone.
A dependable communication facility is needed to allow information exchange between relays at different line ends so that each can compare the local currents with the currents at the remote ends.

The digital current differential relay, type LFCB, offers phase selective, true differential protection for two and three terminal transmission and sub-transmission lines. The relay is an all digital, microprocessor based

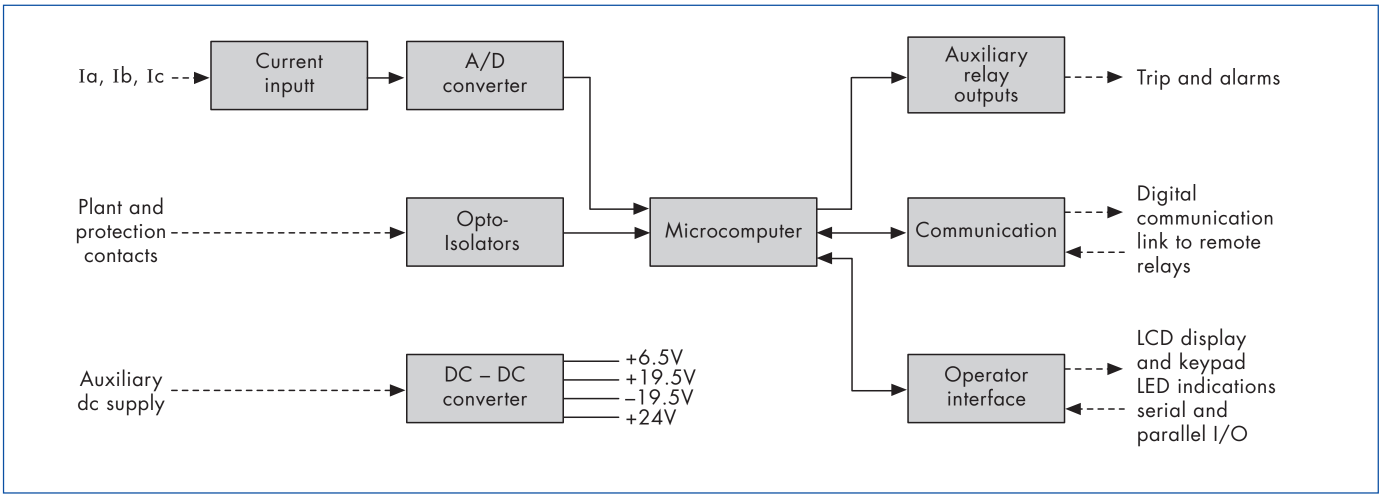


Figure 2: Block diagram

design for use with modern digital communication systems. Since data can easily be mixed and carried within a digital data message, all three phase current signals are transmitted over the same communication channel.
Currents are compared on a per phase basis, obviating the biasing problem of the conventional summation current trans-former approach and providing phase selection information for single pole tripping and to identify the fault type. Relays at all ends operate simultaneously providing rapid fault clearance irrespective of whether the fault current is fed from all terminals or from only one line end.

Intertripping commands and status information are also carried within the data message to provide auxiliary intertripping facilities and other information.

An LFCB102 version is available with segregated phase direct intertripping.

The LFCB202 relay provides redundancy of communication by transmitting and receiving messages over two communication channels. Both channels are monitored continuously by the relay. If one of the channels has failed, communication between the relays can still be maintained by the other healthy channel.
The LFCB202 is applicable to two terminal lines only.

The LFCB does not include harmonic restraint against transformer magnetising in-rush currents and so is not suitable for circuits which have power transformers within the protected zone.

Description

The relay is housed in a 4U (178mm) high case suitable for either rack or panel mounting.
The relay has a modular construction using plug-in modules which are individually tested and calibrated in the factory.
If necessary, modules can be exchanged without any need to recalibrate the relay.

The analogue inputs from main current transformers (1A or 5A) are scaled down by very low burden (<0.1VA) relay current transformers and then converted into digital data by a 12 bit analogue to digital converter. External plant status and control signals are received via opto isolated inputs in the same module.
The analogue and status inputs are sampled at a rate of 8 samples per cycle.

A 16 bit microprocessor module is used to control data acquisition, process protection and control algorithms, and to control the output and communication modules.
It contains read-only memory (ROM) for programmes, non volatile read/ write memory (EEPROM) for settings and operation records and read/ write memory (RAM) for temporary data.

An RS232 serial communication facility is also provided which can be used to interrogate the relay either locally or remotely.

A high performance communication module provides two independent duplex channels for signalling between relays. These are based on the high level data link control protocol (HDLC). The channels are capable of operating at up to 1Mb/s but are normally set to operate at 56 or 64kb/s.
The module incorporates its own microprocessor to handle the high speed data communication and to process part of the protection and signalling functions.

Two output relay modules, each containing eight hinged armature relays, provide twenty six trip and alarm contacts.

A power supply module converts power from a dc supply to internal voltage rails. A power failure monitoring circuit with alarm output contact is included. The relay consumes less than 10W in the quiescent state and less than 20W under tripping conditions.

The front panel operator interface, shown in Figure 1, consists of a 2 row by 16 character alphanumeric liquid crystal display (LCD) together with a seven pushbutton keypad.
With the cover in position only the ‘ACCEPT/READ’ key, for reading

and accepting alarms, and reading the relay settings, and the 'RESET' key, for clearing alarms, are accessible.

Other information available for display includes phase, differential and bias current magnitudes at local and remote ends, fault and alarm records, communication error statistics and setting values.
They are selected for display using the five pushbuttons arranged in a cruciform pattern, four of these act as cursor keys for selecting commands or altering parameters in a menu fashion.
The 'SET' key at the centre is used to confirm new settings and other security related commands.

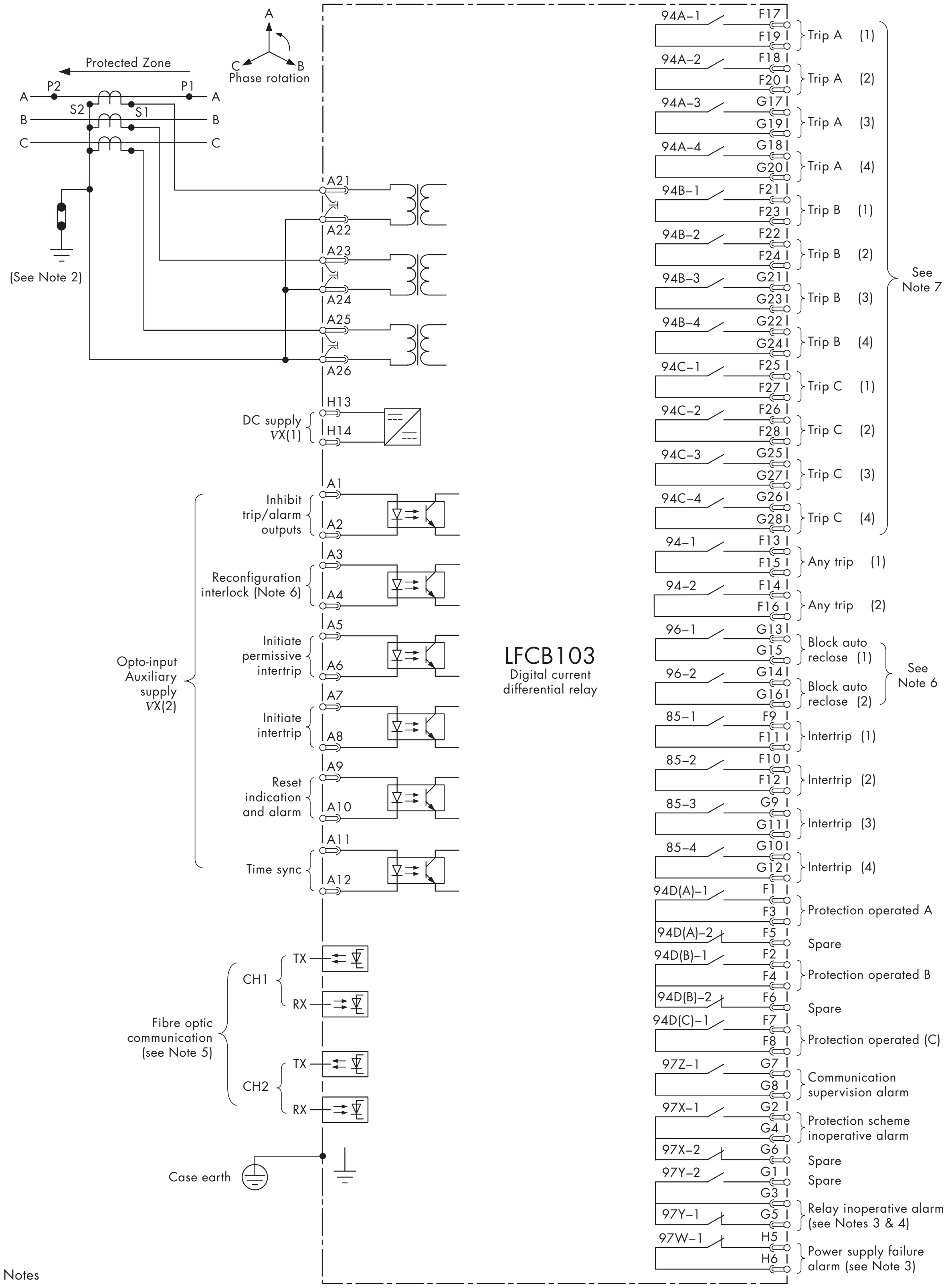
The relay has four indicating lamps and two 25 pin D type sockets mounted on its front panel.
One socket is used for local RS232 serial communication whilst the other is a parallel input/output port which functions either as a parallel printer port or as a test port for connection to computer based injection testing equipment.

Operation

An LFCB current differential protection system consists of identical relay units located at each end of the protected line. In contrast to conventional analogue relays, the three phase currents at each line end are measured by sampling at a fixed frequency. The data samples represent the instantaneous values of the current waveforms and may contain dc offset, harmonics and high frequency components. It is desirable therefore to filter and preprocess the data to a form suitable for the calculation of the magnitudes of differential and bias currents. This is achieved by digital filtering using the One Cycle Fourier filtering technique which yields the power frequency components of the current waveforms in vector form.
The vector values of all three phases together with other relevant timing and status information are transmitted over the communication channels to the other ends of the line. Based on the local and received vector information, the differential currents and bias currents of all three phases can be calculated and compared on a per phase basis to make the tripping decision.

When vector samples from each end are compared, they must correspond to the same sampling instant to prevent an erroneous differential current being measured. Unless the sampling times are synchronised at each end, it is necessary for the vector samples to be time aligned to compensate for the different sampling instants and the channel propagation delay for data to be sent from one end to another.

A number of methods can be used to synchronise data sampling of relays at different ends. Most of the methods however require an external clock reference and complex clock generation and control circuitry.
The LFCB uses a novel software controlled 'poll and answer' technique which has been devised to provide a means of continuously monitoring and measuring the propagation delay of the communication channels during the process of obtaining current vector information from remote ends.
The technique assumes equal channel propagation delay for the data transmit and receive paths.
No synchronisation is required for data sampling at the different line ends as the process of polling vector information also includes measurement of the time deviation of data sampling between line ends.
A software technique is then used to time align current vectors from different line ends to a common time frame before the differential and bias currents are calculated.



Notes

1. (a) CT shorting links make before (b) and (c) disconnect.
   (b) Short terminals break before (c).
   (c) Long terminals.
2. Earthing connections are typical only.
3. All outputs are shown de-energised. Under healthy operating conditions the output is energised. The following conditions will cause the contacts to reset:
   A. Loss of dc supply.
   B. Loss of internal dc rail voltage.
4. The following conditions will also cause the contacts to reset:
   A. Failure detected by micro computer during power-on diagnostics.
   B. Failure detected by micro computer during run-time self monitoring.
   C. Loss of internal clock pulse signals.
   D. Operation of internal watchdog circuit.
5. Optical connectors are of SMA 9mm type unless otherwise specified.
6. The block auto-reclose contacts can be selected to close on permissive intertrip or to close on permissive intertrip and 3 phase fault trip.
7. The trip A, trip B and trip C contacts close for any trip conditions if three pole tripping mode is selected.

Figure 3: External connection diagram: type LFCB digital current differential relay with fibre optic communications interface.

Bias Restraint Characteristic

The relay has a dual slope percentage bias restraint characteristic as shown in Figure 4. The initial bias slope ensures sensitivity to low level faults. As the fault level rises, extra errors may be introduced as a result of current transformer saturation and the bias slope is therefore increased to compensate for this.

Power-on Diagnostics and Continuous Self-Monitoring

Power-on diagnostic tests are carried out automatically by the relay when it is switched on. These tests include checks on the timer, microprocessor, memory and other major components. There are also a number of system checks which continuously monitor the operation of the relay.

In the event of a failure detected by the power-on diagnostic or self-monitoring tests, an error message is displayed on the front panel LCD and the ‘relay inoperative alarm’ output contact closes. The relay will then either lock out or attempt a recovery depending on the type of failure detected.

Test Facilities

Test facilities are provided to enable the relay to be thoroughly tested during commissioning, routine maintenance and fault finding operations. One test facility is the 25 way parallel socket on the front panel which allows the internal voltage rails and the states of the trip and block auto-reclose outputs of the relay to be checked whilst the relay is in service. The socket also has input lines which can be used to emulate keystrokes on the front panel, facilitating the use of computer based secondary injection test sets to interact with the relay and issue operator commands for outputting data or changing settings. This reduces line outage during routine testing.

A number of tests are available through the operator interface. A measurement function is provided which displays local and remote phase and sequence component currents on the LCD. This can be used to check the analogue input hardware and software, also current transformer polarity and connections. Test options are provided to display the on/off states of the opto-isolated status inputs and to perform a lamp test on the four relay indicating lamps.

Further test options enable the relay trip and alarm outputs and their associated circuits to be tested.

Event and Fault Recording

The relay keeps a record of the last ten alarms/events which are stored in non-volatile EEPROM memory and these are preserved, even in case of a power loss. Each event record gives the cause of the event and the time and date of its occurrence.

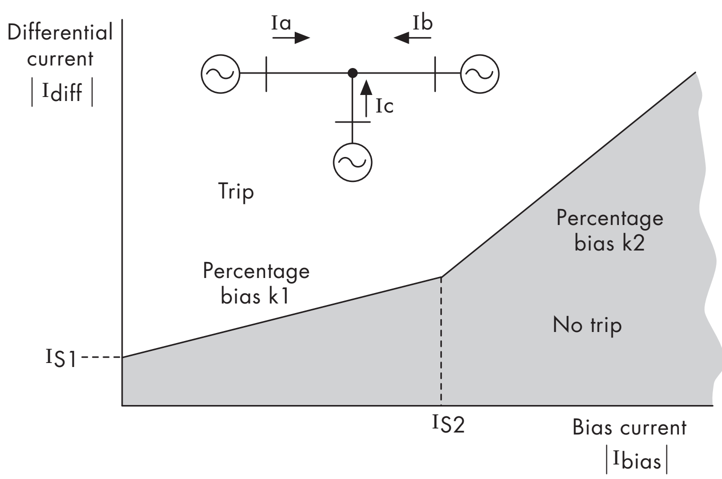
The relay also records the last three fault records in non-volatile EEPROM memory. Each fault record contains information on the fault type and the magnitudes of the local, remote, differential and bias currents of the three phases and time and date of the operation of the relay.

Print Facility

Settings and recorded information stored in the relay can be printed out via the parallel port or the serial port on the front panel.
Each printout contains the user defined relay identification and time and date of printing.

Remote Interrogation via RS232 Serial Link

A 25 pin D type socket is also provided at the rear of the relay to allow an operator to communicate with the relay via the serial port using a visual display unit (VDU) or personal computer. The facility emulates the front panel keypad and LCD and allows access to the



$|I_{diff}| = |I_a + I_b + I_c|$

$|I_{bias}| = 0.5\,(|I_a| + |I_b| + |I_c|)$

The relay operates when

(1) For $|I_{bias}| \leqslant I_{S2}$

$|I_{diff}| > k_1\,|I_{bias}| + I_{S1}$

(2) For $|I_{bias}| > I_{S2}$

$|I_{diff}| > k_2\,|I_{bias}| - (k_2 - k_1)\,I_{S2} + I_{S1}$

Figure 4: Bias restraint characteristic

command menu. Given a suitable serial communication link the operator can interrogate the relay remotely and ask for print-outs of fault and alarm records and other information. It is also possible to change settings, if the relay has been set up to allow full remote access.

Intertrip Facility

This is an auxiliary signalling facility whereby when the 'initiate intertrip' opto isolator is activated, the relay sets a corresponding status bit in its transmit message to command the remote relays to close their intertrip output contacts (85-1 to 85-4).
It may be assigned by the user to any trip or signalling function such as direct transfer trip or to block auto-reclose.

Permissive Intertrip Facility

The permissive intertrip facility is provided to intertrip circuit breakers at the remote ends. The 'initiate permissive intertrip' opto-isolated input may, for example, be connected to an output contact of a busbar relay to intertrip remote breakers upon a busbar fault.
When the 'Initiate permissive intertrip' input is activated, the relay sets a corresponding status bit in its transmit message.
This commands the remote relays to check if the current flowing into the initiating end exceeds the current threshold setting I_{S1} and if so, to trip after the permissive intertrip time setting is exceeded. The permissive intertrip time delay allows time for the fault to be cleared by circuit breakers at the initiating end. This is similar to a conventional interlocked overcurrent scheme except that the overcurrent check is done at the remote ends and no additional relays are needed.
The permissive intertrip shares the trip output contacts of the current differential protection function but always trips three phase.

The relay provides two output contacts for blocking auto-reclose on permissive intertrip. These contacts may also be selected to block auto-reclose on three phase faults.

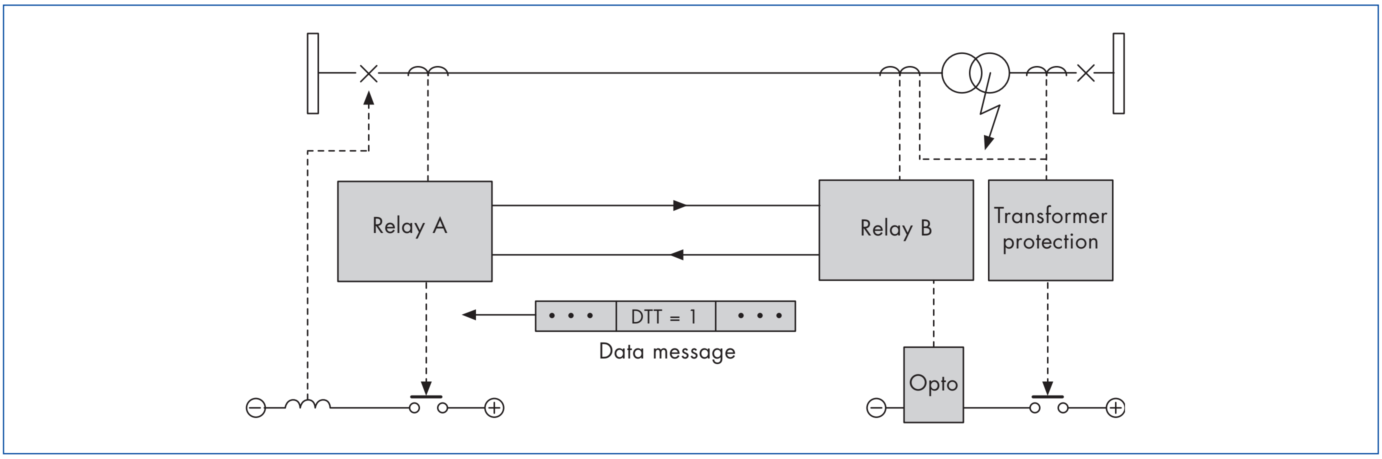


Figure 5: Direct intertrip

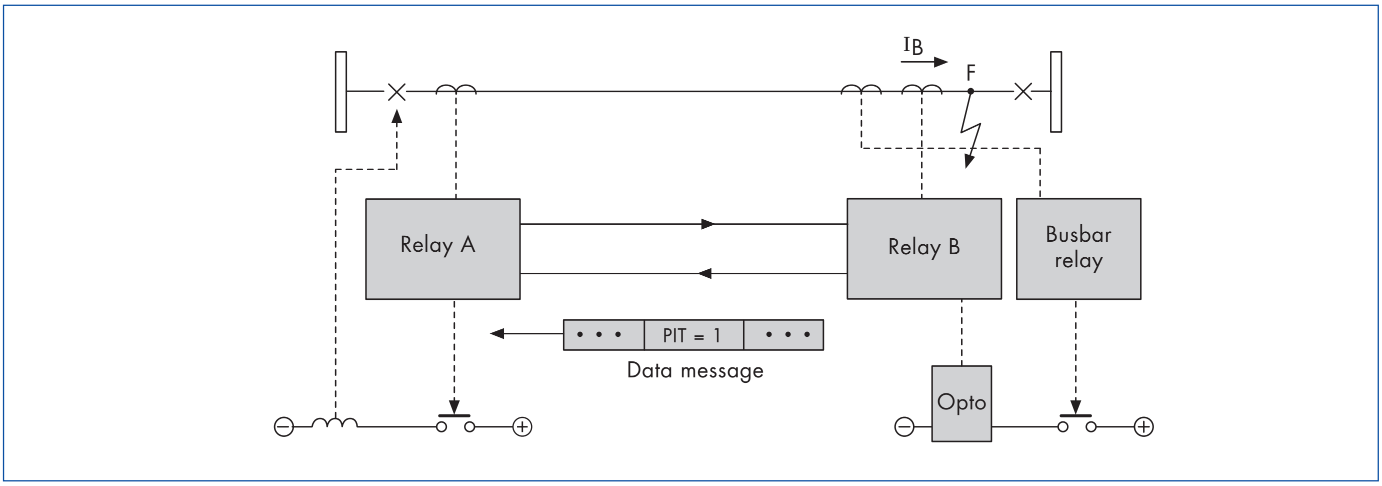


Figure 6: Permissive intertrip

Three to Two Terminal Reconfiguration (LFCB103 or LFCB123 only)

The LFCB103 relay is normally used for the protection of three terminal lines. The relay can, however, be set for two terminal operation.
This allows the relay to be applied to a two terminal line which may be converted to a three terminal line at a later date. Since only a setting change is required to configure the relay for two or three terminal operation, no hardware or wiring changes are required when the third terminal is added. Additional security interlocks are incorporated in the setting procedure to provide added security when changing the relay configuration.

For operational reasons it may be necessary to switch out one of the line ends, and its associated relay, on a three terminal circuit. A second reconfiguration feature is provided with the LFCB103 by which, after all security checks are satisfied, an operator at one end can command the two remote relays to work as a two terminal system. The local relay can then be switched off leaving the now two terminal line to be protected by the two remote relays.
A restore command can similarly be issued to bring the system back to three terminal operation.

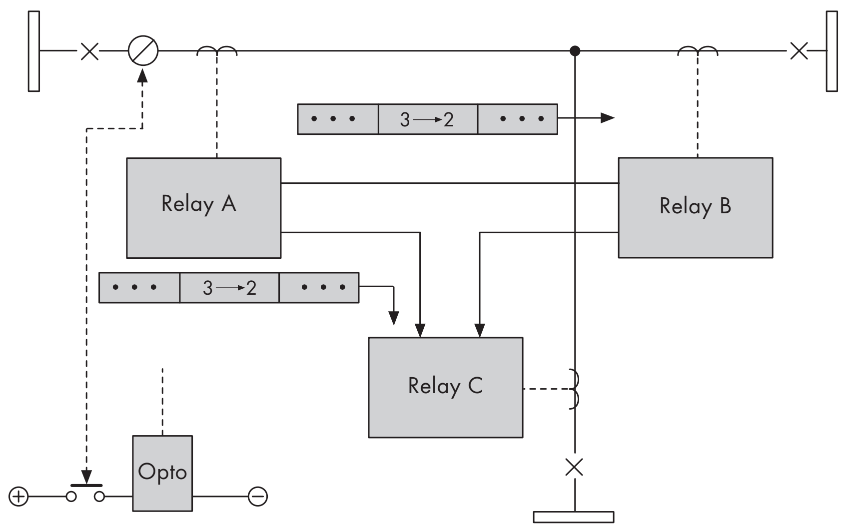


Figure 7: Reconfiguration

Communication Interfacing

To ensure compatibility with a wide range of communication equipment and media the LFCB is designed to work within the signalling bandwidth of a basic 56/64kb/s pulse code modulated (PCM) channel.

Several options are available for interfacing the LFCB to a communications link. The link can be either dedicated to the current differential protection signalling or multiplexed and shared with other protection and telecommunication equipment, employing optical fibres or conventional media (see Figure 8). The modular design of the LFCB means only the communication interface module need be varied to suit different requirements. The basic interface options are described below.

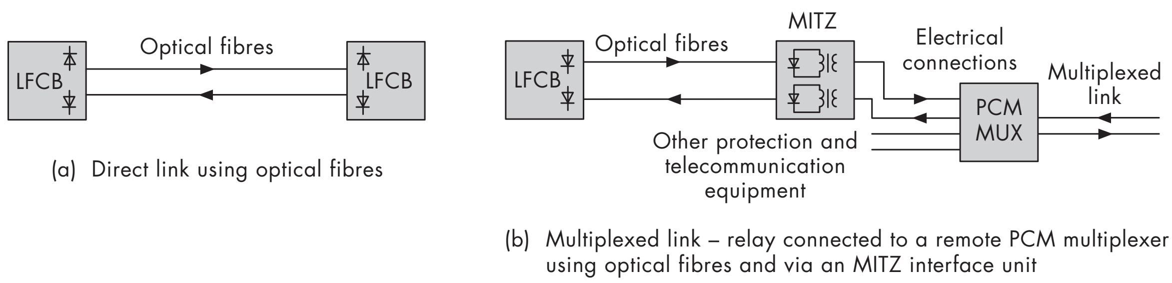


Figure 8: Communications arrangements

Dedicated Optical Link

Different ranges of communication distance require different types of optical transmitting and receiving devices. The LFCB has three basic versions of optical communication interface, all of which operate with 50/125µm multimode fibres at the 850nm wavelength and use SMA 9mm type optical connectors.

The basic short range 850nm interface has an optical budget of 0–14dB. Medium and long range 850nm interfaces are also available.

Details of versions suitable for dedicated 1300nm or 1550nm wavelength applications are available upon request.
The 1300nm interface can be specified for use on either multi mode or single mode optical fibre.
The 1500nm interface can only be used with single mode fibre.
All 1300nm and 1500nm interfaces are available with ST or FC/PC style optical connectors.

Multiplexed Link-Optical Cables Connecting Relay and Multiplexer

When using multiplexers, the LFCB relay should contain the short range 850nm optical interface (see section: Dedicated Optical Link for details).
An MITZ interface is required at the multiplexer end for optical/electrical signal conversions. One MITZ unit is required per communications channel per relay. All MITZ units use the same type of optical transmitter and receiver as the LFCB short range 850nm optical interface.

MITZ versions
The MITZ 01 interface unit supports G.703 co-directional interfacing.

The MITZ 02 interface unit supports V.35 interfacing.

The MITZ 03 interface unit supports X.21 interfacing. This unit may also support subsets of RS449.
Please contact ALSTOM T&D Protection & Control Ltd for any further information.

Note: The co-directional G.703, V.35 and X.21 interfaces comply with CCITT recommendations.

Technical Data

Ratings

Current (I_n)	1A or 5A (4 x I_n continuous) ($100I_n$ or 400A or 1s)	
Frequency	Nominal 50Hz 60Hz	Operative Range 47 to 51Hz 56.4 to 61.2Hz
Auxiliary voltage $V_{x(1)}$ (DC) (Relay power supply)	Nominal 24/27V 30/34V 48/54V 110/125V 220/250V	Operative Range 19.2 – 32.4V 24 – 40.8V 38.4 – 64.8V 88 – 150V 176 – 300V
Auxiliary voltage $V_{x(2)}$ (DC) (Opto-isolator supply)	Nominal 24/34V 48/54V 110/125V 220/250V	Operative Range 19.2 – 40.8V 38.4 – 64.8V 88 – 150V 176 – 300V
	Note: $V_{x(2)}$ may be different from $V_{x(1)}$	

Characteristic

See Figure 4

Settings

Basic differential current (I_{S1}) Threshold for increase bias (I_{S2})	0.2 to $2I_n$ in 0.05 steps 1 to $30I_n$ in 0.05 steps
Bias k_1 ($I_{bias} < I_{S2}$)	30% to 150% in 5% steps
Bias k_2 ($I_{bias} > I_{S2}$)	30% to 150% in 5% steps

Accuracy

Better than ±10% under reference conditions.
The effective accuracy range is up to $30I_n$.

Accuracy is unaffected by dc supply or ambient temperature variations within their operative ranges.

Operating time

Frequency	Minimum	Typical
50Hz	18ms	22 – 30ms
60Hz	16ms	19 – 25ms

Reset time

59ms max (50Hz)

52ms max (60Hz)

Note: The trip contacts remain closed for a minimum of 60ms.

Returning ratio

75%

Note: This is the differential current at which the relay resets, divided by the differential current at which the relay operates.

Contact rating

Make and carry for 0.2s	7500VA (30A or 300V ac or dc maxima)
Carry continuously	5A ac or dc
Break (10^4 operations)	AC 1250VA DC 50W resistive 25W inductive, L/R=40ms 5A or 300V maxima

Durability

Loaded contact	10,000 operations minimum
Unloaded contact	100,000 operations minimum

Burdens

AC	<0.1VA
DC ($V_{x(1)}$)	10W quiescent: 20W tripping
DC ($V_{x(2)}$)	Maximum 0.3W mean burden per input.

Calendar clock

Based on an internal free running crystal oscillator. Accuracy is within ±2s per day.

The clock can be synchronised to an external source at either 5, 10, 15, 30 or 60 minute intervals.

Intertrip

Operating time	20 – 25ms typical (50Hz) 18 – 22ms typical (60Hz)
Reset time	25ms max (50Hz) 21ms max (60Hz)
	Note: The intertrip contacts remain closed for a minimum of 60ms.

Permissive intertrip

Time delay setting	0 – 200ms in 5ms steps
Operating time after delay setting	22 – 27ms typical (50Hz) 19 – 23ms typical (60Hz)
Reset time	26ms max (50Hz) 24ms max (60Hz)
	Note: The trip contacts remain closed for a minimum of 60ms.

Current transformer requirements

BS3938 Class X

For applications where the maximum value of secondary through fault current x primary system X/R is less than $120I_n$, then:

for $I_{S2} = 2I_n$; $k_1 = 30\%$; $k_2 = 100\%$
$V_k > 95I_n (R_{CT} + 2R_L)$

for $I_{S2} = 2I_n$; $k_1 = 30\%$; $k_2 = 150\%$
$V_k > 65I_n (R_{CT} + 2R_L)$; X/R <40

$V_k > 75I_n (R_{CT} + 2R_L)$; X/R <70

For applications where the maximum value of secondary through fault current x primary system X/R is less than $350I_n$, then:

for $I_{S2} = 2I_n$; $k_1 = 30\%$; $k_2 = 100\%$
$V_k > 180I_n (R_{CT} + 2R_L)$

for $I_{S2} = 2I_n$; $k_1 = 30\%$; $k_2 = 150\%$
$V_k > 85I_n (R_{CT} + 2R_L)$

Where V_k = kneepoint voltage of current transformer for through fault stability.

R_{CT} = resistance of current transformer secondary circuit (ohms).

R_L = lead resistance of single lead from relay to current transformer (ohms).

Note: I_F x X/R >120 generally occurs when the feeder being protected is short and is connected directly to a power station busbar, where the generator X/R value is high.

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 circuit connected together. 1kV 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 connected together and the case earth terminal. Three positive and three negative impulses of 5kV peak, 1.2/50µs, 0.5J between all independent circuits. Three positive and three negative impulses of 5kV peak, 1.2/50µs, 0.5J between all terminals, except contact circuits.

Electrical environment

High frequency disturbance IEC 60255-22-1:1988 Class III	2.5kV peak between independent circuits. 2.5kV peak between independent circuits and case earth. 1kV peak across input circuits.
Fast transient disturbance IEC 60255-22-4:1992 Class IV IEC 60801-4:1988 Level 4	4kV, 2.5kHz applied directly to auxiliary supply. 4kV, 2.5kHz applied directly to all inputs.
Electrostatic discharge IEC 60255-22-2:1989 Class IV	15kV – discharge in air with cover in place.
IEC 60801-2:1991 Level 4	8kV – point 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.
Product safety 73/23/EEC	Compliance with the European Commission Low Voltage Directive.
EN 61010-1: 1993/A2: 1995 EN 60950-1: 1992/A11: 1997	Compliance is demonstrated by reference to generic safety standards.

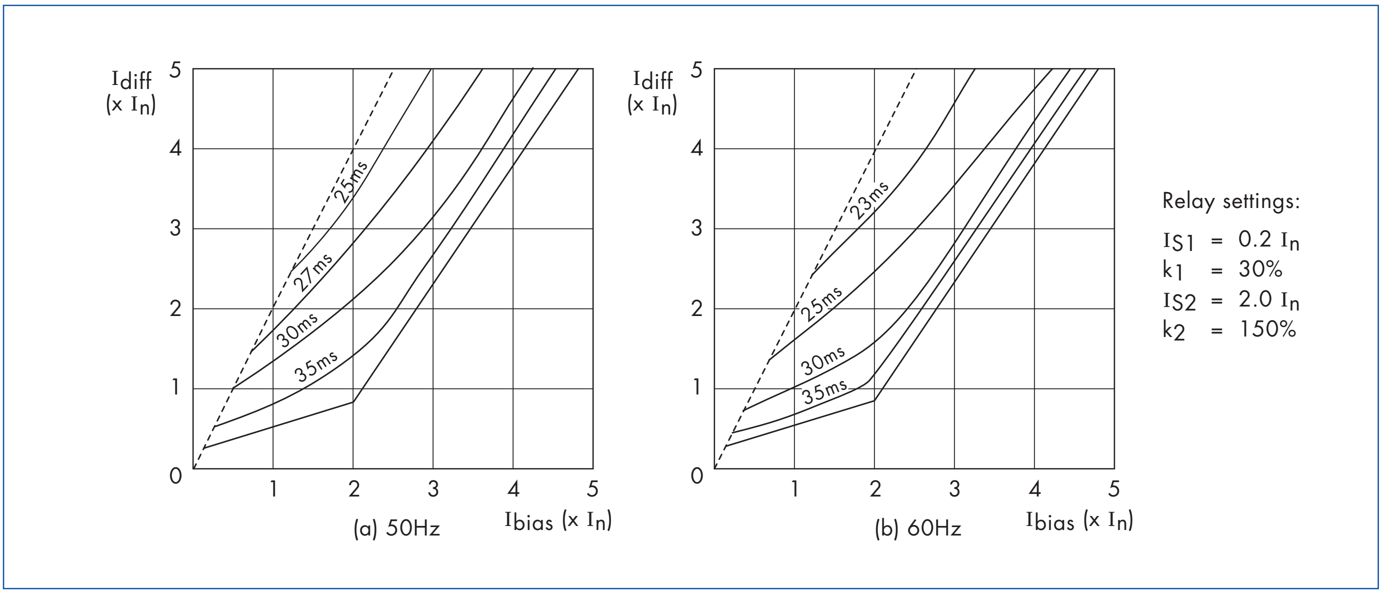


Figure 9: Typical operating times

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

Case

Type LFCB relays are housed in Multi-module MIDOS cases. (See Figure 10).

Information Required with Order

Type of relay		LFCB102, LFCB103 or LFCB202
Rated current		1A or 5A
Rated frequency		50Hz or 60Hz
Auxiliary supply voltages		$V_{x(1)}$ & $V_{x(2)}$
Type of communication interface being used:		
	Direct optical link	Length of link and type of fibre used, including optical loss budget if available.
	Multiplexed link	Channel data rate and interface specification.
		Distance between relay and multiplexing equipment.
		A type MITZ unit is required for optical to electrical signal conversions.
Case mounting		Rack
		Panel.

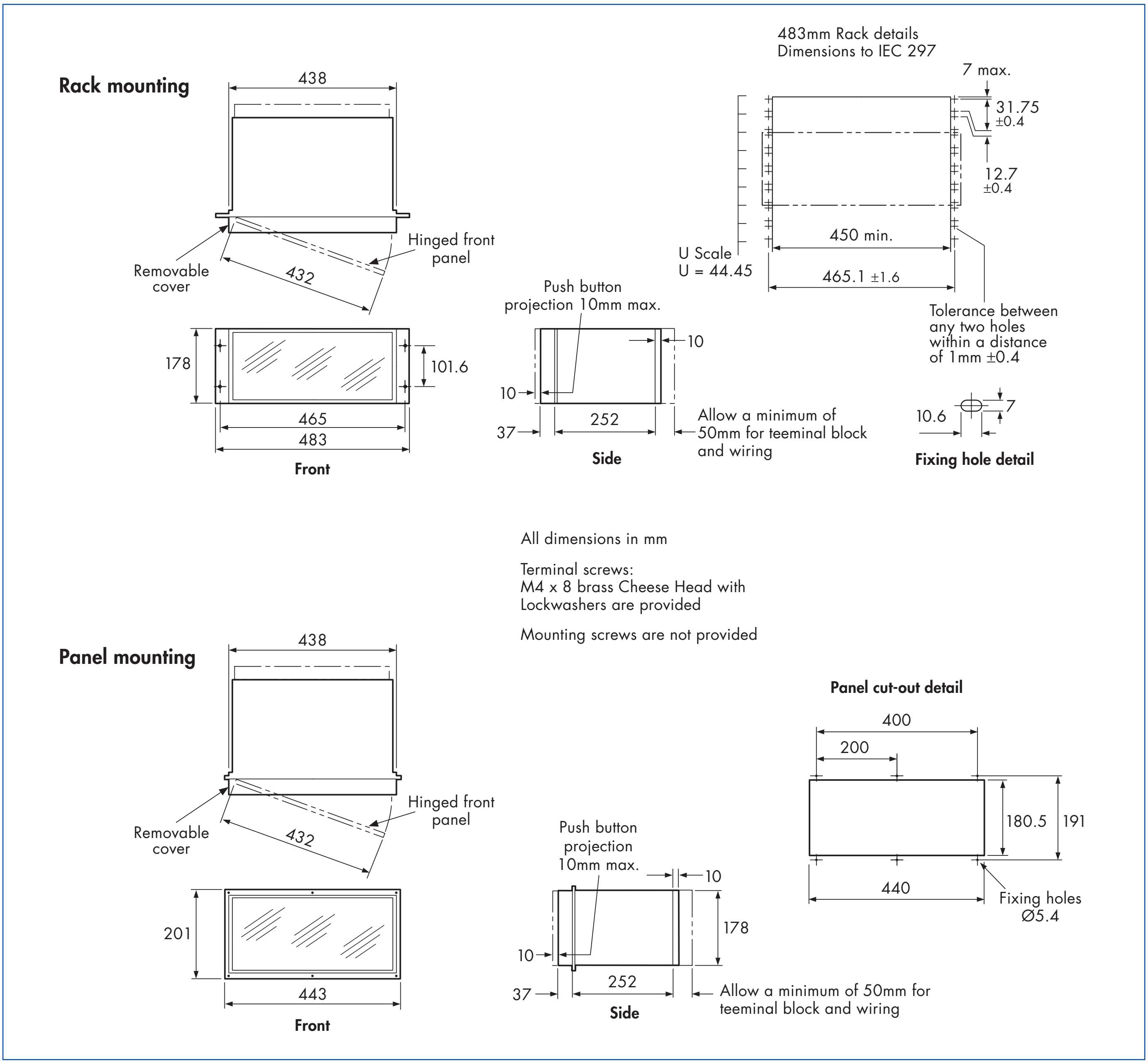


Figure 10: Case outlines

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