MiCOM P54x Series

Current Differential Protection with Optional Subcycle Distance

The MiCOM P543-P546 series provides high-speed current differential unit protection.
The P54x is designed for all overhead line and cable applications, as it interfaces readily with the longitudinal (end-end) communications channel between line terminals.
The interface options support direct fiber optic, or multiplexed digital links. Tripping uses a proven characteristic comparing differential current with through current, for ease of testing. Phase differential elements of this type offer consistent detection of solid and resistive faults, with optimum faulted phase selection, tripping, and indication.
A full range of back-up protection is integrated. This enhances the dependability of the protection, as hot-standby elements can be brought into service whenever a signalling channel outage may occur. The new P54x evolution (from design suffix K) adds high speed subcycle distance elements, allowing use in differential applications, distance, or both in parallel. One relay type thus becomes the standard in all HV-EHV-UHV line protection applications, duplicated where dual redundant main protection is demanded. Spares holdings are reduced, with one universal relay type used instead of two or more discrete models in the past.

CUSTOMER BENEFITS

- Highly selective unit protection.
- Extensive health monitoring for the communications channel.
- Optional mho and quadrilateral subcycle distance zones
- Programmable function keys

KEY FEATURES

- **Current differential protection**
  - Applicable to all lines and cables, long or short, strong and weak infeeds.
  - Phase selectivity without compromise on resistive fault sensitivity.
- **Multi-terminal applications - each relay equipped for 2 or 3 ended schemes**
- **Adapted to suit many different substation and protected unit topologies**
  - In-zone transformer-feeder applications (P543/P545 models).
  - Breaker and a half, or mesh feeding with two sets of CT inputs per end (P544/P546 models).
  - Compensates for line CT ratio mismatches and capacitive charging current.
  - Patented differential CT supervision technique allows independent alarms for each CT (including the remote CTs).
  - Compensed overvoltage features to counter Ferranti effects on lightly loaded long transmission lines.
- **Readily interfaces to end-end communications channels**
  - Differential scheme, and distance teleprotection over MUX or fiber links.
- **InterMiCOM option for end-end protection communication**
  - Reliable and secure, saving the investment in external teleprotection equipment.
- **Distance protection**
  - High speed operation in less than one cycle
  - Load blinder prevents spurious trips cascading through the network, in xtreme conditions such as on the verge of a blackout
- **Power swing alarm and block, plus out of step trip**
  - Unrivalled detection principle - automatic configuration, with no impedance starters or timer bands to set. -
- **Multi-shot autoreclosure with check synchronism**
  - Single circuit breaker applications (P543 & P545)
  - Dual circuit breaker applications (P544 & P546)
- **Programmable Scheme Logic**
- **Readily interfaces to multiple automation protocols, including DNP & IEC 61850**

Schneider Electric

APPLICATION

The P543 - P546 range offers fast, highly selective protection for use in line and cable feeder applications, right up to the highest transmission voltages. All models include differential main protection, with distance protection as an ordering option.

Choose the P544 or P546 in breaker and a half applications, where measurement of two sets of CT inputs offers better stability, and allows circuit breaker fail protection to identify the faulty breaker. Choose the P545 or P546 for extra logical I/O status.

The MiCOM P54x series is supplied with a full suite of protection and control functions as standard.

The configuration column of the menu is used to control which functions the user requires in the intended application, and which may be disabled. Disabled functions are completely removed from the menu, to simplify setting.

Current differential protection by its nature requires few protection settings, and of those all are generally left at the factory defaults. Distance elements have a simple setting mode - an inbuilt wizard, to avoid settings errors.

ANSI	IEC61850	Features	P543	P544	P545	P546
	OptGGIO	Opto coupled logic inputs	16	16	32	24
	RlyGGIO	Standard Relay output contacts	14	14	32	32
		Optional High Speed, High Break Output Contacts	4	4	8	8
		Two breaker configurations		•		•
		Clockwise and Anticlockwise phase rotation	•	•	•	•
	PTRC	Single and 3 pole tripping	•	•	•	•
87	PDIF	Phase segregated current differential	•	•	•	•
		2 and 3 terminal lines/cables	•	•	•	•
		Feeders with in-zone transformers	•		•	
		Suitable for use with SDH/SONET networks (using P594)	•	•	•	•
21P/21G	PDIS	Distance zones - Mho and quadrilateral full scheme relay	(5)	(5)	(5)	(5)
		CVT transient overreach elimination	(•)	(•)	(•)	(•)
		Load blinder	(•)	(•)	(•)	(•)
85	PSCH	Distance and DEF comms. aided schemes, PUTT, POTT, Blocking, Intertrip, Weak Infeed	(•)	(•)	(•)	(•)
50/27	PSOF	Switch on to Fault	(•)	(•)	(•)	(•)
68	RPSB	Power swing blocking	(•)	(•)	(•)	(•)
78		Out of step tripping	(•)	(•)	(•)	(•)
		IRIG-B Time Synchronism	•	•	•	•
50/51/67	OcpPTOC / RDIR	Phase overcurrent stages	4	4	4	4
50N/51N/67N	EfdPTOC / RDIR	Earth/ground overcurrent stages	4	4	4	4
51N/67N/SEF	SenPTOC / RDIR	Sensitive earth fault (SEF) stages	4	4	4	4
67/46	NgcPTOC/ RDIR	Negative sequence overcurrent stages	4	4	4	4
46BC		Broken conductor	•	•	•	•
49	PTTR	Thermal overload	•	•	•	•
27	PTUV	Undervoltage protection stages	2	2	2	2
59	PhsPTOV	Overvoltage protection stages	2	2	2	2
59N	ResPTOV	Residual voltage protection stages	2	2	2	2
		Compensated overvoltage protection stages	2	2	2	2
81U	PTUF	Under Frequency protection	4	4	4	4
81O	PTOF	Over Frequency protection	2	2	2	2
81R	PFRC	Rate of change of Frequency protection	4	4	4	4
50BF	RBRF	High speed breaker fail	•	•	•	•
79	RREC	Autoreclose - shots supported	4	4	4	4
79	RREC	Autoreclose (CBs controlled)	1	1 or 2	1	1 or 2
25	RSYN	Check synchronizing	•	•	•	•
		Alternative setting groups	4	4	4	4
FL	RFLO	Fault locator	•	•	•	•
		Fault Records	15	15	15	15
SOE		Event Records	512	512	512	512
	RDRE	Disturbance recorder, samples per cycle	48	48	48	48
VTS		Voltage transformer supervision	•	•	•	•
CTS		CT supervision (including patented differential CTS	•	•	•	•
	XCBR	Circuit Breaker condition monitoring	•	•	•	•
TCS		Trip circuit supervision	•	•	•	•
		Graphical programmable scheme logic (PSL)	•	•	•	•
		InterMiCOM^{64} Teleprotection	•	•	•	•

Key (•) : denotes optional - add distance protection to obtain

Functional Overview (Description of ANSI code nos., see Protection Function Overview)

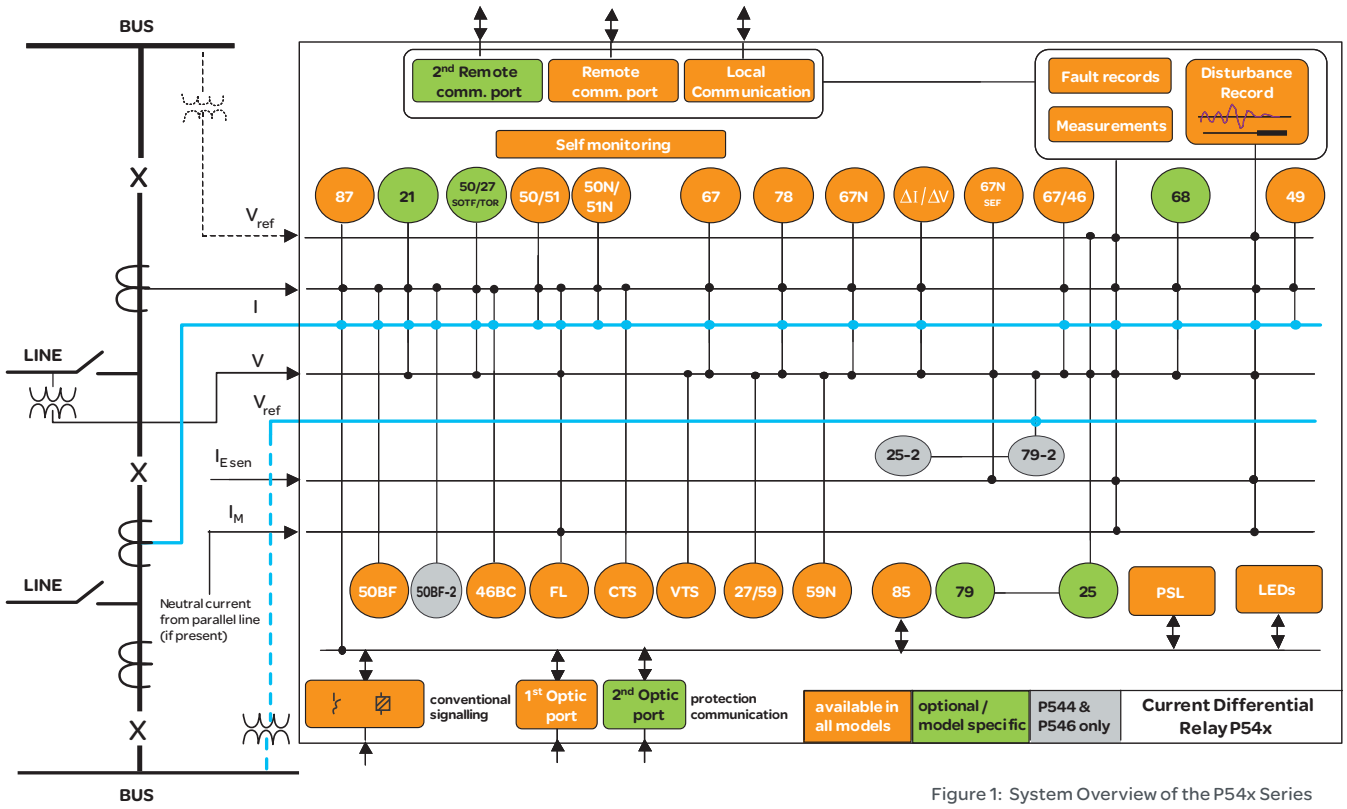
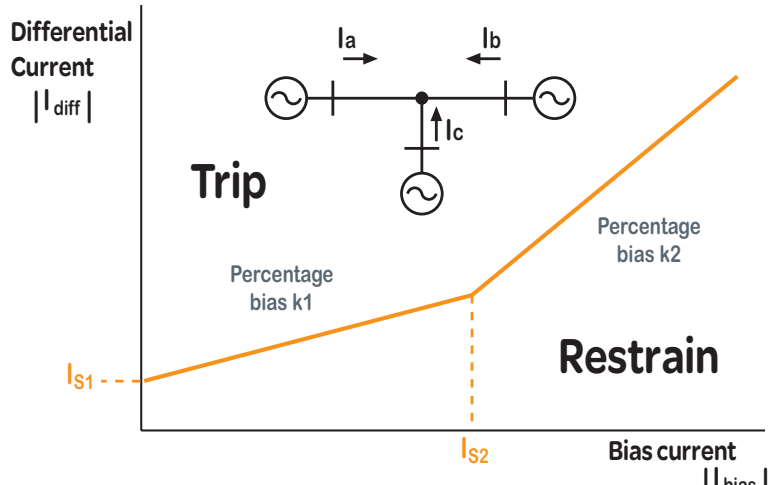


Figure 1: System Overview of the P54x Series

DIFFERENTIAL PROTECTION

The P54x provides true, phase-segregated current differential protection. The measurement algorithm is extremely reliable, offering fast detection of internal faults, and stability for external faults. The algorithm has a dual slope percentage bias restraint, as shown in Figure 2. An internal fault will generate differential current. The bias current is that which merely flows through the protected unit, as a load or through-fed external fault. The initial slope (k1) ensures sensitivity to low current faults, whereas the k2 slope is raised - to counter the effects of current transformer saturation.

Plotting the trip characteristics in the differential plane assists easy testing/commissioning, and to clearly visualize the exact current sensitivity of the scheme.The excellent performance for high resistance and weak infeed faults is clear - unlike characteristics operating in other planes, whereby their true sensitivity may be hidden from view.



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

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

The relay operates when

(1) For $|I_{bias}| < I_{S2}$

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

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

$$|I_{diff}| > k_2 |I_{bias}| - (k2 - k1)\, I_{S2} + I_{S1}$$

Figure 2: Biased current differential protection

LONGITUDINAL SIGNALLING TOPOLOGY

Differential protection requires the transfer of current vectors between all ends of the scheme. Figures 3a - 3d show common configurations.

Figure 3a shows an HV scheme whereby either a direct fiber optic, or a multiplexed link may be used as the chosen channel. Figure 3b shows the triangulated connection typical in 3-terminal applications.

Figure 3c shows a simple direct connection between relays, using a fiber pair. Figure 3d shows a multiplexed application, whereby a P54x can connected directly via fiber optic to a IEEE C37.94TM compliant multiplexer (MUX) or where a MiCOM P59x interface unit performs the optical-electrical conversion for the MUX. The advantage is that the cross-site connections run in optical mode as far as possible, eliminating the chance of noise interference, and any isolation/touch potential problems.

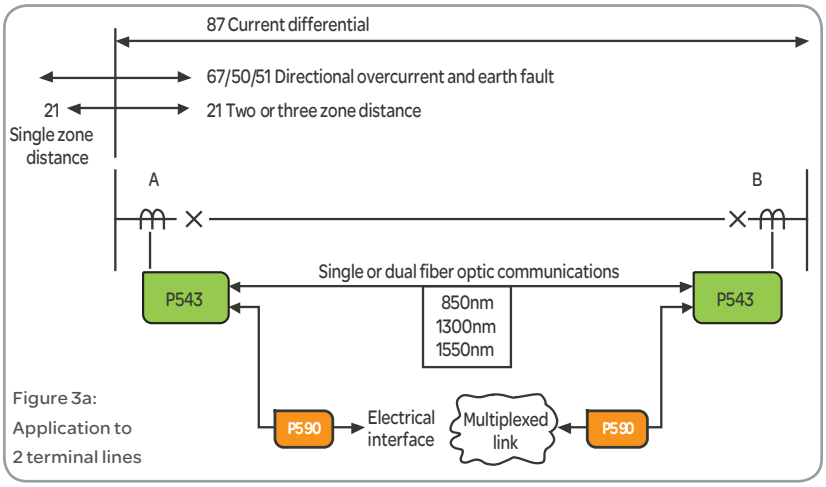


Figure 3a: Application to 2 terminal lines

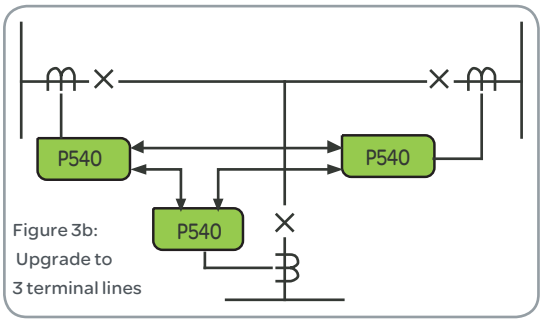


Figure 3b: Upgrade to 3 terminal lines

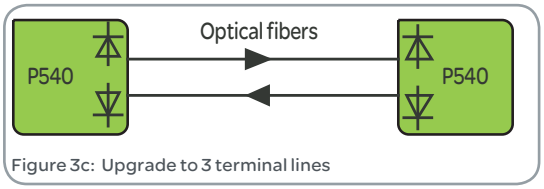


Figure 3c: Upgrade to 3 terminal lines

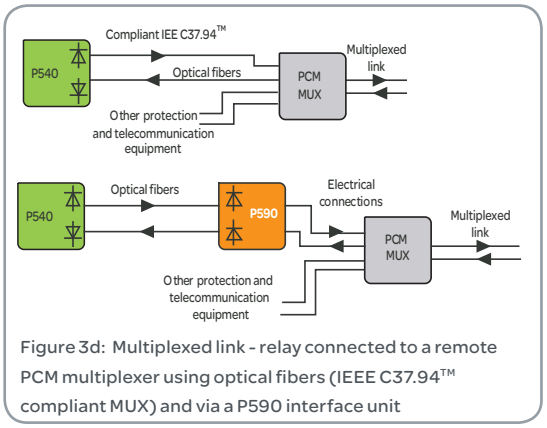


Figure 3d: Multiplexed link - relay connected to a remote PCM multiplexer using optical fibers (IEEE C37.94™ compliant MUX) and via a P590 interface unit

SYSTEM APPLICATION EXAMPLES

Transformers

Figure 4 shows a protected line and transformer "unit". In such applications the P543 or P545 are chosen, as these models compensate for the vector group shift and zero sequence filtering effects of the in-zone transformer. Second harmonic restraint is used to stabilize the protection against magnetizing inrush currents.

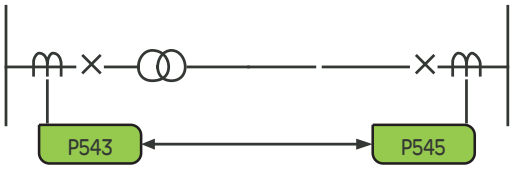


Figure 4: Application to transformer feeders

Where transformer loads are tapped off the protected line, it is not essential to install CTs at the tap. There exists the facility to time grade the differential protection with downstream relays or fuses.

The internal autoreclose function can be used to implement fuse-saving schemes in the latter case, improving supply availability.

Breaker and a Half, Mesh or Ring Feeding

The MiCOM P544 and P546 offer two sets of CT inputs, for connection as in Figure 5. This greatly assists stability, as proper bias current will be measured for through faults flowing bus-bus at one line end. CT knee point voltage mismatch can thus be tolerated, and the risks in finding the best equipotential point for connection of CT secondaries in parallel becomes a thing of the past. Importantly, in the event of breaker failure, the relays are able to identify the individual failed breaker.

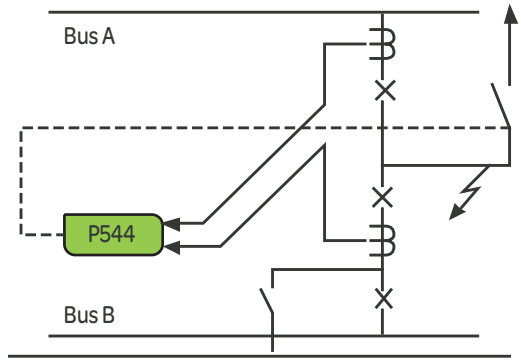


Figure 5: Application to 2 breaker configurations (showing stub bus fault)

Should the line be disconnected (line isolator open) whilst the remaining stub-bus is live, the relay provides differential protection for the stub zone.

Long Line Applications
Capacitive charging current compensation allows the relay to be set according to fault detection requirements with no compromise to account for charging currents.

Compensated Overvoltage
The Compensated Overvoltage function calculates the positive sequence voltage at the remote terminal using the positive sequence local current and voltage and the line impedance and susceptance. This can be used on long transmission lines where Ferranti Overvoltages can develop under remote circuit breaker open conditions.

Network Extensions
All P54x models offer application to two, and three terminal lines. A two terminal scheme is easily reconfigured if a new tee connection is added as a third end.

The P54x compensates for line CT ratio mismatches, even for 1A and 5A differences between line ends. This facilitates easier retrofitting, and network extensions.

GPS Synchronized Differential
Figure 6 shows a typical SDH/SONET ring, employing self-healing. In this topology, the traditional propagation delay measurement ("ping-pong" technique) which relies on the assumption of equal transmit and receive path delays, cannot be used. Real system experience has shown that the difference between a transmit signal sent via the direct path (MUX node B-C), and a receive via the standby path (nodes C-D-E-F-A-B) can be in excess of 5ms. Path differences typically summate based on 1.8ms per 100km, and 0.5ms insertion time per node.

It would not be acceptable to desensitize the protection to offset such a difference, therefore the P54x offers a special optical input which accepts a GPS clock pulse input. At all line ends, a MiCOM P594 module is used to ensure that a common clock reference is used for all timings.
This allows the relays to measure the real propagation delay in either direction. Patented fallback techniques ensure continuity of differential protection, even should GPS outages be encountered.

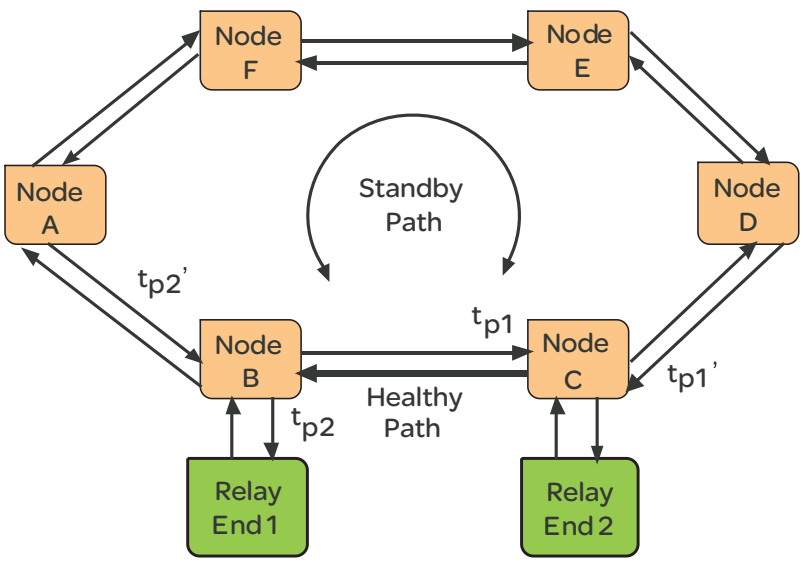


Figure 6: SDH/SONET networks

PROTECTION COMMUNICATIONS

Communication Interfacing
To ensure compatibility with standard communication equipment, the MiCOM P54x series is designed to work within the bandwidth of a 56/64 kbit/s pulse code modulation (PCM) channel. A direct fiber optic connection to a MUX can be done if the MUX is IEEE C37.94TM compliant. Also electrical interfaces conforming to ITU-T G.821 recommendations for V.35, G.703, and X.21 are available via the P59x series of interface units (see publication P59x Series Interface Units). In direct fiber optic applications, 1300nm and 1550nm channel options are available. The transmitters are designed with an "optical budget" to support many kilometres of fiber losses.

Communications Supervision
Dependable communications are essential for highperformance differential protection. Each active longitudinal channel is independently monitored, and reports error statistics in line with guidancefrom ITU-T G.821. Various means exist to implement "hot-standby" protection in the event of degraded communications. Dual redundant communications channels could be considered, whereby there are duplicated links, via diverse communications paths. In such instances, CH1 and CH2 protection channels will both be used. Alternatively, back-up distance or overcurrent elements can be switched into service (either as permanent parallel main protection, or temporary protection only during channel outages).

Retrospective Compatibility
New suffix K P54x relays have differential message compatibility with previous P54x releases equal to suffix B or later. Note that P541 and P542 models have not been migrated to suffix K, but remain available to order at their historical status.

Differential protection calibrated in the differential plane - no compromise on sensitivity

DISTANCE PROTECTION (OPTIONAL)

Five zones of protection are provided. A superimposed current phase selector detects the faulted phase(s) and, controls which of the distance elements will initiate a trip. Combined with the directional decision from a proven delta principle, secure operation of distance zones is assured. The relay allows mho and quadrilateral (polygon) characteristics to be independently selected for the phase and ground distance elements. The mho is shown in Figure 7, and uses well-proven principles to provide dynamic expansion for faults off the characteristic angle.

The quadrilateral characteristics (Figure 8) provide enhanced fault arc resistance coverage. An adaptive technique is used to tilt the reactance reach line of each zone and eliminate under/overreaching effects due to prefault load flow.

Blinder characteristics (Figure 9) prevent false tripping due to encroachment of heavy loads.

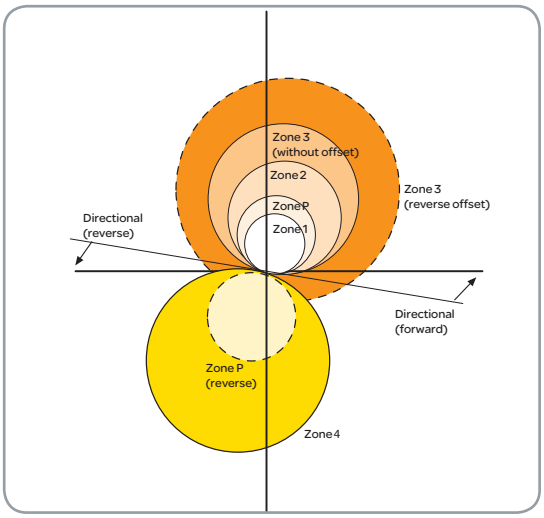


Figure 7: Mho Characteristics

Power Swing Blocking (PSB)

The MiCOM P54x recognizes power swings quickly, by means of the superimposed currents measured by the phase selector. The PSB does not require any impedance band or timers to be set, and the distance trip time for faults occurring during a power swing remains subcycle.

Out of Step Tripping - OST

If severe disturbances risk asynchronism in transmission networks, it may be required to separate into islands, using OST feature. Predictive mode OST initiates separation before damage occurs.

Distance Schemes

Pre-configured distance schemes allow single and three phase tripping with or without a signalling channel.

- Basic scheme logic for stand alone operation (without a signalling channel).
- Trip on Close logic allows accelerated tripping to be selected following manual, or auto-reclose.

Standard distance and DEF schemes may be assigned to traditional hardwired I/O, or routed using the InterMiCOM^{64} teleprotection. Direct transfer tripping, permissive underreach (PUR), permissive overreach (POR), and blocking schemes are supported. Open breaker, weak infeed echo and weak infeed trip features are menu options.

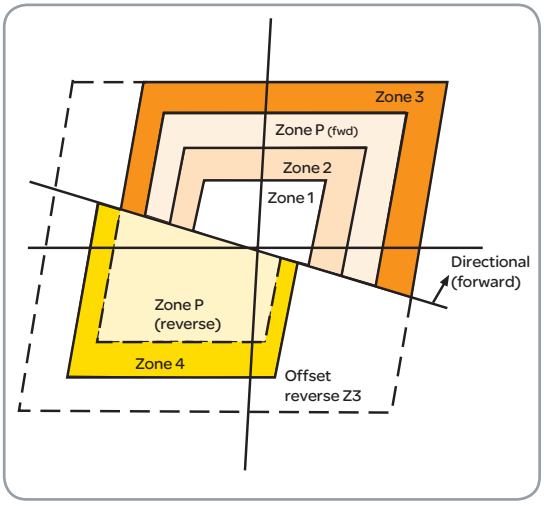


Figure 8: Quadrilateral Characteristics

Directional Earth Fault (DEF)

The DEF element can be used within the aided schemes to detect high resistance ground faults. The innovative “Virtual Current Polarizing” feature even ensures correct operation when the fault generates negligible zero or negative sequence voltage. Traditional relays would have required an extra CT input to cover this scenario.

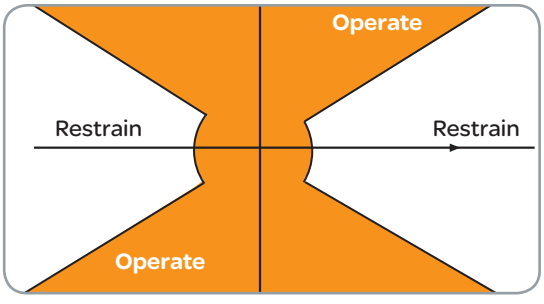


Figure 9: Load Blinder

All your main and backup protection in one device: differential, distance or both, to minimize training needs and to spare holding

InterMiCOM64 TELEPROTECTION

InterMiCOM64 allows high performance permissive and blocking type unit protection to be configured, plus transfer of any digital status information between two or three line ends. Intertripping is supported too, with channel health monitoring and cyclic redundancy checks (CRC) on the received data for maximum message security. InterMiCOM64 provides eight endend signals, assignable to any function within a MiCOM relay's programmable logic. Default failsafe states can be set in case of channel outage.

In applications where differential and distance are enabled together, any InterMiCOM64 signals for distance protection are interleaved with the differential signaling. No slow-down of differential tripping performance occurs. If differential elements are disabled, the distance teleprotection interface is identical to the topologies shown in Figures 3 to 6.

In 3-terminal schemes, the communications are selfhealing if one leg of the triangulation fails.

TYPICAL PROTECTION TRIP TIMES

Differential protection trip time, any point-on-wave including the closure time of a conventional trip relay contact:

- 22 to 28ms (50Hz system)
- 19 to 25ms (60Hz system)

Distance protection trip time, any point-on-wave including the closure time of a conventional trip relay contact:

- 13 to 20ms (50Hz system)
- 13 to 17ms (60Hz system)

InterMiCOM64 end-end signaling, PSL to PSL:

- Approximately 5ms
- Deduct 4ms (contact operating time) from the distance figures above for the time required to key an InterMiCOM64 channel.

BACKUP PROTECTION

- Four stages of both phase and earth (ground) fault protection are provided with a choice of standard IEC and ANSI/IEEE IDMT curves, instantaneous, and definite-time operation.
- Negative sequence overcurrent, and SEF (0.5% In sensitivity) are also available.
- Phase under and overvoltage protection functions are available in addition to residual overvoltage.
- Broken conductor – detects the percentage phase unbalance due to an open phase condition.
- A thermal replica provides alarm and trip stages, to warn and protect in the event of prolonged circuit overloading
- Two stage, high speed circuit breaker failure protection, for backtripping upstream circuit breakers, and re-tripping of the local circuit breaker if required

SUPERVISORY FUNCTIONS

VT Supervision

Voltage transformer supervision is provided to detect loss of one, two or three VT signals for line VTs.

CT Supervision

Current transformer supervision is provided to detect loss of phase CT input signals. Using the "Patented differential CTS" feature, the relay performs an intelligent comparison of the negative sequence current imbalance at line ends, to determine which, if any, CTs have failed. This comparison detects all CT shorts, open circuits, and wiring disconnections without an inherent time delay. Operation of the differential protection can be desensitized during the failure to avoid an unwanted trip. The CTS assures real-time stability of the differential elements, in just the same manner as the VTS assures distance element security.

CONTROL

User Interface

Integrated user function keys and tri-color programmable LEDs provide a cost-effective solution for full feeder scheme applications. The ten function keys operate in two modes, normal and toggled, with an associated LED for clear indication of the logic status. Typical control, maintenance, and commissioning options are initiated directly from simple key presses, rather than the need to navigate a menu.

Single Breaker Autoreclose with Check Synchronism (P543 & P545)

The user may select a single, two, three or four shot autoreclose cycle.

Dual Breaker Autoreclose with Check Synchronism (P544 & P546)

The following additional features are offered in P544 & P546, to permit two breaker reclosing in a leader-follower scheme:

- Two CB Control - CB1 and CB2 are assigned. The user selects which is the leader, and which the follower breaker.
- Individual selection of recloser on or off.
- Follower action - Follows successful close of the leader, reclosing after a settable delay. Alternatively the follower may wait to be closed manually.
- Independent lockout and reset per breaker.

Programmable Scheme Logic
Powerful graphical logic allows the user to customize the protection and control functions. The programmable scheme logic is configured using the graphical MiCOM S1 Studio PC software.

Hot Key Menu
Trip and close commands are facilitated from front panel “hotkeys”, to allow direct CB control without the need to navigate a menu. Other in/out, on/off and enable/disable controls are easily programmed.

Measurements and Recording Facilities
All event, fault and disturbance records are time tagged to a resolution of 1ms. An optional IRIG-B port is available for accurate time synchronization.

Power System Measurements (MMXU)
Instantaneous and time integrated voltage, current and power measurements are provided. These may be viewed in primary, or secondary values.

POST-FAULT ANALYSIS
Fault Location
A fault location algorithm provides distance to fault in miles, kilometres, ohms or percentage of the line length. The proven algorithm used tolerates prefault loading and fault arc resistance.

Event Records
Up to 512 time-tagged event records are stored in battery backed memory. An optional modulated or demodulated IRIG-B port is available for accurate time synchronization.

Fault Records
The last 15 faults are stored :

- Indication of the faulted phase
- Protection operation
- Active setting group
- Fault location (distance to fault)
- Relay and CB operating time
- Pre-fault and fault currents (including remote terminal values), voltages and frequency

Disturbance Records
The oscillography has 12 analog channels, 32 digital and 1 time channel, all at a resolution of 48 samples/ cycle.

Disturbance records can be extracted from the relay via the remote communications and saved in the COMTRADE format.

PLANT SUPERVISION
Trip Circuit Supervision
Supervision of the trip circuit can be implemented using optocoupled inputs and the programmable scheme logic.

CB State Monitoring
An alarm will be generated if there is a discrepancy between the open and closed CB auxiliary contacts.

Circuit Breaker Condition Monitoring
- Monitoring the number of breaker trip operations
- Recording the sum of broken current quantity (wear, interruption duty) ΣI^x, $1.0 \leq x \leq 2.0$
- Monitoring the breaker operating time

COMMUNICATION TO REMOTE OPERATORS AND SUBSTATION AUTOMATION
The wide range of communication options, including Courier/K-Bus, IEC 60870-5-103, DNP3.0, IEC 61850, provides interfacing to almost any type of Substation Automation System or SCADA system. A Rear port providing remote communications and a front port providing local communications.

Second Rear Courier Port
An additional, second rear port can be ordered as an option designed typically for dial-up modem access by protection engineers/ operators, when the main port is reserved for SCADA traffic. This port alternatively offers an extra option of -103 communications when IEC 61850 is the chosen first port protocol.

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