GE

Grid Solutions

MiCOM Agile P543/P545

Current Differential Protection with Subcycle Distance for Petersen Coil Earthed & Isolated Systems

MiCOM P543 and P546 Firmware 92 is designed for all overhead line and cable applications, interfacing readily with the longitudinal (end-to-end) communications channel between line terminals.

Tripping uses a proven characteristic comparing differential current with through current. The phase differential element offers consistent detection of solid and resistive faults. An innovative neutral current differential element complements phase differential in the case of high resistance faults.

MiCOM P543 and P546 Firmware 92 is the ideal choice for solidly-earthed transmission systems and isolated or compensated systems at lower system voltages. A full range of back-up protection is integrated, enhancing the dependability of the relay.

Application

Adapted to suit many different substation and protected unit topologies:

- Line differential protection for 2 or 3-terminal circuits
- In-zone transformer-feeder applications
- Compensates for line CT ratio mismatches and capacitive charging current
- Up to eight distance zones with high speed operation in less than one cycle
- Load blinder prevents spurious trips cascading through the network in extreme conditions such as on the verge of a blackout
- Distance Phase preference tripping logic and transient earth fault detection (TEFD) for Petersen coil earthed and isolated systems

Key Benefits

- Simple set mode: the relay determines its own settings from line data
- Integral teleprotection via MODEM, fiber, or MUX channel
- Compatibility with modern 2 Mbps communications equipment
- Cybersecurity aligned to industry standards and services (NERC® CIP, AAA, RADIUS, RBAC, Syslog)

Protection and Control

- Current Differential Protection applicable to lines and cables, long or short, strong and weak infeeds
- Transient bias feature reduces CT requirements by up to 25%
- Optional Subcycle Distance protection
- Multi-shot autoreclosure with check synchronism and adaptive breaker closing
- Improved system stability by CB failure fast reset element (< 0.75 cycle)

Advanced Communications

- InterMiCOM option for end-to-end protection communications; Readily interfaces with end-to-end communications channels (56/64 kbps or E1 2 Mbps)
- Wide range of supported protocols Courier/K-Bus, IEC 60870-5-103, DNP 3.0 (EAI-492 or Ethernet) and IEC 61850
- Advanced IEC 61850 Edition 2 implementation with device settings via SCL files
- Redundant communications with zero downtime using optional PRP/HSR technology

Cybersecurity

- Provides high-end cybersecurity aligned to industry standards and services (NERC® CIP, AAA, RADIUS, RBAC, Syslog)

Functional Overview

ANSI	IEC 61850	Features	P543	P545
	OptGGIO	Opto coupled logic inputs	16	32
	RlyGGIO	Standard relay output contacts	14	32
		Optional high-speed, high-break output contacts	4	8
		Two breaker configurations		
		Clockwise and anticlockwise phase rotation	•	•
	PTRC	Single and 3-pole tripping	•	•
87P/87N	PhsPDIF/NeuPDIF	Phase segregated / Neutral current differential	•	•
		2 and 3 terminal lines/cables	•	•
		Subcycle current differential	•	•
		Feeders with in-zone transformers	•	•
		Suitable for use with SDH/SONET networks (using RT43x GPS clock)	•	•
21P/21G	PDIS	Distance zones - Mho and quadrilateral full scheme relay	8	8
		CVT transient overreach elimination	•	•
		Load blinder	•	•
32R/32L/320		Phase segregated power stages	4	4
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
50N/51N/67N	EfdPTOC /RDIR	Earth/ground overcurrent stages	4	4
51N/67N/SEF	SenEftPTOC/RDIR	Sensitive earth fault (SEF) stages	4	4
64	SenRefPDIF	High-impedance restricted earth fault protection	•	•
67/46	NgcPTOC/RDIR	Negative sequence overcurrent stages	4	4
TEFD	PTEF	Transient Earth Fault	1	1
46BC		Broken conductor	•	•
49	PTTR	Thermal overload	•	•
27	PTUV	Undervoltage protection stages	2	2
59	PhsPTOV	Overvoltage protection stages	2	2
59N	ResPTOV	Residual voltage protection stages	2	2
		Compensated overvoltage protection stages	2	2
81U	PTUF	Underfrequency protection	4	4
81O	PTOF	Overfrequency protection	2	2
81R	PFRC	Rate of change of frequency protection	4	4
50BF	RBRF	High-speed breaker fail	•	•
79	RREC	Autoreclose - shots supported	4	4
79	RREC	Autoreclose (CBs controlled)	1	1
25	RSYN	Check synchronising	•	•
		Alternative setting groups	4	4
FL	RFLO	Fault locator (Fault records)	•(15)	•(15)
SOE		Event records	1024	1024
	RDRE	Disturbance recorder: samples per cycle	48	48
VTS		Number of channels: Analogue/Digital	16/64	16/64
		Voltage transformer supervision	•	•
CTS		CT supervision (including patented differential CTS)	•	•
	XCBR	Circuit-breaker condition monitoring	•	•
		InterMiCOM^{64} teleprotection	•	•

Key (•): denotes optional

Functional Overview Diagram

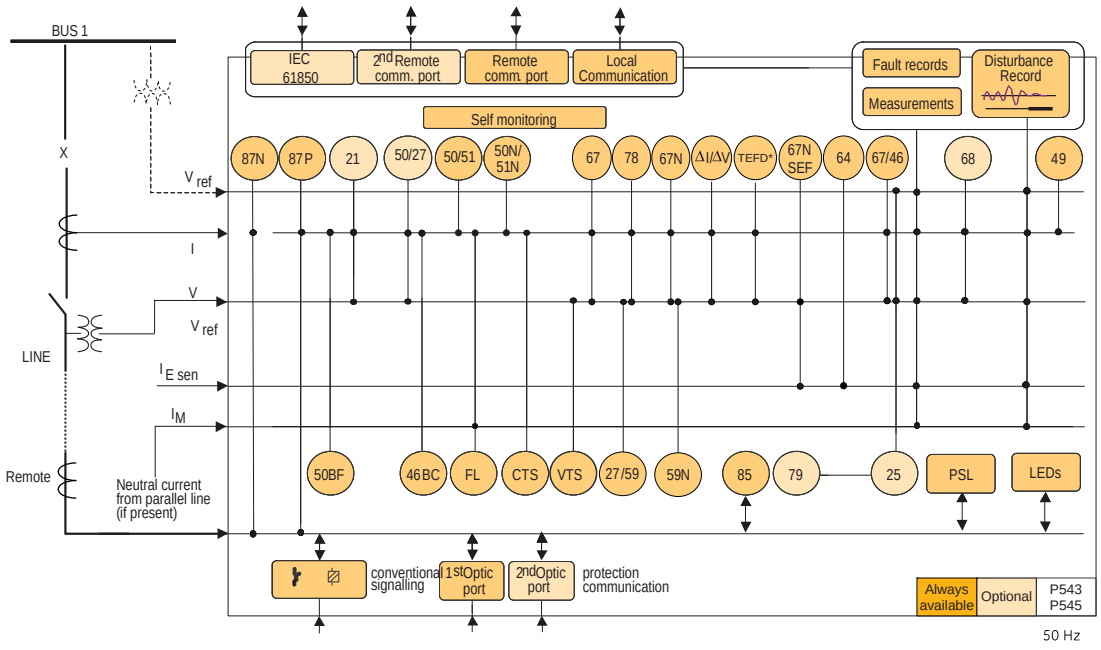


Figure 1: System overview of the P543 and P545 Firmware 92

Applications

Differential Protection (Phase and Neutral)

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 initial slope ensures sensitivity to low current faults, whereas the 2nd slope is raised to counter the effects of Current Transformer (CT) saturation. A Transient Bias technique is used to overcome the effects of CT saturation, without compromising the operating time for internal faults.

The P54x also provides neutral current differential protection, which complements phase current differential during high resistance faults (up to 500 Ohm in 500 kV systems).
The neutral current differential has a single slope characteristic with a cut-off setting.

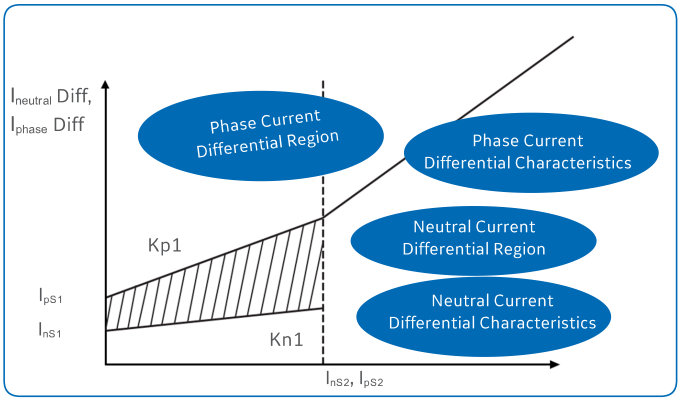


Figure 2: Differential protection characteristic

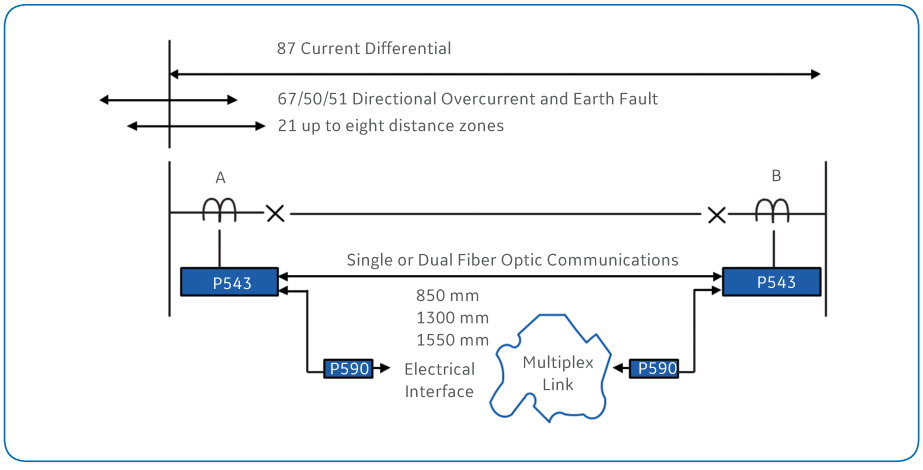


Figure 3a Application to 2 terminal lines

Longitudinal Signaling Topology

Differential protection requires the transfer of current vectors between all ends of the scheme. Figures 3a - 3d show typical configurations. Figure 3a shows a HV/EHV scheme where either a direct fiber optic or a multiplexed link may be used as the chosen channel. Figure 3b shows the triangulated connection required in 3-terminal applications.

Figure 3c shows a simple direct connection between relays, using a fiber pair.

Figure 3d shows a multiplexed application, where a P54x can be connected directly via fiber optics to an IEEE C37.94™ compliant multiplexer (MUX), or where a MiCOM P59x interface unit performs the optical-electrical conversion for the MUX.

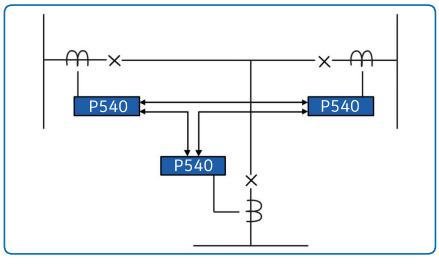


Figure 3b Upgrade to 3 terminal lines

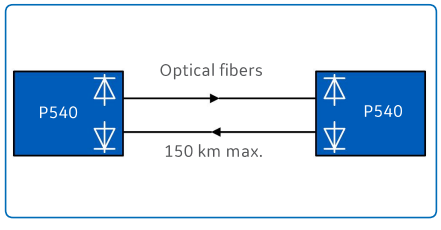
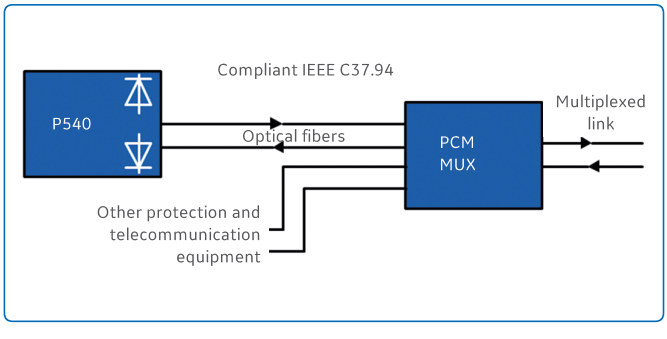


Figure 3c Direct link using optical fiber



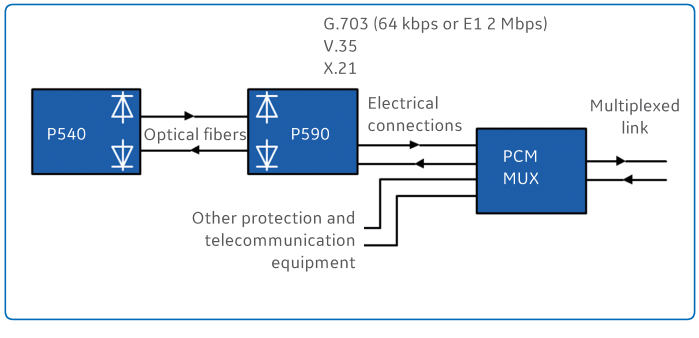


Figure 3d Multiplexed link - relay connected to a remote PCM multiplexer using optical fiber (IEEE C37.94 ™compliant MUX) and via a P590 interface unit

System Application Examples

Transformer

Figure 4 shows a protected line and transformer unit. In such applications, P543 and P545 compensate for the vector group shift and zero sequence filtering effects of the in-zone transformer. Second harmonic restraint or blocking is used to stabilise the protection against magnetising inrush currents. A fifth harmonic blocking feature can also be used to inhibit the differential protection during transformer overfluxing conditions.

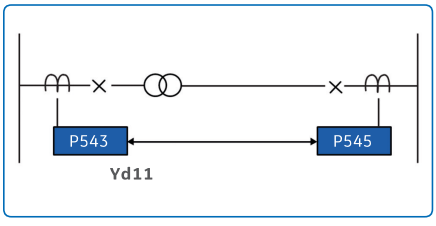


Figure 4 Application to transformer feeders

Long Line Applications

Capacitive charging current compensation allows the current differential protection to be set according to fault detection requirements - with no compromise to account for charging currents. The compensated overvoltage function protects the line from Ferranti overvoltages by calculating the positive sequence voltage at the remote terminal.

Network Extensions

All P54x models offer applications for 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 1 A and 5 A differences between line ends. This facilitates easier retrofitting and network extensions.

GPS Synchronised Differential

Figure 5 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 5 ms. Path differences typically summate, based on 1.8 ms per 100 km and 0.5 ms insertion time per node.

It would not be acceptable to desensitise 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 Reason RT430 GPS clock 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 if GPS outages are encountered.

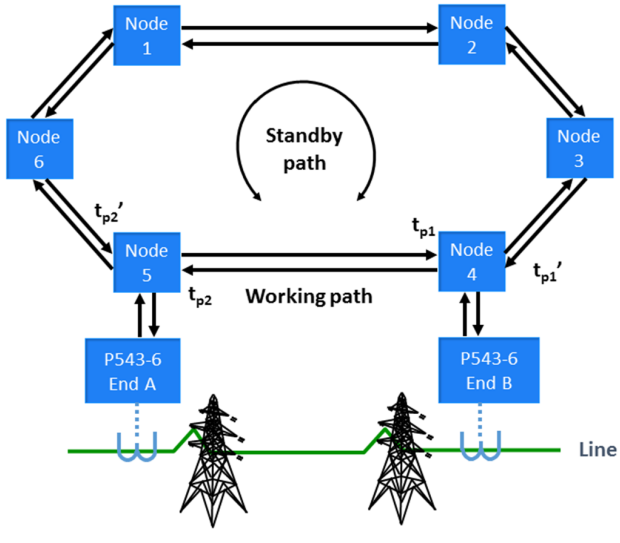


Figure 5 SDH/SONET networks

Communications Interfacing for Protection Schemes

To ensure compatibility with standard communications equipment, the MiCOM P54x Agile 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 is possible if the MUX is IEEE C37.94™ compliant.

Electrical interfaces conforming to ITU-T G.821 recommendations for V.35, G.703 (64 Kbps or 2 Mbps E1) and X.21 are available via the P59x series of interface units.

In direct fiber optic applications, 1300 nm and 1550 nm channel options are available. The transmitters are designed with an "optical budget" to support up to 150 km.

Communications supervision

Dependable communications are essential for high-performance differential protection. Each active longitudinal channel is independently monitored and reports error statistics in line with guidance from 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, thus providing duplicated links via diverse communications paths. In such instances, CH1 and CH2 protection channels will both be used.

In three terminal applications, should one link fail, the protection scheme remains active. This is facilitated by the one relay in the scheme which still has full connected communications adopting a master role. The other two relays temporarily become slaves, able to trip their local breakers.

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.

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

Distance Protection

Eight zones of protection are provided. A superimposed current phase selector detects the faulted phase(s) and controls which 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 shown in Figure 6 uses well-proven principles to provide dynamic expansion for faults off the characteristic angle.

The quadrilateral characteristics (Figure 7) 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.

For simplicity, six zones are shown in Figures 6 and 7. Additional zones ZR and ZS are available.

Blinder characteristics (Figure 8) prevent false tripping due to encroachment of heavy loads.

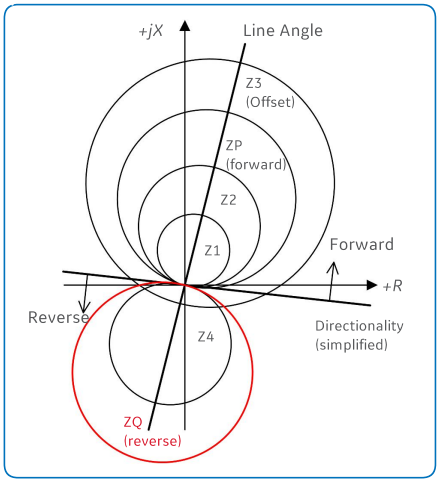


Figure 6: Mho characteristics

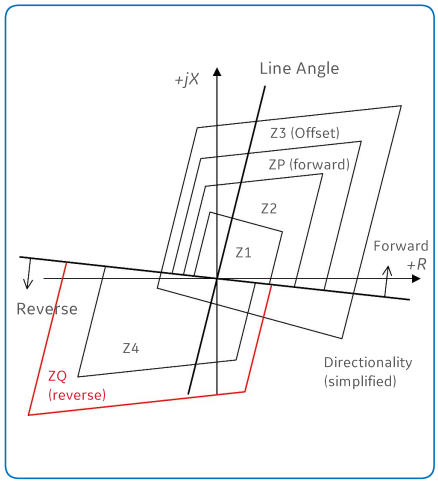


Figure 7: Quadrilateral characteristics

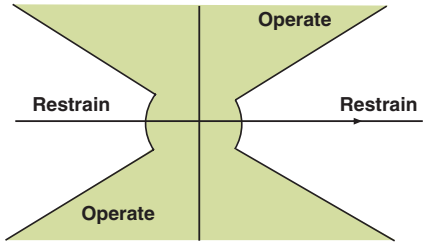


Figure 8 Load blinder

Power Swing Blocking (PSB)

The MiCOM P54x Agile recognises power swings quickly, by means of the superimposed currents measured by the phase selector. A conventional PSB element based on the impedance band is provided to detect slow power swings.

The distance trip time for faults occurring during a power swing remains subcycle.

Out-of-Step Tripping (OST)

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

Distance Schemes

Pre-configured distance schemes allow single and 3-phase tripping, with or without a signalling channel.

A settable alternative distance scheme initiates all the zone timers simultaneously and guarantees faster tripping times for evolving faults.

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 InterMiCOM^{64} teleprotection.

Direct transfer tripping, permissive underreach (PUR), permissive overreach (POR) and blocking schemes are supported, including DACH special schemes, open breaker, weak infeed echo and weak infeed trip features are menu options.

Phase Preference for Petersen Coil Earthed and Isolated systems

MiCOM P543 and P545 are equipped with phase preference tripping logic for Petersen coil earthed and isolated systems. Tripping for a cross-country fault, can be set to follow either a so-called "cyclic" logic or an "acyclic" logic to select a phase preference for the impedance measurement. 1 out of 8 priority criteria can be selected.

Transient Earth Fault Detection*

MiCOM P543 and P545 Firmware 92 incorporate novel transient earth fault detection (TEFD) for Petersen coil earthed and isolated systems, implemented as a software function block, with no need to add unreliable analogue hardware, nor analogue processing boards. This approach achieves the most cost-effective functional integration and protection scheme engineering. The TEFD technique works on a special frequency range centred at 220 Hz. Selecting this interharmonic spectrum avoids the 4th and 5th harmonics which are naturally prevalent in compensated networks.

All your main and backup protection in one device - differential, distance or both - to minimise training needs and spares holdings

Directional Earth Fault (DEF)

The DEF element can be used within the aided schemes to detect high resistance ground faults.

The innovative "Virtual Current Polarising" feature ensures correct operation in the solidly earthed system when the fault generates negligible zero or negative sequence voltage. The "Virtual Current Polarising" feature may be switched-off when used in non-solidly earthed systems.

InterMiCOM^{64} Teleprotection

InterMiCOM^{64} allows high performance permissive and blocking type unit protection to be configured, plus the transfer of any digital status information between two or three line ends (8 end-to-end signals).

Intertripping is supported too, with channel health monitoring and cyclic redundancy checks (CRC) on the received data for maximum message security.

Typical Protection Trip Times

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

- 24 to 30 ms (50 Hz system)

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

- 13 to 20 ms (50 Hz system) for zones Z1, Z2, Z3, Z4

Backup Protection

- Four stages of both phase and earth (ground) fault protection
- Negative sequence overcurrent and SEF (0.5% In sensitivity)
- Phase under/overvoltage protection
- Broken conductor protection
- Two stage high speed circuit-breaker failure protection

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. The CTS ensures real-time stability of the differential elements, in the same manner as the VTS ensures distance element security.

Control

User Interface

Integrated user function keys and tri-colour 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.

User Programmable Curves

A user-programmable curve gives the user additional flexibility, allowing easy customisation of the protection and control functions.

Single Breaker Autoreclose

With check synchronism and adaptive closing considering the circuit breaker time. The user may select a single, two, three or four shot autoreclose cycle.

Programmable Scheme Logic

Powerful graphical logic allows the user to customise the protection and control functions (see Figure 9). The logic includes 32 timers, gates (OR, AND, MAJORITY) and set/reset latch functions, with the ability to invert the inputs and outputs and provide feedback.

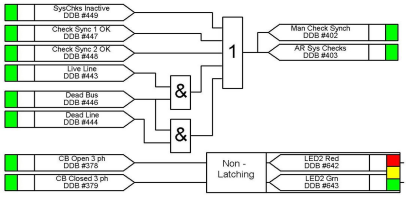


Figure 9 Programmable scheme logic

The system is optimised to ensure that the protection outputs are not delayed by PSL operation. The programmable scheme logic is configured using graphical S1 Agile software. The relay outputs may be configured as latching (lockout) or self-reset. All aspects of MiCOM P40 IED configuration are managed using the S1 Agile software (see Figure 10).

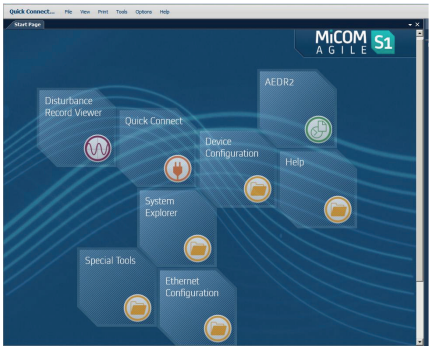


Figure 10 S1 Agile: a powerful and intuitive PC-toolsuite

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.

Measurement and Recording Facilities

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

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 employed tolerates prefault loading and fault arc resistance.

Event Records

Up to 1024 time-tagged event records can be stored. An optional modulated or demodulated IRIG-B port is available for accurate time synchronisation.

Fault Records

The last 15 fault records are stored.

Disturbance Records

The oscillography has 16 analogue channels, 64 digital and 1 time channel, all at a resolution of 48 samples/ cycle.

Plant Supervision

Circuit-Breaker Condition Monitoring

- Monitors the number of breaker trip operations
- Records the sum of broken current quantity (wear, interruption duty)
- SI^x, 1.0 =< x =< 2.0
- Monitors the breaker operating time

Quality Built-In (QBi)

Grid Solutions' QBi initiative has deployed a number of improvements to maximise quality. Harsh environmental coating is applied to all circuit boards to shield them from moisture and atmospheric contamination. Transit packaging has been redesigned to ISTA standards and the third generation of CPU processing boosts not only performance, but also reliability.

GE-branded MiCOM P40 relays have no resident battery, to ease airfreight logistics.

For more information please contact
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Communications with Remote Operators and Substation Automation

The wide range of communications options, including IEC 61850, provides interfacing with almost any type of Substation Automation System or SCADA system.

The following protocols are available:

- Courier/K-Bus
- IEC 60870-5-103
- DNP 3.0 (EAI-485 or Ethernet)
- IEC 61850
- USB front-port communication

P54x devices can be enhanced with an optional redundant Ethernet board. The redundancy is managed by the market's fastest recovery time protocols: IEC 62439-3 PRP and HSR allowing bumpless redundancy and RSTP, offering multi-vendor interoperability. The redundant Ethernet board supports either modulated or demodulated IRIG-B and the SNTP protocol for time synchronization. The redundant Ethernet board also has a watchdog relay contact to alarm in case of a failure.

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 also offers the option of -103 communications when IEC 61850 is the chosen first port protocol.

MiCOM P40 Agile

Grid Solutions' philosophy is one of continuous improvement in our products and solutions. Our emphasis on communications in MiCOM products has become a focus which secures our leadership in digital substations. To mark this phase of evolution, the “P40 Agile” is now applied to the range. P40 Agile is a mark of performance and quality, only available from Grid Solutions.

Device Track Record - High Speed Transmission Protection

P54x series introduced in 1999. Worldwide application, with over 40,000 units delivered.
Optional distance elements in P54x import P443 MiCOMho subcycle technology.

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