GRID SOLUTIONS

# MICOM AGILE P54

## 5th Generation Line Current Differential Protection with Subcycle Distance

The MiCOM Agile P54 provides unparalleled protection of overhead lines and underground cables, accommodating any method of system earthing, and extending to cover the most onerous applications with line differential and up to nine distance zones. One device reaches from distribution and sub-transmission up to the highest transmission voltage applications.

The MiCOM P54 interfaces readily with the longitudinal (end-to-end) communications channel between line terminals. Tripping uses a proven characteristic comparing differential current with through current, for fast detection of solid and resistive faults. Innovative neutral current differential complements the phase differential in the case of high resistance earth faults.

Multiple main protection elements reside inside each relay: differential, distance, delta directional comparison protection and directional earth fault unit protection (DEF) for solidly earthed systems and a novel transient earth fault detection (TEFD) for isolated or compensated earthed systems. This flexibility permits standardised ordering, simplified application and reduces spares holdings.

One-box bay control capabilities for up to two circuit breakers and up to eight other controllable switchgear items are presented using a full colour graphical HMI screen.

## Key Features

- Differential protection applicable to lines and cables, long or short, strong and weak infeeds
- Multi-shot autoreclosure with check synchronism - adaptive technology to detect fault arc extinction and accelerate the dead time or drive to lockout for persistent faults
- Serial and Ethernet concurrent protocols, switchable by settings
- Advanced IEC 61850 Edition 2.1 implementation
- With fast start up time of less than 10s, resulting in protection, control and communications without the need to wait

## Applications

- Line differential protection for 2 or 3-terminal circuits
- Breaker and a half, or mesh feeding with two sets of CT inputs per end, with settable independent CT ratios
- Compensates for line CT ratio mismatches and capacitive charging current
- Up to nine 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

## Protection & Control

- Transient bias feature reduces CT requirements, tested even for TPY/TPZ gapped CTs
- Subcycle distance protection
- Improved system stability by CB failure fast reset element (< 0.75 cycle)

## Advanced Communications

- End-to-end communications channels - multiplexed 64 kbps, E1 2 Mbps, direct fibre, SONET/SDH and MPLS
- Redundant communications with zero downtime using optional PRP/HSR protocols
- Latest communication protocol implementation with IEEE 1588 precisiontime (PTP)

## Cybersecurity

- Designed with an IEC 62443-4-1: 2018 certified Secure Development Lifecycle Process
- Provides the necessary capabilities to build an IEC 62443-3-3: 2013 compliant solution

## One-Box Concept

- Integrated full colour display, for single-line diagram control of the protected bay
- Open, close, local/remote and direct function key access facilitate the control of connected switchgear – two circuit breakers plus eight other controllable plant items
- Select-before-operate, breaker health checks and interlocking capabilities

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## Applications

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 reduce configuration effort. Intelligent dependencies between settings further supervise visibility, serving to declutter and accelerate the configuration experience.

Workable default settings and a simple-set wizard for the distance zones reduce touch time, training needs, and the risk of error when applying a relay.

## Functional Overview
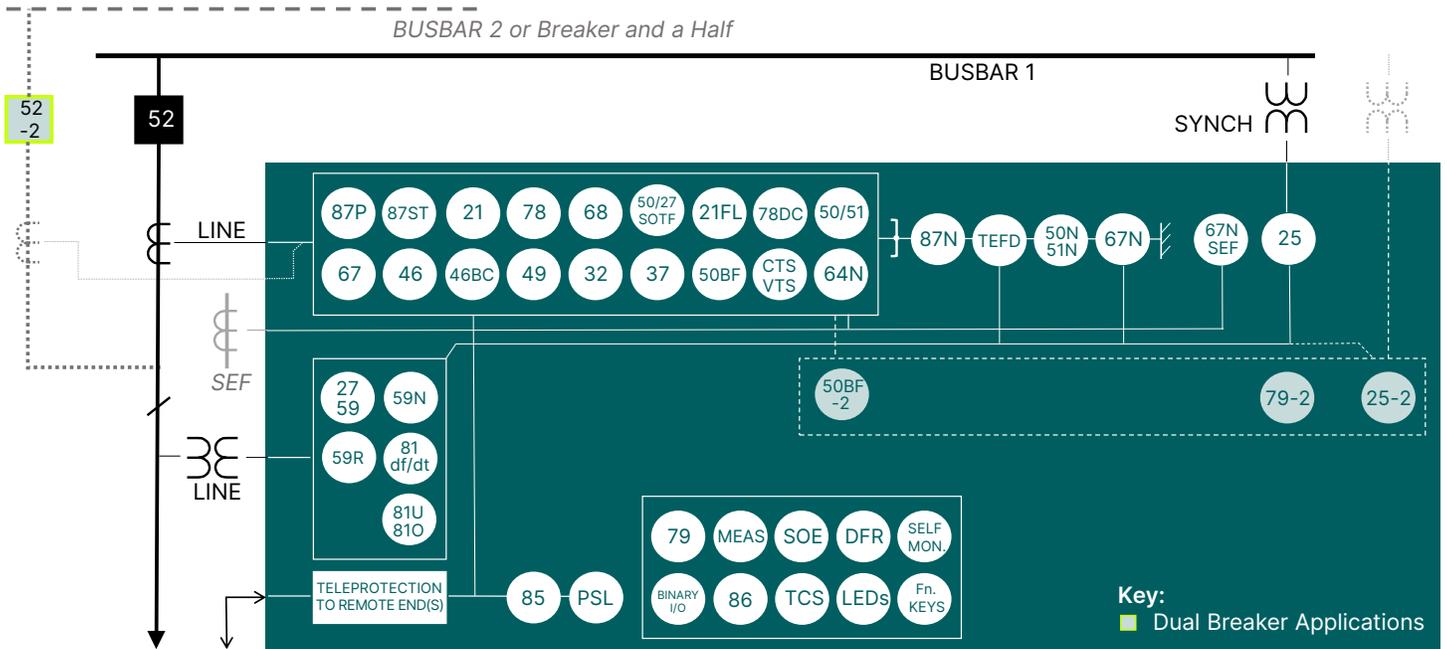


*Figure 1: System overview example – shown for a dual breaker application*

**ANSI® Device Numbers & Functions**

| DEVICE NUMBER | FUNCTION |
|---|---|
| 25 | Check Synchronising |
| 27 | Phase and Line Undervoltage |
| 37 | Undercurrent |
| 46 | Negative Sequence Overcurrent |
| 49 | Thermal Overload |
| 50 | Phase Definite Time Overcurrent |
| 51 | Phase Inverse-Time Overcurrent |
| 52 | Circuit Breaker Control |
| 59 | Phase and Line Overvoltage |
| 67 | Directional Phase Overcurrent |
| 68 | Power Swing Blocking |
| 78 | Out-of-Step Tripping |
| 78DC | Delta (Incremental) Protection |
| 79 | Autoreclose/Adaptive Autoreclose |

| DEVICE NUMBER | FUNCTION |
|---|---|
| 85 | Teleprotection Channel Schemes |
| 86 | Latching/Lockout Contacts |
| 87P | Line Differential - 2 or 3 Ends |
| 87N | Neutral Differential |
| 87ST | Stub-Bus Protection |
| 21BL | Load Encroachment/ Blinder |
| 21FL | Fault Locator |
| 21P/G | Phase and Ground Distance |
| 46BC | Broken Conductor |
| 50/27 | Switch-on to Fault |
| 50BF | CB Failure |
| 50N | Earth Fault Definite Time Overcurrent |
| 50ST | Stub Bus Protection |
| 51N | Neutral/Ground IDMT Overcurrent |

| DEVICE NUMBER | FUNCTION |
|---|---|
| 59N | Neutral Voltage Displacement |
| 50R | Remote End Overvoltage |
| 64N | Restricted Earth Fault |
| 67N | Directional Neutral/ Ground Overcurrent |
| 81df/dt | Rate of Change of Frequency |
| 81O | Overfrequency |
| 81U | Underfrequency |
| CTS | CT Supervision |
| PSL | Programmable Logic |
| SEF | Sensitive Earth Fault |
| TEFD | Transient Earth Fault Detection |
| TCS | Trip Circuit Supervision |
| VTS | VT Supervision |

## Differential Protection (Phase and Neutral)

The P54 provides phase-segregated current differential protection. Themeasurement 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. The initial slope ensures sensitivity to low current faults, whereas the second slope is raised to counter the effects of current transformer (CT) saturation. An intelligent transient bias technique is also used to counter the effects of CT saturation, without compromising the operating time for internal faults.

The P54x offers additional neutral current differential protection, complementing phase differential during high resistance faults (for example, up to 500Ω in 500 kV systems).

Enhanced additional security is provided by fault disturbance detectors, which can optionally be used to supervise the output of current differential elements, improving grid reliability.
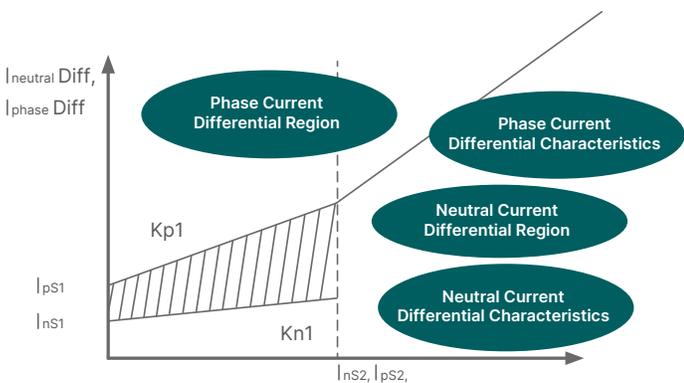


Figure 2: Differential protection characteristic

## Longitudinal Signalling 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 fibre 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 fibre pair.

Figure 3d shows a multiplexed application, where the P54 relay can be connected directly via fibre optics to an IEEE C37.94TM compliant multiplexer (MUX), or where a MiCOM P590 interface unit performs the optical–electrical conversion for the MUX.

Mixed communications channel options are available, for example 850nm MUX connection on Channel 1 and 1300nm direct fibre on Channel 2, supporting diversity in signalling paths.
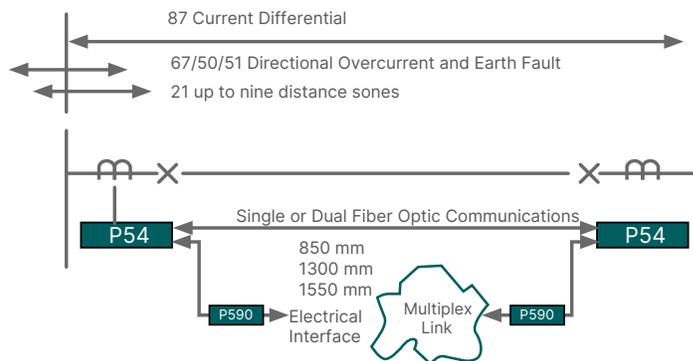


Figure 3a: Application to 2 terminal lines
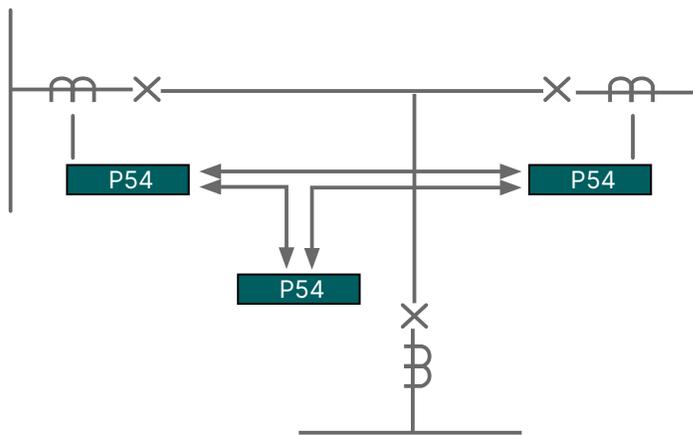


Figure 3b: Three-terminal line applications
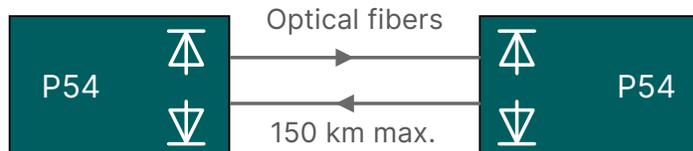


Figure 3c: Direct link using optical fibre
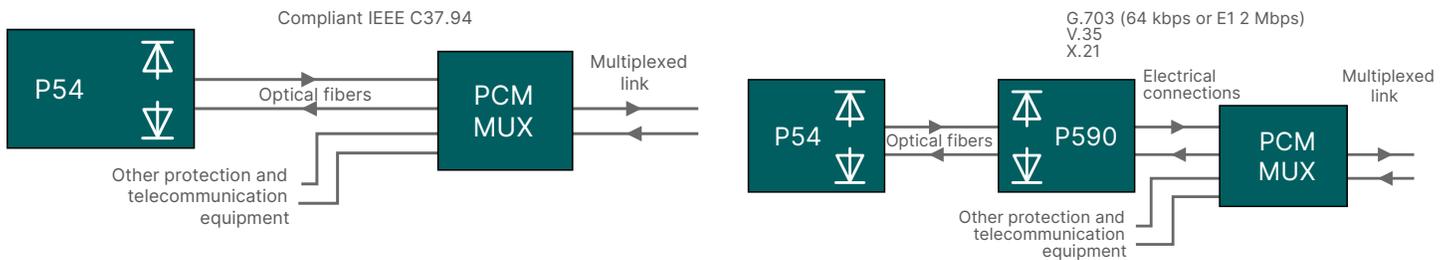
Figure 3d: Multiplexed link - relay connected to a remote PCM multiplexer using optical fiber (IEEE C37.94TM compliant MUX) or via a P590 interface unit

## System Application Examples

### Transformer

Figure 4 shows a protected line and transformer unit. In such applications, the relay compensates 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.
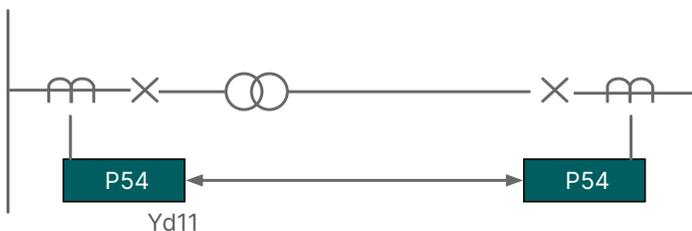
Figure 4: Application to transformer feeders (P543)

### 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.

### Flexibility in Network Extensions

All P54 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 P54 also compensates for line CT ratio mismatches, even for 1 A and 5 A differences between line ends and CT polarity inversions. This facilitates easier retrofitting and network extensions.

The line differential and communications channel can work in a retrospective compatibility mode. This permits asset replacement per line end when not all ends can be accessed to upgrade at exactly the same time. Protection will operate among a mix of installed MiCOM generations.

### Breaker and a Half, Double Bus or Ring/Mesh Feeding

The P546 order code offers two sets of CT inputs for connection as in Figure 5. The two CTs may have different ratios, which are independently settable in the relay. 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 be tolerated, and, importantly, in the event of breaker failure, the relays will identify the individual failed breaker. If the line is disconnected (line isolator open), the relay provides differential protection for the stub bus zone.

### GPS Synchronised 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 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 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.
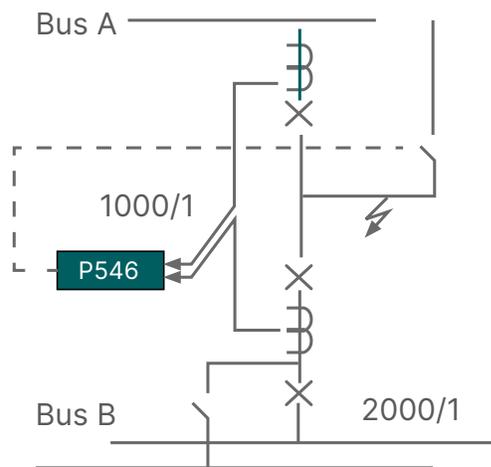
Figure 5: Application to 2 breaker configurations (showing stub bus fault)
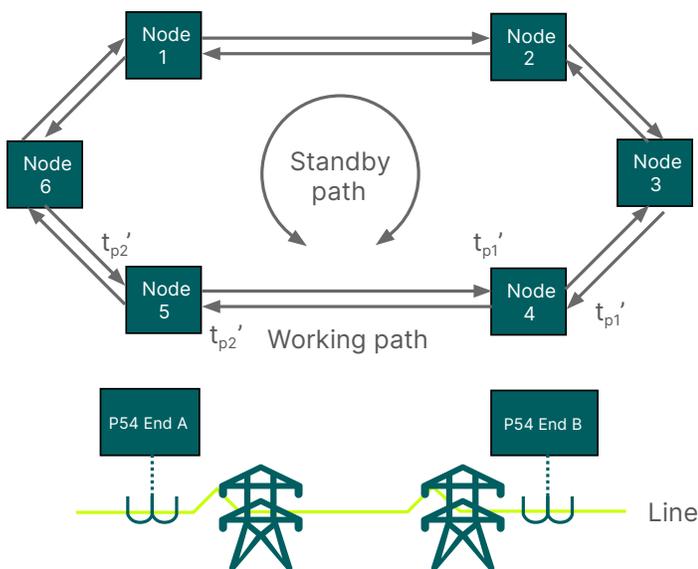
*Figure 6: SDH/SONET networks*

## Communications Interfacing for Protection Schemes

The MiCOM P54 series is designed to work within the bandwidth of a 64 kbps, pulse code modulation (PCM) channel. A direct fibre optic connection to a multiplexer (MUX) is possible if the MUX is IEEE C37.94TM compliant. Electrical interfaces conforming to ITU-T G.821 recommendations for G.703 (64 kbps or 2 Mbps E1) and X.21 are available via the P59x series of interface units.

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

## Communications Supervision and Automatic Reconfiguration

The P54 uses advanced error detection to secure itself against maloperation due to erroneous data. A CRC checksum addresses the concerns of multiple bit errors due to high channel noise. Unique addressing ensures that each relay is corresponding with the correct intended remote relay(s). Integrated channel monitoring provides real time diagnostic data, and in the event of deterioration or failure it can activate an alarm, optionally used to enable backup protection.

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, Ch. 1 and Ch. 2 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 followers, able to trip their local breakers based on the differential instructions from the master. 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.

## Three to Two Terminal Adaptation

For maintenance reasons, occasionally there will be an outage at one substation, for example end 'A' in Figure 7. Opening of the disconnector has signalled that there is no more infeed at this terminal. The P54 relay can instruct the other two ends to switch into two terminal operation, such that Relay A can even be de-energised. Once maintenance is complete, Relays B and C receive the instruction to revert to three terminal mode. This reconfiguration occurs automatically from end A, without the need for personnel to visit the other substations.
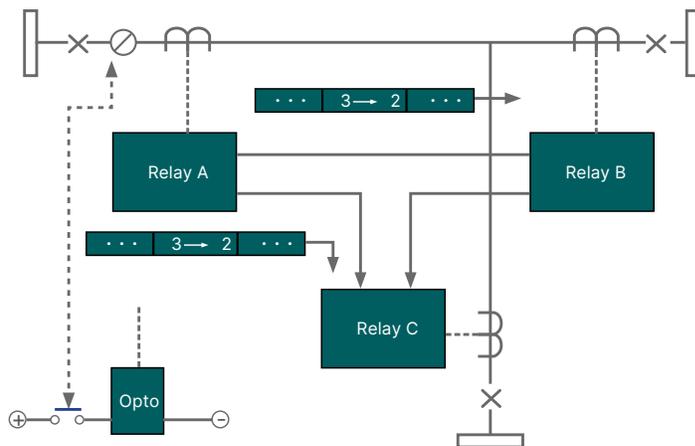


*Figure 7: Three to two terminal reconfiguration*

## Distance Protection

Nine zones of protection are provided, with a subcycle order option available. 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.

Quadrilateral characteristics (Figure 9) 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.

For simplicity, six zones are shown in Figures 8 and 9. Additional zones ZR, ZS and Z1e are available.

The distance protection includes CVT (capacitor voltage transformer) filtering for optimum performance with CVTs. This adaptive filtering retains subcycle operation up to a source: line impedance ratio (SIR) of 30, as may apply for weaker renewable infeeds.
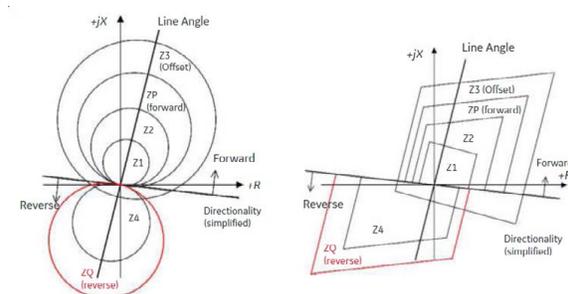


*Figures 8 & 9: Mho and Quadrilateral zones*

Blinder characteristics (see Figure 3) prevent false tripping due to encroachment of heavy loads. The load blinder action is selectively inhibited per phase if the phase voltage drops, indicating the inception of a fault. This ensures that the blinder serves to avoid trips on load, but it does not desensitise distance zone response to genuine resistive faults.
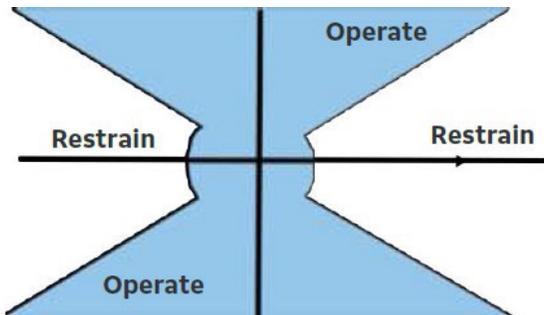


*Figure 10: Load blinder*

### Settings-Free Power Swing Blocking (PSB)

The MiCOM P44 recognises power swings quickly, by means of the superimposed currents measured by the phase selector. This approach is automatic and settings-free, with no impedance bands nor timers to set. The user does not need to anticipate the speed (Hz) spectrum of power swings which may develop on the grid – no need to conduct expensive modelling studies.

A conventional PSB element based on an impedance band is also provided for users with a more traditional preference.

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, just as the acceleration is building and before the current gets high.

As the out-of-step will be experienced right along a transmission corridor, it is desirable to split the system at just one point, close to the electrical centre of the pole-slip. As several distance zones are available in the relay, two which are not used for regular tripping can be assigned for this purpose.

### Distance Schemes

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

A settable alternative distance scheme mode initiates all the zone timers simultaneously and guarantees faster tripping of time-delayed zones for evolving faults, mimicking the operation of and time-grading with legacy relays deployed in the grid.

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 onboard InterMiCOM64 teleprotection.

Direct transfer tripping, permissive underreach (PUTT), permissive overreach (POTT) and blocking schemes are supported, including DACH special schemes (Germanic), open breaker, weak infeed echo and weak infeed trip features. The logic adapts to 2 or 3-terminal distance scheme applications, with phase-segregated teleprotection possible thanks to the large number of InterMiCOM64 end-end signalling bits available.

### InterMiCOM64 Teleprotection

InterMiCOM64 allows high performance permissive and blocking type protection to be configured, plus the 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 24 end-to-end signals, assignable to any function within the P44 relay's programmable logic. Default fail-safe states can be set in case of channel outage.

### Phase Preference for Petersen Coil Earthed and Isolated systems

MiCOM P44 is 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 "cyclic" or an "acyclic" logic order, so that only one feeder is tripped, not disrupting the supply to both feeders experiencing single phase to earth faults.

### Delta Directional Comparison – Incremental Protection

Superimposed voltage and current signals are used to make highly secure fault directional decisions. The respective forward/reverse decisions at each line end can be used in a teleprotection scheme for full line unit protection, as proven in the LFDC product.

### Transient Earth Fault Detection

MiCOM P44 incorporates 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 costeffective functional integration and protection scheme engineering.

### 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 solidly earthed systems, even when a fault generates negligible zero or negative sequence voltage. Traditional relays would have required an extra CT input to cover this scenario.

## Typical Protection Trip Times*

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

- 23 to 28 ms (50 Hz system – using 1 slot 64 kbps MUX)
- 19 to 24 ms (60 Hz system - using 1 slot 64 kbps MUX)
- 20 to 25 ms (50 Hz system – direct fibre or 12 slots MUX)
- 16 to 21 ms (60 Hz system – direct fibre or 12 slots MUX)

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

- 13 to 19 ms (50 Hz system – subcycle option)
- 12 to 17 ms (60 Hz system – subcycle option)
- 20 to 27 ms (50 Hz system – three-pole tripping model)
- 18 to 25 ms (60 Hz system – three-pole tripping model)

*All trip times are 5 ms faster than shown when using optional highspeed/high-break contacts (HSHB).*

## Backup Protection

### Phase and Earth Overcurrent

Four stages of both phase and earth fault protection are provided, each selectable as non-directional or directional (forward/reverse). In addition to definite time and predefined IDMT curve selection (see Figure 4), the P44 supports user programmable curves for customised operation and resetting. The profile can be chosen to optimise the protection, without constraining loadability. If a standard curve is not suitable for the application, the user can program and upload a custom variant.

Negative sequence overcurrent and sensitive earth fault (SEF) with 0.5% x In sensitivity are also provided.
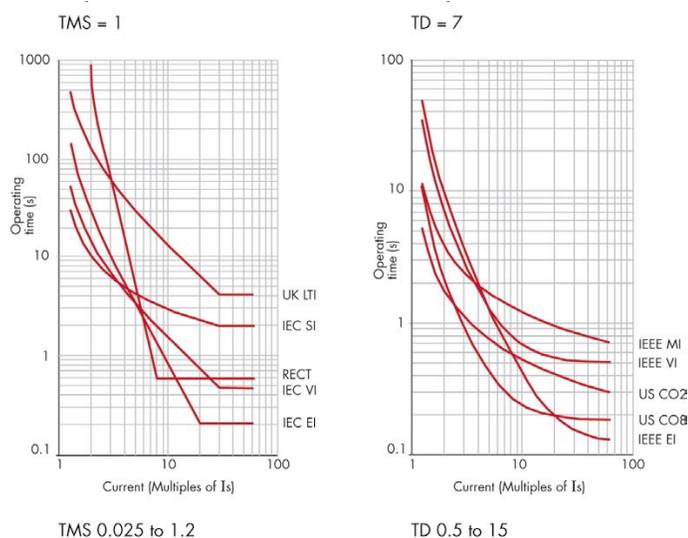


*Figure 11: Standard IDMT curve types*

### Voltage Protection

Under/overvoltage protection may be configured to operate from either phase-phase or phase-neutral quantities. Four independent stages are provided, with a mix of definite time and inverse-time characteristics. A compensated overvoltage function protects the line from Ferranti overvoltages by calculating the positive sequence voltage at the remote terminal.

Residual overvoltage protection is available for detecting earth faults in high impedance earthed or isolated systems.

### Broken Conductor

The broken conductor protection detects unbalanced conditions caused by broken conductors, or maloperation of a single phase of switchgear. It operates on the ratio of I2 to I1.

### Thermal Overload

A single time constant characteristic as per IEC 60255-8 is provided to protect cables, dry type transformers and capacitor banks. An additional dual time constant characteristic is suitable to protect in-zone oil-filled transformers, serving to protect the winding insulation from ageing and to minimise gas production by overheated oil.

### Power Protection

Four stages of directional power protection are provided and each stage can be independently configured to operate as overpower or underpower and forward or reverse direction.

### Frequency Protection

Nine stages each of: overfrequency, underfrequency, rate of change of frequency, frequency supervised rate of change of frequency, average rate of change of frequency – for frequency-based load shedding during severe system disturbances.

## Supervisory Functions

### VT Supervision (Fuse Fail)

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

### CT inputs – Safety and Supervision

All CT inputs are dual-rated at 1 A and 5 A to simplify ordering and strategic spares inventories. The terminal block features integral shorting to prevent dangerous voltages being present should the block be removed. This affords additional safety to personnel who may be working near live apparatus.

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.

**Circuit Breaker Failure**

Two-stage, phase-segregated circuit-breaker failure protection may be used for tripping upstream circuit-breakers and for re-tripping the local circuit-breaker if required. The undercurrent elements used in the CB fail reset mechanism detect the breaker opening in real-time, even when there are subsidence currents in the CT secondary caused by the remnant flux.

## IEC 61850-9-2 LE Process Bus Interface

An optional process bus interface is available, allowing the relay
to receive current and voltage sampled data from digital instrument transformers. In other digital substation architectures, the -9-2 data is generated by merging units in the yard which digitise conventional 1 A/5 A and 100/120 V secondaries, for safer and
more economical cross-site communications to IEDs via fibre optics.

Grid Solutions' -9-2 LE implementation is designed to be especially resilient and reliable in the presence of "noise", such as latency, jitter or missing/suspect data.

## Control

**User Interface**

Ten function keys in 60 and 80TE case sizes operate in two modes, normal and toggled, with integrated tricolour programmable LEDs. These replace traditional hardwired control scheme switches and annunciation, saving on engineering time and wiring costs. Thirteen further tricolour LEDs are available, freely-configurable, in addition to five fixed-function LEDs

In addition to support of English, French, German, Spanish, Italian, Portuguese and Polish languages, the ability to customise the menu text and alarm descriptions is available. Easily switch between English and an additional language on the local display without uploading new firmware.

A USB front port offers ready access by field personnel's laptop computers.
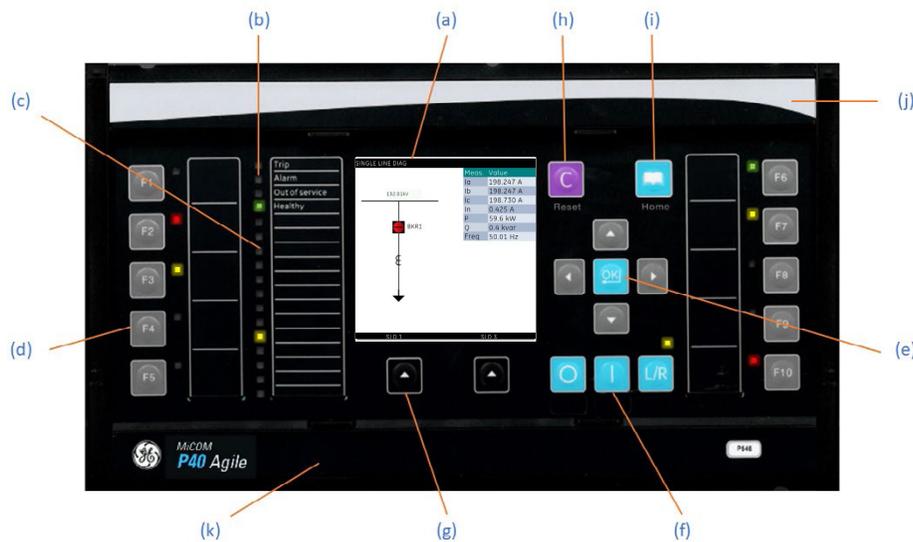


*Figure 12: Front fascia view*

a. Colour Screen

b. Four Fixed-Function LEDs

c. 13 Tricolour Programmable LEDs

d. Ten Function Keys with Tricolour LEDs

e. Menu Navigation and Data Entry

f. Bay Control and Local/Remote with LED

g. Context-Sensitive Keys

h. Clear Key – Long Press to Reset

i. Read Key – Long Press to Return to Home Screen

j. Top Flap Conceals CORTEC and Rating Labels

k. Bottom Flap Conceals USB(B) Access Port

## One-Box Switchgear Control

Circuit-breaker control is available from the front panel user interface, optically isolated inputs and remotely via the substation communications. 8 sets of switch control logic, LN CSWI/XSWI for controlling/monitoring of disconnectors and earth switches are also available.

Operation of the bay is greatly assisted using the colour graphical HMI, open/close buttons and local/remote control mode switching.

## Single Breaker Autoreclose (P443 model)

The user may select a single, two, three or four shot autoreclose cycle. The associated check synchronising feature has predictive close control, to ensure that the CB contacts touch at the instant of synchronism, minimising the stress on plant assets when paralleling.

## Dual Breaker Autoreclose (P446 model)

The following additional features are offered in the P446 model to permit two breaker reclosing in a leader/follower scheme:

- Two CB Control - CB1 and CB2 are assigned
- Individual selection of recloser 'on or off'
- Leader-follower configuration
- Independent lockout and reset per breaker

## Adaptive Reclosing

The MiCOM P44 has adaptive reclosing, allowing the instant of fault arc extinction to be detected. Reclosing is made possible without having to wait for a regular long, fixed dead time. In so doing, synchronising power is flowing in all three phases quicker, lessening the stability risk to weakly-interconnected systems and/or those with long transmission corridors. Conversely, it allows better identification of persistent faults, allowing a drive to lockout response. Unnecessary operations of switchgear can be prevented, avoiding an extra close and trip shot, thus avoiding additional circuit breaker wear.
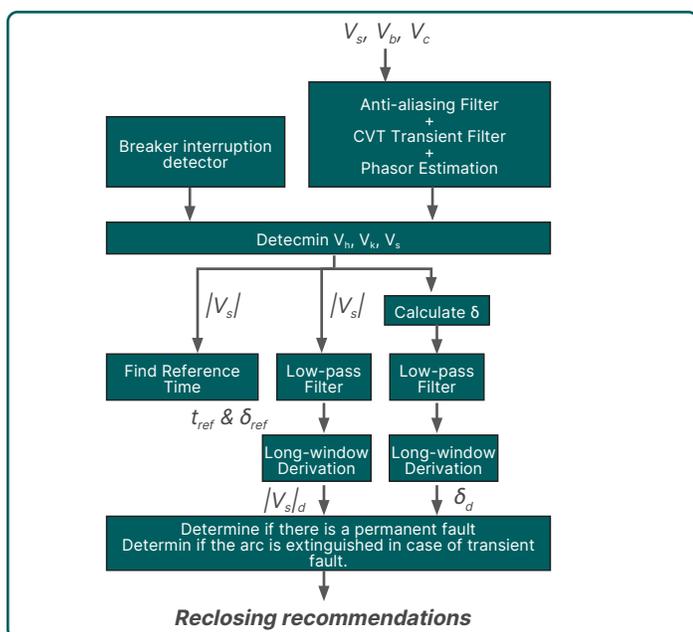


Figure 13: Adaptive reclose logic processing

The algorithm (see Figure 6) uses the rate of change of the faulted phase voltage and angle to distinguish between transient and persistent faults and to detect the time when the arc is extinguished. Typically, the transient fault dead time can adapt to less than 0.25s – half of a traditional fixed dead time – to be ready to reclose as soon as the circuit breaker's trip-free mechanism has reset.

## Programmable Scheme Logic (PSL)

Powerful graphical logic allows the user to customise the protection and control functions (see Figure 7). The logic includes 32 timers, 32 counters, 512 gates (OR, AND, MAJORITY) and set/reset latch functions, with the ability to invert the inputs and outputs and provide feedback. Each gate can support a large array of inputs, with a simple right-click of inputs or outputs serving to invert the signal. Output contacts have optional latching (lockout) functionality.
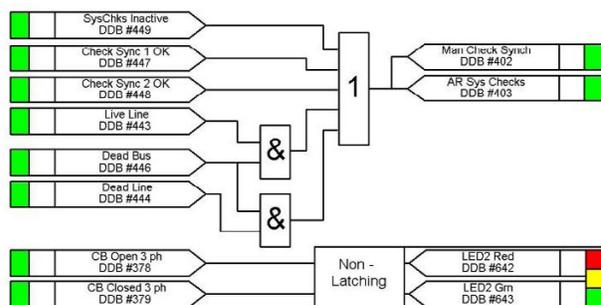


Figure 14: Programmable Scheme Logic

The PSL can be used to implement trip circuit supervision or implement complex logic such as frequency restoration schemes. Schemes are developed capable of supervising the trip coil and circuit with the circuit breaker open or closed, achieving full 'H7' performance.

GE's MiCOM Agile is deterministic – intensive logic and multiple nested gates do not affect the speed of protection tripping, I/O processing, measured or sampled values acquisition nor GOOSE response. The logic gates are processed concurrently, such that logic 'race' scenarios are eliminated.

All aspects of MiCOM P40 IED configuration are managed using the S1 Agile software (see Figure 8). The software is license-free, and able to support interfacing with .xrio and CAPE simulation environments, and easy Excel import/export where required.



Figure 15: S1 Agile: a powerful and intuitive PC-toolsuite

### Binary Inputs and Outputs

Opto-isolated binary inputs comply to the ESI 48-4 EB2 standard and are immune to inductive fields created in substations where wiring runs for hundreds of metres in the yard and neighbouring wires, busbars and power conductors create strong fields. The inputs support programmable pickup with no spurious pickup during battery ground faults or capacitive discharges, thereby making them perfect for plant status monitoring.

Each output relay module provides normally-open (form A) and a generous mix of changeover (form C) contacts. Optional high-speed/high-break contacts are available, with 30A high break rupturing ensuring no burn-out of contacts during normal operations or situations such as breaker failure or defective CB auxiliary contacts.

## Measurement and Recording

All event, fault and disturbance records are time tagged to a resolution of 1 ms. IEEE 1588, NTP or an optional IRIG-B port are available for accurate time synchronisation.

### Power System Measurements

Instantaneous and time integrated voltage, current and power measurements are provided. These may be viewed in primary, orsecondary 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 innovative algorithm employed tolerates prefault loading and fault arc resistance.

### Event Records (SOE)

Up to 5000 time-tagged event records can be stored.

### Fault Records

The last 100 fault records are stored as minimum.

### Disturbance Records

The oscillography has 16 analogue channels, 128 digitals and 1 time channel, all at a high resolution of 48 samples/ cycle. With 1050s of recording capability, ability to store 100 waveforms of maximum duration of upto 10.5 second duration can be stored.

### Circuit-Breaker Condition Monitoring
- Monitors the number of breaker trip operations
- Records the sum of broken current quantity (wear, interruption duty)
- $\Sigma Ix$, $1.0 =< x =< 2.0$
- Monitors the breaker operating time

## Communications with Remote Operators and Substation Automation

The following protocols are available:
- Courier/K-Bus
- IEC 60870-5-103
- DNP 3.0 (EAI-485 serial)
- IEC 61850 Edition 2.1 station bus
- IEC 61850-9-2LE process bus
- IEEE 1588 precision-time protocol
- SNTP time synchronisation
- IRIG-B time synch, modulated or demodulated
- RSTP, or PRP and HSR as per IEC 62439-3
- SNMP v2c and v3
- USB front-port communication

P54 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 Ethernet boards include a dedicated RJ45 engineering port, typically for engineering access by protection engineers/operators when the main Ethernet ports are reserved for SCADA traffic.

To help smooth transition from the existing protocol to IEC 61850, the P54 relay has been designed to provide Courier, -103 or DNP3 on the RS485 port, whilst providing IEC 61850 on the Ethernet port(s). This allows customers to future-proof their investment, getting ready for any future SCADA/DCS upgrade.

### Second Rear Serial Port

An additional second rear Courier port can be ordered as an option, designed typically for engineering access by protection engineers/operators when the main port is reserved for SCADA traffic.

# Ordering Options

| | | | |
|---|---|---|---|
| **Current Differential with Distance and Autoreclose/Check Synchronising** | | **P54** | `** ` |
| Single Breaker Application | | | 3 |
| Breaker and a Half or Dual Breaker Appplication | | | 6 |

**Nominal Auxiliary Supply Voltage**
| | |
|---|---|
| 24-54 Vdc | 7 |
| 48-125 Vdc (40-100 Vac) | 8 |
| 110-250 Vdc (100-240 Vac) | 9 |

**CT and VT Ratings**
| | Hardware Opt. Compatibility | |
|---|---|---|
| In = 1A/5A ; Vn = 100-120Vac | All | 1 |
| IEC 61850-9-2LE Redundant Sampled Analogue Values Ethernet - process bus model * | Options R,S,T only | C |

**Hardware Options**
| | |
|---|---|
| Standard - 1 x RS485 rear serial communications port provided with all ordering options (Courier, -103, DNP3 ready) | 1 |
| With additional IRIG-B (Modulated) | 2 |
| With additional IRIG-B (Modulated) & Serial Fibre Optic comms | 4 |
| With 2nd Courier protocol Rear Port + IRIG-B modulated * | F |
| Redundant Ethernet PRP/HSR/RSTP/Failover: 2 multi-mode fibre ports + Modulated/Un-Modulated IRIG-B * | R |
| Redundant Ethernet PRP/HSR/RSTP/Failover: 2 copper ports RJ45 + Modulated/Un-Modulated IRIG-B * | S |
| Single and Redundant Ethernet Failover: 1 copper port RJ45 + 1 multi-mode fibre port + Modulated/Un-Modulated IRIG-B * | T |
| Single Ethernet 1 LC Duplex port + Universal IRIG-B + 1588 + 1 RJ45 Maintenance Port** | U |
| Redundant Ethernet PRP/HSR/RSTP/Failover 2 LC Duplex port + IEC870-103 Serial Fibre ST ports + Universal IRIG-B + 1588 + 1 RJ45 Maintenance Port** | V |
| Redundant Ethernet PRP/HSR/RSTP/Failover 2 RJ45 + Universal IRIG-B + 1588 + 1 RJ45 Maintenance Port** | W |
| Redundant Ethernet PRP/HSR/RSTP/Failover 2 LC Duplex ports + Universal IRIG-B + 1588 + 1 RJ45 Maintenance Port** | Y |

\* only available with SW AA
\*\* only available with SW AB

**Input/Output Options**
| | Case Size Compatibility | |
|---|---|---|
| 8 inputs, 7 outputs | 40TE, 60TE | A |
| 8 inputs, 8 outputs | 40TE, 60TE | B |
| 8 inputs, 14 outputs | 60TE | C |
| 12 inputs, 12 outputs | 60TE | E |
| 16 inputs, 14 outputs | 60TE | G |
| 16 inputs, 16 outputs | 60TE | H |
| 16 inputs, 16 outputs + 4 High-Speed High-Break | P543 only 60TE, 80TE | J |
| 16 inputs, 21 outputs | P543 only 60TE, 80TE | K |
| 16 inputs, 24 outputs | P543 only 60TE, 80TE | L |
| 20 inputs, 20 outputs ** | P543 only 60TE, 80TE | P |
| 24 inputs, 16 outputs ** | P543 only 60TE, 80TE | S |
| 24 inputs, 16 outputs + 8 High-Speed High-Break | 80TE | T |
| 24 inputs, 24 outputs ** | 80TE | U |
| 24 inputs, 32 outputs | 80TE | V |
| 28 inputs, 43 outputs | P543 only - 80TE | Y |
| 32 inputs, 24 outputs ** | 80TE | 1 |
| 32 inputs, 32 outputs | P543 only - 80TE | 2 |
| 40 inputs, 24 outputs | P543 only - 80TE | 4 |
| 40 inputs, 32 outputs ** | P543 only - 80TE | 5 |

**Line Differential Channel Options**
| | |
|---|---|
| Ch1=850nm multi-mode, Ch2=850nm multi-mode | A |
| Ch1=1300nm single-mode, Ch2=not fitted  (2 Terminal only) | B |
| Ch1=1300nm single-mode, Ch2=1300nm single-mode | C |
| Ch1=1300nm multi-mode, Ch2=not fitted  (2 Terminal only) | D |
| Ch1=1300nm multi-mode, Ch2=1300nm multi-mode | E |
| Ch1=1550nm single-mode, Ch2=not fitted  (2 Terminal only) | F |
| Ch1=1550nm single-mode, Ch2=1550nm single-mode | G |
| Ch1=850nm multi-mode, Ch2=1300nm single-mode | H |
| Ch1=850nm multi-mode, Ch2=1300nm multi-mode | J |
| Ch1=850nm multi-mode, Ch2=1550nm single-mode | K |

**Case Size and Mounting**
| | Product Compatibility | |
|---|---|---|
| 80TE Case - Flush/Panel Mounting with Harsh Env. Coating, with USB Port and 10 Function Keys | P543, P546 | S |
| 80TE Case - 19" Rack Mounting with Harsh Env. Coating, with USB Port and 10 Function Keys | P543, P546 | T |
| 40TE Case - Flush/Panel Mounting with Harsh Env. Coating, with USB Port, without Function Keys | P543. P546 with IEC 61850-9-2LE | U |
| 60TE Case - Flush/Panel Mounting with Harsh Env. Coating, with USB Port and 10 Function Keys | P543, P546 | V |

**Product Features**
| | |
|---|---|
| Subtransmission/Distribution Distance Protection, 3 Pole Tripping Only | A |
| Subcycle Transmission Distance | B |

**Software Version**
| | |
|---|---|
| Major Version - please visit On-Line Store to select | ** |

**Customer-Specific Additions**
| | |
|---|---|
| Standard version | 0 |
| Customer-specific configuration/options | A |

**Hardware Version**
| | |
|---|---|
| 5th Generation Hardware, Graphical Colour HMI with High Performance Processing | Q |

## Asset Life Extension

In addition to new-build, GE's 5th generation MiCOM relays can be used to refurbish time-served protection schemes. As the P44 is pin-pin compatible with forerunner P441, P442, P443, P444, P445 and P446 relays from Alstom, AREVA and GE, they can be interchanged in minutes for an easy upgrade. This dramatically reduces the retrofit time and cost.

## Environmental Responsibility

The Relays are manufactured in a lead-free soldering process using leadfree components. Power dissipation is low, for smaller station batteries and to reduce the global warming potential (GWP) during the installed life.

GE-branded MiCOM P40 relays have no resident battery, to ease airfreight logistics and dispense with a maintenance item.

## Cybersecurity

The sophistication of protection schemes, coupled with the advancement of technology, increasingly leads to devices and substations being networked. This introduces a potential security risk making the grid vulnerable to cyber-attack. To secure communication within such environments, MiCOM Agile P44 offers NERC®-compliant cyber security.

All of GE's MiCOM range is manufactured in ISO 27001 certified factories.

## Quality Built-In (QBi)

Parts stress analysis in R&D, rigorous component supplier selection, and a shipping carton compliant with ISTA protection requirements all are examples of best-practice to maximise long-life reliability. All circuit boards have harsh environmental coating, to resist moisture, salt, corrosive atmosphere and industrial ambient pollution – as standard. The relay's case offers full encapsulation, with no ventilation holes for dust ingress.

Circuit board production uses in-circuit tests, boundary scanning, builtin self-test, automated optical inspection, and X-ray scanning to achieve maximum test coverage.

In addition to the standard -25°C to +55°C operating temperatures claim as per IEC 60255-6, the P40 range has proven withstand capability at extremes of temperature as per IEC 60068-2. These onerous tests were passed at -40°C and +85°C for 96 continuous hours in each case.

All MiCOM models offer power-up diagnostics and continuous selfmonitoring for high availability.

## Case Parameters

| CASE TYPES | 40 TE / 60 TE / 80 TE |
|---|---|
| Weight (40TE case) | 7 kg - 8 kg* |
| Weight (60TE case) | 9 kg - 12 kg* |
| Weight (80TE case) | 13 kg - 16 kg* |
| Dimensions in (40TE case) | W: 206.0 mm H: 177.0 mm D: 243.1 mm |
| Dimensions in (60TE case) | W: 309.6 mm H: 177.0 mm D: 243.1 mm |
| Dimensions in (80TE case) | W: 413.2 mm H: 177.0 mm D: 243.1 mm |
| Mounting | Panel, rack or retrofit |

*Depending on chosen options*



| GE'S MICOM TRACK RECORD | |
|---|---|
| 400 000 | MiCOM P40 relays shipped from GE's plants |
| 45 000 | P54x line and cable differential shipped |
| 75 000 | P44x line and cable distance shipped |
| 160 000 | Feeder manager and line terminal relays shipped |

## For more information
visit **GEGridSolutions.com**

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