GE
Grid Solutions

MiCOM Agile P547

Phase Comparison Line Protection

MiCOM Agile P547 relay offers phase comparison main protection, with distance protection as an option. The simplicity of the protection principle and scheme of the MiCOM Agile P547 relay allows fast fault clearance times. Two and three terminal line applications interfacing with power line carrier equipment can be protected. The carrier operates via the power line itself, thus the end-to-end scheme communications require no external signalling channel.

Model options allow the addition of VT inputs to enhance the stability and sensitivity of the protection in long line applications - even where single pole tripping is required. The addition of voltage inputs automatically supports distance protection, fault location and other enhanced functions inside the P547.

A full range of back-up protection is integrated. This increases the dependability of the protection, as hot-standby elements can be brought into service whenever a signalling channel outage may occur. Subcycle distance elements are included, allowing P547 use in phase comparison scheme applications, distance, or both in parallel.

Key Features

Phase Comparison Protection
- Applicable to all lines, long or short, strong and weak infeeds
- Single pole tripping (80TE case variants)
- VT option compensates for charging current effects
- VT or fuse failures do not compromise protection availability

Multi-terminal Applications
- Each relay equipped for 2 or 3 ended schemes
- Transformer tee-feeds supported via distance zone and residual current
- Supervision of phase comparison elements

Readily Interfaces with End-End PLC Channel
- Easy commissioning using manual channel test options
- In-service “reflex” tests on channel availability and propagation delay
- PLC channel is keyed at the point on wave to avoid line corona discharge

Distance Protection
- 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

Power swing alarm and block, plus out of step trip

Multi-shot autoreclosure with check synchronism
- Single circuit breaker applications

Key Benefits

- Highly selective unit protection
- Cost-effective alternative to current differential
- Signalling medium is the power line itself
- No dependence on VT signals for tripping
- Optional mho and quadrilateral subcycle
- distance zones
- Improved system stability by CB failure fast reset element (< 0.75 cycle)
- Readily interfaces with multiple automation protocols, including IEC 61850
- Redundant Ethernet (IEC 62439 PRP
- or RSTP) is available as an option

Imagination at work

Functional Overview

ANSI	IEC 61850	Features	40TE	80TE MODELS			
			A	B	C	D	E
	OptGGIO	Opto coupled logic inputs	8	16	24	16	24
	RlyGGIO	Relay output contacts	8	24	32	8	16
		High speed, high break contacts				4	8
		Fast scan I/O for phase comparison	2+2		2+2		
		Voltage transformer inputs			•		
	PTRC	Single and 3-pole tripping	3ph		1 or 3		
87PC	PDIF (PPDF)	Phase comparison unit protection	•		•		
		Number of line ends supported	2		2 or 3		
		Channel reflex check on availability and propagation delay	•		•		
		Line charging current compensation	•		Advance		
		Distance zone supervised “permissive” tripping			•		
21P/21G	PDIS	Distance zones – Mho and quadrilateral full scheme relay			5		
		Load blinder			•		
85	PSCH	Distance and DEF communication aided schemes, PUTT, POTT, Blocking, Intertrip, Weak Infeed			•		
50/27	PSOF	Switch on to fault			•		
68	RPSB	Power swing blocking			•		
78	RPSB	Out of step tripping			•		
50/51/67	OcpPTOC	Phase overcurrent stages	4		4		
50N/51N/67N	EfdPTOC	Earth/ground overcurrent stages	4		4		
51N/67N/SEF	SenEftPTOC	Sensitive earth fault (SEF)	4		4		
64	SenRefPDIF	High-impedance restricted earth fault protection			•		
67/46	NgcPTOC	Negative sequence overcurrent	•		•		
67/67N/SEF/46	RDIR	Directionalised back-up overcurrent for all PTOC			•		
46BC		Broken conductor	•		•		
49	PTTR	Thermal overload	•		•		
27	PTUV	Undervoltage protection stages			2		
59	PhsPTOV	Overvoltage protection stages			2		
59N	ResPTOV	Residual voltage protection stages			2		
50BF	RBRF	High speed breaker fail	•		•		
79	RREC	Autoreclose - shots supported			4		
25	RSYN	Check synchronising			•		
		Alternative setting groups	4		4		
FL	RFLO	Fault locator			•		
		Fault records	5		15		
SOE		Event records	500		512		
	RDRE	Disturbance recorder, samples per cycle	24		48		
VTS		Voltage transformer supervision			•		
CTS		CT supervision	I2/I1		•		
	XCBR	Circuit-breaker condition monitoring	•		•		
TCS		Trip circuit supervision	•		•		
		Graphical Programmable Scheme Logic (PSL)	•		•		
		IEC 61850-8.1 Ethernet communications			Optional		

Functional Overview Digagram

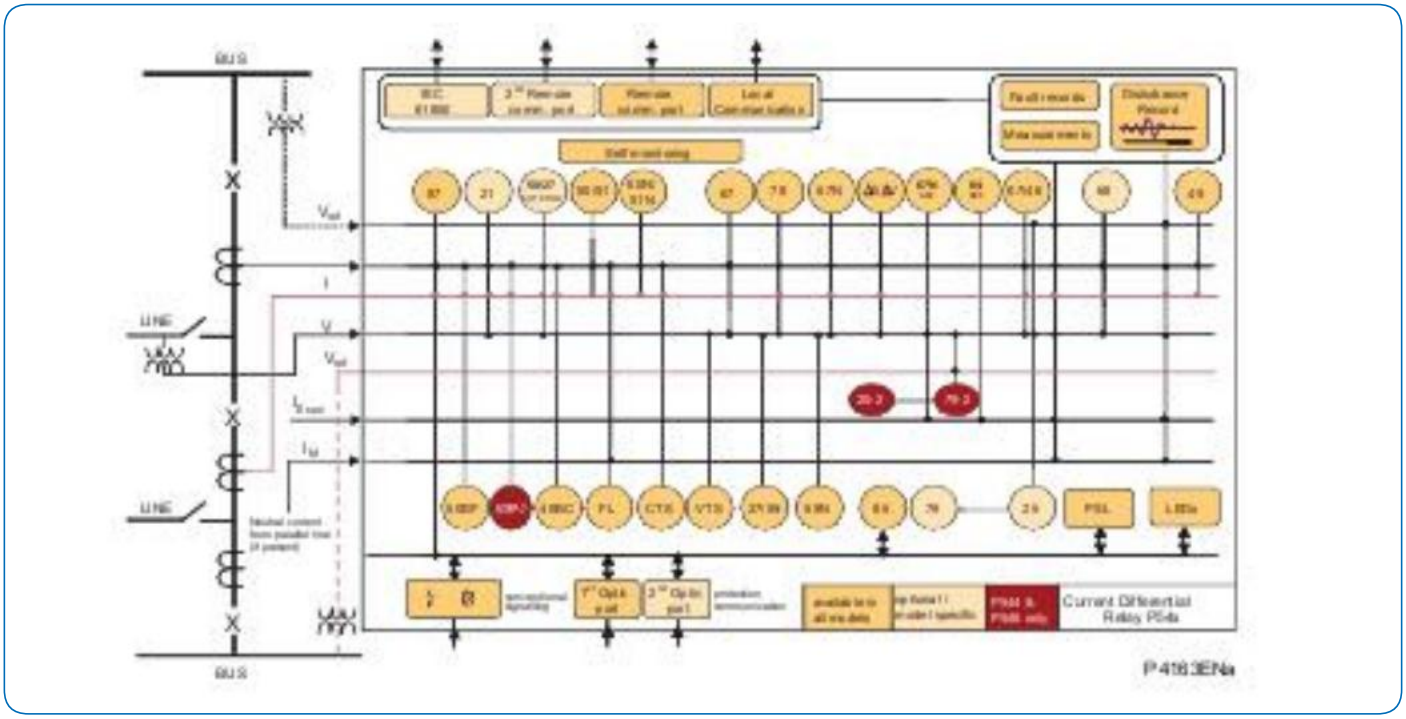

Figure 1 System overview of the P547 phase comparison

Application

Introduction

Phase comparison is an established mode of protection for medium and high voltage lines. The P547 operates in blocking mode, using highly dependable On/Off carrier signalling over third party Power Line Carrier (PLC) equipment. It is supplied with a full suite of protection and control functions as standard.

Different case size options exist – with the larger case (80TE) offering VT inputs and permitting additional binary I/O inclusion.

Phase Comparison Protection

Phase comparison protection essentially performs a phase angle check on the polarity of the current entering the protected circuit, compared with the same current phase angle measurement at the remote line end (or ends). For loadflow, external faults, or any other through-fed conditions, the measured currents will be in antiphase. For an internal fault, using the same reasoning, both ends will detect current infeed (currents are in phase).

The relay is especially designed to operate over a Power Line Carrier (PLC) channel, hence the end-to-end signalling scheme has been designed to operate with the typical ON-OFF keying. Where a utility does not have the high bandwidth digital communications required by current differential relays, the MiCOM Agile P547 is the preferred unit protection scheme.

In order to interface with the PLC channel, the relay operates according to several discrete principles. Firstly, on detection of a fault the channel must be initiated, such that the current phase angle information is transmitted. This requires the use of fault detectors or “starters”. There are multiple starters used by the relay, to ensure that all fault types are detected. Secondly, the remote line end must also start and send a respective carrier signal. Thirdly, the individual per-phase current information must be combined as a single representative quantity, such that only one PLC channel is needed between line ends.

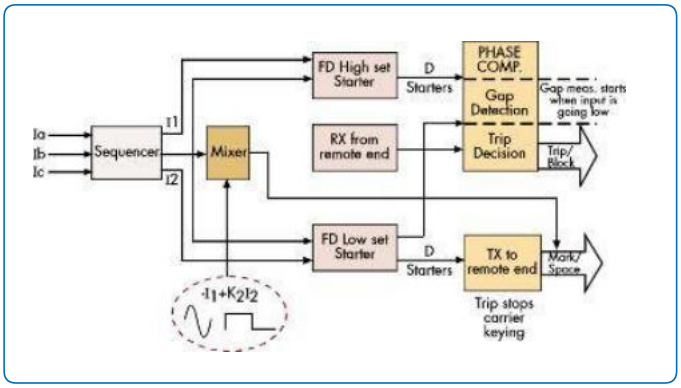

Figure 2 Phase comparison protection functional diagram

Fault Detection

The phase comparison elements use positive sequence and negative sequence quantities for fault detection. Each starter has a low-set and a high-set setting. The low-set enables carrier transmission (blocking for external faults) and the high-set enables phase comparison (tripping for internal faults).

Delta Starters

Delta starters work on the phasor change in the respective sequence quantity (negative sequence current and positive sequence current). Phasor quantities are particularly useful when the fault causes a change in angle of the quantity being compared, perhaps with no significant change in magni-tude. This is particularly true of a 3-phase fault near one end of a long line. As delta elements respond to step changes they do not need to discriminate with prevailing load current levels and hence can be set very sensitively – such as to detect even high resistance earth faults.

Threshold Starters

Threshold starters (positive and negative sequence) operate when the current threshold is exceeded and reset when the sequence quantities return to normal.

Voltage-dependent Starting

(80TE models only) For long line applications, additional starting criteria can improve performance. The relay offers distance zone underimpedance starters and negative sequence voltage starters. The negative sequence voltage starters are compensated, performing a line drop voltage calculation to estimate the negative sequence voltage as viewed at the centre of the protected line.

Modulating Quantity

The power line carrier signal is modulated by a composite quantity derived from the positive and negative sequence components.

Negative sequence components are present for all types of faults except 3-phase faults, hence a mix of negative and positive sequences is ideal for all types of faults. This gives a general formula of Im= -I1+ K*I2 (K is a factor which provides amplification for the negative sequence component).

The relay has a user mode and an intelligent adaptive mode of operation. In the user mode, K is set by the user (between 3 and 20) and in the adaptive mode the relay chooses the amplification factor based on the pre-fault load and the required earth fault sensitivity.

Gap Detection

In case of a fault, the carrier at both ends is modulated by the derived composite quantity, producing a mark and space pattern. For an internal fault the combined signal at the receiver will have a gap more than the set stability angle s (plus charging current compensation angle c - see Figure 3). If a trip condition results, then the carrier will be switched off to prevent blocking at the other end and the low set starters will reset. If not, the carrier will continue to send a blocking signal to prevent tripping and allow clearance of an external fault. at the centre of the protected line.

Unstabilising Facility

Under apparent external fault conditions, for example a fault in the unprotected short zone where the CTs are on the line side of the circuit-breaker, the P547 would issue a block condition. Under these circumstances, an input from the external protection (in this case busbar protection) can be input to the phase comparison scheme as an unstabilising input via the P547 universal opto-isolated inputs. The relay at end X will then cease carrier transmission, causing the relay at end Y to trip.

Charging Current Compensation

The MiCOM Agile P547 relay ensures protection stability when applied to lines with capacitive charging currents. A value of charging current or admittance is entered as a setting in the relay and this is taken into account for both line energisation and steady state charging current conditions. 80TE models offer the possibility of more accurate compensation using the phase voltage inputs from the VT.

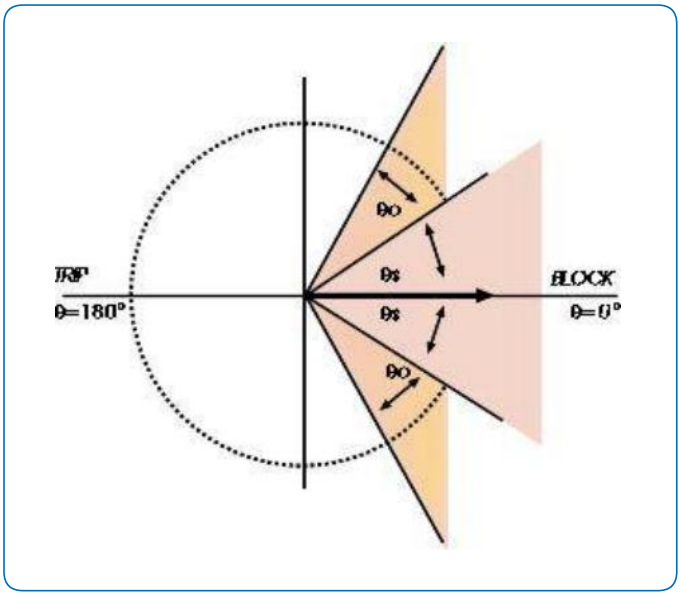

Figure 3 System stability diagram

Protection Signalling

The MiCOM Agile P547 is only to be used with compatible Power Line Carrier (PLC) and coupling equipment. Details of equipment approved can be obtained through your local GE's representative. In order to interface with the PLC equipment, dedicated fast-scan inputs and outputs are provided.

Digital Inputs

Two opto-isolated digital inputs are provided to receive the pulsed outputs from the PLC equipment. The digital inputs are capable of operating from any nominal battery voltage in the range of 12 to 54 Vdc.

Digital Outputs

Two solid-state normally-open output contacts are provided to send the pulsed signal to the PLC equipment. The contact outputs are potential free, being able to switch 500 mA and withstand up to 60 V. The relay's own 48 V field supply is ideal to operate these inputs and outputs.

Signalling Channel Checks

A facility is provided by the relay for checking the continuity of the PLC signalling channel. This feature can be enabled either as a periodic check at a time interval set by the user, or manually from the user interface. Failure of the channel checking function causes an alarm to be generated, which can also be used to disable the phase comparison protection.

The relays utilise the channel checking facility to measure the propagation delay and asymmetry in the transmitted signal. The asymmetry can result from the elongation of the transmitted signal by the PLC equipment. The relays use these measurements to compensate for the phase shift and decreased gap caused by propagation delay and asymmetry respectively.

Corona Discharge (80TE Models Only)

The relay offers the means to phase shift the modulated carrier signals so as to avoid problems in the event of any corona discharge/tracking across insulators. The phase shift can be adjusted to give best performance taking into account which of the three phases has the PLC coupling equipment attached.

Distance protection (80TE models only)

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 4 and uses well-proven principles to provide dynamic expansion for faults off the characteristic angle. The quadrilateral characteristics (Figure 5) 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.

Zone 3/P are independently selectable Forward/Reverse/Offset. Blinder characteristics (Figure 6) prevent false tripping due to encroachment of heavy loads.

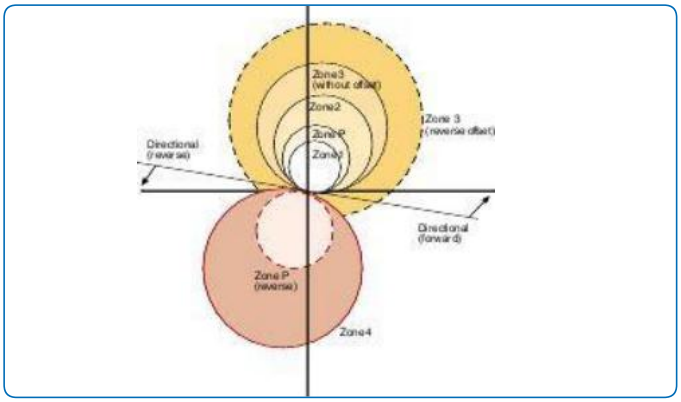

Figure 4 Mho characteristics

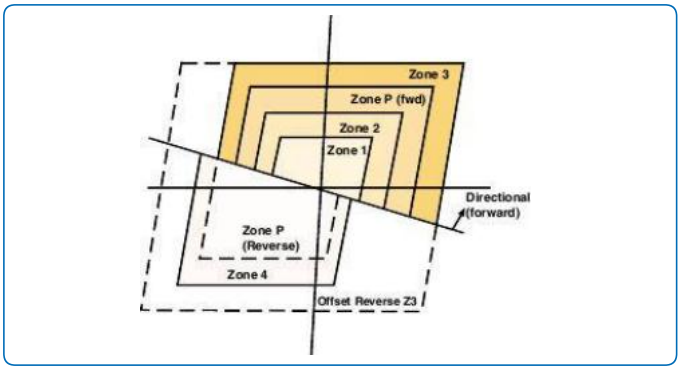

Figure 5 Quadrilateral characteristics

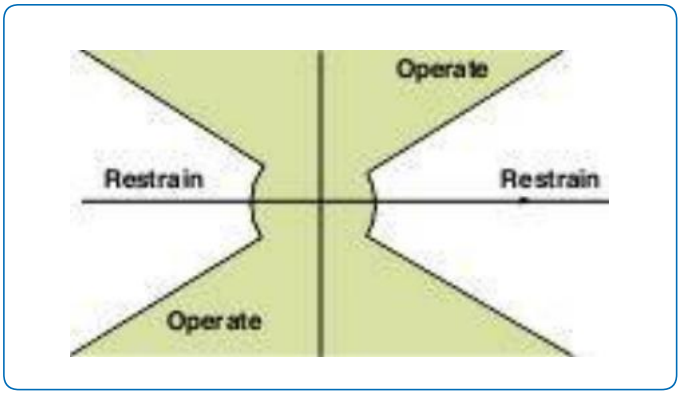

Figure 6 Load blinder

Power Swing Blocking (PSB)

The MiCOM Agile P547 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. 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.

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 can be switched-off when used in non-solidly earthed systems.

Typical Protection Trip Times

Phase comparison trip time (any point-on-wave including the closure time of a conventional trip relay contact):

- Scheme trip times are in the range of 15 ms to 40 ms for a 50 Hz system, with an average of 27 ms
- Scheme trip times take into account relay operation time, PLC operation time and propagation delay time

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

- 13 to 20 ms (50 Hz system)

High Speed - High Break Contacts

The trip times quoted relate to a MiCOM Agile P547 with standard relay contacts and include the contact closure time. When fitted with High Speed- High Break (HSHB) contacts, all trip times are reduced by 3 to 4 ms. HSHB contacts easily rupture repetitive shots of 10 A trip or close coil currents.

Supervisory Functions (80TE Models Only

VT Supervision

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

CT Supervision

Current transformer supervision is provided to detect loss of phase CT input signals.

Fast fault clearance unit protection, using the power line itself for signalling

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 and it allows easy customisation of the protection and control functions.

Autoreclose With Check Synchronism (80TE Model Only)

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 7). 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.

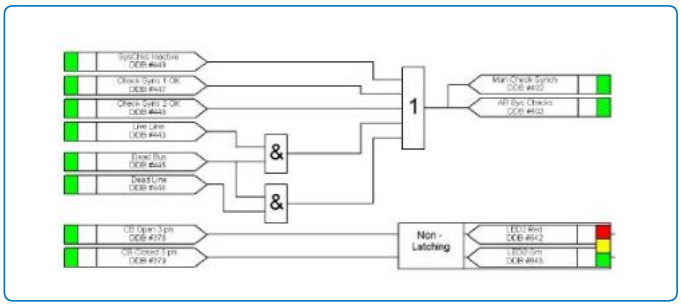

Figure 7 Programmable scheme logic

The system is optimised to ensure that the protection outputs are not delayed by the PSL operation. The programmable scheme logic is configured using the graphical MiCOM 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 8).

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.

Figure 8 S1 Agile: a powerful and intuitive PC-tool suite

Power System Measurements (MMXU)

Instantaneous and time integrated voltage, current and power measurements are provided. These may be viewed as primary, or secondary values.

Post-Fault Analysis

Fault Location (80TE Models Only)

A fault location algorithm provides distance to fault in miles, kilometres, ohms or percentage of the line length. The proven algorithm tolerates pre-fault loading and fault arc resistance.

Event Records

Up to 1024 time-tagged event records are stored in battery-backed memory. An optional modulated or demodu-lated 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.

80TE models display the modulated carrier sent and received ON/OFF signals in the COMTRADE file.

Plant Supervision

Circuit-Breaker Condition Monitoring

- Monitoring the number of breaker trip operations
- Recording the sum of broken current quantity (wear, interruption duty)
- Monitoring the breaker operating times

Quality Built-In (QBI)

The QBi initiative has deployed a number of improvements to maximise field 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.

Communications with Remote Operators and Substation Automation

The wide range of communications options, including IEC 61850 (80TE models only), 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 (80TE models only)

Redundant Ethernet is available, optionally managed by the market's fastest recovery time protocols: 'self-healing' ring and 'dual homing' star, allowing bumpless redundancy. IEC 62439 PRP and RSTP are also available, offering multi-vendor interoperability.

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 (80TE models only) is the chosen first port protocol.

About MiCOM P40 Agile

GE's philosophy is one of continuous improvement in our products and solutions. Our emphasis on communication in MiCOM has become a focus which secures leadership in the digital substation. To mark this phase of evolution, the P40 Agile livery is applied to the range. P40 Agile is a mark of performance and quality, proudly available from GE, and only from GE.

Device Track Record - Phase Comparison and Transmission relays

Over 250 P10 phase comparison relays delivered since launch in 1972.
P40 - version of P10 for the South African market.
P54x series introduced in 1999. Worldwide application, with over 29 000 units delivered.
Distance elements in 80TE models import MiCOMho subcycle technology.
Market leaders in the supply of phase comparison protection in the UK and Russia.

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