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Grid Solutions

MiCOM Agile P441, 42, 44

Full Scheme Distance Relay

MiCOM Agile P441, P442 and P444 numerical full scheme distance relays provide flexible and reliable protection, control and monitoring of transmission and subtransmission lines

A Combination of Speed, Security and Selectivity

The relays can be applied to a wide range of overhead lines and underground cables in high and extra high voltage systems. Based on a patented, proven algorithm with more than two decades of established field application, the P441, MiCOM P442 and P444 relays provide an unparalleled combination of speed, security and selectivity for any kind of power system fault.

The wide range of communications options help in easily connecting the relay to any type of digital control system or SCADA.

The optional redundant ethernet board (P442/P444 only) reduces the costs since the relay is natively embedded in the switchboard.

This reduces the amount of standalone switches needed, reducing the wiring, power supply and maintenance costs. Furthermore, increasing the availability rate decreases the risk of power outages.

MiCOM Agile P40 series extends IEC 61850-8-1 station bus to include parallel redundancy protocol (PRP), which offers a vendor-interoperable solution to implement redundant communications. It has the advantage of taking zero time to recover from a failure, as parallel alternative paths are continually operative. This compares to 25ms or more healing time for legacy techniques such as RSTP.

Key Benefits

- Dual algorithms
- Polygonal characteristic (quadrilateral)
- Fastest operating time: 0.85 cycles
- Wide choice of channel aided schemes
- Powerswing detection/out of step protection
- Inter relay protection communication
- Option of multiple communications protocols and interfaces, including IEC61850-8-1 (station bus)
- IEC 61850-9-2 process bus interface
- Redundant communications with zero downtime using optional PRP technology
- User customisable with graphical tools

Imagination at work

Application

MiCOM Agile P441, P442 and P444 numerical full scheme distance relays provide comprehensive distance protection for different applications such as: lines, cables, tapped lines, lines with multiple zero sequence sources, non-homogeneous lines, series compensated lines and parallel lines. The independently configurable resistive reach for each zone allows easy application to short lines and cable protection. Using well-proven, patented techniques to directionalise - and making full use of digital memory - the relays can be applied in situations that may cause classic distance implementations to maloperate (crosscountry faults, close-up faults, etc.).
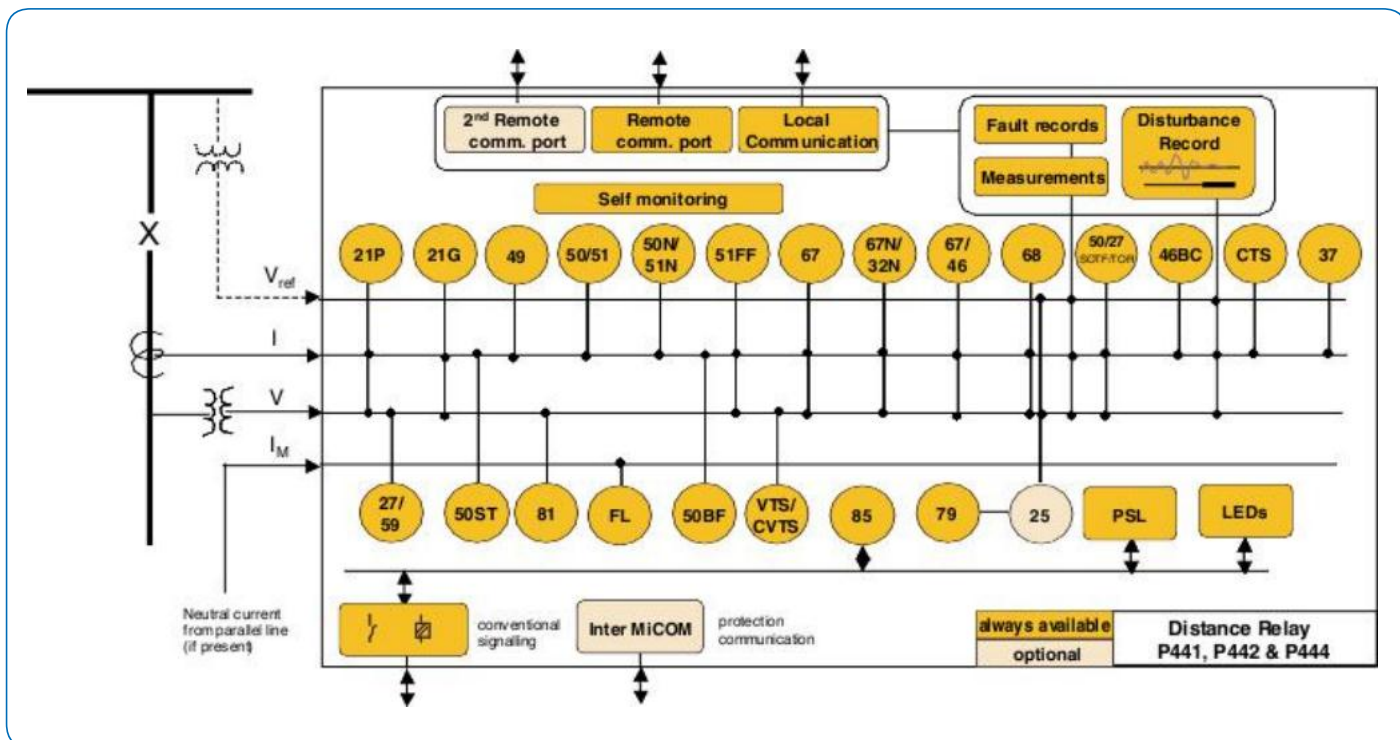
The P441, P442 and P444 all contain a library of channel aided scheme logic and supplementary and back-up protection. They provide complete protection (four alternative setting groups) to solidly earthed systems, from distribution to transmission voltage levels. 3-phase tripping with faulted phase indication is provided for all protection functions. In addition models P442 and P444 allow single-phase tripping for distance protection and channel aided DEF protection (67N). The P441, P442 and P444 distance relays, equipped with 150 MHz CPU and coprocessor board, have now been enhanced as described in the following table.

Functional Overview

ANSI	IEC 61850	Features	P441	P442	P444
21P	PDIS	Quadrilateral full scheme phase distance protection (5 zones)	•	•	•
21G	PDIS	Quadrilateral full scheme ground distance protection (5 zones)	•	•	•
50/51/67	OcpPTOC / RDIR	Directional / non-directional phase overcurrent (4 stages)	•	•	•
50N/51N/67N	EfdPTOC / RDIR	Directional / non-directional stand by earth fault (2 stages)	•	•	•
67N	EfaPSCH	Channel aided directional earth fault protection (DEF)	•	•	•
32N		Directional zero sequence power protection	•	•	•
67/46	NgcPTOC / RDIR	Directional / non-directional negative sequence overcurrent	•	•	•
68	RPSB	Power swing blocking & out of step tripping (using PSL)	•	•	•
50/27	PSOF	Switch on to fault / trip on reclose (SOTF/TOR)	•	•	•
85	PSCH	Channel aided schemes (PUTT, POTT, Blocking)	•	•	•
		Weak infeed echo logic	•	•	•
		Accelerated trip feature: Loss of Load - Zx extension	•	•	•
49	PTTR	Thermal overload protection	•	•	•
	PTRC	Tripping	3P	1/3P	1/3P
79	RREC	Auto reclose (4 shots)	3P	1/3P	1/3P
25	RSYN	Check synchronising	option	option	option
27	PTUV	Undervoltage (2 stage)	•	•	•
59	PTOV	Overvoltage (2 Stage)	•	•	•
37		3 Phase undercurrent		•	•
81U/O		Under/Over frequency		•	•
46BC		Broken conductor (open jumper)	•	•	•
50ST	OcpPTOC	Stub bus protection	•	•	•
50BF	RBRF	Circuit breaker failure	•	•	•
VTS		Voltage transformer supervision (1, 2 & 3 phase fuse failure detection)	•	•	•
CVTS		Capacitive voltage transformer supervision	•	•	•
CTS		Current transformer supervision	•	•	•
51FF	PTOC	Emergency overcurrent on VT failure	•	•	•
	OptGGIO	Digital inputs	8	16	24
	RlyGGIO	Output relays (fast output optional)	14	21	32 or 46
	SV	IEC61850-9-2 sampled values			•
		Front communication port (RS232/K-Bus)	•	•	•
		Rear communication port (RS485/Optic/Ethernet) * Second rear communication port (RS232/RS485/K-Bus) *	• NA	• option	• option
		Time synchronisation port (IRIG-B) *	NA	option	option

* It may not be possible to get all in one particular model, refer to data sheet for model selection.

NA: Not Applicable

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Management Functions

To complement the wide range of protection functions listed in the table, the P441, P442 and P444 relays are provided with the following measurement, control, monitoring, post fault analysis and self-diagnostic functions:

- Fault locator
- Display of instantaneous measured and derived values
- Circuit breaker control, status & condition monitoring
- Trip circuit and coil supervision
- Four alternative setting groups
- Programmable scheme logic
- Programmable allocation of digital inputs and outputs

- Sequence of event recording
- Comprehensive disturbance recording (waveform capture)
- User configurable LEDs
- Local and remote communication ports
- Multiple communication protocols and interface options
- Time synchronisation
- Fully customisable menu texts
- Multi level password protection
- Test facilities
- Power-up diagnostics and continuous self monitoring of the relay
- User friendly settings and analysis software (S1 Agile)

A wide range of features to suit the protection needs for all types of applications

Distance Protection

The operation of the distance relay is based on the combined use of two fault detection algorithms:

- Calculation of the superimposed current and voltage values that are characteristic of the fault ("delta" algorithm).
- Measurement of impedance values ("conventional" algorithm).

This dual algorithm offers reliable detection of all types of faults in the network. The impedance calculations are performed every sample for all six loops AN, BN, CN, AB, BC and CA, making this a true full scheme numerical distance relay.

Based on transient components, the delta algorithm is a patented technique with nearly two decades of application in various relays. The delta algorithm uses the super-imposed signals, which appear during faults, for fault detection, phase selection and direction determination. The directional element uses the sign of the energy calculated from V and I to decide the direction of the fault:

- For a forward fault, V and I are of opposite polarity (sign of energy: negative)
- For a reverse fault, V and I are of the same polarity (sign of energy: positive).
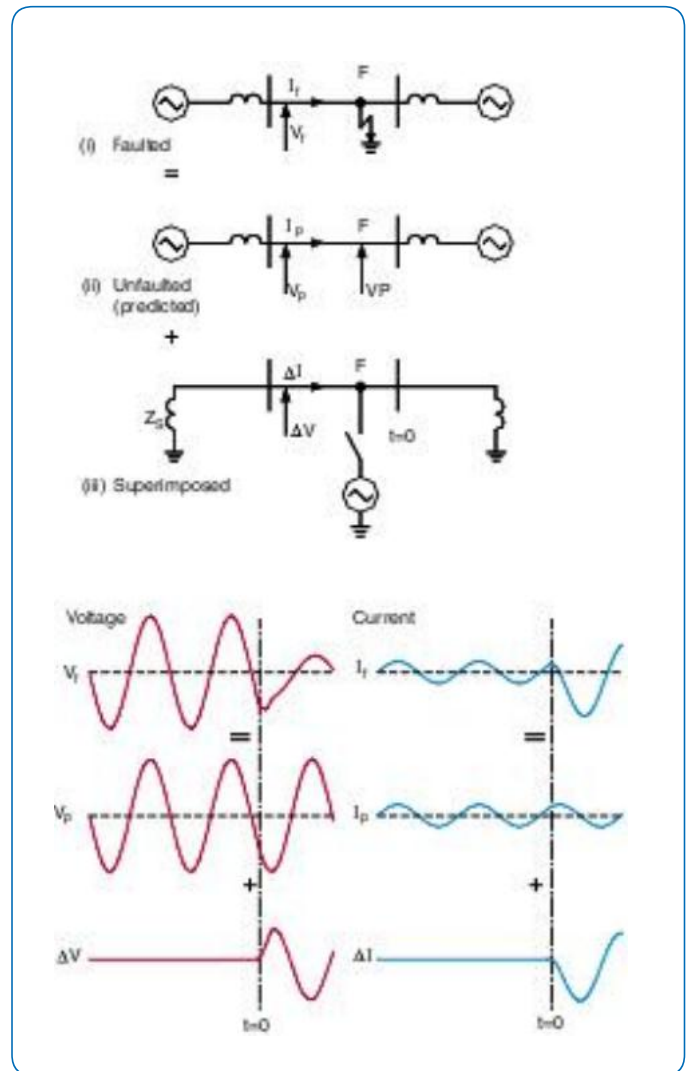
The directional and phase selection elements will change their decisions if required, for example during evolving faults.

The conventional algorithm uses the impedance measurement criteria with quadrilateral-shaped characteristics. Phase selection is enhanced for high current faults by utilising current phase selection. If the fault current is low, impedance based phase selection is used.
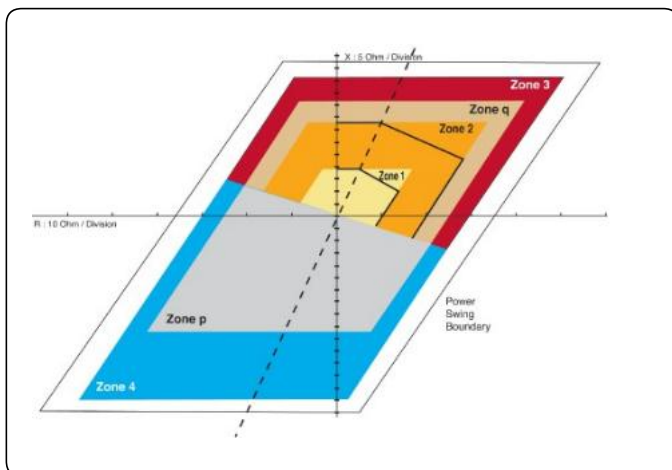
Both algorithms work in parallel, independently monitoring the system, measuring the impedance loops and calculating delta values continuously. From the B1.0 version onwards, the distance algorithm chaining is optimised to ensure a typical time of 1 - 1.1 cycles for any type of fault and SIR (from 1 to 30).t inustenisit alit.

Six independently configurable quadrilateral zones, for phase faults and earth faults, are provided. Four independent earth fault residual compensation coefficients are provided for non-homogeneous line protection, or the back-up protection of transformers. Zp and Zq can be selected as forward or reverse.

The distance to fault measurement is immune to fault resistance and load current. A least squares method is used to get the algorithms to converge rapidly.

Relationship between superimposed and faulted power system

Impedance characteristics (optional tilt with Z1/Z2/Zp/Zq if selected fwd)

Power Swing Blocking

A power swing is detected when the impedance locus takes more than 5 ms to cross the R and X band. Any of the zones (Z1/Z1X, Z2, Z3, Zp, Zq or Z4) can be selectively blocked. Four separate elements can be set to override the power swing blocking in case of major faults (the delta method is used in phase selection). The relay can differentiate a stable power swing from out of step conditions, by monitoring the sign of the resistance.

Switch-on-to-Fault (SOFT) & Trip-on-Release (TOR)

The switch-on-to-fault and trip-on-reclose protection offers fast fault clearance following manual or auto-reclosing of circuit breakers respectively.

Channel Aided Scheme Logic

The relay is provided with a comprehensive selection of IEC and ANSI/IEEE compatible channel-aided schemes:

- Permissive under reach protection, accelerating zone 2 (PUP Z2),
- Permissive under reach protection, tripping via forward start (PUP forward),
- Permissive overreach protection with overreaching zone 1 (POP Z1),
- Permissive scheme unblocking logic, (loss of guard, loss of carrier)
- Blocking overreach protection with, overreaching zone 2 (BOP Z2),
- Blocking overreach protection with, overreaching zone 1 (BOP Z1),
- Weak infeed and echo logic.

Current reversal guard logic is also available to prevent tripping of a healthy line in double circuit lines.

Channel-Aided Directional Earth Fault (Aided DEF)

Channel aided directional earth fault protection operates in co-ordination with one or two remote end relays.

The aided DEF protection is able to trip single or three-pole using permissive or blocking scheme logic. The transmission channels may be the same as those used by the distance protection or may be independent. The directionality of the earth fault elements is provided by either zero sequence or negative sequence polarisation.
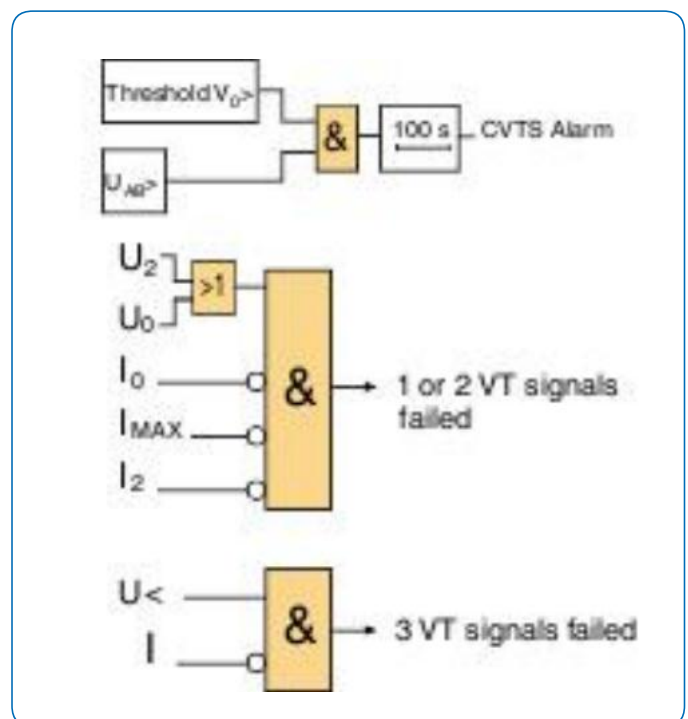
INTERMiCOM (OPTIONAL)

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

Back-up/Time Delayed Protection

- Phase overcurrent: four independent stages of phase overcurrent protection with two stages settable as directional and IDMT are available. Nine IEC/IEEE IDMT curves are provided to choose from
- Earth fault: four standby earth fault elements, where all can be set to directional and either DT or IDMT, with an option of timer hold on reset. Both elements can be enabled at the same time
- Voltage: two independent stages of over and undervoltage protection are provided. One of them can be configured to operate with inverse characteristics
- The broken conductor protection provided detects unbalanced conditions caused by broken conductors, maloperation of single phase of switchgear or by other single phasing conditions.

VT / CVT Supervision (VTS/CVTS)

Voltage transformer supervision is provided to detect loss of one, two or three phases of the VT signal, providing indication and inhibition of voltage dependent protection elements. An opto-input may also be configured to initiate the voltage transformer supervision alarm and blocking when used with MCBs or other external forms of voltage transformer supervision. A separate capacitive voltage transformer supervision element is also provided to detect a voltage error due to a capacitor short-circuited in a CVT. The relay detects a permanent small zero sequence voltage and gives an alarm (adjustable timer).

CVT & VT supervision

Thermal Overload

A thermal replica (single or dual characteristic) provides alarm and trip stages, to warn and protect in the event of prolonged circuit overloading.

Trip Circuit Supervision

The relay supervises the trip circuit in both breaker-open and closed states using dedicated programmable scheme logic.

Current Transformer Supervision (CTS)

Current transformer supervision is provided to detect loss of phase CT signals and inhibit the operation of current-dependent protection elements. This is achieved by detecting the presence of residual current in the absence of residual voltage.

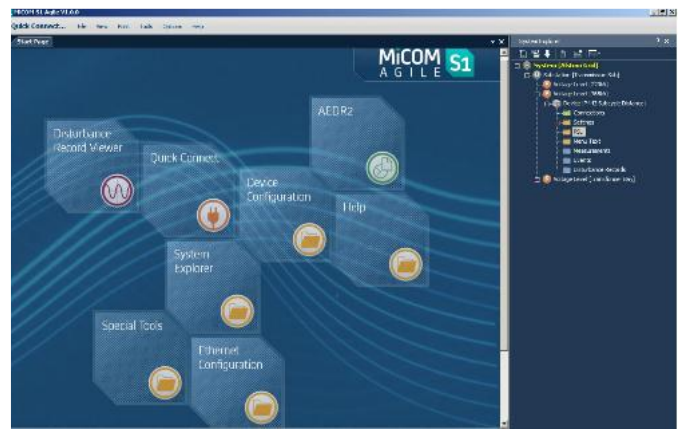## Circuit Breaker Failure Protection (LBB)

Circuit breaker failure protection can be used for backtripping upstream circuit breakers, and/or for retripping via a second breaker trip coil when a local breaker failure is detected. The circuit breaker failure logic may also be initiated externally from other protection devices if required.

Autoreclose with Check Synchronising

The P441 provides three pole multi-shot (up to four shots) autoreclose with optional check synchronising. The P442 and P444 provide one and three pole multishot (up to four shots) autoreclose with optional synchronism check. For both models, the user may select a single, two, three or four shot autoreclose cycle, with independently settable dead times and reclaim time. The check synchronising function offers independent settings for manual closing and autoreclosing.

Programmable Scheme Logic

Programmable scheme logic (PSL) allows the user to customise the protection and control functions. It is also used to program the functionality of the optically isolated inputs, relay outputs, LED indications, Intermicom (control input) and virtual input/ouput using GOOSE. The programmable scheme logic comprises gate logic and general purpose timers. The gate logic includes OR, AND and majority gate functions, with the ability to invert the inputs and outputs, and provide feedback. All aspects of MiCOM P40 IED configuration are managed using the MiCOM S1 Agile software.

Programmable scheme logic

S1 Agile: a powerful and intuitive PC-toolsuite

Fault Location

A fault location algorithm, immune to fault resistance and load current, provides distance to fault in miles, kilometres, ohms or percentage of line. A mutual compensation feature is provided to eliminate the effect of zero sequence mutual coupling from parallel lines.
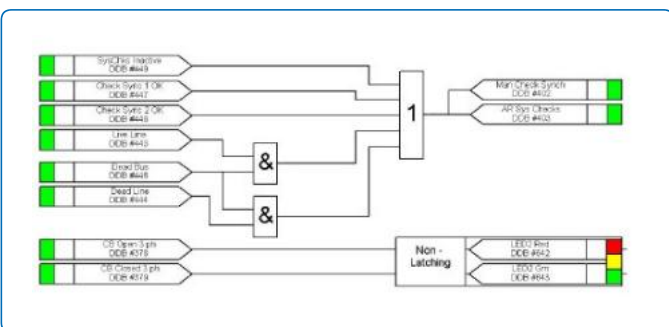
Measurement and Recording

A wide range of information can be displayed and stored in P441, P442 and P444 relays. All events, fault and disturbance records are time tagged to a resolution of 1 ms using an internal real time clock. An optional IRIG-B port is also available for accurate time synchronisation. A lithium battery provides a back-up for the real time clock and all records in the event of supply failure. This battery is supervised and easily replaced from the front of the relay.

The measurements provided, which may be viewed in primary or secondary values, can be accessed by the backlit liquid crystal display, or the communications ports. A wide range of instantaneous and derived parameters are available. Phase notation is user definable using the S1 Agile text editor.

Up to 500 time-tagged event records are stored, and can be extracted using the communications ports or viewed on the front panel display.

Records of the last 5 faults are stored.
The information provided in the fault record includes:

- Indication of faulted phase
- Protection operation
- Active setting group
- Fault location
- Relay and CB operating time
- Currents, voltages and frequency

CB Condition Monitoring

The circuit breaker condition monitoring features include:

- Monitoring the number of breaker trip operations per phase
- Recording the sum of the broken current quantity Ix, 1.0
- Monitoring the breaker operating time
- Monitoring the number of breaker operations within a predetermined period.

Control - Hotkey 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.

Disturbance Records

The internal disturbance recorder has eight analogue channels, 32 digital and one time channel. 28 records of 3s duration each can be stored. All channels and the trigger source are configurable. Disturbance records can be extracted via remote communications and saved in the Comtrade format. These records can be viewed using S1 Agile or any other suitable software program.

Local and Remote Communciations

Two communications ports are available as standard: a rear port providing remote communications and a front port providing local communications.

The front RS232 port is designed for use with S1 Agile, which fully supports functions within the relay by providing the ability to program the settings off-line, configure the programmable scheme logic, extract and view event, disturbance and fault records, view the measurement information dynamically and perform control functions (using Courier protocol).

The default remote communications are based on RS485 voltage levels.

Any of the protocols listed below can be chosen at the time of ordering:

- Courier / K-bus
- Modbus
- IEC 60870-5-103
- DNP 3.0
- IEC 61850-8-1

Second Rear Communication Port

An optional second rear courier port is available which may be configured as RS232, RS485 or K-Bus. The second port is designed typically for dial-up modem access by protection engineers/operators, when the main port is reserved for SCADA. Selecting this board also ensures that the relays have Intermicom hardware fitted, as both options reside on the same board.

IEC 61850-9-2 Process Bus Interface

An optional process bus interface is available, allowing the relay to receive current and voltage sampled data from non-conventional instrument transformers such as optical and Rogowski devices. 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 communication to IEDs by fibre optic. GE's -9-2 implementation has been designed to be especially resilient and reliable in the presence of "noise", such as latency, jitter or missing/suspect data.

40TE and 80TE cases

Diagnostics

Automatic tests performed including power-on diagnostics and continuous self-monitoring ensure a high degree of reliability. The results of the self-test functions are stored in battery backed memory. Test features available on the user interface provide examination of input quantities, states of the digital inputs and relay outputs. A local monitor port provides digital outputs, selected from a prescribed list of signals, including the status of protection elements. These test signals can also be viewed using the communications ports and front panel user interface.

Hardware

All models include:

- A backlit liquid crystal display (3 lines)
- 12 LEDs (8 programmable)
- An optional IRIG-B port (not P441)
- An RS232 port & an RS485 port
- An optional second RS232/RS485/K-Bus port (not P441)
- A download/monitor port
- A battery (supervised)
- N/O and N/C watchdog contacts
- Supervised +48 V field voltage
- 1 A/5 A dual rated CTs
- Optional redundant ethernet ports (IEC 61850-8-1): Px4x devices can be enhanced with an optional redundant ethernet board. The redundancy is managed by the market's fastest recovery time protocols.

The redundant ethernet board supports either modulated or demodulated IRIG-B and the SNTP protocol for time synchronisation. The redundant ethernet board also has a watchdog relay contact to set alarms in case of a failure.

The opto-inputs, relay outputs and eight of the LEDs are preconfigured by default, but can be changed by the user. The universal voltage range opto inputs (from 24 to 250 Vdc) are independent and may be powered (if necessary) from the 48 V field voltage available from the relay. The relay outputs may be configured as latching or self-reset.

Device Track Record

- LFZP launched in 1989 & sold 12 000 units
- First P440 launched in 1999, 26 000 relays sold
- Phase II hardware in 2004
- Launch of IEC 61850-9-2 LE in 2005 (pilot projects) and IEC 61850-8-1 in 2006

Quality Built-in (QBi)

GE's 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 standard, and the third generation of CPU processing boosts not only performance, but also reliability.

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 brand "P40 Agile" is applied to the range. P40 Agile is a mark of performance and quality, proudly available from GE, and only from GE.

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