MiCOM P642 / 643 / 645

Advanced Transformer Protection and Control

Figure 1: P645 relay

Transformers are high capital cost assets in electrical power systems. Elimination of all electrical and mechanical stresses, although desirable to preserve transformer life, is impractical. Adaptive techniques to measure and alarm (or trip) in such instances, and advise on cumulative service duty, can help to schedule preventive maintenance – before a costly failure occurs.

Internal faults are a risk for all transformers, with short-circuits dissipating the highest localized energy. Unless cleared quickly, the possibility to rewind windings reduces, and core damage may become irreparable.

The MiCOM P642, P643 and P645 address all these issues - preserving service life, and offering fast protection for transformer faults. Hosted on an advanced IED platform, the P64x incorporates differential, REF, thermal, and overfluxing protection, plus backup protection for uncleared external faults. Model variants cover two and three winding transformers (including autotransformers), with up to 5 sets of three-phase CT inputs. Large CT counts are common in ring bus/mesh corner applications, where the P64x summates currents to create each total winding current, easing application of backup protection. Backup overcurrent can be directionalized, where the user includes the optional 1 or 3-phase VT input in their chosen model.

CUSTOMER BENEFITS

- Universal IED for all transformer (or reactor) configurations
- Protection, control, monitoring, measurements and recording in-one device
- Backup and logging of through faults
- Simple to specify, set, and commission
- Programmable function keys

KEY FEATURES

- **High-speed transformer differential protection**
  Simple setting – wizard requires only nameplate data
- **Restricted earth fault (REF) boosts trip sensitivity**
- **Voltage, frequency, thermal and overfluxing elements**
- **CT, VT, trip circuit and self-supervision:**
  Patented CT supervision ensures no spurious trip for CT or wiring failures
- **Integrated backup overcurrent per winding**
- **Readily interfaces to multiple automation protocols, including dual port IEC 61850**

Schneider Electric

APPLICATION

The MiCOM P642 is intended for two-winding transformer applications, with one set of three phase CTs per winding. The P643 covers up to 3 bias inputs (three CT sets) - either a three winding application, or two-winding with dual CTs on one side. Where 4 or 5 feeding connections to the protected transformer exist, the P645 offers five bias input sets. All models have a single-phase VT input, mainly for overfluxing application, and the P643 and P645 allow an additional 3-phase VT input, and P642 allows an additional 1-phase VT to be connected. This allows overcurrent backup to be directionalised, and expands the measurement and recording analog channels available.

As well as transformer protection, the P64x range may be applied to other unit applications, such as reactor and motor.

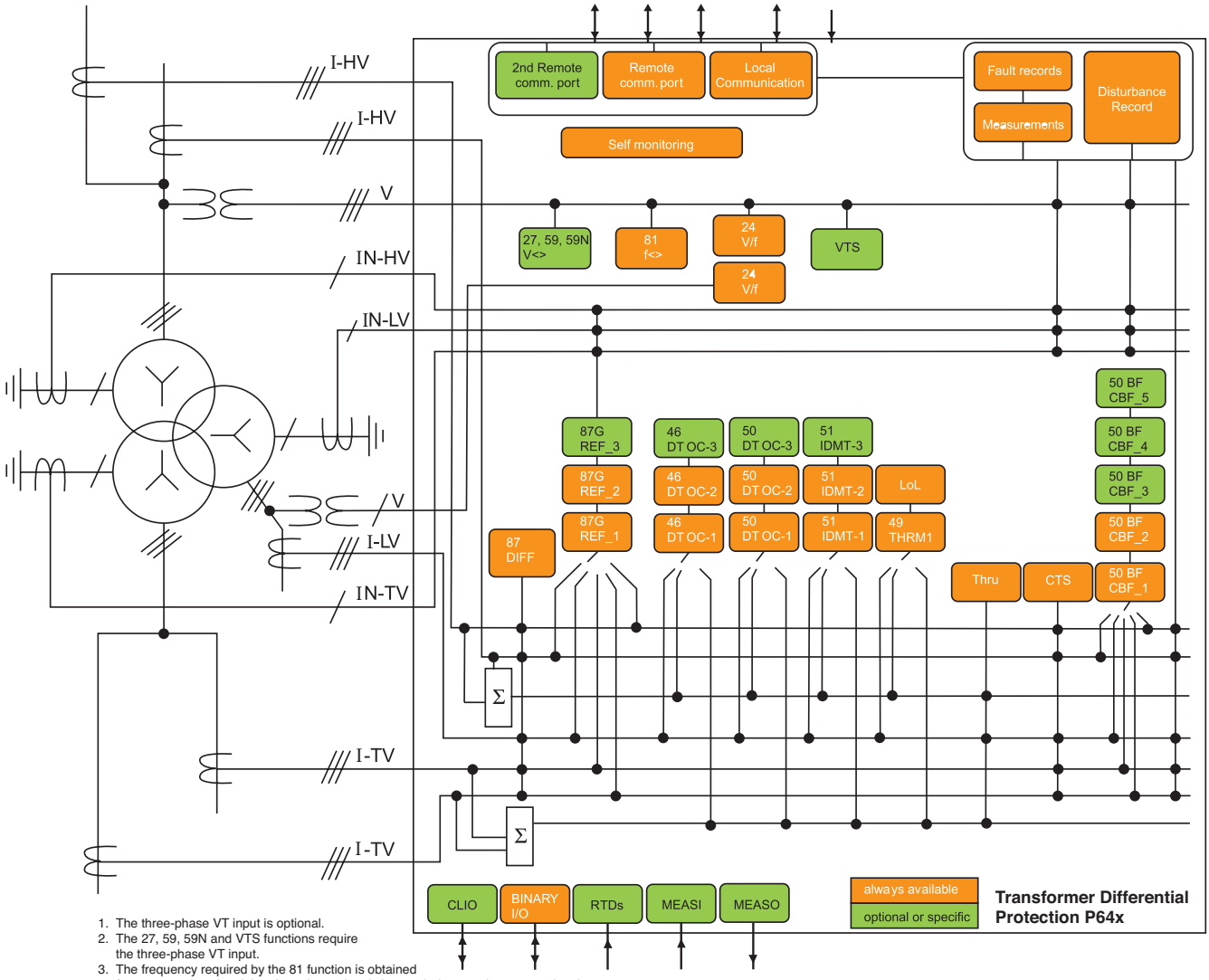
The MiCOM P64x series is supplied with a full suite of protection and control functions as standard. The configuration column of the menu is used to control which functions the user requires in the intended application, and which may be disabled. Disabled functions are completely removed from the menu, to simplify setting. Differential elements have an inbuilt configuration wizard, to avoid settings errors.

ANSI	IEC 61850	Features	P642	P643	P645
		Number of bias inputs (3-phase CT sets)	2	3	5
		Number of residual/star-point CTs	2	3	3
		Single phase VT input	1	1	1
		Additional 1-phase VT	(•)		
		Additional 3-phase VT		(•)	(•)
87T	LzdPDIF	Transformer differential protection	•	•	•
64	RefPDIF	Restricted earth fault protection (windings)	2	3	3
49	ThmPTTR	Thermal overload	•	•	•
24	PVPH	V/Hz overfluxing	1	1 (2)	1 (2)
LoL		Loss of life	•	•	•
Thru		Through fault monitoring	•	•	•
RTD	RtfPTTR	RTDs x 10 PT100 temperature probes	(•)	(•)	(•)
CLIO	PTUC	Current loop transducer I/O (4 input / 4 output)	(•)	(•)	(•)
50/51	OcpPTOC	Overcurrent protection per winding	•	•	•
50N/51N	Ef_PTOC	Derived or measured standby earth fault per winding	•	•	•
46	NgcPTOC	Negative phase sequence o/c per winding	•	•	•
67/67N	RDIR	Directionalized o/c, SBEF, and NPS elements (with optional 1Φ or 3Φ VT addition)	(•)	(•)	(•)
51V		Voltage controlled overcurrent	•	•	•
50BF	RBRF	Breaker fail protection (number of breakers)	2	3	5
27/59/59N	PTUV/PTOV	Undervoltage, overvoltage and residual VN> (with optional 1Φ or 3Φ VT addition)		(•)	(•)
47	NSPTOV	Negative sequence overvoltage (with optional 1Φ or 3Φ VT)	(•)	(•)	(•)
81U/81O	PTUF/PTOF	Under/overfrequency (with optional 3ΦVT addition)		(•)	(•)
VTS		VT Supervision		(•)	(•)
CTS		Differential CTS (patented)	•	•	•
TCS		Trip circuit supervision	•	•	•
IRIG-B		IRIG-B time synchronizing input	(•)	(•)	(•)
	OptGGIO	Optocoupled logic inputs	8...12	16...24	16...24
	RlyGGIO	Relay output contacts	8...12	16...24	16...24
	FnkGGIO	Function keys		10	10
	LedGGIO	Programmable LEDs (R-red, G-green, Y-yellow)	8R	18R/G/Y	18R/G/Y
PSL		Graphical programmable scheme logic	•	•	•
		Alternative setting groups	4	4	4
SOE		Sequence of event records	•	•	•
		Fault waveform disturbance records	•	•	•

(Key: brackets (•) denote optional features)

Functional Overview

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



1. The three-phase VT input is optional.
2. The 27, 59, 59N and VTS functions require the three-phase VT input.
3. The frequency required by the 81 function is obtained from any analog signal, but the voltage signals have priority over the current signals.

Figure 2: System Overview of the P64x series – example 3 winding, 5 bias application

Fast, Sensitive protection for your valuable asset

MAIN PROTECTION

87T Transformer Differential

The algorithm has a triple slope percentage bias restraint, as shown in Figure 3. An internal fault will generate differential current. The bias current is that which merely flows through the protected unit, as a load or through-fed external fault. The initial characteristic is flat, for ease of commissioning, rising then to bias slope (k1). K1 is a low slope for sensitivity to faults whilst allowing for mismatch when the power transformer is at the limits of its tapchanger range, in addition to any current transformer ratio errors At currents above rated, extra errors may be gradually introduced as a result of CT saturation, hence the bias slope is increased to k2. The P64x incorporates transient bias and this combined with the k2 bias ensures that CT knee point voltage requirements are minimized.

Besides, a CT saturation detection element is included to distinguish a saturation condition from a magnetizing, and improve tripping times of the low set element for internal faults with heavy CT saturation.

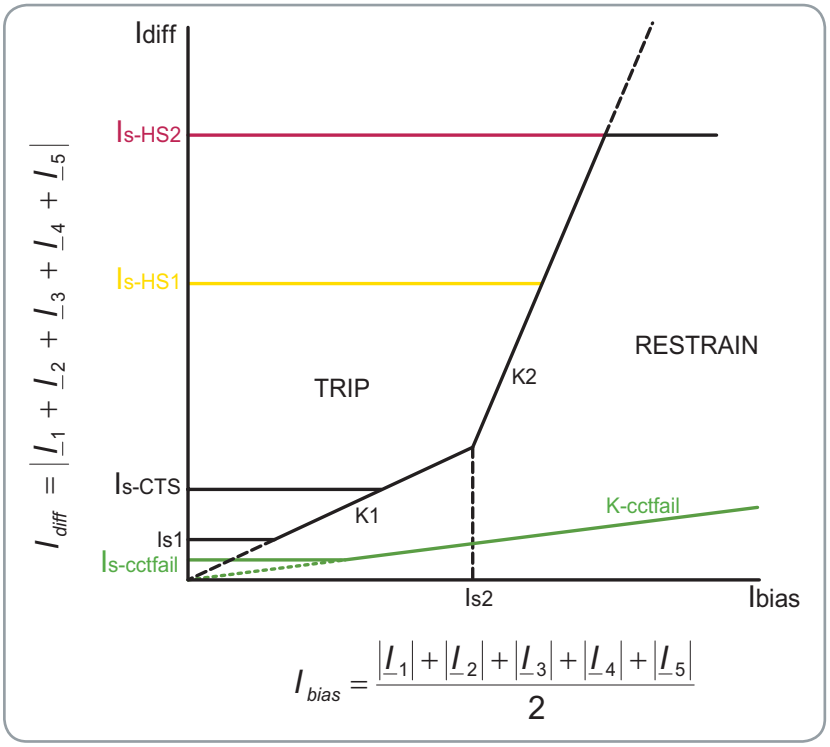


Figure 3: Biased differential protection (87T)

Energization of a transformer causes magnetising inrush current to flow in one winding only, and the differential elements may need stabilizing whilst the inrush persists. A proven second harmonic current ratio scheme is used. The differential protection may also be restrained when the transformer is overfluxed so that an instantaneous trip is not issued for transient overfluxing. Overfluxing restraint is conditioned by the percentage of fifth harmonic current present.

A high set instantaneous differential element, not subject to harmonic restraint, is provided to ensure rapid clearance of high current faults.

The differential protection setting configuration utility requires only known data – that which resides on the transformer rating plate, the CT rating plate, and information on any in-zone earthing transformer.

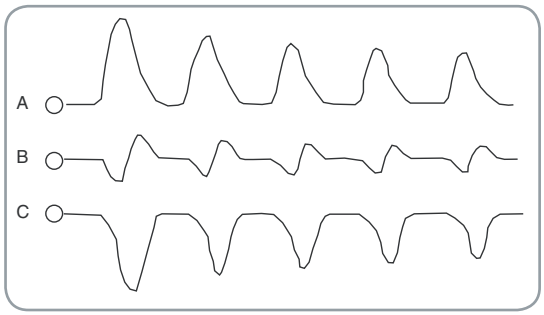


Figure 4: Typical magnetizing inrush waveform –showing harmonic distortion

REF: Restricted Earth (Ground) Fault

Restricted earth fault protection is included to cover a larger percentage of the transformer windings than might be possible with the main differential elements. The P64x provides REF protection for both Conventional and Auto Transformer.

For conventional transformers, a separate element per winding is provided. For auto transformer, an additioanl element is provided for the TV tertiary winding.

For each REF element, operating mode can be chosen between Low Impedance or High Impedance.

Figure 5 shows a typical restricted earth fault application. Low Impedance REF is used, to avoid the need for any stabilizing resistor or varistor Metrosil. REF elements operate independently of inrush detection, potentially offering faster tripping for low or moderate fault currents, in addition to enhanced sensitivity.

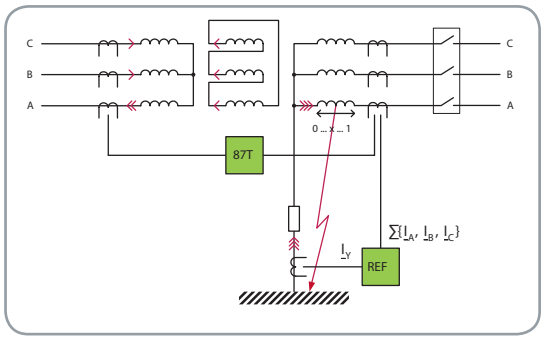


Figure 5: Restricted earth fault application

Thermal Overload

All models offer thermal overload protection, with the extent of protection being the choice of the customer. The most simple application employs I^2t characteristic. Time constants are set, such that the thermal model can follow the correct exponential heating and cooling profile, replicating the winding hotspot temperature.

Alarm and trip thresholds are available as outputs.

To enhance the thermal replica, ambient and/or top-oil temperature compensation may be applied. This is achieved by fitting the RTD board option, and positioning the PT100 probes appropriately (outdoors, or within the transformer tank). Additionally, alarm and trip setpoints can be applied for any probe input, should an absolute measured temperature at the probe location be of interest. Ten independent probe inputs are available, making radiator pump and fan control an additional possibility using the relay's programmable scheme logic (PSL).

Thermal overload protection is a closely-related companion function to the Loss of Life monitoring feature described later.

V/Hz Overfluxing Protection

The single phase voltage input may be connected phph or ph-neutral and is provided to enable overfluxing detection. Alarm and tripping characteristics, which are based on a measurement of the voltage/frequency ratio, are provided. The alarm is definite time delayed whilst the trip characteristic may be applied with up to four definite time (DT) elements, or an IDMT curve plus up to three DT elements. The optional additional 3-phase VT input available in P643 and P645 allows overfluxing to be applied on both HV and LV sides of the transformer, to ensure optimum protection, irrespective of the loadflow direction.

Both thermal overload and overfluxing elements are essentially thermal based, modelling winding and oil heating, or heating of core bolts and laminations. Due to time constants being in minutes (rather than seconds), heating and cooling of both replicas can be relatively slow. A pre-trip countdown is provided, displaying the time remaining to trip if the present level of load, or flux were to be maintained.

A pre-trip alarm can be applied, notifying the dispatcher that he/she has a certain number of minutes for remedial action, before a trip is likely. After any injection testing, all replicas can be forced to reset via a user command.

Circuit Breaker Failure

The breaker failure protection may be initiated from internal protection within the P64x, and also from external devices. In the case of Buchholz (sudden pressure) relays, the CBF elements for all breakers must be initated in parallel. Where external feeder or busbar protection is applied to trip only one (or more) breaker(s), the P64x has the ability to initiate the CBF scheme on a per breaker basis. Retripping and backtripping schemes are supported, all with a fastacting undercurrent check.

Simple setting:
intuitive wizards need only nameplate data

SUPERVISORY FUNCTIONS

Voltage transformer supervision is provided to detect loss of one, two or three VT signals (P643 and P645 models fitted with a 3-phase VT). Current transformer supervision is provided to detect loss of phase CT input signals. Using the "differential CTS" feature (patented), the relay performs an intelligent comparison of the negative sequence current imbalance at all CT terminals, to determine which, if any, CTs have failed. This comparison detects all CT shorts, open circuits, and wiring disconnections without an inherent time delay. Operation of the differential protection can be blocked during the failure, or alternatively temporarily desensitised to avoid an unwanted trip. The CTS thus assures real-time stability of the differential elements, and any applicable REF protection.

BACK-UP PROTECTION

The MiCOM P642, P643, and P645 are delivered with comprehensive back-up protection. Typically this will be used in time-delayed mode to improve fault detection dependability for system (out-of-zone) faults. System integrity can also be improved, utilizing internal elements for load-shedding, interlocking, alarm, or other purposes.

Current-Based Protection

Each winding, whether the current is directly measured from one CT input, or is a virtual summation from two CTs, has the following elements available:

- Phase fault overcurrent
- Negative sequence overcurrent
- Earth (ground) fault.
- Voltage controlled overcurrent

Up to four stages of each element, per winding, are available – with a choice of standard IEC and ANSI / IEEE IDMT curves, instantaneous, and definite time operation. Where a P643/P645 has the 3-phase VT option fitted and a P642 has the 1-phase VT option fitted, any of the current protection applied on the same winding as the VT location may be directionalized. Overcurrent elements, directionalized if necessary, can be useful to clear reverse-fed upstream faults, or for protection of adjacent busbars.

At distribution and industrial voltage levels, low-cost bus protection schemes can be configured using the “reverse interlocking” principle. This is a logic-based scheme, which will trip should a fault current flow onto the busbar not be accompanied by an external fault start on an outgoing circuit.

The earth fault protection is configurable to operate either in measured, or derived mode. “Measured” denotes that the winding (or external earthing transformer) has a star-point single phase CT available in the Y-ground connection, and the user wishes this current to be used to implement standby earth fault (SBEF). “Derived” is set for delta windings, or other cases where the user prefers to use the calculated residual current from the three phase CTs.

Voltage Protection

Two stages of voltage controlled overcurrent are available in P64x. It provides back-up protection for remote phase faults whilst remaining insensitive to load.

When 3-phase VT input is fitted in P643 or P645, two stages each are available for phase overvoltage, phase undervoltage, and residual overvoltage (neutral displacement). Such elements are particularly useful to detect voltage regulation errors.

One stage of negative sequence overvoltage will be implemented in P643 and P645 when the 3-phase VT is fitted. For P642, two VTs are required in order to implement this functionality and the inputs of VTs are phase-phase.

Frequency Protection

Four stages of underfrequency and two stages of overfrequency are provided, permitting load shedding and restoration schemes to be implemented.

CONTROL

User Interface

Integrated user function keys and programmable LEDs provide a cost-effective solution for full transformer schemes. The P643 and P645 offer higher functionality, with ten function keys operating in two modes, normal and toggled, each with an associated tricolour LED for clear indication of the logic status. Typical control, maintenance, and commissioning options are initiated directly from simple key presses, rather than the need to navigate a menu.

Programmable Scheme Logic

Powerful graphical logic allows the user to customize the protection and control functions. The gate logic includes OR, AND and majority gate functions, with the ability to invert the inputs and outputs, and provide feedback. The system is optimized to ensure that the protection outputs are not delayed by the PSL operation. The programmable scheme logic is configured using the graphical MiCOM S1 Studio PC software, as shown in Figure 6. The relay outputs may be configured as latching (eg “Lockout”) or self-reset.

Time delays and interlocking schemes are possible within the PSL.

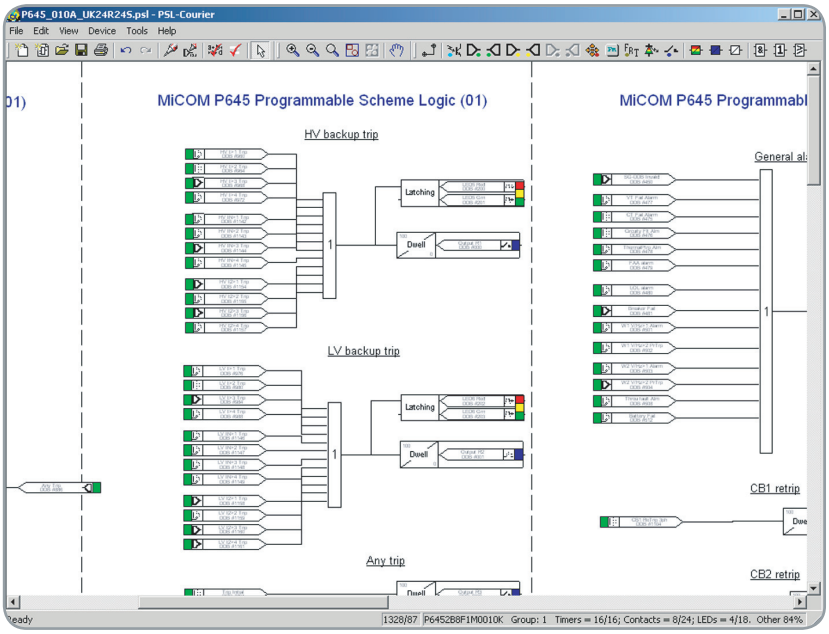


Figure 6: Programmable Scheme Logic editor

Programmable logic and control scheme flexibility

MEASUREMENTS AND RECORDING

Loss of Life (LoL)

Frequent excesses of transformer rated current or operation at elevated temperatures will shorten the life expectancy of the transformer. The P64x provides a transformer loss-of-life calculation, using a thermal model that estimates the hot spot temperature.The insulation deterioration is assumed to follow an adaptation of the Arrhenius theory where insulation life and absolute temperature are inversely proportional (as per IEEE Std. C57.91-1995).

The LoL implementation includes:

- Daily writing into non-volatile memory
- Accumulated Loss of Life, Rate of Using Life, Ageing Acceleration Factor, and Residual Life Hours stored
- Alarm setpoints available on attaining instantaneous or cumulative levels
- Statistics can be reset if a device is relocated to monitor another transformer

Through Fault Monitoring

Through faults are a major cause of transformer damage and failure, stressing the insulation and mechanical integrity. An I^2t calculation based on recorded duration and maximum current is stored for each phase. Calculation results are added to cumulative values, and monitored so that users can schedule transformer maintenance or identify a need for system reinforcement. The last five triggers are stored as special individual records.

Power System Measurements (MMXU)

Multiple measured analog quantities, with phase angles, are provided. These include:

- Phase and neutral currents for all windings, plus sequence components
- Measurements of all voltage inputs
- Frequency, power factor, Watts and VArs
- Maximum demand and rolling values
- Bias currents, differential currents
- All thermal states, temperatures, and loss-of-life

Measurands can be assigned to CLIO

Event Records

Time-tagged event records are stored in battery

backed memory. An optional modulated or demodulated IRIG-B port is available for accurate time synchronization.

Fault Records

- Indication of the faulted phase
- Protection operation
- Active setting group
- Relay and CB operating time
- Pre-fault and fault currents
- Bias and differential currents

Disturbance Records

High performance waveform records contain all CT and VT input channels, plus up to 32 digital states, extracted in COMTRADE format.

PLANT SUPERVISION

Trip Circuit Supervision

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

Analog (Current Loop) Inputs and Outputs (CLIO)*

Four inputs are provided for transducers with ranges of 0-1mA, 0-10mA, 0-20mA or 4-20mA. Associated with each input there are two time delayed protection stages, one for alarm and one for trip. Each stage can be set for 'Over' or 'Under' operation.

Four outputs are provided with ranges of 0-1mA, 0-10mA, 0-20mA or 4-20mA which can alleviate the need for separate transducers. These may be used to feed standard moving coil ammeters for analog indication of certain measured quantities or for input to SCADA using an existing analog RTU. (* Available when optional CLIO card is ordered).

INFORMATION INTERFACES

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

The front RS232 port has been designed for use with MiCOM S1 Studio, 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.

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 (optic interface also available)
- Modbus (optic interface also available)
- IEC60870-5-103 (optic interface also available)
- DNP 3.0 (optic interface also available)
- IEC 61850 (over 100 Mbit/s fiber/copper Ethernet)

IEC 61850 is available when the optional Ethernet port is ordered. IEC 61850 offers high-speed data exchange, peer-to-peer communication, reporting, disturbance record extraction and time synchronization.

Redundant Ethernet is available in various options (Self healing ring, RSTP and Dual homing star). P64x has 64 virtual inputs with an improved GOOSE performance.

An optional second rear courier communications port is available which may be configured as RS232, RS485 or K-Bus.

TRACK RECORD - TRANSFORMER PROTECTION RELAYS

- Over **15 000 MiCOM transformer differential relays** supplied since 2001.
- **MiCOM P642, P643, P645 range** advances on this technology.
- Over **80 000 units** of such relay types **are in-service, worldwide**.

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