MiCOM ALSTOM P642,P643, P645

Advanced transformer protection and control

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 localised energy. Unless cleared quickly, the possibility of rewinding windings decreases, and core damage may become irreparable.

Front view P64x

The MiCOM ALSTOM 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 incorporate differential, REF, thermal, and overfluxing protection, plus backup protection for uncleared external faults. Model variants cover two and three-winding transformers (including auto-transformers), with up to five sets of 3-phase CT inputs. Large CT counts are common in ring bus/mesh corner applications, where the P64x summate currents to create each total winding current, easing application of backup protection. Backup overcurrent can be directionalised, where the user includes the optional 3-phase VT input in their chosen model.

Key features

- High-speed transformer differential protection
- Simple settings – 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 with multiple automation protocols, including IEC 61850

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 configure, set, and commission
- Programmable function keys

Application

The MiCOM ALSTOM P642 is intended for two-winding transformer applications, with one set of 3-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.

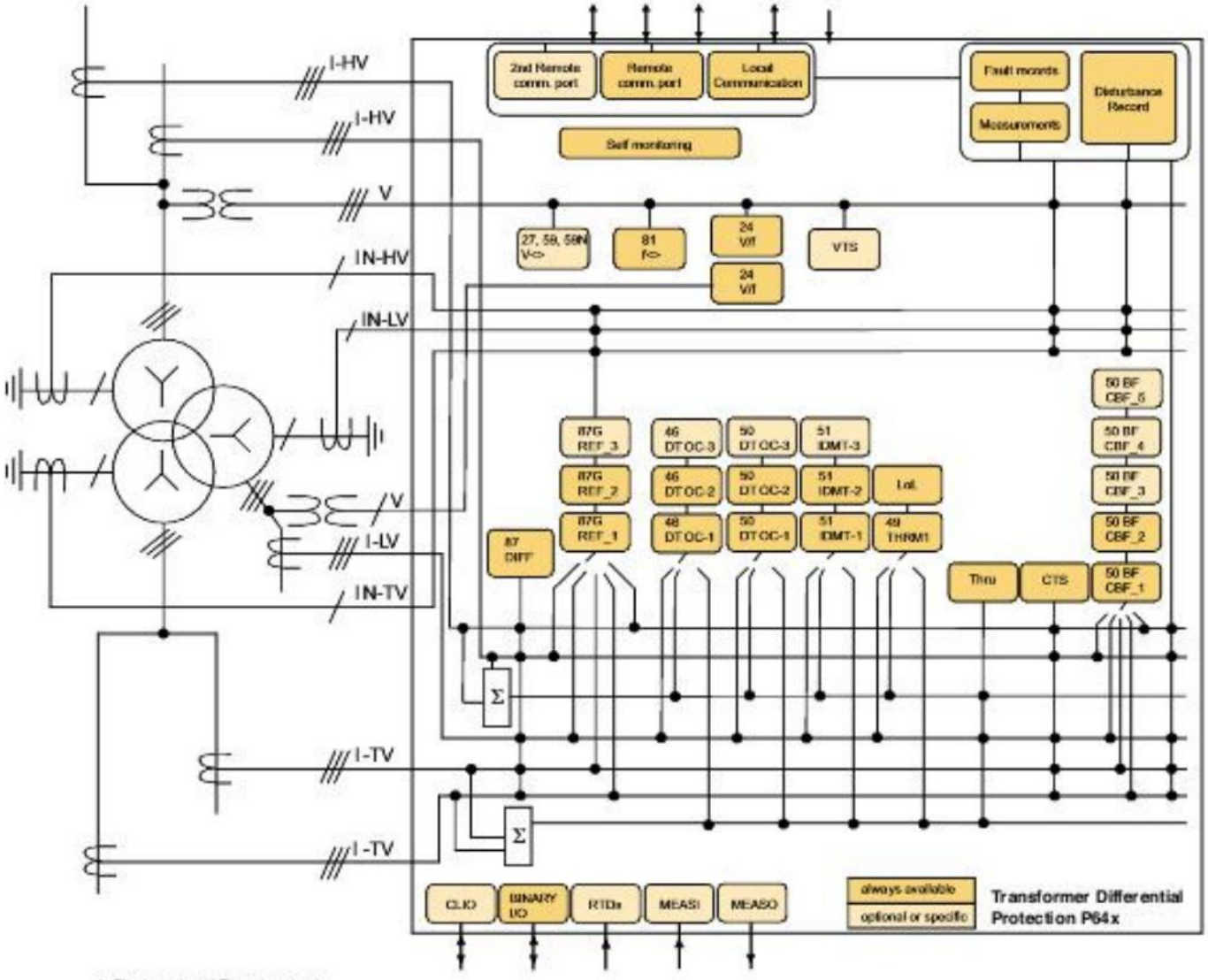
All models have a single-phase VT input, mainly for overfluxing application, and the P643 and P645 allow an additional 3-phase VT input to be connected. This allows overcurrent backup to be directionalised, and expands the measurement and recording analogue channels available. As well as transformer protection, the P64x range may be applied to other unit applications, such as reactors and motors.

The 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 settings. Differential elements have an inbuilt configuration wizard, to avoid settings errors.

ANSI	IEC61850	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 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	Directionalised o/c, SBEF, and NPS elements (with optional 3 VT addition)		(·)	(·)
50BF	RBRF	Breaker fail protection (number of breakers)	2	3	5
27/59/59N	PTUV/PTOV	Undervoltage, overvoltage and residual VN> (with optional 3 VT addition)		(·)	(·)
81U/81O	PTUF/PTOF	Under/overfrequency (with optional 3 VT 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



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 1: System Overview of the P64x series – example 3-winding, 4 bias application

Fast, sensitive protection for your valuable assets

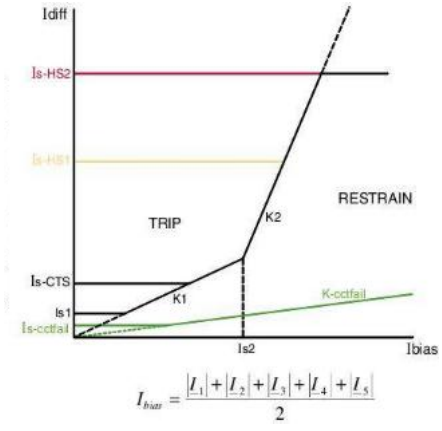


Figure 2: Biased differential protection (87T)

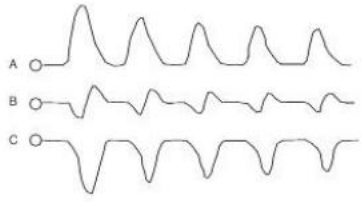


Figure 3: Typical magnetizing inrush waveform –showing harmonic distortion

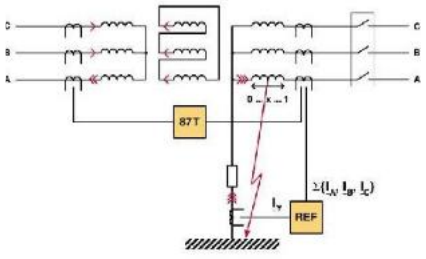


Figure 4: Restricted earth fault application

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 increases to k2. The P64x incorporates transient bias, and this combined with the k2 bias ensures that CT knee point voltage requirements are minimised.

Energisation of a transformer causes magnetising inrush current to flow in one winding only, and the differential elements may need stabilising 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.

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. A separate element per winding is provided (P642: HV and LV. P643/P645: HV, LV, and if required, the TV tertiary too). Figure 5 shows a typical restricted earth fault application. Biased REF is used, to avoid the need for any stabilising 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.

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 ph-ph 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 the 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 fast-acting undercurrent check.

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 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, utilising 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.

Simple settings:
intuitive wizards need only nameplate data

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, any of the current protection applied on the same winding as the VT location may be directionalised. Overcurrent elements, directionalised 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 3-phase CTs.

Voltage protection *

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.
(* Available when optional 3-phase VT input is ordered in P643 or P645).

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 customise 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 optimised to ensure that the protection outputs are not delayed by the PSL operation. The programmable scheme logic is configured using the graphical S1 Studio PC software, as shown in figure 6. The relay outputs may be configured as latching (e.g. "Lockout") or self-reset. Time delays and interlocking schemes are possible within the PSL.

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

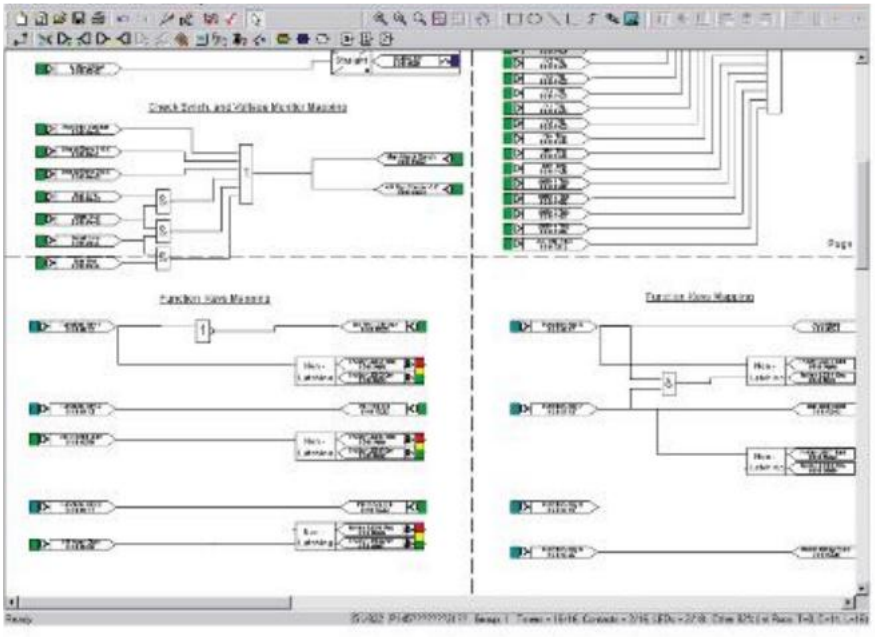


Figure 5: Programmable scheme logic editor

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
- Measurements 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 synchronisation.

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.

Analogue (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 analogue indication of certain measured quantities or for input to SCADA using an existing analog RTU.

(* Available when optional CLIO card is ordered).

Communication to remote operators and substation automation

Two auxiliary communication ports are available; a rear port providing remote communications and a front port providing local communications. An additional, second rear port can be ordered as an option. Any of the following rear port protocols can be chosen at the time of ordering: Courier/K-Bus, MODBUS, IEC60870-5- 103, DNP3.0, or IEC 61850.

Second rear courier port

The optional second port is designed typically for dialup modem access by protection engineers / operators, when the main port is reserved for SCADA traffic.

Programmable logic and control scheme flexibility

Alstom track record - Transformer protection

- Large installed base and pedigree of transformer differential relaysupply, with models including DTH, MBCH, MX3DPT, KBCH, and MiCOM ALSTOM P64x.
- Over 50 000 units of these relay types are in service worldwide.
- Couple a P64x with P14x feeder solutions and KVGC voltage regulation for a full transformer protection and control solution.

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