GE
Grid Solutions

MiCOM Agile P345 & P348

Generator Protection for Variable Speed, Double Fed Induction Machines

Pumped storage is one of the most efficient and flexible forms of storing bulk electrical excess energy. While pump storage was traditionally based on fixed speed synchronous rotating machines, power electronics from the drive system industry is now available for extremely large pump motor applications, offering variable speed and power. Varying power provides a powerful tool for the Independent System Operator (ISO) to cope with the growing need to efficiently integrate renewable power generation.

Contrary to fixed speed pump storage machine construction, variable speed machines are an asynchronous three-phase wound rotor design fed from power electronic inverters with magnetizing current of frequencies varying from near DC to the network frequency. Frequencies vary dynamically during normal operation from 0.1 Hz to typically 6 Hz depending on the power variation set by the ISO control centre. Starting imposes a wider variation in frequency from standstill at near DC up to rated network frequency at full speed for synchronisation.

Electromagnetic coupling of the wound rotor with the stator brings specific duties during transient phenomena namely during power network short-circuits that are conditioned by network low voltage ride-through requirements. Standard protection relays are not capable of measuring near DC frequency values within a reasonable accuracy and allow for continuous variation of the main operating frequency for protection.

Protection for Both Rotor and Stator

MiCOM Agile generator protection relays provide flexible and reliable integration of protection, control, monitoring and measurement functions for large variable speed double fed induction pumped storage machines.

The MiCOM Agile P348 has been developed for this specific purpose and is combined with the P345 to provide a full scheme of protection covering both the rotor and stator. The scheme comes with Non Conventional Instrument Transformers (NCITs) and an IEC 61850-9-2 LE digital acquisition chain in lieu of standard current and voltage transformers that cannot be used at such low frequencies. NCIT characteristics are customised to the application and are supplied along with the P345/P348.

Advanced Protection

- Comprehensive protection for the variable speed DFI machines (rotor and stator)
- Field proven protection functions developed to protect the rotor against damaging transients
- Unique peak and RMS algorithms providing rotor and stator protection down to 0.1 Hz
- A full digital substation approach enabling greater asset utilisation and system stability

Substation Digitisation

Using IEC 61850 station and process bus simplifies substation architecture & delivers:

- A common IEC 61850 protocol for station and process bus provides a standard interoperable solution making integration of different vendors' products easier
- Increased dependability through GOOSE repetition feature
- Bumpless station bus redundancy with IEC 62438-3 PRP and HSR increases reliability
- Using Fiber Optic Ethernet instead of copper wiring eliminates risk of induced interference

Application

The MiCOM Agile P345 is suitable for protection of conventional fixed speed and variable speed generator/motors which require cost effective high quality protection over the range 5 to 70 Hz. To learn more about the P34x relays, refer to the P34x sales brochure or manual.

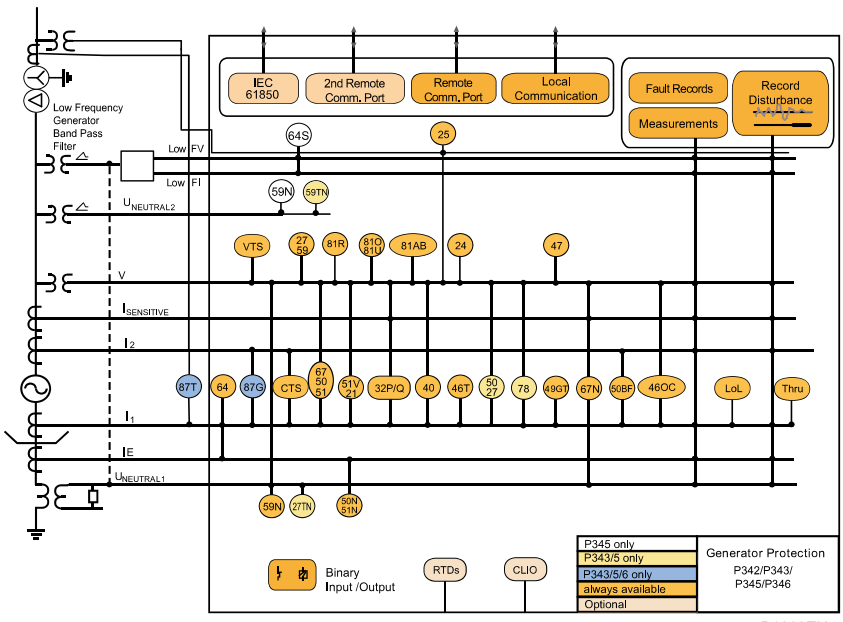
The MiCOM Agile P345 includes a large number of protection, condition monitoring and supervision functions as described in the features table. The P345 includes 100% stator ground fault protection via a low frequency injection technique which can also be used for rotor earth fault protection of variable speed double fed induction machines.

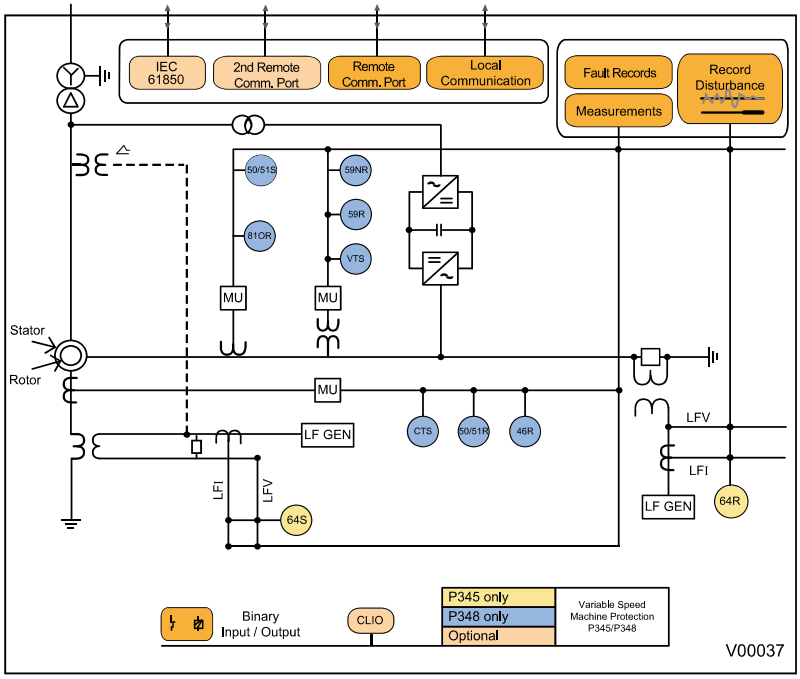
For large variable speed Double Fed Injection (DFI) machines, the P345 protection is complemented by a new relay, P348, to mainly provide rotor protection and additional stator protection of the machine. The P348 provides a unique peak overcurrent and peak overvoltage protection to protect against damaging rotor transients as well as RMS protection. The P348 provides rotor overcurrent (Peak and RMS), overvoltage (Peak and RMS) and RMS neutral voltage displacement (NVD) protection over the range 0.1 to 70 Hz with VT supervision for the NVD protection.

The P348 also includes stator overcurrent (Peak and RMS) and NPS overcurrent (RMS) protection over the range 0.1 to 70 Hz to provide stator protection during the machine start-up and run down over a wider frequency range than the P345. Stator CT supervision is provided to supervise the NPS overcurrent protection. NCITs are used to measure the low frequency rotor and stator signals. The P348 uses IEC 61850-9-2 LE process bus communications to interface to the NCITs via a merging unit and primary converters.

ANSI	IEC 61850	Features	P345	P348
87GT	DifHzd/LzdPDIF/XfrPDIF	Generator/transformer differential	1	-
50DT	DifIntPDIF	Interturn (Split Phase)	1	-
50/51/67	OcpPTOC	Directional / non directional, instantaneous/ time delayed phase overcurrent	4	4(PEAK), 4(RMS)
50N/51N	EfmPTOC	Non directional, instantaneous / time delayed phase ground fault	2	-
67N/67W	SenSefPTOC	Sensitive directional ground fault / wattmetric ground fault	1	-
64	SenRefPDIF	Restricted ground fault	1	-
51V	SbkOcpPVOC	Voltage dependent overcurrent	1	-
21	SbkUzpPDIS	Underimpedance	2	-
59N	VtpResPTOV	Neutral voltage displacement/residual overvoltage, interturn- measured (M), derived (D)	2M/2M/2D	2D
27/59	VtpPhsPTUV/PTOV	Under/Over voltage	3/2	0/2(PEAK), 2(RMS)
81U/81O/81R	FrqPTUF/PTOF/DfpPFRC	Under/Over frequency/df/dt	4/2/4	0/4/0
81AB	TafPTAF	Turbine abnormal frequency	6	-
32P/Q	PwrPPWR	Reverse/Forward Under/Over Power/VAr	4	-
40	ExcPDUP	Loss of field	2	-
46T	RtpTrpPTTR	Negative phase sequence thermal	2	-
46OC	NpsPTOC	Directional / non directional, negative phase sequence overcurrent	4	4(RMS)
47	NpsPTOV	Negative phase sequence overvoltage	1	-
49G/T	ThmPTTR,Hot/TopPTTR	Stator/Transformer thermal overload	2/3/3	-
24	VhzPVPH	Overfluxing	5	-
LoL/Thru	LolMMTR/MMXU	Loss of life/Thru fault monitor	1/1	-
78	PszPPAM	Pole slipping	1	-
27TN/59TN	StaHa3PTUV/PTOV	100% stator ground fault (3rd harmonic neutral under/over voltage) with GPM-S	1	-
64S/64R	StaLfiPEFI	100% stator/rotor ground fault (low frequency injection)	1	-
50/27	DmpPDMP	Unintentional energisation at standstill	1	-
50BF	CbfRCFB	CB Fail	2	-
	SvnRVCS	Current transformer supervision	2	1
	SvnRVCS	Voltage transformer supervision	1	1
25	AscRSYN	Check synchronising	2	-
	RtfPTTR	RTDs x 10 PT100	Option	-
	CliAlm/TrpPTUC	CLIO (4 analogue inputs+4 analogue outputs)	Option	Option
		IRIG-B time synchronisation (modulated/demodulated)	Option	Option
		Front USB Communication port	1	1
		Rear communications port (EIA (RS)485 / K-Bus) (COMM1/RP1)	1	1
		Rear communications fibre optic/ethernet/ redundant ethernet port (COMM1/RP1)	Option	Option
		2nd rear communications port (COMM2/RP2)	Option	Option
	OptGGIO	Opto Inputs	24-32	16-32
	RlyGGIO	Output Contacts	24-32	16-32
	FnkGGIO	Function Keys	10	10
	LedGGIO	Programmable LEDs, Red/Green/Yellow (R/G/Y)	18R/G/Y	18R/G/Y

Functional Overview





Global Functions

The following global functions are generally available in GE's MiCOM Agile devices:

- 4 setting groups
- Metering
- Event recording
- Disturbance recording
- Fault recording
- Trip circuit supervision via PSL
- 6 languages - English, French, German, Spanish, Russian, Chinese

Main Protection Functions

The main protection functions are autonomous and can be individually enabled or disabled to suit a particular application. Each protection function is available in 4 separate setting groups which can be individually enabled or disabled. 3-phase tripping with faulted phase indication is provided for all protection functions.

Comprehensive protection for variable speed machine protection applications

Rotor/Stator Overcurrent (P348)

Four independent non directional RMS and Peak overcurrent stages are available.

Each peak overcurrent stage has a sampled value iterations setting for the number of samples required above setting to start. Each Peak overcurrent stage is definite time (DT) with a definite time reset to prevent chattering for sinusoidal waveforms.

All RMS overcurrent stages have definite time (DT) delayed characteristics, two of the stages may also be independently set to one of twelve inverse definite minimum time (IDMT) curves (IEC and IEEE) or to one of 4 user programmable curves. The IDMT stages also have a definite time reset to reduce clearance times where intermittent faults occur.

The CT source can be selected for each Peak and RMS overcurrent stage to the rotor current inputs (IA-1 IB-1 IC-1) or the stator current inputs (IA-2 IB-2 IC-2). Each stage can operate for stator / rotor phase-phase and 3 phase faults.

Stator Negative Phase Sequence Overcurrent (P348)

Four non directional definite time RMS negative phase sequence overcurrent stages are available. Each stage can operate for stator and remote phase-phase and phase-ground faults even with delta-star transformers present.

Rotor Overvoltage (P348)

Two independent stages of RMS and two independent stages of Peak rotor overvoltage protection are available. Each peak overvoltage stage has a sampled value iterations setting for the number of samples required above setting to start. Each Peak overvoltage stage is definite time (DT) with a definite time reset to prevent chattering for sinusoidal waveforms. Each RMS stage is definite time. The first stage can also be configured to an inverse time characteristic or to one of 4 user programmable curves.

The rotor overvoltage protection may be configured to operate from either phase-phase or phase-neutral voltage elements.

Rotor Overfrequency (P348)

Four independent stages of rotor overfrequency are provided to detect excessive levels of rotor slip frequency when the machine is running. Each stage is definite time. Inhibit inputs are available to block operation when the machine is running up or down.

Rotor Neutral Displacement/Residual Overvoltage (P348)

Two RMS residual overvoltage protection stages are available for detecting rotor ground faults where there is a high impedance ground. The residual voltage is calculated from the 3-phase to neutral voltage measurements. Each stage can be set with a definite time delay or an inverse time delay characteristic or to one of 4 user programmable curves.

Substation digitization incorporating NCITS with IEC 61850 station and process bus to simplify architectures and device interoperability

100% Stator And Rotor Ground Fault Low Frequency Injection Method (P345)

Injecting a 20 Hz voltage to detect ground faults at the neutral point or terminals of a generator is a reliable method for detecting ground faults in the entire generator stator winding and all electrically connected equipment. It has an advantage over the third harmonic method in that it is independent of the generator's characteristics and the mode of operation. Also, protection is possible at generator standstill. This method can also be used to provide rotor ground fault protection of a variable speed machine. An artificial neutral point needs to be created to form a star point to ground via an earthing impedance for the injection circuit in the rotor. Two underresistance and one overcurrent stage of definite time protection are available. The measurement circuit is also monitored with a 20 Hz undervoltage and undercurrent element which can be used to block the protection.

The GPM-S-G 20 Hz generator and GPM-S-B bandpass filter modules can be used for the 20 Hz injection.

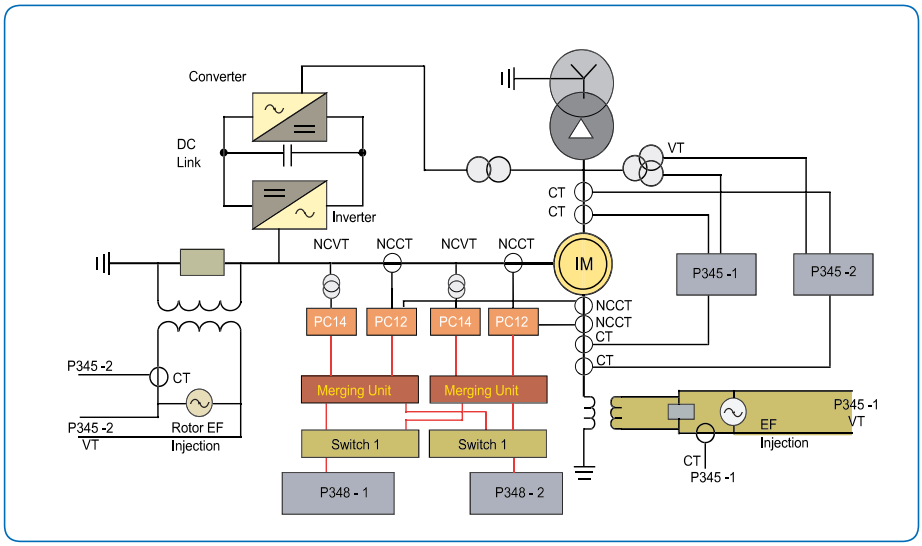
Analogue (Current Loop) Inputs And Outputs (Clio) (P345/8)

Four analogue (or current loop) inputs are provided for transducers with ranges of 0-1 mA, 0-10 mA, 0-20 mA or 4-20 mA. The analogue inputs can be used for various transducers such as temperature and vibration monitors, tachometers and pressure transducers. 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 analogue (or current loop) outputs are provided with ranges of 0-1 mA, 0-10 mA, 0-20 mA or 4- 20 mA, 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 into a SCADA using an existing analogue RTU.

Single Line Diagram Of Typical Protection Scheme

- NCVT: Non-Conventional Voltage Transformer (voltage sensor)
- NCCT: Non-Conventional Current Transformer (current sensor)
- PC 12 and 14: Analog to digital signal converter (GE's proprietary protocol)
- GE's XMU 800 Merging unit: Digital signal (PC BUS or IEC 61850-9-2) to IEC 61850-9-2 digital signal converter including time synchronising (1 Pulse Per Second or IEEE1588 protocol)
- EF: Rotor Earth Fault protection devices
- Hardwired connection: ___
- Digital connection: ——



Supervisory Functions

Voltage transformer supervision (P348)

Voltage transformer supervision (VTS) using a voltage balance method is provided if redundant rotor VTs are available to detect loss of phase VT signals and inhibit the operation of the rotor NVD protection elements.

Current transformer supervision (P348)

Stator current transformer supervision (CTS) is provided to detect loss of phase CT signals and inhibit the operation of the NPS overcurrent protection elements.

Trip circuit supervision (P345/8)

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

Programmable Scheme Logic (PSL)

Programmable scheme logic 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 and LED indications.

The programmable scheme logic may be configured using the graphical S1 Agile PC based support software.

Independent Protection Settings Groups

The settings are divided into two categories: protection settings and control and support settings. Four setting groups are provided for the protection settings to allow for different operating conditions and adaptive relaying.

Control Inputs

Ten function keys are available for implementing scheme control functionality. The function keys operate in two modes, normal and toggled, and activate associated signals in PSL that can easily be used to customise the application. Each function key has an associated tri-color LED (red, green, yellow) allowing for clear indication of the associated function's state.

Indication

Eighteen tri-colour LEDs are available for user programming. The LED colours (red, green or yellow) are driven via digital databus signals in PSL and can be programmed to indicate up to four conditions/states for example.

- Off - Not in service
- Red - CB closed
- Green - CB open
- Yellow - CB not healthy

Information Interfaces

Information exchange is done via the local control panel, the front PC interface, the main rear communications interface (COMM1/RP1) or an optional second rear interface (COMM2/RP2).

Local Communication

The front USB communication port has been designed for use with the S1 Agile software and is primarily for configuring the relay settings and programmable scheme logic. It is also used to locally extract event, fault and disturbance record information and can be used as a commissioning tool by viewing all relay measurements simultaneously.

Rear Communication

The main rear communications interface supports the five protocols listed below (selected at time of order) and is intended for integration with substation control systems.

- Courier/K-Bus (P341-8)
- Modbus (P341-6)
- IEC 60870-5-103 (P341-6)
- DNP 3.0 (P341-6)
- IEC61850 (P341-8)

IEC 61850 and DNP3.0 are available when the optional Ethernet or redundant Ethernet port is ordered. IEC 61850 offers high-speed data exchange, peer-to-peer communication, reporting, disturbance record extraction and time synchronisation. An optional fibre-optic interface is available for any of the above protocols. An optional 2nd rear communications port with the Courier protocol is also available. This port is intended for central settings or remote access with S1 Agile. Clock synchronisation can be achieved using one of the protocols or using the IRIG-B input or using an opto input.

Redundant Ethernet Ports (IEC 61850/DNP 3.0)

Px4x 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 (Rapid Spanning Tree) protocol, offering multi-vendor interoperability. 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 and an SNMP interface to alarm in case of a failure.

Measurement and Recording (P348)

Power System Measurements (MMXU)

Multiple measured analog quantities, are provided. These include:

- Peak and RMS stator and rotor phase currents
- RMS stator NPS current
- Peak and RMS rotor phase voltages
- RMS rotor neutral voltage
- Stator and rotor frequency
- Measurements can be assigned to CLIO

Event Records

Up to 512 time-tagged event records are stored in non volatile memory. An optional modulated or demodulated IRIG-B port is available for accurate time synchronisation.

Fault Records

Records of the last 5 faults are stored in non-volatile memory. The information provided in a fault record includes:

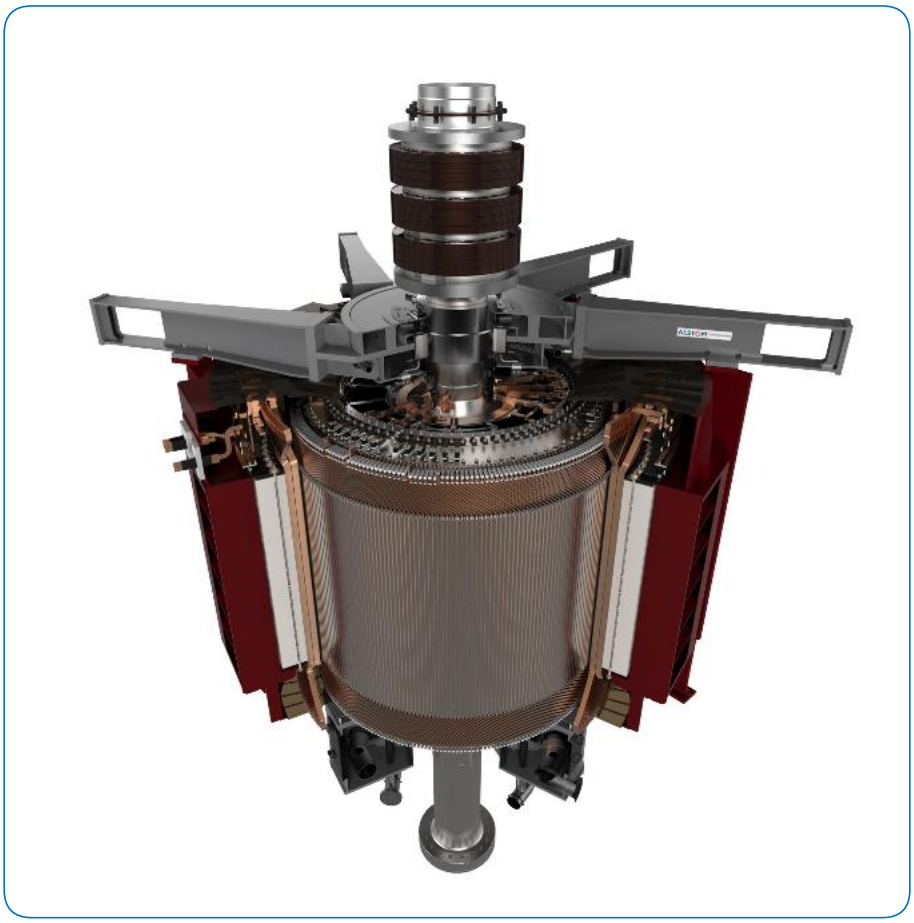
- Indication of faulted phase
- Protection operation
- Active setting group

Disturbance Records

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

IEC 61850-9-2 LE Process Bus Interface (P348)

A process bus interface is available, allowing the relay to receive current and voltage sampled data from non-conventional instrument transformers such as optical, Rogowski and resistive voltage divider sensors. In digital substation architectures with Rogowski CTs and resitive voltage dividers, the analogue output of the Rogowski CT and resistive voltage divider is converted to a digital signal by a Primary Converter (PC) such as the GE PC12 (current) and PC14 (voltage).



The digital output of the PC can be converted to a -9-2 LE data stream using a digital merging unit such as the GE XMU800 which can be connected to the P348 IEC 61850-9-2 LE port. The merging unit can also provide time synchronization of the sampled values if multiple merging units are required to be synchronized.

One advantage of using IEC 61850-9-2 LE is that data generated by merging units in the yard is transmitted safer and more economically cross-site to IEDs by fibre optic than using traditional copper wiring from 1 A/5 A CTs and 110 V VTs.

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

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.

Track Record - Generator Protection

- LGPG: First numerical generator protection relay.
  First released in 1994. Over 1500 devices installed
- MX3IPG1A: Numerical generator protection relay.
  First released in 1997. Over 500 devices installed
- P34x: Numerical generator protection relays designed
  for all generator applications.
  First released in 1999. Over 11 000 devices installed

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