**P342/3/5/6 Guideform Specification**

25th Jan, 2022

The P342/3/5/6 generator protection and control relays shall provide complete protection and management for small, medium and large size generators as well as generator-transformer groups. Comprehensive generator protection and control shall be provided in one integrated package suitable for incorporation in an integrated control system.

**Mechanical Specifications**

**Design**

* The device shall be housed in a case width of 40TE (8 inches, 203.2mm) , 60TE (12 inches, 304.8mm) or 80TE (16 inches, 406.4mm) depending upon the engineered scheme requirements.
* The device shall be presented in a 4U case height format (177mm), for ease of integration/standardization in standard protection racks and panels.
* The case width must be a multiple of 10TE (2 inches) to ensure easy engineering in 19 inch rack panels.

**Enclosure Protection**

The degree of protection offered shall be as per IEC 60529: 2002:

* IP 52 Protection (front panel) against dust and dripping water.
* IP 50 Protection for the rear and sides of the case against dust.
* IP 10 Product safety protection for the rear due to live connections on the terminal block.
* The device shall be housed in a metallic case wrapper.
* The device case shall not include any ventilation louvres or other deliberate holes – it shall be an enclosed unit.

**Weight**

* The weight of the device shall be 7kg – 8kg (depending on chosen options) for 40TE case, 9kg – 12kg (depending on chosen options) for 60TE case and 13kg – 16kg (depending on chosen options) for 80TE case.

**General Input/Output Terminals**

All terminals shall be ring-lug screw type for security and robustness:

* The screw size shall be M4 to allow suitable torque tightness.
* Connection of up to two independent ring lugs per terminal shall be supported, to permit daisy-chaining of connections where required, without resorting to inserting two wires in a ferrule.

**Front Port Serial PC Interface**

A front panel USB communication port shall be provided for service access by relay technicians/engineers, communicating with the PC tool suite software:

* Isolation shall be to ELV level.
* A Cable length up to 15m shall be supported.

**Rear Ethernet Connections**

* The relay shall have two fibre optic ports as an ordering option, to support communication redundancy, for IEC61850-8-1 or DNP3.0 communication. A choice of redundancy protocols shall be available, such as IEC 62439-3 PRP or HSR, RSTP based on IEEE 802.1w, Self-Healing Ring (SHR) and Dual Homing Star (DHS). PRP and HSR shall be provided in a single ordering option, switchable with a software configurator.
* The ports shall be a 100 Base FX interface in accordance with IEEE802.3 and IEC 61850, wavelength 1300nm, for multi-mode 50/125µm or 62.5/125µm fibre, connector style: IEC 874-10 BFOC 2.5 -(ST®)
* A single RJ45 or fibre optic Ethernet port shall also be available as an option for IEC61850 / DNP3.0 communication
* Hot standby redundancy (Ethernet failover) shall also be available as an ordering option.

**Rear Serial Communication interface for SCADA**

* The relay shall have a minimum of one rear EIA (RS-485 port) for SCADA communications.
* It shall be possible to have an additional rear-panel EIA-232 or EIA-485 port.
* A fibre optic port shall be available for serial communication, as an option.
* Protocols supported shall be: Courier, Modbus, IEC60870-5-103 and DNP3

**Batteries**

* Batteries shall not be included to maintain the records such as event, fault and disturbance records or the real time clock when power is lost to the relay

**Ratings**

**AC Measurement Range**

* The device shall be suitable for power systems operating at 50 and 60Hz.
* The operating range for the network frequency shall be from 5 to 70Hz.
* The relay shall be suitable for current transformer secondary ratings of 1A and 5A and shall be selectable, as required. The standard and sensitive current transformer inputs shall have a continuous rating of 4 times the rated current and a short time thermal withstand capability of 100 times the rated current for 1 second.
* The dynamic range for the standard CT inputs shall be 16 times rated current and the sensitive current inputs shall be 2 times rated current
* The current inputs shall have automatic CT shorting when the analogue module is removed, to enhance the safe working environment of technicians and relay engineers.
* The voltage transformer inputs shall be rated for 100/120V or 380/480V AC and shall have a continuous rating of 2 times the rated voltage. The inputs shall have a short time thermal withstand capability of 2.6 times the rated voltage for 10 sec.

**Auxiliary Voltage (Vx)**

The device auxiliary power supply input shall accommodate at least two standard battery voltage ratings used by the utility, such as to minimize or eliminate multiple ordering options and spares holdings. Typical ratings most common in the utility environment shall include:

* 48V to 125Vdc nominal range (covering both 48/54V and 110/125V battery supplies in a single ordering option).
* 110V to 250Vdc nominal range (covering both 110/125V and 220/250V battery supplies in a single ordering option).
* The device shall operate for a deviation from the nominal range of -20% lower nominal voltage, up to +20% of higher nominal voltage.
* Auxiliary power supply interruption ride-through according to IEC 60255-11: 2008, with all communications ports active, all binary I/O energized, and LCD backlight on: 20ms.
* With a tolerable ac ripple of up to <15% for a dc supply, as per IEC 60255-11: 2013.
* The quiescent burden of the energized device shall be less than 11W.
* The initial current inrush at switch-on shall be limited to no more than 8A

**Digital (“Opto”) Inputs & Output Contacts**

To accommodate a multitude of protection functions and high number of switchgear elements, the relay shall offer flexibility in being able to order up to 32 opto inputs and 32 output contacts.

**Opto Inputs**

* Opto inputs shall provide independent terminals for wiring. Grouped optos shall not be acceptable.
* The opto inputs shall be universal range, rated from 24V to 250Vdc nominal, with a withstand up to 300Vdc.
* The opto inputs shall have a software-selectable pick-up setting, without needing an ordering option nor any need to change jumpers.
* The pick-up setting shall be matched at approximately 80% of battery nominal, with reset hysteresis such that drop-off is at approximately 60% of battery nominal. Such operation shall ensure that spurious pickup is avoided for battery earth faults where half-voltage may be falsely experienced by capacitive coupling.
* Opto inputs shall be compliant to ESI 48-4 EB2, presenting a “high burden” to prevent spurious pickup for capacitive discharge, with intelligent switching to reduce the burden to a low quiescent value under genuine operated conditions.
* Opto inputs shall be immune to capacitor discharge and power frequency without the need for external suppression. External resistors shall not be permitted.
* It shall be possible to connect two opto inputs in series, with voltage sharing across the pair, permitting deployment in trip circuit supervision schemes (if required) covering breaker open and breaker closed conditions (full H7 scheme).

**Output Contacts**

The relay output contacts shall be electromechanical type and shall provide optional high break output contacts as ordering option.

**Standard Contacts:**

The rating of the output contacts shall be as follows, in accordance with IEC 60255-1: 2009:

* Maximum continuous current shall be 10A, or 8A as measured by the harsher UL-compliant method.
* The short term make and carry rating shall be 30A for 3s, 250A for 30ms.
* The DC break capacity shall be 50W resistive or 62.5W inductive (L/R = 50ms)
* It shall be possible to configure a software latching (lockout) function for output contacts, whose status is memorized for reapplication after a power supply interruption

**High Break Contacts:**

* High speed, high break contacts shall be available optionally (Op. time <0.2 ms, DC inductive break – 2500W – L/R = 50 ms).

**Watchdog Contacts:**

Watchdog contacts shall be provided, with relay healthy (normally open) and relay fail/de-energised (normally closed) connection outputs available. Watchdog contact shall be in addition to the standard contacts available in the relay. Any error detected by the device self-motoring shall cause an alarm to be raised, such that hardwiring of an alarm to adjacent devices is possible, if required. The contact ratings of watchdog contact shall be:

* DC breaking capacity 30W resistive, 15W inductive (L/R = 40ms)

**CLIO and RTD**

The relay shall have the option for up to 4 configurable current loop outputs and 4 current loop inputs for transducers (vibration, tachometers etc.).

Each analogue (or current loop) input shall have a definite time trip and alarm stage and each input shall be set to operate for ‘Over’ or ‘Under’ operation. Each input shall be independently selectable as 0-1/0-10/0-20/4-20 mA.

4 analogue (or current loop) outputs shall be provided for the analogue measurements in the relay. Each output shall be independently selectable as 0-1/0-10/0-20/4-20 mA.

10 RTDs (PT100) shall be provided to monitor the temperature accurately in the windings and bearings of the machine. Each RTD shall have an instantaneous alarm and definite time trip stage.

**LED Indicators**

Up to eight/eighteen freely-programmable LED indicators shall be provided, in addition to fixed function LEDs for Alarm, Trip, Out of Service and Healthy indication.

* It shall be possible to configure a software latching function for the LEDs, whose status is memorized for reapplication after a power supply interruption
* In relays with function keys, it shall be possible to set all the programmable LED’s in three different colours - RED / YELLOW / GREEN as per the scheme requirement using the programmable logic scheme.

**HMI Display**

* A textual LCD display screen shall be provided on the product, capable to display power system measurements, fault and event records, interrogate alarms, implement passworded access control, initiate commissioning test modes, monitor I/O status, alter protection settings, and change settings groups.
* The device menu shall incorporate dependency rules, such that menu cells which are rendered inapplicable as a result of a previous menu selection are removed/hidden. Any whose range of options or settings range is affected shall also be automatically adapted.
* Multi-language support shall be provided, the following being the minimum: English, French, German, Spanish and Russian. Whichever local language is applied, simple switching to English shall always be possible to allow factory support, 3rd party commissioning etc.

**Functional Specifications**

**Protection, Monitoring and Control**

Generator protection shall be provided by a numerical microprocessor-based relay equipped with the following protection, monitoring, control, automation, and reporting functions. The relay shall have a wide working frequency range (5 – 70Hz) to cater for generator start-up and run-down conditions where the speed differs from the nominal value. The relay shall have self-supervision to monitor the integrity of the hardware and such functions.

Optimised model options shall be available adapted to the different applications for power plants of different ratings:

* Small generators (<1.5MVA, no need for differential protection)
* Medium sized generators (with differential protection)
* Large generators (>10 MVA, with 100% stator earth fault, dead machine and pole slipping protection)

Specific requirements are as follows:

**Generator Differential (87G)**

Phase segregated generator differential protection shall be provided. The differential protection shall have three options biased, high impedance or interturn. The biased differential shall have a dual slope characteristic with additional measures such as delayed bias, transient bias and maximum bias for enhanced external fault stability. When set as high impedance, additional stabilising resistance and a Metrosil shall be required. When set as interturn (split phase), the element shall operate as a definite time overcurrent function with independent current setting per phase.

**Generator-Transformer Biased Differential (87GT)**

A biased transformer differential protection with triple slope tripping characteristics shall be included for 2 windings. The setting of the relay should be simple to set based on the transformer name plate details such as MVA rating, voltage rating of the winding, transformer vector group and current transformer ratio.

The relay shall have settings to compensate for the transformer vector group in 30 degree steps and include automatic amplitude compensation in the range 0.5 (for undersized CTs) up to 12 (for oversized CTs), to accommodate current transformers of different ratios.

The relay shall have two high-set elements which are unrestrained by any inrush detection, to back up the biased differential function. One of the unrestrained elements shall follow a bias characteristic and the other one shall be independent of bias characteristic.

The transformer differential protection function shall include transformer inrush blocking based on the ratio of the second harmonic component to the fundamental component for the differential currents. The differential protection shall have an option to block the tripping either across all three measuring phases or selectively per phase.

The transformer differential protection function shall include blocking for over fluxing conditions of the transformer by measuring the ratio of the fifth harmonic to the fundamental for the differential current.

**Restricted Earth Fault (64)**

The restricted earth fault protection shall have two options a high impedance or a biased low impedance element. When set as high impedance, additional stabilising resistance and a Metrosil shall be required. The biased differential shall have a dual slope characteristic with a setting to select the CT input between 2 sets of CT inputs (phase side or neutral side). For low impedance REF protection, it shall be possible to use different ratios of current transformers on phase and neutral side of transformers.

**Power/VAr (32P/Q)**

Four definite time stages of power protection shall be provided and each stage can be independently configured to operate as under/over and forward/reverse and active (W) / reactive (VAr) power. A single sensitive power/VAr element or a 2 phase wattmetric power/VAr element shall also be provided which can be used with dedicated metering class CTs using the sensitive current inputs. The minimum possible power setting shall be 0.2% of the rated power.

**Field Failure (40)**

A two stage offset mho definite time impedance element with a supervising directional line shall be provided to detect failure of the machine excitation. A power factor alarm element shall also be available to offer more sensitive protection.

**Negative Phase Sequence Thermal Overload (46T)**

To protect against unbalanced stator currents caused by external faults or unbalanced loading, two stages of negative sequence protection shall be provided. They shall comprise a definite time alarm stage and a trip stage that operates with a thermal characteristic. It shall be possible to set a minimum operating time to grade with the downstream devices. It shall also be possible to have a maximum operating time to ensure that the maximum thermal rating of the machine is never exceeded.

**System Back-up (voltage dependent overcurrent 51V and underimpedance 21)**

A voltage dependent overcurrent (controlled or restrained) and underimpedance protection shall be provided for back-up protection of phase faults. Both voltage dependent overcurrent and underimpedance function should be settable independently. The voltage dependent overcurrent protection shall have two options set as controlled or restrained with an Inverse Definite Minimum Time (IDMT) or Definite Time (DT) or a user programmable curve. The underimpedance element shall be a 3-phase non-directional underimpedance element with 2 stages and a definite time delay.

**Overcurrent Protection (50/51/67)**

Four overcurrent protection stages shall be provided and each stage shall be selectable between non-directional, directional forward or directional reverse via a setting. All stages shall have Definite Time (DT) delayed characteristic and two of the stages shall be able to be set to one of nine Inverse Definite Minimum Time (IDMT) curves (IEC and IEEE) or to one of 4 user programmable curves. The IDMT stages shall have a programmable reset timer for grading with electromechanical relays and to reduce clearance times where intermittent faults occur. The phase fault directional elements shall be internally polarised by quadrature phase-phase voltages. A synchronous polarising signal shall be maintained after voltage collapse to ensure that the instantaneous and time delayed overcurrent elements operate correctly for close-up 3-phase faults.

The CT input shall be selectable between 2 sets of CT inputs (phase side or neutral side).

**Negative Phase Sequence Overcurrent Protection (46OC)**

Four definite time stages of negative phase sequence overcurrent protection shall be provided for remote back-up protection for both phase to earth and phase to phase faults. Each stage shall be selectable between non-directional, directional forward or directional reverse via a setting.

The CT input shall be selectable between 2 sets of CT inputs (Phase side or neutral side).

**Generator Thermal (49G)**

Generator thermal overload protection based on I1 and I2 shall be provided to protect the stator/rotor against overloading due to balanced and unbalanced currents. Both alarm and trip stages shall be provided. There shall be separate time constants for heating and cooling and in the event of a loss of auxiliary supply the thermal state shall be stored in non-volatile memory.

**Transformer Thermal Overload Protection & Loss of Life (49T)**

Transformer thermal overload protection shall be provided based on the winding hot spot temperature and top oil temperature model and shall comply to IEEE C57.91 - 1995. There shall be provision to monitor the actual ambient and top-oil temperatures using RTD probes or current transducers required by the thermal protection. The relay setting shall be such that it shall be easy to set using the transformer name plate data.

The relay shall have a loss of life monitoring feature based on IEEE C57.91 – 1995. The loss of life feature shall be available to monitor the deterioration of insulation based on the hottest spot temperature. The recording of accumulated loss of life, rate of using life, ageing acceleration factor, and residual life hours shall be included in non-volatile memory. Setting shall be available for an alarm when the instantaneous or the cumulative set points are reached. It shall be possible to select the winding to be monitored for thermal overload and loss of life monitoring.

**Through Fault Monitoring**

Transformer through fault monitoring shall be available to monitor the possible damage during through faults where the transformer winding may be subjected to heavy fault currents. The transformer through fault monitoring function shall provide an output based on the summation of I2t performed during each through fault condition and provide an alarm when the cumulative set point is reached.

**Earth Fault (50N/51N)**

Two stages of non-directional earth fault protection shall be provided for stator earth fault protection. Both stages shall have definite time (DT) delayed characteristics, the first stage shall also be able to be independently set to one of ten inverse definite minimum time (IDMT) curves (IEC and IEEE) or to one of 4 user programmable curves.

**Rotor Earth Fault (64R)**

Rotor earth fault protection shall be provided by a low frequency injection method. There shall be 2 stages of definite time under resistance protection. An external injection, coupling and measurement unit shall be required with this function. The measurement of the rotor resistance shall be passed to the relay via a current loop input. The injection frequency shall be selectable 0.25/0.5/1 Hz.

**Sensitive Earth Fault (67N/67W)**

One sensitive earth fault element shall be provided for discriminative earth fault protection of parallel generators. The protection shall be selectable between either non-directional, directional forward or directional reverse. The polarizing method shall be selectable between either zero sequence or negative sequence polarizing.

The Sensitive Earth Fault element shall be selectable between an IcosΦ, IsinΦ or VIcosΦ (Wattmetric) element for application to isolated and compensated networks.

**Residual Overvoltage (59N)**

Residual overvoltage protection shall be available for stator earth fault protection where there is an isolated or high impedance earth. The residual voltage can be measured from a broken delta VT, from the secondary winding of a distribution transformer earth at the generator neutral, or can be calculated from the three phase to neutral voltage measurements. Two independent stages of protection shall be provided for each measured neutral voltage input and also for the calculated value, each stage shall be selectable as either IDMT or DT or a user programmable curve. The relay shall provide up to 2 neutral voltage inputs with 2 measured stages of residual overvoltage from each input and 2 calculated stages.

**100% Stator Earth Fault Based on 3rd Harmonic (27TN/59TN)**

A 3rd harmonic voltage element shall be provided to detect earth faults close to the generator star point. This element combined with the standard stator earth fault protection (59N/50N/51N) shall provide 100% stator earth fault protection.

A definite time 3rd harmonic undervoltage element shall be provided if neutral voltage measurement is available at the neutral of the machine. This element shall be supervised by a 3 phase undervoltage element and optionally by 3 phase W/VA/VAr elements. A 3rd harmonic overvoltage element shall be provided if neutral voltage measurement is available from the terminals of the machine.

**100% Stator Earth Fault Based on Low Frequency Injection (64S)**

100% stator earth fault protection shall also be provided by a low frequency injection method, to protect the stator winding against earthfault, irrespective of the state of the machine whether the machine is stopped or running. There shall be 2 stages of definite time under resistance protection and 1 stage of definite time overcurrent protection. An external 20 Hz generator and bandpass filter shall be required with this function.

**Overfluxing (24)**

A five stage overfluxing (V/Hz) element shall be provided to protect the generator, or connected transformer, against overexcitation. Both alarm and trip stages shall be available. DT shall be available in all stages with IDMT and a user programmable curve available in one stage.

**Dead Machine (50/27)**

A voltage supervised overcurrent scheme shall be provided for dead machine/generator unintentional energisation at standstill (GUESS) protection to detect if the machine circuit breaker is closed accidentally, when the machine is not running. The CT input shall be selectable from 2 sets of CT inputs (phase side or neutral side).

**Undervoltage (27)**

A 3 stage undervoltage protection element, configurable as either phase to phase or phase to neutral measuring shall be provided to back up the automatic voltage regulator. Definite-time shall be available for all stages with IDMT or a user programmable curve available for at least the first stage.

**Overvoltage (59)**

A 2 stage overvoltage protection element, configurable as either phase to phase or phase to neutral measuring shall be provided to back up the automatic voltage regulator. Definite-time shall be available for all stages with IDMT or a user programmable curve available for at least the first stage.

**Negative Phase Sequence Overvoltage (47)**

A definite time negative phase sequence overvoltage protection element shall be provided for either a tripping or interlocking function upon detection of unbalanced supply voltages.

**Underfrequency / Overfrequency (81U/O)**

A 4 stage definite time underfrequency and 2 stage definite time overfrequency protection shall be provided for load shedding and back-up protection of the speed control governor.

**Rate of Change of Frequency (81R)**

A 4-stage definite time rate of change of frequency element (df/dt) shall be provided for Loss of Mains/Grid and load shedding applications.

For the first stage a deadband around the nominal frequency, within which this element is blocked shall be selectable. Each stage shall have a direction setting - Negative, Positive, Both. The df/dt shall include settings for the number of averaging cycles and number of iterations of the averages cycles before a start. Settings shall also be available to select a rolling or fixed window calculation of the df/dt.

**Turbine Abnormal Frequency (81AB)**

Turbine abnormal frequency protection shall be provided to protect the turbine blade from potential damage due to prolonged under/overfrequency operation of the generator. Up to six frequency bands shall be available, each having an integrating timer to record the time spent within the band. The time in each band shall be stored in non-volatile memory so that loss of auxiliary supply to the relay does not lead to a loss of the recorded time.

**Circuit Breaker Failure (50BF)**

A 2 stage circuit breaker failure function shall be provided with a 3 pole initiation input from external protection.

**Pole Slipping (78)**

A lens shaped impedance characteristic shall be used to detect loss of synchronization (pole slipping) between the generation and the power system. A reactance line shall be used to create two zones to distinguish whether the impedance centre of the pole slip is located in the power system or in the generator. Separate counters shall be used to count pole slips in the 2 zones. A setting shall also be provided to determine whether the protection operates in a generating mode, motoring mode or both.

**Voltage Transformer Supervision (VTS)**

Voltage transformer supervision shall be provided (1, 2 & 3 phase fuse failure detection or MCB opening) to prevent mal-operation of voltage dependent protection elements on loss of a VT input signal. The VTS uses negative phase sequence quantities ensuring correct operation for 3 single phase VTs, 5 limb and 3 limb VTs and vee connected VTs.

**Current Transformer Supervision (CTS)**

Current transformer supervision shall be provided to prevent mal-operation of current dependent protection elements upon loss of a CT input signal. An alarm shall be given after a set time delay if the CT supervision function operates.

The relay shall have inbuilt differential current transformer supervision function, which is not reliant on voltage inputs, to supervise the current transformers and their circuitry, associated with all the terminals / windings.

**Check Synchronisation (25)**

Check synchronising (2-stage) with advanced system split features and breaker closing compensation time shall be provided. Live and Dead voltage checks shall also be provided.

**Phase Rotation**

Phase rotation settings shall be available to cater for ABC or ACB primary system senses for all 3 phase current and voltage channels. Also, for pumped storage applications where 2 phases are swapped, the swapping of 2 phases shall be possible to emulate independently for the 3 phase voltage and 3 phase current channels.

**Disturbance Recording**

The device shall include on-board disturbance recording, suitable to record a minimum of 8 fault clearance events:

* The disturbance records shall have up to 20 analogue, 32 digital and 1 time channel.
* All channels and the trigger source shall be user configurable.
* The disturbance records time length shall be configurable from 0.1 s to 10.5 s.
* It shall be possible to retrigger the recording in case a long duration record is required
* The disturbance records shall be able to be extracted from the relay via the remote communications and saved in the COMTRADE format.
* The resolution of the records shall be 24 samples per cycle.
* The record storage shall be maintained even after the device has been powered-down.

**Event Recording**

The device shall include on-board event recording, suitable to record a minimum of 512 time-tagged events:

* The time stamp resolution of the records shall be 1ms.
* The record storage shall be maintained even after the device has been powered-down.
* The menu and PC toolsuite shall provide shortcut access to at least the last 20 fault trip records.
* Any maintenance events captured by the IED self-monitoring shall be visible in the Event Log
* Filtering of events shall be possible at the relay configuration stage so the use of event buffer may be limited to relevant events only.

**Programmable Scheme Logic**

The device shall include a graphical programmable logic facility, to enable customizing of the device response to the utility’s exact requirements:

* Programmable logic shall be provided including OR, AND and majority gate functions, with the ability to invert the inputs and outputs, and provide feedback paths in the logic. A minimum of 100 logic gates shall be available.
* Time elements shall be provided, including delay on pick-up (DPU), delay on drop-off (DDO), combined DPU/DDO, pulsed, and minimum dwell time functions. A minimum of 16 timers shall be provided (not counting the timer functions which are expected to be an inherent provision with each output contact and LED indicator function).
* A minimum of 16 counter functions shall be provided. The output of each counter shall go high when the count threshold value is exceeded. Each counter trigger type shall be selectable as Rising Edge or Falling Edge and the trigger threshold shall be configurable. The value of each counter shall be stored in non-volatile memory and be available on both local and remote interfaces. The counter labels shall be configurable.
* The logic shall not take the form of logic equations, but must be formed with graphical drag and drop gates, with all logic processed concurrently. There shall be no need to observe sequential “rules” which constrain in what order gates are processed, and how they affect any declared result.
* The concurrent processing of the logic shall ensure that the full logic declares a stable result without any race effects due to calculation lag.
* The amount of logic programmed shall not in any way affect the deterministic behavior of the protection, control and communication functions in the relay. Whether the logic is sparsely used, or used up to its maximum capacity, this shall not change the operating time of those functions.
* Vice-versa, the programmable logic shall remain deterministic regardless of the extent of other device functions enabled.
* A license-free graphical PC tool shall be provided, to configure the programmable logic.
* The IED shall be supplied with pre-loaded default PSL schemes that provide a typical application scheme, to save on engineering / implementation time in projects.

**Measurements**

* The device shall include capabilities for real-time AC measurements, derived power and energy quantities, and demand values.

**Setting Groups**

The device shall offer four programmable setting groups, including independent logic schemes.

**PC Toolsuite**

The device shall be supported by a license-free Windows®-based toolsuite, with support for operating systems up to Windows 10. The toolsuite shall support:

* Creation of offline protection settings, downloading and uploading to the device.
* Standard application template creation for protection settings, such that the utility can standardize on a number of global templates, where only local (feeder-specific) thresholds change at each site.
* Settings file export and import in Excel format.
* Graphical creation and editing of programmable logic.
* Comparison of setting and programmable logic files to identify any differences between versions.
* Creation of IEC 61850 configuration and reports.
* Retrieval of fault, event and disturbance records, and cybersecurity logs.
* Display of extracted records, including disturbance record waveform graphics.
* Changing of settings groups, control and resetting commands.
* Polling of measurement values.
* Export of settings files in .xrio format, for compatibility with protection testing equipment.

**Communications**

**Station Bus – IEC 61850-8-1**

* The relay shall support up to 16 concurrent IEC61850 client connections
* The relay shall support up to 64 GOOSE Inputs and 64 GOOSE Outputs
* The relay shall support IEC 61850 Edition 2 (91SW)
* The relay shall support IEEE 1588 PTP for time synchronization (SW91)
* The relay shall support software switchable option between PRP/HSR/RSTP or hot standby
* The relay shall support 8 instances of report control block for client initialization (multi-client RCB in SW91)
* The relay shall support the detection of Duplicate GOOSE messages on the network (91SW).
* The relay shall be able to subscribe to fixed-length encoded GOOSE messages (SW91)
* The logical devices (LD) and logical nodes (LN) shall be editable; such that the LN and LD instances may be renamed, deleted, restored or moved as necessary. This shall allow the user to tailor the IEC 61850 data model in line with the specific application (91SW)
* Simple Network Management Protocol (SNMP) shall be provided to manage the device in an IP network. Two versions of SNMP shall be supported: version 2c, and a cybersecure implementation of version 3 (91SW)
* The device shall include IEC 61850 Edition 2 test modes. The device may be set into its test mode, where it shall respond only to control commands from clients with the ‘Test’ flag set, with or without contact closure as desired (91SW)

**Serial Communication based on EIA RS485**

* The relay shall have a serial communication port based on EIA RS485, that supports the communication protocols Courier, MODBUS, IEC60870-5-103, and DNP3 which shall be selected by an ordering option.

**Cybersecurity (91 SW)**

* The relay shall be provided with a NERC-CIP compliant display
* The relay shall support at least three password levels of access. Relay passwords shall support alpha numeric and special characters, capital and low case letters.
* The relay shall allow users to configure what actions to take when unsuccessful password access attempts are made. Users shall have the ability to configure how many unsuccessful attempts are made before users are locked out of the device, as well as have the ability to configure how long users will be locked out from re-entering the password once this limit is reached.
* Security Audit Trail elements shall be supported. This element must capture setting changes, Log-in/out related events and information.
* The relay shall support 4 access roles (Administrator, Engineer, Operator and Viewer) with independent passwords. Authentication shall be available at the device level (passwords stored locally in the relay) and at the server level via RADIUS (users, credentials and passwords managed from a RADIUS Server). Communication between the Radius Server and the relay shall be secured (RADIUS over TLS).
* Password complexity shall meet NERC-CIP-5 requirements (minimum 8 characters, three or more different types of characters - uppercase alphabetic, lowercase alphabetic, numeric, non-alphanumeric).
* The relay shall provide security event reporting through the Syslog protocol for supporting Security Information Event Management (SIEM) systems and centralized cyber security monitoring.
* There shall be multiple security by-pass modes (local, remote, local HMI) that allows for reduced security when testing the relay.
* The relay shall have a mechanism to reset all user content in it (default the relay to factory settings/records).. This command shall only be available via the relay front panel.
* An authentication bypass setting shall be provided for ease of access when performing lab tests.
* End users shall have the capability of disabling any Ethernet port when not used. Settings for this purpose must be available.
* It shall be possible to disable unused logical ports. This shall require administrative access.
* The relay shall support SNMP v3
	+ Shall be possible to limit the number attempts to enter the correct password, beyond which the password shall be blocked
	+ It shall be possible to block the physical and logical communication interfaces.
	+ Event records shall include events related security management.

**Time synchronization**

* The device shall support up to two-time synchronisation sources such as IRIG-B, IEEE 1588 and SNTP with the ability to configure the priority (main and backup) for the time sources and dynamically switch based on the availability of each of the two chosen sources;
* IEEE 1588 Precision Time Protocol shall be delivered according to the C37.238 power profile standard as a slave (91SW)
* The relay shall support a universal IRIG-B option for Modulated or Unmodulated signal (91SW)

**Environmental Conditions**

The following norms and standards compliance shall be demonstrated. All shall be carried out at an ILAC accredited laboratory:

**Ambient Temperature Range**

As per IEC 60255-27: 2005

* Operating temperature range: -25°C to +55°C (or -13°F to +131°F).
* Storage and transit: -25°C to +70°C (or -13°F to +158°F)

Tested as per IEC 60068-2-1: 2007:

* -25°C storage (96 hours), -40°C operation (96 hours).

IEC 60068-2-2: 2007:

* +70°C storage (96 hours), +70°C operation (96 hours)

**Ambient Humidity Range**

* As per IEC 60068-2-78: 2001: 56 days at 93% relative humidity and +40°C
* As per IEC 60068-2-30: 2005: Damp heat cyclic, six (12 + 12) hour cycles, 93% RH, +25 to +55°C

**Corrosive Environments**

The device shall provide harsh environmental coating of printed circuit boards as standard. The coating shall be applied after printed circuit boards have been subjected to a cleaning and drying process.

The environmental claims achieved shall be:

* As per IEC 60068-2-60: 1995, Part 2, Test Ke, Method (class) 3. Industrial corrosive environment/poor environmental control, mixed gas flow test. 21 days at 75% relative humidity and +30oC exposure to elevated concentrations of H2S, (100 ppb) NO2, (200 ppb) Cl2 (20 ppb).
* As per IEC 60068-2-52 Salt mist (7 days)
* As per IEC 60068-2-43 for H2S (21 days), 15 ppm
* As per IEC 60068-2-42 for SO2 (21 days), 25 ppm

**Type Tests**

The following norms and standards compliance shall be demonstrated:

**Insulation**

As per IEC 60255-27: 2005

* Insulation resistance > 100MΩ at 500Vdc (using only electronic/brushless insulation tester).

**Creepage Distances and Clearances**

As per IEC 60255-27: 2005

* Pollution degree 3,
* Overvoltage category III,
* Impulse test voltage 5 kV.

**High Voltage (Dielectric) Withstand**

EIA(RS)232 ports excepted.

1. As per IEC 60255-27: 2005, 2 kV rms AC, 1 minute:

Between all case terminals connected together, and the case earth.

Also, between all terminals of independent circuits.

* 1kV rms AC for 1 minute, across open watchdog contacts.
* 1kV rms AC for 1 minute, across open contacts of changeover output relays.
1. As per ANSI/IEEE C37.90-2005:
* 1.5 kV rms AC for 1 minute, across open contacts of changeover output relays.

**Impulse Voltage Withstand Test**

As per IEC 60255-27: 2005

* Front time: 1.2 µs, Time to half-value: 50 µs,
* Peak value: 5 kV, 0.5J
* Between all terminals, and all terminals and case earth.

**Electromagnetic Compatibility (EMC)**

The following norms and standards compliance shall be demonstrated. All shall be carried out at an ILAC accredited laboratory:

**1 MHz Burst High Frequency Disturbance Test**

As per IEC 60255-22-1: 2008, Class III, and IEC 60255-26: 2013

* Common-mode test voltage: 2.5 kV,
* Differential test voltage: 1.0 kV,
* Test duration: 2s, Source impedance: 200Ω
* EIA(RS)232 ports excepted.

**100kHz Damped Oscillatory Test**

As per EN61000-4-18: 2011: Level 3, 100 kHz and 1 MHz. Level 4: 3 MHz, 10 MHz and 30 MHz, IEC 60255-26:2013:

* Common mode test voltage: 2.5kV and 4kV
* Differential mode test voltage: 1kV

**Immunity to Electrostatic Discharge**

As per IEC 60255-22-2: 2009 Class 3 and Class 4, IEC 60255-26:2013:

* 15kV discharge in air to user interface, display, and exposed metalwork.
* 8kV discharge in air to all communication ports.

**Electrical Fast Transient or Burst Requirements**

As per IEC 60255-22-4: 2008 and EN61000-4-4:2004. Test severity level lll and lV, IEC 60255-26:2013:

* Applied to communication inputs: Amplitude: 2 kV, burst frequency 5 kHz and 100 KHz (level 4)
* Applied to power supply and all other inputs except for communication inputs: Amplitude: 4 kV, burst frequency 5 kHz and 100 KHz (level 4)

**Surge Withstand Capability**

As per IEEE/ANSI C37.90.1:2002:

* 4kV fast transient and 2.5kV oscillatory applied common mode and differential mode to opto inputs (filtered), output relays, and power supply.
* 4kV fast transient and 2.5kV oscillatory applied common mode to communications.

**Surge Immunity Test**

EIA(RS)232 ports excepted. As per IEC 61000-4-5: 2005 Level 4,

* Time to half-value: 1.2/50 µs,
* Amplitude: 4kV between all groups and case earth,
* Amplitude: 2kV between terminals of each group.

**Immunity to Radiated Electromagnetic Energy**

As per IEC 60255-22-3: 2007, Class III, and IEC 60255-26:2013:

* Frequency band 80 MHz to 3.0 GHz
* Spot tests at 80, 160, 380, 450, 900, 1850, 2150 MHz
* Test field strength 10 V/m
* Test using AM 1 kHz @ 80%

As per IEEE/ANSI C37.90.2: 2004:

* 80MHz to 1000MHz, zero and 100% square wave modulated.
* Field strength of 35V/m.

**Radiated Immunity from Digital Communications**

As per EN61000-4-3: 2006, Level 4:

* Test field strength, frequency band 800 to 960 MHz, and 1.4 to 2.0 GHz: 30 V/m,
* Test using AM: 1 kHz / 80%.

**Radiated Immunity from Digital Radio Telephones**

As per IEC 61000-4-3: 2006, and IEC 60255-26: 2013:

* 10 V/m, 900MHz and 1.89GHz.

**Immunity to Conducted Disturbances Induced by Radio Frequency Fields**

As per IEC 61000-4-6: 2008, Level 3,

* Disturbing test voltage: 10 V

**Power Frequency Magnetic Field Immunity**

As per IEC 61000-4-8: 2009, Level 5,

* 100A/m applied continuously,
* 1000A/m applied for 3s.

As per IEC 61000-4-9: 2001, Level 5,

* 1000A/m applied in all planes.

As per IEC 61000-4-10: 2001, Level 5,

* 100A/m applied in all planes at 100kHz/1MHz with a burst duration of 2s.

**Conducted Emissions**

As per EN 55022: 2010: Class A:

* 0.15 - 0.5MHz, 79dBμV (quasi peak), 66dBμV (average)
* 0.5 - 30MHz, 73dBμV (quasi peak), 60dBμV (average).

**Radiated Emissions**

As per EN 55022: 2010: Class A:

* 30 - 230MHz, 40dBμV/m at 10m measurement distance
* 230 - 1GHz, 47dBμV/m at 10m measurement distance
* 1 – 2 GHz, 76 dBµV/m at 10 m measurement distance

**Power Frequency**

As per IEC 60255-22-7:2003, IEC 60255-26:2013:

* 300 V common-mode (Class A)
* 150 V differential mode (Class A)

**EU Directives**

A declaration of conformity shall evidence compliance with EU directives, and each device shall display a  mark.

**EMC Compliance**

As per 2004/108/EC: Compliance to the European Commission Directive on EMC shall be claimed. Product specific standard EN 60255-26: 2009 shall be used to establish conformity.

**Product Safety**

As per 2006/95/EC: Compliance to the European Commission Low Voltage Directive (LVD) shall be claimed. Product specific standards shall be used to establish conformity: EN 60255-27: 2005

**R&TTE Compliance**

Radio and Telecommunications Terminal Equipment (R&TTE) directive 99/5/EC.

* Compliance demonstrated by compliance to both the EMC directive and the Low voltage directive, down to zero volts. Applicable to rear communications ports.

**Other Approvals to be demonstrated**

Underwriters Laboratory (UL)

 compliance shall be demonstrated.

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(Complies with Canadian and US requirements).

**Mechanical Robustness**

The following norms and standards compliance shall be demonstrated:

**Vibration Test**

As per IEC 60255-21-1: 1996

* Response Class 2
* Endurance Class 2

**Shock and Bump**

As per IEC 60255-21-2: 1995

* Shock response Class 2
* Shock withstand Class 1
* Bump Class 1

**Seismic Test**

As per IEC 60255-21-3: 1995

* Class 2

**Transit Packaging Performance**

The primary packaging carton shall comply with the international freight standard ISTA 1C specification, to minimize the risk of damage in transit:

* Vibration tests in 3 orientations, vibratory movement 7 Hz, amplitude 5.3 mm, acceleration 1.05g
* Drop tests - 10 drops from 61 cm height on multiple carton faces, edges and corners

**Quality**

* The company’s quality management system shall be accredited and independently audited to ISO 9001: 2015
* The company’s environmental management system shall be accredited and independently audited to ISO 14001: 2015
* The company’s occupational health and safety management system shall be accredited and independently audited to OHSAS 18001: 2007
* The company’s information security system shall be accredited and independently audited to ISO 27001: 2013
* Each device shall be subjected to a 24 hour heat-soak during the manufacturing process, in order to mimimise the risk of early-life failures.
* The vendor shall supply the actual measured Mean-Time Between Failures (MTBF) for the device upon request.
* The device shall include a ten-year warranty for material and workmanship defects.
* The vendor shall offer a nominal 5 day turn-around for warranty repairs
* The relay shall incorporate a rating label which is accessible and visible from the front of the relay, without needing to open any cubicle door to expose the terminal side (rear) of the relay. This label shall show the model number, serial number, month of manufacture and rating details of the device.