**Guideform Specification – Transformer Protection Relays:**

**MiCOM P40 Agile 5th Generation P64 – P642, P643, P645**

31st July, 2024

The transformer protection and control relay shall be delivered in a single family which provides scalable protection and management for low, medium and high MVA-rated power transformers, autotransformers and reactors. The family shall cover transformers with up to three windings and 5 sets of three-phase bias CT inputs. Comprehensive transformer protection and control shall be provided in one integrated package suitable for incorporation in an integrated substation control system.

**Mechanical Specifications**

**Design**

* The device shall be presented in a 4U case height format (177mm), for ease of integration/standardization in standard protection racks and panels.
* The device shall be housed in a case width between 40TE (8 inches, 206mm) and 80TE (16 inches, 412mm)
* The case width must be a multiple of 10TE (2 inches) to ensure easy engineering in 19 inch rack panels.
* 10 function keys shall be available in 60TE and 80TE case variants

**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.
* The maximum cable length supported up to the PC connection shall be 5m.

**Rear Ethernet Connections for IEC 61850**

Station bus (IEC 61850-8-1) and process bus (IEC 61850-9-2LE) physical ports shall be provided.

The relay station bus shall have two fibre optic or two RJ45, or one fibre optic and one RJ45 ports as an ordering option, to support communication redundancy, for IEC 61850-8-1 communication. A choice of redundancy protocols shall be available, such as IEC 62439-3 PRP or HSR, RSTP based on IEEE 802.1w. 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 -(LC®)
* 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, IEC 60870-5-103, and DNP3
* Windows®-based PC software for setting, event and disturbance record retrieval, metering, and control.

**Rear Engineering Ethernet port**

The relay shall have a dedicated 10/100Mbps RJ45 maintenance/engineering port as an ordering option, to support relay configuration.

**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 45 to 65Hz.
* The relay shall be suitable for current transformer secondary ratings of 1A and 5A and shall be selectable, as required. The 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 CT inputs shall be in excess of 50 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 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: 2013, 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; extra 1.25W when fitted with second rear comms port, additional 0.13W per energized output relay, additional per energized opto input: 0.065W (24/27V, 30/34V), 0.125W (48/54V), 0.36W (110/125V), 0.9W (220/250V)
* 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 ordering up to 48 opto inputs and up to 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 in series, with voltage sharing across the pair, permitting deployment in trip circuit supervision schemes (if required). It shall be possible to implement a full trip circuit supervision scheme via the optos: the supervision shall be active for CB open as well as closed conditions (full H7 scheme).

**Output Contacts**

**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 of the transformer. Each RTD shall have an instantaneous alarm and definite time trip stage.

**LED Indicators**

Up to 13 configurable tri-colour LEDs (40/60/80TE case) + 10 configurable tri-colour LEDs associated with the Fn keys (60/80TE case) shall be provided, in addition to fixed function LEDs for Alarm, Trip, Out of Service, Healthy indication and L/R mode:

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

**HMI Display**

* A 4” (480x480 resolution) colour graphical display screen shall be provided on the product, capable to display a single line diagram (SLD) of the bay circuit, 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 setting 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 of those ranges of options or settings range affected shall also be automatically adapted;
* Multi-language support shall be provided, the following being the minimum: English, French, German, Spanish, Italian, Polish and Portuguese. Whichever local language is applied, simple switching to English shall always be possible to allow factory support, 3rd party commissioning etc.
* CB control keys (Trip/Close, Local/Remote) shall be provided to operate the CB and switches of the SLD
* Reset and Home keys and context sensitive keys shall be provided for simplicity of navigation
* The SLD Editor shall support IEC and ANSI symbols with selectable colour coded open/close indication.

**Functional Specifications**

**Protection, Monitoring and Control**

Transformer 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 self-supervision to monitor the integrity of the hardware and such functions.

Optimised model options shall be available adapted to the different applications of transformer protection:

* Two winding transformers
* Three-winding transformers
* Applications requiring up to five sets of biased inputs (5 ends)

Specific requirements are as follows:

**Transformer Differential Protection (87T)**

A biased transformer differential protection with triple slope tripping characteristics shall be included for up to 5 ends. The settings of the relay shall 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 with a setting range 0.5pu - 40pu (per unit). One of the unrestrained elements shall follow a bias characteristic and the other one shall be independent of bias characteristic. The unrestrained element should operate in sub-cycle for fastest clearance of heavy internal fault.

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. In order to achieve faster operation for internal faults and to avoid any slow-down of protection elements on energisation, alternative inrush current detection based on waveshape recognition shall be provided, whereby any gaps (prolonged periods of low current flow in each half-cycle) are used to detect inrush.

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 Protection (64R)**

The REF function shall be selectable for each winding and programmable as either high or low impedance. The REF function shall be able to share phase CTs with the biased differential function. It shall also be possible to configure the REF protection for auto-transformers.

For low impedance REF protection, it shall be possible to use different ratios of current transformers on phase and neutral side of transformers. The relay shall support amplitude compensation ranging from 1 - 40.

**Overfluxing Protection (24)**

Over fluxing protection (Volts/Hertz) shall be available to protect the transformers against overfluxing. A minimum two elements of overfluxing protection shall be available to protect the primary (high voltage) and secondary (low voltage) winding of the transformers, particularly where transformers may be energized from high-side and/or low-side voltage levels.

Four stages per element shall be available for accurate adaptation to the power transformer over fluxing characteristic. This shall include one alarm and one trip element with an IDMT characteristic.

**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.

**Overcurrent and Earth Fault Protection (50/51, 50N/51N)**

The relay shall have overcurrent and earth fault protection for each protected winding and shall be flexible enough to select and configure the winding to be protected, as required. Earth fault protection shall be either measured or derived type and shall be configurable as per the requirement.

The relay shall have 4 independent time delayed overcurrent and earth fault stages for each winding. 2 stages shall be programmable as either DT characteristic or IDMT characteristics. Time overcurrent curve characteristics; IEEE, IEC, and definite time shall be available. The phase and earth elements shall include optional 2nd harmonic blocking.

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

The relay shall have negative phase sequence overcurrent protection for each protected winding and shall be flexible enough to select and configure the winding to be protected, as required. The relay shall have 4 independent time delayed NPS overcurrent stages for each winding. 2 stages shall be programmable as either DT characteristic or IDMT characteristics. Time overcurrent curve characteristics; IEEE, IEC, and definite time shall be available. Each stage shall be selectable between non-directional, directional forward or directional reverse via a setting.

**Voltage Controlled Overcurrent Protection (51V)**

A voltage controlled overcurrent element with 2 stages shall be provided, configurable to any of 3 windings (high-side, low-side or tertiary) or configurable to any set of the 3 phase current inputs. Time overcurrent curve characteristics; IEEE, IEC, and definite time shall be available. Each stage shall be configurable as directional forward/reverse/non directional.

**Undervoltage (27)**

A 2 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 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 both stages with IDMT 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 applications.

**Residual Overvoltage (59N)**

Two independent stages of residual overvoltage protection shall be available for earth fault protection where there is an isolated or high impedance earth. The residual voltage can be can be calculated from the three phase to neutral voltage measurements. Definite-time shall be available for all stages with IDMT available for at least the first stage.

**Circuit Breaker Failure Protection (50BF)**

The relay shall have a built in circuit breaker failure protection for all the terminals / windings and shall have the option to be initiated from external and internal protection. The circuit breaker failure reset time shall be less than a cycle in order to permit tighter grading of upstream protection. Multiple reset criteria shall be provided based on the fast under current reset and/or circuit breaker status.

**Current Transformer Supervision (CTS)**

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. The function shall differentiate between a fault and a CT circuitry problem. An alarm shall be given after a set time delay, if the CT supervision function operates. There shall also be provision to block the differential protection.

**Voltage Transformer Supervision (VTS)**

When fitted, voltage transformer supervision shall be provided (1, 2 and 3 phase fuse failure detection, or MCB opening) to prevent maloperation of voltage dependent protection elements on loss of a VT input signal.

**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 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 disturbance recording, suitable to record up to 1050s with a maximum of 100 records :

* The resolution of the records shall be 48 samples per cycle;
* The record storage shall be maintained even after the device has been powered-down;
* The disturbance records shall have 16 analogue, 128 digital and 1 time channel;
* All channels shall be user configurable;
* The trigger source for the first 32 digital channels shall be user configurable;
* The disturbance records time length shall be configurable from 0.5 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 available from the relay via the remote communications and saved in the COMTRADE format.

**Event Recording**

The device shall include event recording, suitable to record a minimum of 5000 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 tool suite shall provide shortcut access to at least the last 100 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.

**Single Line Diagram (SLD)**

The PC tool suite shall include a graphical programmable Single Line Diagram Editor, to enable customizing of the relay HMI to the utility’s exact requirements:

* SLD logic shall be configurable in the Editor and transferred to the relay using the same file transfer technique as the programmable logic and settings.
* The SLD shall be displayed on the HMI by selecting the Single Line Diagram page.
* The SLD shall support IEC and ANSI symbols with selectable colour coded open/close indication.
* The single breaker relays shall have the ability to visualise and control up to one circuit breaker.
* The dual breaker relays shall have the ability to visualise and control up to two circuit breakers.
* All relays shall have the ability to visualise and control up to eight switchable devices, load breakers, disconnectors, earthing switches etc.
* All Circuit breakers and switchable devices shall be controlled via the physical CB control keys (Trip/Close, Local/Remote) using the SLD when configured for Local control.
* It shall be possible to append alarm and other logic statuses on the same graphical HMI display, alongside the single line diagram. Colour-coding to indicate whether the logic signal is asserted (high) or not (logic zero) shall be provided.
* It shall be possible to display real-time analogue measurement values on the same graphical HMI display, alongside the single line diagram. The set of measurements available for selection shall include voltage, current, power, frequency, local & remote differential and bias current, differential channel measurements etc.
* The measurements shall be shown in either Primary or Secondary terms depending up on the measurement mode configuration.
* The SLD shall also have the ability to display user configured text, with selectable font size, colour and background colour.

**Programmable Logic**

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

* Programable 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 200 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. 32 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);
* Each timer shall also have the option for the time duration to be configured in the settings file. The type of timer DPU/DDO etc shall be configured in the programmable logic.
* Counter elements shall be provided, including an increment (+), a decrement (-) and Reset (R) input and a count output (Q) which goes high when the count threshold value is exceeded
* The concurrent processing of the logic shall ensure that the full logic declares a stable result without any race effects due to calculation;
* 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 amount of logic programmed shall not in any way affect the deterministic behaviour 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 tool suite, with support for operating systems up to Windows 11. The tool suite 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, CSV, CAPE and XML format;
* Export of settings files in .xrio format, for compatibility with protection testing equipment
* Graphical creation and editing of programmable logic;
* Comparison of setting files to identify any differences between versions;
* Graphical creation and editing of SLD;
* Creation of IEC 61850 configuration file 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;

**Communications**

**Station Bus – IEC 61850-8-1**

* The relay shall support up to 16 concurrent IEC 61850 client connections;
* The relay shall support up to 128 GOOSE Inputs and 128 GOOSE Outputs;
* The relay shall support IEC 61850 Edition 2.1;
* The relay shall support IEEE 1588 PTP for time synchronization;
* The relay shall support software switchable option between PRP/HSR/RSTP;
* The relay shall support 8 instances of report control block for client initialization (multi-client RCB);
* The relay shall support the detection of Duplicate GOOSE messages on the network;
* The relay shall be able to subscribe to fixed-length encoded GOOSE messages;
* 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;
* 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;
* 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.
* The device shall support top-down engineering with configuration of GOOSE from the SCD file

**Serial Communication based on EIA RS485**

* The relay shall have a serial communication port based on EIA RS485, that supports the communication protocols Courier, IEC 60870-5-103, DNP3 which shall be selected by an setting within the device.

**Ethernet Engineering port**

* The relay shall have a dedicated RJ45 Ethernet engineering port that supports configuration of the device, segregating the engineering port (IT technology) from station bus communications (OT technology), as required in some cybersecurity architectures

**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.
* The relay shall support a universal IRIG-B option for Modulated or Unmodulated signal

**Cybersecurity**

* An appropriate Use Banner shall be displayed on the device screen prior to allowing access to the features.
* The device shall support all the mandatory pre-defined roles as per IEC 62351-8:2020.
* User accounts with user name and password shall be configurable for Device Authentication. A minimum of 10 such accounts shall be available in the device.
* It shall be possible to map a device authentication user with one or more pre-defined roles.
* The user credentials for device authentication shall be stored in the device using an industry standard encryption / hash algorithm.
* The device should enforce changing of default password for device authentication during the first time log on process.
* Device authentication password shall be configurable as ‘Strict’ (As per IEEE 1686:2013 – Upper, Lower Alphabets, Numeric and Special Characters, Minimum 8 Characters, Passwords cannot contain the user's account name or parts of the user's full name that exceed two consecutive characters) or ‘Normal’ ( Any 3 of 4 type of characters, min 8 characters).
* 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.
* 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).
* The relay shall provide security event reporting aligned to IEC 62351-14, through both a proprietary security event log (separate from the main events file) and the Syslog and SNMP protocols for supporting Security Information Event Management (SIEM) systems for centralised cybersecurity monitoring.
* There shall be multiple security by-pass modes (local USB, local HMI) that allows for increased flexibility when testing the relay. Bypass shall not be possible on the interfaces connected to the Ethernet.
* The device shall provide the capability to remove sensitive information in non-volatile memory. (Settings, Records etc)
* The device shall support Secure Firmware Updates
* The device shall support the INSTALLER role which is the only role, as defined in IEC 62351-8 : 2020, allowed to do firmware updates.
* The device shall support device hardening. This shall be done by presenting the users the ability to enable or disable any physical or logical ports.
* An optional device password expiry with a configurable period shall be provided. The tools / device should force changing of passwords if the expiry policy is enforced.
* The relay shall support SNMP v3

**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 60255-1: 2009:

* 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 60068-2-42: 2003, IED 60068-2-43: 2003, 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**

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:
* 1.0 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 accredited laboratory:

**1 MHz Burst High Frequency Disturbance Test**

As per IEC 60255-26: 2013:

* Common-mode test voltage: 2.5 kV;
* Differential test voltage: 1.0 kV;
* Test duration: 2s, Source impedance: 200Ω;

**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, 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**

As per IEC 61000-4-5: 2005 Level 4 & IEC 60255-26:2013:

* 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 60255-26:2013:

* 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 IEC 61000-4-3: 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 & IEC 60255-26:2013,

* Disturbing test voltage: 10 V

**Power Frequency Magnetic Field Immunity**

As per IEC 61000-4-8: 2009, Level 5 & IEC 60255-26:2013:

* 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 & IEC 60255-26:2013:

* 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 & IEC 60255-26:2013:

* 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).

**Mechanical Robustness**

The following norms and standards compliance shall be demonstrated:

**Vibration Test**

As per EN 60255-21-1: 1996:

* Response Class 2;
* Endurance Class 2.

**Shock and Bump**

As per EN 60255-21-2: 1995:

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

**Seismic Test**

As per EN 60255-21-3: 1995:

* Class 2.

**REGULATORY COMPLIANCE**

A declaration of conformity shall evidence compliance with EU, UK and Moroccan directives, and each device shall display ,  and  marks.

Underwriters Laboratory (UL/CUL) Compliance

 compliance shall be demonstrated

 (Complies with Canadian and US requirements).

The relevant UL file number and ID shall be shown on the equipment.

**Transit Packaging Performance**

The primary packaging carton shall comply with the international freight EN 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: 2008;
* The company’s environmental management system shall be accredited and independently audited to ISO 14001: 2004;
* The company’s occupational health and safety management system shall be accredited and independently audited to OHSAS 18001: 2007;
* 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, based on in-service field experience;
* 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