**Guideform Specification – Line Differential Protection Relays:**

**MiCOM P40 Agile P541, P542, P543, P544, P545, P546**

10th Jan, 2020

The longitudinal differential protection shall be designed for all overhead line and cable applications, interfacing readily with the end-end communications channel(s) between line terminals. The interface options shall support direct fibre optic, or multiplexed digital links, including the ability to support SONET/SDH, IP/MPLS and TP/MPLS networking. Model options shall be available to offer resident subcycle distance protection, to complement the powerful suite of main and backup protection. Such distance protection shall be full scheme, five-zone.

**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, 203.2mm), 60TE (12 inches, 304.8mm) and 80TE (16 inches, 406.4mm) depending upon the engineered scheme requirements.
* 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 as an ordering option

**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 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) ports shall be provided.

The relay shall have two fibre optic or RJ45 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, IEC60870-5-103, MODBUS and DNP3
* Windows®-based PC software for setting, event and disturbance record retrieval, metering, and control.

**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 current input shall be in excess of 64 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 seconds.

**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 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 in series, with voltage sharing across the pair, permitting deployment in trip circuit supervision schemes (if required). It shall be possible to implementation 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 capacity 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 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 (operating 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. Any error detected by the device self-monitoring shall cause an alarm to be raised, such that hardwiring of an alarm to adjacent devices is possible, if required. The contact ratings shall be:

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

**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 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 LEDs 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 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, Russian, Portuguese and Chinese. Whichever local language is applied, simple switching to English shall always be possible to allow factory support, 3rd party commissioning etc.

**Functional Specifications**

**Protection and Control**

Optimised models shall be available, considering typical applications:

* EHV transmission applications (sub-cycle tripping), single breaker;
* EHV transmission applications (sub-cycle tripping), dual breaker;
* Sub-transmission and distribution.

The relay shall be capable of providing the following functions:

* Phase differential;
* Neutral differential;
* Subcycle distance with 6 zones;
* Minimum 3 stages of directional / non-directional, instantaneous / time delayed phase overcurrent;
* Minimum 2 stages of directional / non-directional, instantaneous / time delayed earth overcurrent;
* Directional / non-directional negative sequence overcurrent;
* RMS thermal overload (single / dual time constant);
* Restricted earth fault;
* Auto reclose with check synchronizing;
* Minimum 4 stages of undervoltage;
* Minimum 4 stages of overvoltage;
* Minimum 2 stages residual overvoltage (neutral displacement);
* Minimum 2 stage of underfrequency;
* Minimum 2 stage of overfrequency;
* Minimum 2 stage of rate of change of frequency protection;
* Circuit-breaker failure.
* Transient Ground Fault (TGFD) (50Hz applications only, P543/5)

**Differential Protection (87)**

The relay shall have per phase line differential protection with inbuilt distance protection available as a permanent parallel main protection function, or selectively enabled in the event of failure of differential element communications. Capacitive charging current compensation shall be provided.

In distribution applications it shall be possible to apply the relay to feeders with transformers in their zone. For such applications the relay shall provide phase compensation settings, inrush restraint and CT ratio correction factor settings.

The relay shall have starters for the current differential protection to improve differential protection stability during communication path switching and other communication issues. The starters shall offer current magnitudes, sequence components and delta step-changes as detection methods.

The relay shall have supervision of standing differential current for alarm purposes.

It shall be possible to configure the line differential relays for two and/or three terminal lines in a single variant, without changing any order code.

The relay shall have a neutral differential protection element to clear high resistive ground faults which can be below the phase current differential’s minimum sensitivity.

The differential protection shall support G.703, V.35, X.21, IEEE C37.94, SONET/SDH, IP/MPLS, TP/MPLS, 1300nm direct fibre and 1550nm direct fibre connections between protected circuit ends.

**Distance Protection (21, SOTF, PSB, OST)**

Distance protection shall be available, full scheme, and with six zones.

Instantaneous tripping in Zone 1 and aided channel signal send shall be in no greater than one power system cycle (20ms on a 50Hz system, 16.7ms on a 60Hz system) for faults up to 80% of the zone reach. This shall be true for all source-line impedance ratios up to 30 (50Hz system) and 5 (60Hz system).

The distance characteristics shall be selectable between mho and quadrilateral for all 6 zones of protection (8 zones for sw. 92 and above).

Simple and advanced setting modes shall be available for zone settings. All zone characteristic parameters (reach, angle, resistive coverage etc.) shall be independently settable for each zone in the advanced mode.

The distance protection shall include a load blinder feature for security in the presence of heavy loading. The load blinder shall be released by phase-selective undervoltage detection.

Protection zones shall have a settable minimum current sensitivity for pickup.

The distance protection shall include CVT (capacitor voltage transformer) filtering for optimum performance with CVTs. This shall be affected as intelligent filtering such as to retain fast operation.

There shall be provision for two independent channel aided schemes. In addition to the standard Aided Schemes, there shall be provision for a programmable (user configurable) aided scheme utilizing the available zone signals.

The distance zones shall offer a switch on to fault (SOTF) function to detect zero-voltage close-up faults present on line energisation.

Power swing blocking (PSB) shall be provided, with the response of each zone element during power swings being configurable: to allow tripping, block, or to affect an unblock after a settable delay. An adaptive power swing detection method shall be provided, which is able to recognise the waveform trend of a power swing, without needing to employ starter zones or impedance bands.

Out of step tripping (OST) shall be provided, able to separate the power system in the event that synchronous connection between power system islands has been lost. The OST feature shall employ impedance-based detection, with the means to delay the system separation to when the current passing through the circuit breaker is expected to be minimized.

**Directional / Non-directional Overcurrent and Earth Fault Protection (50/51, 50N/51N, 67/67N)**

The relay shall have the freedom to set directionality (forward/reverse) independently for all the overcurrent and earth fault protection stages. The earth fault protection shall provide two options for directional earth fault (DEF) polarization: residual voltage (zero sequence) or negative sequence. For the phase fault elements, the device shall determine directionality by internal polarization from the quadrature phase-phase voltages. For close up three-phase faults, the device shall include a synchronous polarization feature that stores the pre-fault voltage information and continues to apply this to the directional overcurrent elements for a time period of a few seconds. This ensures that either instantaneous or time-delayed directional overcurrent elements will be allowed to operate, even with a three-phase voltage collapse.

Time overcurrent curve characteristics; IEEE, IEC, and definite time shall be available. The phase and earth elements shall include optional 2nd harmonic blocking.

The DEF element shall have an inverse time/definite time characteristic with a possibility to configure the DEF in both channel-aided and/or channel-independent modes of operation.

**Transient Earth Fault (TEFD) (P543/5)**

The relay shall have transient earth fault protection for earth fault protection for isolated or compensated earthed systems. The function shall not need any additional analogue processing boards. (for 50 Hz applications).

**Undervoltage (27)**

A minimum of 4 stages of undervoltage protection, configurable as either phase to phase or phase to neutral measuring shall be provided. The protection shall be configurable as any phase or three phase operation. Definite-time shall be available for all stages with IDMT available for at least the first stage.

**Overvoltage (59)**

A minimum of 4 stages of overvoltage protection, configurable as either phase to phase or phase to neutral measuring shall be provided. The protection shall be configurable as any phase or three phase operation. Definite-time shall be available for both stages with IDMT available for at least the first stage.

**Residual Overvoltage (59N)**

Residual overvoltage protection shall be available for earth fault protection where there is an isolated or high impedance earth. The residual voltage shall be can be calculated from the three phase to neutral voltage measurements. A minimum of two independent stages of protection shall be provided.

**RMS Thermal Overload (49)**

The relay shall two characteristics for thermal overload protection - a single time constant characteristic and a dual time constant characteristic. Single time constant characteristic shall use same equation as in IEC60255-8 and suitable to be used to protect cables, dry type transformers and capacitor banks. The dual time constant characteristic shall be suitable to be used to protect equipment such as oil-filled transformers with natural air cooling. The dual time constant characteristic serves to protect the winding insulation from ageing and to minimise gas production by overheated oil.

**Circuit Breaker Fail (50BF)**

* The function shall be applicable to single and dual circuit breaker configurations;
* The function may be triggered by operation of internal protection only, external relays only, or both;
* Multiple reset criteria shall be provided based on fast undercurrent reset and/or the circuit breaker(s) status;
* The function shall have a retrip option in addition to backtripping;
* The function shall have a fast reset time, in line with the requirements of transmission class devices (<0.75 cycles).

**Fault Locator (21)**

The relay shall include a fault locator function, which identifies the fault location by measuring the fault voltage and current magnitude and phasors. The fault locator shall uses pre-fault and post-fault analogue input signals to calculate the fault location, reading in kilometres, miles or % of protected circuit length.

The fault locator shall offer built-in mutual compensation for parallel circuits.

**Current Transformer Supervision (CTS)**

The relay shall have an inbuilt differential current transformer supervision function, which is not reliant on voltage inputs, to supervise the current transformers and their circuitry, at all ends of the scheme. 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)**

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. There shall also be a provision to block the voltage dependent protection.

**Auto reclosing (79)**

The relay shall include up to 4 shots of auto-reclose with facilities for single pole / three pole / or single and three pole tripping. The autoreclose function shall have the option to be initiated from external and internal protection elements/relays.

The function shall be applicable to single or dual breaker configurations.

In the case of dual breaker applications, leader / follower schemes shall be configurable.

**Check Synchronisation (25)**

Check synchronising (2-stage) with advanced system split features shall be provided. Live and dead voltage checks shall also be provided.

In dual breaker applications, two check synchronism reference voltages shall be provided, in addition to the three-phase line VT.

**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.

**Disturbance Recording**

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

* The resolution of the records shall be 24 samples per cycle or greater;
* The record storage shall be maintained even after the device has been powered-down;
* The disturbance records shall have 16 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 0.5 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 1024 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 5 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 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 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);
* 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 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;
* It shall be possible to view all remote end currents on the local IED.

**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 7. 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 format;
* Graphical creation and editing of programmable logic;
* Comparison of setting files to identify any differences between versions;
* 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;
* 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 32 GOOSE Inputs and 32 GOOSE Outputs
* The relay shall support IEC 61850 Edition 2
* IEC61850 shall be switchable between Ed1 Ed2 via software (SW91)
* 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.
* 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
* 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

**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, 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

**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

**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 60068-2-42: 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 60255-22-1: 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;

**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**

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 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,

* 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

(Complies with Canadian and US requirements).

**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.

**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.