**Guideform Specification - Process Bus Protection Relays:**

**MiCOM Agile P441, P446, P546, P645, P841**

10th Jan, 2020

**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 no greater than 40TE (8 inches, 206mm) to allow two such devices to be housed side by side in a single rack tier.
* 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 less than 3.5kg.

**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 USB communication port shall be provided for service access by relay technicians/engineers, communicating with the PC toolsuite 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 ports used in the active installation 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®)
* The process bus connection shall offer an alternative switched test port, where RJ45 virtual injections of sampled values can be made direct to the device using a suitable relay test set, without disturbing the main fibre process bus connection. This port shall be a 100BaseTX communications interface in accordance with IEEE802.3 and IEC 61850-9-2LE, isolation level 1.5kV, connector type RJ45.

**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.

**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: 1979.
* The quiescent burden of the energized device shall be less than 11W; (extra 1.25W when fitted with second rear comms port), additions: 0.13W per energized output relay, 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**

A small complement of 8 opto-isolated binary inputs shall be available. In a full digital substation these may not be strictly required, however this provides future-proofing in case a need arises later, or where panel mechanical switches are fitted.

* 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.
* Opto inputs shall be possible to connect two in series, with voltage sharing across the pair, permitting deployment in trip circuit supervision schemes (if required).

**Output Contacts**

A small complement of 8 output contacts shall be available. In a full digital substation these may not be strictly required, however this provides future-proofing in case a need arises later, or where hardwiring of certain signals is preferred.

**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

**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-motoring 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**

Eight 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

**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.

**Functional Specifications**

**Protection and Control**

The utility shall detail the required protection and control elements, and their performance required.

**Disturbance Recording**

The device shall include on-board 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

**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 5 fault trip records

**Programmable 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).
* 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.

**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 IEC 61850 Edition 2
* 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 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. There shall also be a setting for field testing with simulated IEC 61850-8-1 GOOSE and -9-2LE sampled values. In this mode, the device shall be able to distinguish between ‘real’ and ‘simulated’ data (from a test set, for example) on the Ethernet LAN and respond appropriately.

**Process Bus – IEC 61850-9-2LE**

* The process bus shall not be vendor proprietary in any way. Standards-compliant IEC 61850-9-2LE shall be provided.
* The supplier shall ensure that a workable family of process bus devices is available, in order to implement full substation schemes, where required. This shall include feeder protection, distance protection, line differential protection for up to 3 ended schemes, transformer protection, and busbar protection schemes for up to 28 bays.
* The protection algorithms used shall be equivalent to those used in conventional CT/VT models, to demonstrate at least two years installed experience. The standardization shall ensure that any product re-approval (homologation) by the utility is the bare minimum.
* The performance of the device from sampled analogue values received up to GOOSE issuance of the protection trip command shall be equivalent to, or faster than a conventional equivalent relay up to relay contact closure.
* The device shall support subscription to logical node sources from multiple merging units (each being up to three phase and neutral current, and three phase and neutral voltage), achieving the same scaleability as traditional CT/VT applications.
* The device shall support dynamic switching of the VT logical node references, such that up to 3 bus VT references can be switched between, and up to 2 line VT references. This shall cater for instances where the position of circuit breakers and disconnectors in the substation alters which voltage transformer set is used to input to the protection.
* The device shall support error correction of sampled value streams, in order to interpolate and ride through a number of missing messages in any power cycle.
* The device shall be compatible with merging units having up to 3ms of delay in publishing sampled values, compared to the true real-time sampling instant.

**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.

**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 operating (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**

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

**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 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 minimise 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.