Numerical motor protection and control in medium voltage networks
Protection and Control REX640

The freely configurable relay is an all-in-one protection and control relay for use in feeder, transformer, on-load tap changer, motor, generator, busbar, interconnection, autosynchronizer, Petersen coil and high-speed bus transfer applications.

The modularity and scalability of both software and hardware facilitates the coverage of any protection application requirement that may arise during the complete life cycle of the relay and substation. The relay offers the user a possibility to upgrade and modify the hardware and the functionality on site throughout the relay's life cycle.

Mechanical and construction details
- The protection and control device shall comprise of a main unit (relay) and a human-machine interface (HMI).
- The relay shall have dimensions not exceeding 6U in height.
- The relay shall be possible to mount inside of the LV compartment of the switchgear or on the backside of the LV compartment door.
- The relay shall be possible to mount in a 19" relay cabinet.
- The LHMI shall be possible to flush mount or semiflush mount with or without a raising frame or tilted frame.
- To facilitate quick replacement, the relay shall have detachable connectors with secure current transformer (CT) secondary side shorting. It shall be possible to quickly replace the faulty module or complete relay with a spare one without disturbing any of the wiring.
- CT and VT connectors shall be available as ring lug type and screw type terminals
- Signal connectors shall be available as screw type and push-in type terminals
- The relay and the HMI shall have an option for conformal coating.
- The relay shall meet IP 20 ingress protection requirements from the front/connector side, IP 30 from the top/bottom side and IP 40 from rear side.
- As flush mounted, the HMI shall meet IP54 ingress protection requirements from the front side.

Human-machine-interface (HMI)
- The relay shall support two alternatives for human-machine interface.
  - o   Local human-machine-interface (LHMI). The LHMI is a relay specific unit dedicated to a certain relay.
  - o   Switchgear human-machine-interface (SHMI). A single SHMI must be able to serve up to 20 relays. The SHMI shall provide switchgear level status information as well as an access point to the LHMI level relay information.
- The relay engineering tool shall be able to replicate the same views than the physical HMI

Swichgear human-machine-interface (SHMI)
- The SHMI shall have a color touch screen with capacitive touch sensing technology. The touch screen shall be no less than 7"in size, with a no less than 800 x 480 pixel resolution.
- The relays shall be able to operate normally even without the SHMI.
- SHMI navigation page shall provide an overview of the complete switchgear lineup. Four switchgear panels shall be shown simultaneously on the navigation page, and the other panels must be accessible by tapping the SHMI panel Home button or by swiping the screen.
- A single SHMI must be able to serve up to 20 relays, and there shall be a possibility to have several non-overlapping SHMI panels within the installation.
- On the navigation page, each switchgear panel shall be possible to represent by a dynamic single-line diagram, static figure or even by a photo of the actual panel. The panel-wise representation shall include a virtual home button indicating the status of the relay within the panel. After tapping on selected switchgear panel on the navigation page, the SHMI shall connect to the relay and shall provide all the same features as the LHMI.

- The SHMI shall have a dedicated Home button in a fixed location to indicate complete switchgear lineup status. Status indications: steady green (no active alarms), blinking red (unacknowledged alarm(s)), steady red (alarms acknowledged but one or several alarms still active), blinking green (any of the relays in test mode).
- SHMI shall automatically store backups of the connected relays' configurations. If a relay needs to be replaced with a spare relay that has at least same capabilities as the original one, the relay configuration and parameters can be restored from the SHMI panel.
- The SHMI shall support 24 -250 VDC and 100-240 VAC auxiliary power supply.
- It shall be possible to mount the SHMI at a remote location. Communication to the relays shall take place over the substation Ethernet based communication network.

Local human-machine-interface (LHMI)
- The LHMI of the relay shall have a color touch screen with capacitive touch sensing technology. The touch screen shall be no less than 7"in size, with a no less than 800 x 480 pixel resolution.
- The relay shall be able to operate normally even without the LHMI.
- The LHMI shall have two categories of data presentation and command handling:
  - Information presented in customizable pages for operator's normal activities such as single-line diagram, controls, measurements, events and alarms.
  - Information presented in predefined pages supporting relay parametrization, testing, analyzing and commissioning as well as troubleshooting.
- Features to be supported by the customizable pages:
  - It shall be possible to have up to ten user-definable pages.
  - It shall be possible to create fully-customized pages or use pre-defined elements or complete pages.
  - On the event page it shall be possible to filter the event list based on function category, e.g. protection, control, measurement etc.
  - The LHMI shall support graphical presentation of the measured values in the form of bars, gauges, curves and vector diagrams.
  - The LHMI shall include a comprehensive symbol library and provide possibility to create custom symbols.
  - The single-line diagram (SLD) shall provide primary device related interlocking information.
  - Controllable primary devices shall be highlighted by a rectangular area around the device in the SLD.
  - It shall be possible to present alarms in a dedicated alarm page. The alarms shall be presented in two categories: persisting alarms and fleeting alarms. For each alarm it shall be possible to freely define a description text.
- Features to be supported by the predefined pages:
  - It shall be possible to view and modify relay parameters.
  - It shall be possible to monitor and simulate relay inputs, as well as force relay outputs and function block outputs. This functionality shall be available only when the relay is in test mode.
  - Secondary injection testing of the relay shall be supported by a dedicated page. On this page it shall be possible to disable selected protection functions in order to facilitate testing of a specific protection function. This functionality shall be available only when relay is in test mode. When relay is set back to normal mode it shall resume the original settings.
  - For testing the communication it shall be possible to generate MMS events one by one or as a group without related function activation. This functionality shall be available only when the relay is in test mode.
  - Monitoring of sent and received IEC 61850-8-1 GOOSE data sets and their content.
  - Monitoring of sent and received IEC 61850-9-2LE SMV streams and their values.
- The LHMI shall have a dedicated Home button in a fixed location to indicate relay status. Status indications: steady green (no active alarms), blinking red (unacknowledged alarm(s)), steady red (alarms acknowledged but one or several alarms still active), blinking green (relay in test mode).
- The home button shall also work as navigation button to scroll between custom pages. By pressing the home button for a longer duration (>1 sec…), it shall be possible to access the bookmarks page.
- Merely tapping the home button shall not trigger any control action.
- The LHMI shall support 24 -250 VDC and 100-240 VAC auxiliary power supply.
- It shall be possible to mount the LHMI close to the relay with a direct Ethernet connection or at a remote location over a substation Ethernet based communication network.
- LHMI shall automatically store backup of the connected relay configuration. If a relay needs to be replaced with a spare relay that has at least same capabilities as the original one, the relay configuration and parameters can be restored from the LHMI panel.
- It shall be possible to create an alarm annunciation view with up to 64 channels using ready made template.

Inputs and outputs
- The phase current inputs and the residual current input of the relay shall be rated 1/5 A. The selection of 1 A or 5 A shall be software-based.
- For applications requiring sensitive earth-fault protection, the relay shall offer an optional 0.2/1 A residual current input. The selection of 0.2 A or 1 A shall be software-based.
- When measuring the currents and voltages utilizing traditional instrument transformers the relay shall have up to 20 analog inputs.

- The relay must offer optional current (Rogowski coil) and voltage divider sensor inputs and support the use of combined current and voltage sensors connected with one connector per phase. The current sensor inputs must facilitate the usage of sensors within the nominal range of 40...4000 A.
- The relay shall support combined usage of traditional instrument transformers and sensors, e.g. transformer differential protection may have primary side current inputs from traditional instrument transformers and secondary side current inputs from sensors and vice versa.
- The relay shall have up to 56 binary inputs and up to 42 binary outputs and all of them shall be freely assignable towards relay internal logics.
- To enable direct tripping of the circuit breaker, the relay must have three double-pole power output relays with integrated trip-circuit supervision (TCS). The output relays shall be rated to make and carry 30 A for 0.5 s with a breaking capacity of ≥1 A (L/R<40 ms).
- To enable fast direct tripping of the circuit breaker, the relay must have up to three optional high-speed static power outputs with trip circuit supervision (TCS) with an operate time of ≤ 1 ms. The static power outputs shall be rated to make and carry 30 A for 0.5 s with a breaking capacity of ≥3 A (L/R<40 ms).
- For protection scheme communication purposes, the relay shall support two high speed static signal outputs with an operate time of ≤ 1 ms.
- The threshold voltage of the relay's binary inputs shall be settable between 16...176 V DC for each input module separately.
- The binary inputs of the relay shall, when energized, utilize a higher inrush current to facilitate the separation of possible dirt or sulfide from the surface of the activating contact.
- The relay shall offer up to 20 optional RTD inputs and up to four mA channels which can be used either in output or input mode. The mode selection of the mA channel operation shall be software-based.
- The relay shall offer four optional arc sensor inputs which can be either of loop or lens type. The combination of loop or lens type sensors shall be freely selectable. The relay shall supervise the condition of both loop and lens type arc sensors.

Protection and control functions – base functionality for all relay variants
- The relay shall have non-directional phase overcurrent (50P/51P) and earth-fault protection (50G/50N // 51G/51N) with nine stages each (three low-set, three high-set and three instantaneous stages). The operation characteristic of the low and high-set stages shall be settable to either definite time (DT) or inverse definite minimum time (IDMT), supporting various types of inverse curves, including a user-definable one. The instantaneous stage shall support the peak-to-peak measurement mode enabling protection fast operation even under primary CT saturation conditions.
- The relay must have six-stage directional phase overcurrent protection (67) with voltage memory and selectable positive and negative-sequence polarization.
- The relay must have eight-stage directional earth-fault protection (67N) with selectable negative and zero-sequence polarization. I_0 and U_0 shall be derived either from the phase currents and voltages or from the measured neutral current and residual voltage.
- The relay shall have arc protection based on simultaneous detection of current and light. During maintenance work at the substation, it shall be possible to change the operation criteria to light only via a binary input.
- The relay shall have three-stage negative-sequence overcurrent protection (46) settable between 0.01 and 5 times In and operation based on selection as definite time (DT) and inverse definite minimum time (IDMT), and IEC and ANSI/IEEE operating curves.
- To detect phase unbalance caused by a broken conductor, the relay shall have phase discontinuity protection (46PD). For optimum sensitivity and stability, the operation must be based on the ratio between the positive and negative-sequence current.
- The relay shall have two-stage directional negative-sequence overcurrent protection (67Q).
- The relay shall have comprehensive voltage protection, including at least overvoltage (59), undervoltage (27), positive-sequence overvoltage(59PS), positive-sequence undervoltage (27PS), negative-sequence overvoltage (59NS) and residual overvoltage (59G/59N) protection.
- The relay must have 12-stage frequency protection (81) including at least overfrequency, underfrequency and frequency rate-of-change protection with rate-of-rise or rate-of-fall freely selectable for each stage.
- The relay shall include a six-stage frequency-based load shedding and restoration function (81LSH) for automatic disconnection and reconnection of non critical loads in network overload situations.
- For overhead line applications, the relay shall have multishot auto-reclose functionality (79) capable of handling one-and-half breaker scheme.
- The relay shall have circuit breaker failure protection (50BF) for up to three circuit breakers including independent timers for repeated tripping of the same breaker and backup tripping of the upstream breaker.
- The relay shall have under current protection (37) for detecting feeder disconnection, low-load and loss-of-phase conditions.
- The relay shall have three phase voltage-dependent overcurrent protection (51V) with 2 stages for protecting generators against short circuit faults occurring close to the generator terminals. The function shall include settable definite time (DT) and inverse definite minimum time (IDMT) characteristics. The function shall operate when the current exceeds a set value dynamically calculated based on the measured terminal voltage. It shall also be possible to select either a voltage restrained/voltage slope or voltage controlled/voltage step characteristic.
- The relay shall include Switch-On-To-Fault (SOTF) logic ensuring a fast trip when the breaker is closed onto a faulted feeder or bus. The function shall complement the non-directional or directional overcurrent protection functions and accelerate the operation of the protection.

- The relay shall support both high-impedance (87NHI) and low-impedance (87NLI) restricted earth-fault protection principles for up to two windings.
- The restricted low-impedance earth-fault protection (87NLI) shall be based on the numerically stabilized differential current principle and the neutral-current second harmonic shall be used for blocking the function in a transformer inrush situation. No external stabilizing resistor nor non-linear resistors shall be required. The operating characteristics shall be according to the definite time.
- The relay shall include three-phase inrush detector function (68HB) with two stages.
- The relay shall include a synchro-check (25) function for circuit breaker closing for three breakers. The function shall ensure that the voltage, phase angle and frequency across of an open circuit breaker meet the requirements for safe interconnection of two networks. The function shall include energizing check functionality and support the operation modes dead-line/live-line and dead-bus/live-bus. To enable circuit breaker closing when reconnecting two asynchronous networks, the function shall consider the circuit breaker closing delay and the measured slip frequency to ensure that the closing command is given at the right moment. The function shall include phase-shift compensation for cases where the reference voltage is measured across a power transformer. In case of a fuse failure it shall be possible to block the energizing check.
- To permit the circuit to operate close to thermal limits, at the same time providing adequate protection, the relay shall have three-phase thermal protection (49F) for feeders, cables and distribution transformers. The thermal model shall be compliant with the IEC 60255-149 standard.
- The relay shall support the control of at least 14 primary switching devices out of which at least 3 circuit breakers and 11 disconnectors/earthing switches freely selectable for control & indication or for indication only.
- It shall be possible to freely apply the relay as multi-function controller like bay control unit (BCU) as per the application requirement.
- When applied as bay control unit (BCU) – it shall have adequate capacity for the inuts and outputs, a LHMI enabling control of each primary device with in the bay with interlock logic for the station and bay level, supervision, indication and monitoring functionality with optional auto-reclosing and backup protection.
- The relay shall have a directional negative sequence impedance protection (Z2Q) in order to detect unsymmetrical faults in networks with strong source(s).
- The relay shall be equipped with primary switch condition monitoring for breakers and motor controlled disconnertors/earthing switches.
- The relay shall include load blinder/load encroachment functionality (21LB) which shall be used to block selected protection functionality under heavy load conditions.

Optional protection and control functions – motor protection
In addition to the base functions the following optional functions shall be included for motor protection

Asynchronous and synchronous motors
Differential protection
- The relay shall have comprehensive three-phase stabilized differential protection (87M/87G) with one low-set (biased) and one high-set (instantaneous) stage for motor winding protection.
- The stabilized differential protection shall have a DC restraint feature to temporarily decrease the sensitivity of the differential protection and so to avoid unnecessary disconnection of the motor due to spurious differential current, caused by uneven CT saturation resulting from long lasting DC components.
- The relay shall have flux-balance based differential protection (87HIM) providing winding short-circuit protection for motors.
- The relay shall support phase segregated high-impedance differential protection (87_A/87_B/87_C) to provide motor differential protection.

Functions for startup and control
- The relay shall include motor start-up supervision. The function shall offer protection in case of an excessive start-up time of the motor.
- The start-up supervision shall be based on monitoring the true RMS value of all the phase currents and optionally enhanced by monitoring the status of the primary switching device.
- The relay shall include support for connecting a speed switch indicating whether the motor shaft is rotating or not.
- The phase reversal protection (46R) of the relay must be based on the calculated negative phase-sequence (NPS) current. During motor startup the relay shall, by monitoring the NPS current values, detect incorrectly connected phases and trip the motor rotating in the wrong direction.
- The relay shall include motor load jam protection i.e. locked rotor protection (50TDJAM) for a running motor. It shall be possible to block the motor load jam protection function by the motor startup supervision function for the duration of the motor startup.
- The relay shall include loss of load supervision (37), as loss of load is considered a fault condition. The function shall operate when the current drops below the set value. The relay shall differentiate between loss of load and standstill situations.
- The relay shall include an emergency start function (EST,62), which shall allow motor startup during emergency conditions. The function shall be incorporated in the related protection functions in the relay to allow a motor restart. After the emergency start has been activated, it shall be possible to start the motor normally.

- The relay shall have a motor start counter (66) which can distinguish between motor cold and warm starts. It shall be possible to define maximum number of starts respectively. If the maximum number of starts is reached restart of the motor shall be blocked. The counter values shall be counted down based on a settable cooling time delay.

Thermal protection
- The relay shall include motor thermal overload protection (49M) to protect the electric motor from overheating. In case of an emergency situation it shall be possible to start the motor despite of its thermal status.
- The motor thermal overload protection shall consider both the true RMS and negative-sequence currents. In case of unbalanced phase currents, the negative-sequence current must be considered since it causes additional heating. For accurate calculation of the motor's different thermal conditions, the relay shall have three time constants for the different running conditions of the motor, i.e. start-up, nominal speed and standstill.
- The relay shall include thermal overload protection for rotors (49R) to protect the rotor from overheating, especially during the startup of a motor using direct online starter. The function shall estimate the rotor slip and take into account both true RMS phase currents and negative sequence current. The rotor slip shall be estimated based on the line voltages and load current without the need for any additional equipment.
- The relay shall include two stages of negative-sequence overcurrent protection (46M) settable between 0.01 and 5 times pu.

Additional functions for synchronous motors
- The relay shall have directional overpower protection (32O) to detect whether the motor consumes reactive power due to the loss of excitation field. It shall be possible to select the operating direction with the combination of the settings directional mode and power angle, where directional mode can be either forward or reverse and power angle set between reactive or active power. The power setting shall settable between 1...200 % of the machine's apparent power in steps of 1% and the operate time to 0,04...300 seconds.
- The relay shall include two-stage functionality for detecting underexcitation (40) and loss of excitation conditions, which may cause excessive heating in the end region of the stator winding, damaging the insulation of the stator winding and the iron core. The function shall prevent the motor from operating in the asynchronous mode, which increases the rotor speed, causing heating in the rotor iron and damper windings.
- The relay must have impedance monitoring based out-of-step/pole slip protection (78PS). An out-of-step condition (pole slip) is characterized by periodic changes in the rotor angle. The out-of-step protection function shall detect stable power swings and out-of-step conditions based on the measured impedance travel time through the settable impedance blinders (inner and outer blinders). For selective relay operation during power swing conditions (near or far), it shall be possible to divide the impedance characteristic into two zones. The number of pole slips shall be independently settable for each zone. To avoid breaker stress, it shall be possible to include the breaker opening time to optimize the tripping.
- The relay shall have two-stage rotor earth-fault protection (64R) based on the fundamental frequency injection method. The function shall detect insulation failures in motor with brushes between the field winding and the rotor iron, requiring disconnection of the motor to avoid further damage.
- For complete (100%) stator earth-fault protection, the relay shall have third harmonic-based stator earth-fault protection (64TN) in addition to fundamental frequency-based residual overvoltage protection. The third harmonic-based protection shall offer the following alternative protection methods :
  - Differential of the third harmonic component measured both at the motor neutral and terminal side
  - Neutral side third harmonic undervoltage

Measurements, alarms and reporting
- The relay shall have several three-phase current and voltage measurement functions (fundamental or RMS-based as selectable options) with an accuracy of ±0.5% and zero-, negative- and positive-sequence current and voltage measurement with an accuracy of ±1% within the range of ±2 Hz of the nominal frequency. It shall be possible to assign the measurement functions freely for current and voltage inputs within the relay. The measurement functions shall be available also for received IEC 61850-9-2 LE based current and voltage values.
- IEC 61850-9-2LE based measurements shall be treated as local measurements what it comes to connectivity to protection, measurement, disturbance recorder and supervision functions.
- The relay shall have several power and energy measurement functions (P, Q, S, kWh and kVArh) with an accuracy of ±1.5% and power factor measurement with an accuracy of ±0.015 shall also be included. It shall be possible to assign the measurement functions freely for each three phase current and voltage inputs within the relay. The measurement functions shall be available also for received IEC 61850-9-2 LE based current and voltage values.
- The relay shall be able to monitor power quality based on measured currents and voltages.
- Voltage quality monitoring shall include phase segregated harmonic distortion including total harmonic distortion (THD), individual harmonics and direct current component, short duration voltage variations (dips, swells and interruptions) and voltage unbalance. Voltage quality monitoring shall comply with EN 50160.
- Current quality monitoring shall include phase segregated harmonic distortion including total harmonic distortion (THD), total demand distortion (TDD), individual harmonics and direct current component.
- The relay shall be able to visualize the harmonic distortion values of currents and voltages as well as individual harmonic content in the LHMI and share it with upper level system using the station communication.

- To collect sequence-of-events (SoE) information, the relay must include a non-volatile memory with a capacity of storing at least 1024 event codes with associated time stamps.
- The relay must support the storage of at least 128 fault records in the relay's non-volatile memory.
- The fault record values must at least include phase currents, phase voltages, zero-, negative- and positive-sequence currents and voltages, differential and bias currents and the active setting group.
- The relay shall have a disturbance recorder supporting a sampling frequency of 32 samples per cycle and featuring up to 24 analog and 64 binary signal channels.
- The relay's disturbance recorder shall support not less than 12 three-second recordings at 32 samples per cycle for 10 analog channels and 64 binary channels.
- The relay shall store up to 100 disturbance recordings.
- The relay must have a load profile recorder for phase currents and voltages supporting up to 12 selectable load quantities and more than 1 year of recording length. The load profile recorder output shall be in COMTRADE format.

Communication
- The relay must support both IEC 61850 Edition 1 and Edition 2.1.
- The relay shall support two IP subnetworks assigned to different Ethernet ports.
- The relay must support flexible product naming (FPN) to facilitate the mapping of relay's IEC 61850 data model to a customer defined IEC 61850 data model.
- The relay must support, besides IEC 61850, simultaneous communication using one of the following communication protocols: Modbus® (RTU-ASCII/TCP), IEC 60870-5-103, IEC 60870-5-104 or DNP3 (serial/TCP/UDP). With external adapter it shall support Profibus where needed.
- Relay shall support secure DNP3 TCP/IP and IEC 60870-5-104 based on IEC 62351
- The serial interface shall be offered both with optical and galvanic connections.
- The LHMI must have an Ethernet port (RJ45) for local parametrization and data retrieval.
- The LHMI shall have a USB port for connecting a memory stick. It shall be possible to read the following data from the relay: disturbance records, fault records, events, load profile, device information, settings and log files. It must be possible to electrically disconnect the USB port with a setting.
- The relay shall support up to five IEC 61850 (MMS) clients simultaneously.
- For redundant Ethernet communication, the relay shall have either two optical or two galvanic Ethernet network interfaces with HSR and PRP.
- The relay shall have a third Ethernet port, galvanic or optical, for providing connectivity for any other Ethernet device to the IEC 61850 station bus. This Ethernet port shall also support IEC 61850-8-1 based remote I/O signals.
- The relay must support IEC 61850 GOOSE messaging and meet the performance requirements for tripping applications (<10 ms) as defined by the IEC 61850 standard.
- The relay shall support sharing analog values, such as temperature, resistance and tap positions using IEC 61850 GOOSE messaging.
- The relay shall support a possibility to receive simulated GOOSE messages and Sampled Measured Values (SMV). Simulated values can be used for testing purposes instead of the actual values.
- The relay must support IEEE 1588 v2 using Power Profile IEEE C37.238-2011 or Power utility profile IEC 61850-9-3 for high-accuracy time synchronization (< 4 µs) in Ethernet-based applications. The relay shall also support the SNTP (Simple Network Time Protocol) and IRIG-B (Inter-Range Instrumentation Group - Time Code Format B) time synchronization (<4 µs) methods.
- The relay must support IEC 61850-9-2 LE process bus for sending sampled values of currents and voltages.
- The relay shall be able to receive four full streams (4 currents and 4 voltages) of IEC 61850-9-2 LE and must be able to switch between the streams based on predefined conditions.
- The relay shall have dedicated point-to-point protection communication for distances up to 50 km (31 miles) with the integrated optical link, or up to 8 km (5 miles) with a galvanic link using an external modem. The protection communication channel shall support line differential protection and in addition include a possibility to transfer at least 16 additional binary signals between the line ends to be used for example with line distance protection scheme communication. In order to take into account future needs, this interface shall be available in all of the communication modules despite if it is initially needed or not.
- When reporting analogue (measured) values over the IEC 61850 (MMS), it shall be possible to select between change value based or cyclic reporting.

Cyber security
- The relay shall have a certificate of compliance of Achilles Level II.
- The relay shall support the possibility to define access control for individual users based on different roles.
- The relay must support role-based access control (RBAC) according to IEC 62351-8.
- The relay shall support individual user accounts for up to 50 users.
- The relay shall support centralized administration of users and roles using either Active Directory (AD) or Lightweight Directory Access Protocol (LDAP) servers.
- The relay shall support security log with up to 2048 events stored in a non-volatile memory.

- The relay shall support centralized security logging using the Syslog protocol.
- The relay must support the possibility to update the X.509 certificate used for secure communication and device identification.
  - Automatically using Public Key Infrastucture (PKI)
  - Manually using relay configuration tool
- It shall be possible to disable unused Ethernet and serial communication ports.
- It shall be possible to define the supported services for each Ethernet subnetwork.
- The relay shall be in line with the relevant parts of NERC CIP, IEEE 1686 and IEC 62351
- The relay shall offer an Ethernet filter and Ethernet rate limiter functionality to limit the Ethernet/TCP network traffic in case of e.g. Denial of Service attack.
- Cryptographic component shall use cryptographic security mechanisms according to internationally recognized and proven security practices and recommendations.
- Any human user interface shall be capable to display a configurable system use notification before authenticating.
- The relay shall offer a capability to erase all sensitive information once decommissioned.
- Maintenance tool shall be capable to verify the firmware upgrade/update authenticity prior to the installation.

Engineering and configurability
- The relay must have 6 independent settings groups for the relevant protection settings (start value and operate time). It must be possible to change protection setting values from one setting group to another in less than 20 ms from the binary input activation. The change of the setting group shall not cause rebooting of the relay.
- The relay must have a web browser-based human-machine interface (WHMI) with secured communication (TLS) and shall provide the following functions:
  - Alarm and event lists
  - System supervision
  - Parameter settings
  - Measurements
  - Fault records
  - Phasor diagram
  - Single-line diagram (SLD)
  - Reading and writing of parameters, reading of sequence-of-event (SoE) information and disturbance records
- The relay LHMI and configuration tool shall have multilingual support.
- The relay LHMI and configuration tool shall support both IEC, ANSI and user definable protection function codes.
- The relay shall have at least 33 freely configurable and programmable two-color virtual alarm LEDs.
- The relay shall have a graphical configuration tool for the complete relay application including multi-level logic programming support and editor for LHMI views.
- It must be possible to freely configure the physical and Sampled Measured Values (SMV) based current and voltage measurements towards protection and measurement functions and disturbance recorder analog input channels.
- The relay configuration tool must include online visualization of the relay application state.
- When a protection function is disabled or removed from the configuration, neither the relay nor the configuration tool shall show the function-related settings.
- It must be possible to keep the relay configuration tool up-to-date using an online update functionality.
- The relay configuration tool shall support viewing of relay events, fault records and visualization of disturbance recordings.
- The relay configuration tool must include the complete relay documentation including operation and technical details.
- The relay configuration tool must include functionality for comparing the archived configuration to the configuration in the relay.
- The relay configuration tool must allow configuration of IEC 61850 vertical and horizontal communication including GOOSE and Sampled Measured Values (SMV).
- The relay configuration tool must support importing and exporting of valid IEC 61850 files (ICD, CID, SCD, IID).
- The relay configuration tool shall support engineering of IEC 61850 Edition 1 and Edition 2 ((amendment 1) relays in the same system
- The latest version of the configuration tool must be compatible also with older relay versions.
- The relay configuration tool must have an IEC 61850 Edition 2 certificate from an accredited Level A testing laboratory.
- The configuration tool shall support a possibility to upgrade and modify the relay hardware and the functionality, on site, throughout the relay's life cycle without the need of manufacturer personnel involvement.

Type tests and other compliance requirements

- The relay shall have a continuous operating temperature range of -25 … +55°C and transport/storage temperature range of -40...+85°C.
- The relay must fulfill the mechanical test requirements according to IEC 60255-21-1 and -2, Class 2 for vibration, shock and bump compliance.
- The relay's maximum auxiliary power consumption shall be less than 25 W (under operating conditions).
- The relay must have an IEC 61850 Edition 2 certificate from an accredited Level A testing laboratory.
- The relay must fulfill the electromagnetic compatibility (EMC) test requirements according to EN 60255-26 and comply with EMC directive 2014/30/EU.
- The relay shall comply with RoHS directive 2011/65/EU.
- Type test certificate for mechanical, environmental, safety and EMC tests shall be provided by an accredited third party laboratory.
- An Environmental Product Declaration (EPD) about products' environmental performance throughout their entire life cycle shall be publicly available and verified by third-party.

Additional information

For more information, please contact your local ABB representative or visit our website at:
abb.com/substationautomation
www.abb.com/mediumvoltage