The IED shall comprise hardware, time synchronization, monitoring, communication capabilities and other specifications as described in the 1MRG033843_en_Sample_specification_General_specifications_Relion_670 document. For the common protection, control, monitoring functionalities please refer to 1MRG033842_en_Sample_specification_Common_functions_Relion_670 document.

The IED shall support protection and control functionality. Control functionalities are described in 1MRG033840_en_Sample_specification_Bay_control_REC670.

For a complete overview of the functions available in this device, please refer to the Product Guide. For more details about the design of the functions and their applications, please refer to the Technical Manual and the Application Manual respectively.

The functions listed below are most typically specified in RET670, but are available for selection in other types as well, as per the comments under each description.

**Transformer differential protection**

The IED shall include a transformer differential protection function, with a biased operate/restrain characteristic, internal CT ratio matching, vector group compensation and settable zero sequence current elimination. It shall include two sets of current restrain inputs for each winding. It shall be possible for the function to be released or blocked by any kind of logic created by the end user.

The bias current shall be the highest measured current in case of a single breaker arrangement, or the highest measured or calculated – as a vector summation from the CTs on the same side of the transformer – in case of a multi-breaker arrangement.

The differential operate characteristic shall have two main areas: the restrained area, and the unrestrained area.

- The restrained area shall contain three sections. The first section shall have the constant operating level independent of the bias current; the remaining two sections shall have settable slopes.
- The unrestrained level shall have a constant pickup value, irrespective of the bias current, and shall be selectable from 1 up to 100 times of the base current.
- If a substantial amount of the second or fifth harmonic is detected, the restrained operation of the function shall be blocked; levels of second or fifth harmonic required for blocking the operation shall be settable by the end user.
- If the operating point is above the unrestrained level, the function shall issue a trip signal without consideration of any type of restrain. It shall be possible for the unrestrained characteristic to be released or blocked by any kind of logic created by the end user.
- The function shall include the capacity to recognize a switch-onto-fault condition inside the differential protection zone, in which case it shall allow the differential protection to trip, even if the second or fifth harmonic content of the differential currents is enough to block the operation of the function. This switch-onto-fault option shall be configurable by the end user.
- If any blocking condition is detected in one phase, then the end user shall have the flexibility to block the operation of the differential protection only in that phase, or in all three phases. This feature shall be settable by a parameter setting.
In addition, the transformer differential protection shall include the following features:

- It shall be possible for the differential protection to temporarily desensitize during external faults, by adding a DC component to the pickup level of the protection. The DC component shall be extracted from the measured instantaneous differential currents, and the highest DC in all three phases shall be selected for addition to the pickup level; this feature shall be settable by a parameter setting.

- The function shall be able to calculate the fundamental frequency negative sequence differential current, and it shall be possible to record this in the disturbance recorder, reported as a service value.

The function shall include an internal/external fault discriminator based on the negative sequence currents. This feature shall be settable by the end user. It shall have a settable minimum amount of the negative sequence current required for the calculation, as well as the angle defining the area in which negative sequence current phasors have to be positioned in order to declare an internal or external fault. This function shall be well coordinated with other features of the differential protection, in order to provide more stability and dependability for internal faults, external faults, and evolving faults.

- This function shall include an additional feature for detecting low turn-to-turn faults based on negative sequence current, and this feature shall be able to issue a trip without the operating point being in the restrained or unrestrained area.

- The function shall be able to detect an open CT circuit, and consequently block the operation of the transformer differential protection; it shall be possible for this signal to be recorded in the disturbance recorder and reported, a functionality that shall be settable by the user. The configuration shall also enable the end user to trip the breaker with the CT open detection signal, while blocking the differential protection.

- The function shall be able to receive the position of the on-line tap changer (OLTC), for all OLTCs used for voltage regulation on the power transformer, in order to dynamically adjust the ratio of the power transformer inside the differential protection algorithm. If there is an internal failure in the OLTC, or an error in reporting the correct OLTC position, differential protection shall be able to recognize this and revert to a safe pickup level.

- The function shall continuously monitor the fundamental frequency differential current level, and in the event all three differential currents are above the set threshold, an alarm shall be issued. The value of the threshold and the time delay for the differential protection alarm shall be settable by the end user.

[OPTIONAL] The IED can be specified with up to two transformer differential protection functions, in order to protect two transformers with one IED.

In 670 series, this function is available in the following product types: REG670 and RET670.

**Restricted earth fault protection**

The IED shall include restricted earth fault protection of the low impedance type, for directly or low impedance earthed windings. The function shall include internal CT ratio matching, and shall be able to cover autotransformers with two restrain inputs per winding. The REF function block shall have an additional set of current inputs in the event of auto-transformers.

It shall be possible to release or to block the function by any kind of logic created by the end user.

The operating characteristic shall contain three sections. In the first, the constant operating level shall be independent from the bias current, while the remaining two sections shall have slope.

The protection shall have an internal/external fault discriminator based on zero-sequence currents, and this functionality shall be automatically activated if the residual current measured is at least 3% the base current. It shall have a settable angle defining an area in which zero sequence current phasors have to be positioned in order to declare an internal or external fault.

The protection shall be able to cause a trip if the differential current is in the operating area while residual current is less than 3% the base current.

The REF protection shall be able to calculate the second harmonic content of the neutral current. If the ratio between second harmonic and fundamental frequency exceeds 60%, REF protection shall be blocked.

In 670 series, this function is available in the following product types: RED670, REG670 and RET670.
**Self-adaptive differential protection for two-winding power transformers**

The IED shall have a self-adaptive differential protection for two-winding phase-shifting transformers (PST), which are also called phase-angle regulating transformers (PAR).

The function shall be able to automatically learn and adopt to the actual transformation ratio and phase-angle shift across the protected transformer. Thus, the function shall be able to protect any PST/PAR regardless of its construction principles (symmetrical or asymmetrical) and design details (single-core, double-core or even of complex design).

The function shall be provided with three-phase currents from both sides of the protected transformer, as well as with a single-phase or three-phase voltage input, from each side of the protected transformer.

The function shall be self-adaptive in a way that it shall be able to calculate and use the actual transformation ratio and phase-angle shift across the protected PST/PAR, by using current and voltage measurements only.

The function shall be able to operate correctly without receiving the position of built-in on-load tap changers, as well as without any external auxiliary (interposing) current transformers.

The differential operate characteristic of the protection shall have two main areas: the restrained area, and the unrestrained area. The restrained area shall contain three sections. The first section shall have the constant operating level independent of the bias current; the remaining two sections shall have settable slopes.

It shall be possible for the protection to temporarily desensitize during external faults, by adding a DC component to the pickup level of the protection. The DC component shall be extracted from the measured instantaneous differential currents, and the highest DC in all three phases shall be selected for addition to the pickup level; this feature shall be settable by a parameter setting.

This function shall include an additional feature for detecting low turn-to-turn faults based on negative sequence current, and this feature shall be able to issue a trip without the operating point being in the restrained or unrestrained area.

*This function is available only in RET670.*

**Overexcitation protection**

The function shall be able to measure voltage and current, and shall have settable leakage reactance in primary ohms, in order to be able to calculate induced voltage.

The function shall be capable of working without current measurement, in which case measured voltage shall be assumed induced voltage.

The function shall have the option to choose an IEEE-defined curve that relates V/Hz ratio to operate time delay, or alternatively, to create an arbitrary or tailor-made curve. The minimum trip time delay, maximum trip time delay, transformer magnetic core cooling time constant, alarm level and alarm time delay shall be settable by the end user.

For the IEEE curve, the time multiplier shall be settable by the end user.

For the tailor-made curve, six separate time delays shall be settable by the end user.

*In 670 series, this function is available in the following product types: RED670, REG670, REL670 and RET670.*

**Capacitor bank protection**

The IED shall include a function that is specially designed to provide protection and supervision features for shunt capacitor banks (SCBs). It shall also be possible to release or block the function by any kind of logic created by the end user.

The function shall include the following built-in features. It shall be possible to enable or disable each one, and to release or block each one separately, by any kind of logic created by the end user:

- overcurrent stage, with a settable level for the pickup level and the operation time delay
- undercurrent stage, with a settable level for the pickup level and the operation time delay
- reconnection inhibit, with a settable value of current below which the SCB is considered disconnected, and the time delay for the capacitor bank voltage to discharge to <5% of the base voltage
• harmonic overload with two stages; the first stage shall be based on inverse time delay (IDMT) with a settable time multiplier, and the second stage shall be based on definite time delay (DT), with a settable time delay; each stage shall have a settable pickup level

• reactive power overload, with a settable level for the reactive power overload pickup and the operation time delay

For the overcurrent, undervoltage, harmonic overload and reactive power protection features, the function shall be able to report pickup/start signals per phase.

This function is available in the following product types: REB670, REC670, and RET670.

Transformer through fault monitoring

The function shall be able to calculate \( I^2t \) value per winding, for each fault event, and provide an alarm when the set limit of \( I^2t \) is exceeded. Also, the accumulated \( I^2t \) shall be calculated throughout the transformer lifetime and compared with the set limit of cumulative \( I^2t \), and an alarm shall be raised when the limit is exceeded. Additionally, the function shall monitor the time between subsequent through faults against the set time. If this time is shorter than the set time, then the alarm shall be issued.

It shall be possible to block the calculation of the function, for example during the internal faults, or during transformer energization inrush.

Function shall also report last fault duration, overall number of faults detected, maximum through fault \( I^2t \) in % of set limit, and maximum cumulative through fault \( I^2t \) in % of set limit.

The function shall have an external input, which can be used as a trigger in order to capture the instantaneous values in the system.

It shall be possible to export the report from the function in XML format.

This function is available in the following product types: REC670, RED670, REG670, REL670 and RET670.

Insulation supervision for gas medium

The IED shall include a function for the supervision of the gas medium in circuit breakers.

The function shall be able to receive information about pressure and temperature of the gas medium directly from the circuit breaker sensors, using mA inputs. The function shall be able to issue temperature and pressure alarms, as well as lockout, based on evaluation of measured values and the settable thresholds. The function shall be able to receive binary information about pressure alarms and lockouts.

In 670 series, this function is available in the following product types: REB670, REC670, RED670, REG670, REL670, RES670 and RET670.

Insulation supervision for liquid medium

The IED shall include a function for transformer oil condition monitoring.

The function shall be able to receive information about temperature of the oil medium directly from the transformer sensors, using mA inputs. The function shall be able to issue temperature and pressure alarms, as well as lockout, based on evaluation of measured values, input values, and the settable thresholds. The function shall be able to receive binary information about temperature alarms and lockouts.

In 670 series, this function is available in the following product types: REB670, REC670, RED670, REG670, REL670, RES670 and RET670.

Estimation of transformer winding insulation life

The IED shall include a function for the estimation of the remaining transformer winding insulation life. The function shall give warning and alarm signals when the winding hot spot temperature reaches a set value. Hot spot temperature calculation shall be calculated from top oil temperature, which shall be a measured value taken through sensors, or calculated by the function. Top oil temperature calculation shall be done according to the IEC 60076-7 standard.

It shall be possible for the function to calculate the oil and winding time constants based on settable transformer parameters, or to insert the oil and winding time constants directly as the parameter settings.
Ambient temperature shall be provided to the function through a sensor, or it shall be settable as a monthly average ambient temperature.

The function shall calculate loss-of-life in the form of days and years. This information shall be updated at settable intervals, hourly or daily. The transformer winding percentage loss-of-life shall be calculated every day, and the information shall be provided as a total percentage loss-of-life from the installation date, and as a yearly percentage loss-of-life.

It shall be possible for the function to use transformer parameters defined according to IEC 60076-7 standard or IEEE C57.96-1995 standard. This selection shall be settable by the end user.

This function is available in the following product types: REC670, REG670 and RET670.

**Automatic voltage control**

The following applies both to the automatic voltage control for tap changer for single control, and to the automatic voltage control for tap changer for parallel control:

The IED shall have the functionality of automatic voltage control for the single transformer. The main principle of this function shall be to measure the voltage, compare it to the set voltage, and then take appropriate action.

The set voltage value shall be parametrized:

- by a parameter setting
- from the SCADA computer, using IEC 61850 service

The function shall be able to measure any phase or line voltage, or positive sequence voltage. This selection shall be available via a parameter setting. The voltage deadband values, based on the difference between measured and the set voltage, shall be settable by the end user.

The control mode of the voltage control shall be manual and automatic. The switching between manual and automatic control shall be possible from:

- LHMI
- binary inputs, connected to, e.g., a selector switch
- using IEC 61850 GOOSE or MMS services

In the event of manual control, the tap changer shall be operated from the LHMI or from a remote place, respecting the hierarchy of the control in the bay.

The function shall include automatic overcurrent blocking of the automatic voltage control. The threshold used for blocking shall be settable by the end user.

The undervoltage limit for blocking the operation shall be settable by the end user.

Blocking due to a reverse action of the tap changer, with the respective time setting for the duration of the blocking signal, shall be settable by the end user.

A fast step-down activation shall be available, with a settable timer.

Functionality shall be available to generate an alarm when voltage control gives an abnormal number of commands or an abnormal sequence of commands within a predefined period of time (hunting detection), with available settings for the number of operations in one hour, the number of operations in one day, time window for detection, and the maximum number of the operations within the time window.

The function shall include alarms for a settable amount of active and reactive power in both directions, with a settable time delay for an alarm.

The function shall include two separate time stages, defining the time that elapses between the moment when the measured voltage exceeds the deadband interval, until the appropriate command is initiated. The first time stage shall define the time delay for the first command to occur in one direction. It shall have a definite or inverse time characteristic, and shall be settable by the end user. The second time stage shall be used for the consecutive commands in the same direction as the first command. The characteristic and the time setting for the second stage shall be settable by the end user.
The function shall include line voltage drop compensation to control the voltage closer to the load point, utilizing the measured voltage and current from the low voltage side of the power transformer in the combination with line reactance and resistance. Setting for the capacitive load shall also be available, in the event voltage closer to the load has a higher magnitude than the voltage on the secondary side of the power transformer.

The function shall include load voltage adjustment functionality with two alternatives. One alternative shall offer automatic load voltage adjustment proportional to the load current, with the available setting for the automatic load voltage adjustment in a percentage of the base voltage. The other alternative shall offer a constant load voltage adjustment with four different adjustment factors that are settable by the end user, applied via binary inputs, through the local LHMI or customized logic, or by an IEC 61850 MMS client.

It shall be possible for the end user to define alarms or the blocking of OLTC control for the following conditions:

- command error
- overcurrent detection
- overvoltage detection
- reverse action
- tap changer error
- end position reached
- undervoltage detection

The function shall be able to receive the position of the OLTC via mA input, or via binary inputs. If the position is received via binary inputs, the following types of code conversion shall be available to the end user: BIN, BCD, Gray, and Single.

The pulse duration for the command to the tap changer shall be settable by the end user.

A counter that represents the remaining number of operations (decremental counter) at rated load and the number of operations shall be available within the function. Both counters shall be stored in non-volatile memory and include the times and dates of their last reset. These dates shall be stored automatically when the command to reset the counter is issued.

Controlling parallel OLTCs

*The following applies only to the automatic voltage control for parallel transformers:*

The IED shall be capable of providing control for up to four parallel tap changers in one single device. The IED shall be capable of providing control for up to eight parallel tap changers in a group using between two and eight devices of the same type, applying IEC 61850-8-1 GOOSE communication between the devices. In case of different set voltages, the IEDs shall be able to calculate the mean set voltage value, or use the respective set voltage values. This shall be available via a parameter setting.

The function shall have three alternative parallel control methods, settable by the end user: master-follower, circulating current, and the reverse reactance method.

For the master-follower method, a settable parameter shall determine whether the followers follow the position or the command of the master.

For the circulating current method, it shall be possible to manually control the transformers as a group, if one of the transformers in the group is in the manual mode, and the others are in the automatic mode. In this case, transformers in the automatic mode shall adapt to the manual tapping of the transformer that has been put in manual mode. The adapt mode shall be settable by a parameter.

For both the circulating current method and the master-follower method, it shall be possible to alarm only, or block automatic control, or block both automatic and manual control of the tap changer in the event of high circulating current. The threshold for the circulating current, and the timer delay for alarm or blocking, shall be settable by the end user.

The function shall be able to alarm or block the automatic control of the tap changer in the event of different tap positions, if the master-follower method is used.
It shall be possible for the function to enable or disable simultaneous tapping via a parameter setting.

When the transformer is disconnected on the low-voltage side, it shall be possible for the function to follow the voltage regulation of loaded parallel transformers, and thus be on a proper tap position when the low-voltage circuit breaker closes. This functionality shall be available both for the circulating current method and for the master-follower method.

It shall be possible for the function to issue an alarm in case the voltage measurement in one transformer bay deviates to the mean value of all voltage measurements in the parallel group. The deviation of the measured voltage, as well as the time delay for the alarm, shall be settable by the end user.

For the master-follower method, a predefined offset of the tap position can be defined between the followers and the master, settable via a parameter. A separate setting shall be available that shall alarm, after the settable time, in case the offset between a follower and the master is equal or greater than the set value.

*In 670 series, this function is available in the following product types: REC670 and RET670.*

*The automatic voltage control for parallel transformers is available only in 670 series.*