The IED shall comprise hardware, time synchronization, monitoring, communication capabilities and other specifications as described in the 1MRG033852_en_Sample_specification_General_specifications_Relion_650 document. For the common protection, control, monitoring functionalities please refer to 1MRG033851_en_Sample_specification_Common_functions_Relion_650 document.

The IED shall support protection and control functionality. Control functionalities are described in 1MRG033849_en_Sample_specification_Bay_control_REC650 document.

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 RET650, 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/restraint 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.
The REF protection shall be able to calculate the residual current if the differential current is in the operating area, while residual current is less than 3% of the base current. It shall have a settable 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 settable by a parameter setting.

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

This function shall include an internal/external fault discriminator based on the zero sequence currents. 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, and after a set time delay, 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.

In 650 series, this function is available only in RET650.

**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 case of auto-transformers.

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

The operating characteristic shall contain three sections, the first of which shall have the constant operating level independent of the bias current, while the other two sections shall have slope.

The protection shall have an internal/external fault discriminator based on the zero-sequence currents, and this functionality shall be automatically activated if the residual current measured is at least 3% of 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 issue a trip if the differential current is in the operating area, while residual current is less than 3% of 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 650 series, this function is available only in RET650.
**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 as induced voltage.

The function shall have the option of choosing 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 650 series, this function is available only in RET650.*

**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 650 series, this function is available in the following product types: REB650, REC650, RED650, REL650, REQ650 and RET650.*

**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 650 series, this function is available in the following product types: REB650, REC650, RED650, REL650, REQ650 and RET650.*

**Automatic voltage control**
The IED functionality shall include automatic single transformer voltage control. 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 a SCADA computer, using IEC61850 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 set voltage, shall be settable by the end user.

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

- LHMI
- binary inputs, connected to, e.g., selector switch
- using IEC61850 GOOSE or MMS services
In the case 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 of 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 the voltage control gives an abnormal number of commands or abnormal sequence of commands within a predefined period of time (hunting detection), with available settings for the number of operations within one hour, the number of operations within one day, a 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 elapsed time between the moment measured voltage exceeds the deadband interval and 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 combination with line reactance and resistance. Setting for the capacitive load shall also be available, in case voltage closer to the load has a higher magnitude than the voltage on the secondary side of the power transformer.

The function shall include two alternatives for load voltage adjustment functionality. 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 IEC61850 MMS client.

It shall be possible for the end user to define alarms or 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. In case 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.

In 650 series, this function is available only in RET650.