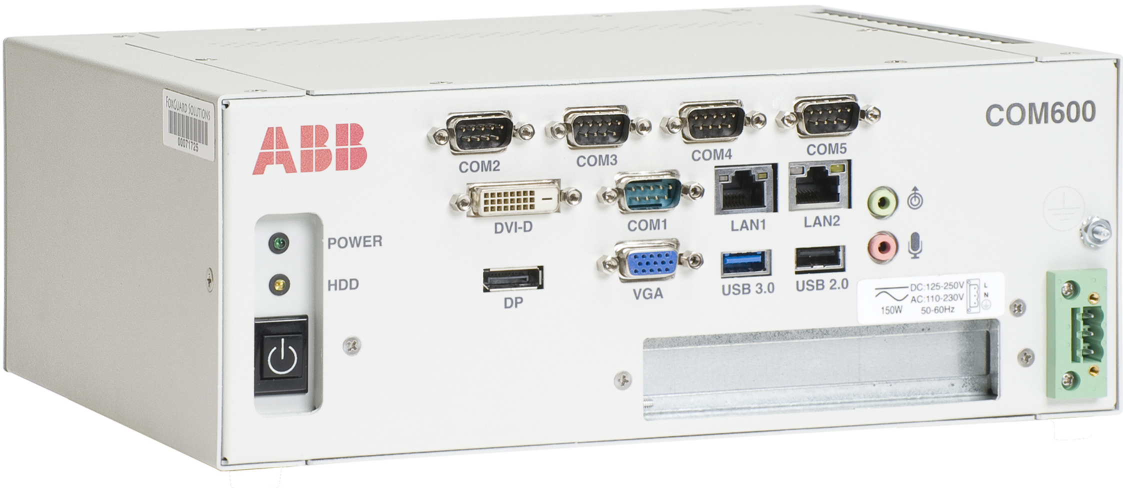
COM600 series 5.1

Substation Analytics Technical Manual



Contents:

1. About this manual

1.1. Copyright

Warranty

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http://www.abb.com/substationautomation

1.2. Disclaimer

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This product is designed to be connected and to communicate information and data via a network interface, which should be connected to a secure network. It is sole responsibility of person or entity responsible for network administration to ensure a secure connection to the network and to establish and maintain any appropriate measures (such as but not limited to the installation of firewalls, application of authentication measures, encryption of data, installation of anti virus programs, etc) to protect the product, the network, its system and the interface against any kind of security breaches, unauthorized access, interference, intrusion, leakage and/or theft of data or information. ABB is not liable for damages and/or losses related to such security breaches, unauthorized access, interference, intrusion, leakage and/or theft of data or information.

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1.3. Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC). This conformity is the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The product is designed in accordance with the international standards of the IEC 60255 series.

1.4. Trademarks

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1.5. General information

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service

1.6. Document conventions

The following conventions are used for the presentation of material:

- The words in names of screen elements (for example, the title in the title bar of a window, the label for a field of a dialog box) are initially capitalized.
- Capital letters are used for the name of a keyboard key if it is labeled on the keyboard. For example, press the ENTER key.
- Lowercase letters are used for the name of a keyboard key that is not labeled on the keyboard. For example, the space bar, comma key, and so on.
- Press CTRL+C indicates that you must hold down the CTRL key while pressing the C key (to copy a selected object in this case).
- Press ESC E C indicates that you press and release each key in sequence (to copy a selected object in this case).
- The names of push and toggle buttons are boldfaced. For example, click **OK**.
- The names of menus and menu items are boldfaced. For example, the **File** menu.

- The following convention is used for menu operations: **MenuName** > **Menu-Item** > **CascadedMenuItem**. For example: select **File** > **New** > **Type**.
- The **Start** menu name always refers to the **Start** menu on the Windows taskbar.

- System prompts/messages and user responses/input are shown in the Courier font. For example, if you enter a value out of range, the following message is displayed:

```
Entered value is not valid. The value must be 0 - 30  .
```

- You can be asked to enter the string MIF349 in a field. The string is shown as follows in the procedure:

    MIF349

- Variables are shown using lowercase letters:

sequence name

1.7. Use of symbols

This publication includes warning, caution, and information icons that point out safety-related conditions or other important information. It also includes tip icons to point out useful information to the reader. The corresponding icons should be interpreted as follows.

The electrical warning icon indicates the presence of a hazard which could result in electrical shock.

The warning icon indicates the presence of a hazard which could result in personal injury.

The caution icon indicates important information or warning related to the concept discussed in the text. It may indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.

The information icon alerts the reader to relevant facts and conditions.

The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

1.8. Document revisions

Document version/date	Product revision	History
A/24.5.2017	5.0	Document created
B/9.4.2018	5.1	Document revised

1.9. Functions, codes and symbols

Function Description	IEC 61850 Identification	IEC 60617 Identification	ANSI / IEEE Identification
Circuit-breaker condition monitoring	SSCBR1	CBCM(1)	CBCM(1)
Fault locator function	SCEFRFLO	FLOC	21FL
Fault report function	SCERRFRP		

2. Overview

2.1. Overview

COM600 contains two substation analytics applications: fault locator and circuit breaker condition monitoring. These application operate on data gathered from IEDs on the substation.

2.2. Operating Principle

Data is gathered from IEDs in different formats. The measurement data is gathered from disturbance records in COMTRADE format. This data is added with data reported on IEC 61850.

Analytics is run on top of this data and published on OffSide OPC server. The results of the analytics can be mapped onwards to slave protocols such as IEC 104.

The COM600 analytics applications are designed to run on-demand whenever there is data available from the IEDs which the application needs. For both fault locator and circuit breaker condition monitoring, there are set of data points that trigger the analytics.

The accuracy of the analytics depends on the accuracy of the input data. The measurements in disturbance records is contains small errors due to measuring accuracy and decimation done in the IED. This recorded data is then again processed by COM600 which adds another layer of inaccuracy to the results.

3. Application Configuration

3.1. PCM600 Configuration

COM600 applications are configured in PCM600. Both fault locator and circuit breaker condition monitoring applications are split into multiple different main applications. The on-demand semantics is achieved with these main applications.

In general, there are different main applications listening to trigger data from the IEDs. When trigger data point is updated, the logics inside application determine whether analytics needs to be performed. The main analytics logic is also built into one or more main applications. These application publish data on IEC 61850 model which is visible on OffSide OPC server.

3.2. Fault Locator Application Design

3.2.1. Fault Locator Application Design

The fault locator consists of four different main applications: trigger, main fault analytics, developing fault analytics and IEC 61850 main applications.

3.2.2. Trigger Main Application

Trigger main application listens to data changes of trigger data points coming from the IED. One trigger condition is autorecloser status. When a new reclosing sequence starts the analytics is launched to calculate unsupplied time. In addition to unsupplied time, the fault locator application calculates the distance to fault and determines whether the fault was cleared by reclosing or if it developed into a permanent fault.

Fault location analytics is also triggered by the trip signal coming from the IED. In this mode, analytics locates the distance to the fault. The final trigger signal is availability of a new disturbance recording. In this mode, analytics analyses the new recording and tries to calculate distance to the fault. In this case, a successful analytics indicates that there is a developing fault in the network.

3.2.3. Fault Analytics Main Application

The main fault analytics main application is responsible to determining the distances to the fault as well as calculation of fault type and unsupplied time.

In order to make the application work correctly, the function block “FaultLocator_sc_A” needs to be configured correctly. See chapter 4 for details.

3.2.4. Developing Faults Analytics Main Application

The developing faults main application run every time there is a new disturbance recording from the IED. This part of the logics does not try to determine the fault type; instead all results are categorized as developing faults.

Similarly to the Fault analytics main application, the “FaultLocator_sc_A” needs to be parametrized correctly. In addition, timeout period needs to be adjusted to match the length of the disturbance record used in the particular developing faults analytics application. This timeout is configured in function named “CONST_TIMEOUT”. The default value is 250 application cycles, which means 5000 ms in practice.

3.2.5. IEC 61850 Main Application

The IEC 61850 main application contains mappings to the OffSide OPC server. This is a crucial part of piping the results onwards from the analytics. The application is run whenever either of the fault analytics application is reporting new fault analytics results.

3.3. Circuit Breaker Condition Monitoring Application Design

3.3.1. Circuit breaker Condition Monitoring Application Design

The circuit breaker condition monitoring consist of seven different main applications: SCBR trigger, spring charge trigger, gas pressure trigger, main circuit breaker condition monitoring, main spring charge monitoring, main gas pressure monitoring and IEC 61850 main applications.

3.3.2. SCBE Trigger Application

SCBR trigger application listens to data changes of trigger data points coming from the IED. Trigger conditions are based on status changes of the circuit breaker position and periodic triggering. When position is changed the trigger application trigger execution of SCBR main application.

Periodic triggering is used for circuit breaker inactivity calculations.

3.3.3. Spring Charge Trigger Application

Spring charge trigger application listens to data changes of trigger data points coming from the IED. Trigger condition are based on status changes of the spring charge signal and periodic triggering. This will then trigger the execution of spring charge main application.

Periodic triggering is used to ensure the accuracy of charge time calculation.

3.3.4. Gas Pressure Trigger Application

Gas pressure trigger application listens to data changes of trigger data points coming from the IED. Trigger condition are based on status changes of the gas pressure signal. This will then trigger the execution of gas pressure main application.

3.3.5. Circuit Breaker Condition Monitoring Main Application

The circuit breaker condition monitoring main application calculates circuit breaker condition monitoring data according to the inputs from the IED. Without comtrade data for the triggering time it will produce circuit breaker trip time, circuit breaker inactivity and operations count calculations. If comtrade data is available it will additionally produce circuit breaker accumulated energy data and circuit breaker trip time calculation is produced with better accuracy.

3.3.6. Spring Charge Main Application

Spring charge main application calculates the spring charge time and activates alarm out according to input and setting values.

3.3.7. Gas Pressure Main Application

Gas pressure main application activates alarm out according to input and setting values.

3.3.8. IEC 61850 Main Application

The IEC 61850 main application contains mappings to the OffSide OPC server. This is a crucial part of piping the results onwards from the analytics. The application is run whenever any of the main applications are reporting new results.

4. Fault locator SCEFRFLO

4.1. Identification

Function Description	IEC 61850 identification	IEC 60617 identification	ANSI/IEEE identification
Fault locator function	SCEFRFLO	FLOC	21FL

4.2. Functionality

The fault locator function FaultLocator_sc_A provides impedance-based fault location. It is designed for radially operated distribution systems. It is applicable for locating short circuits in all kinds of distribution networks. Earth faults can be located in effectively earthed and in low-resistance/low-reactance earthed networks. Under certain limitations, FaultLocator_sc_A can also be applied for an earth fault location in unearthed distribution networks.

The fault distance calculation is based on locally measured fundamental frequency current and voltage phasors. The full operation of FaultLocator_sc_A can requires that all three currents and phase-to-earth voltages are measured.

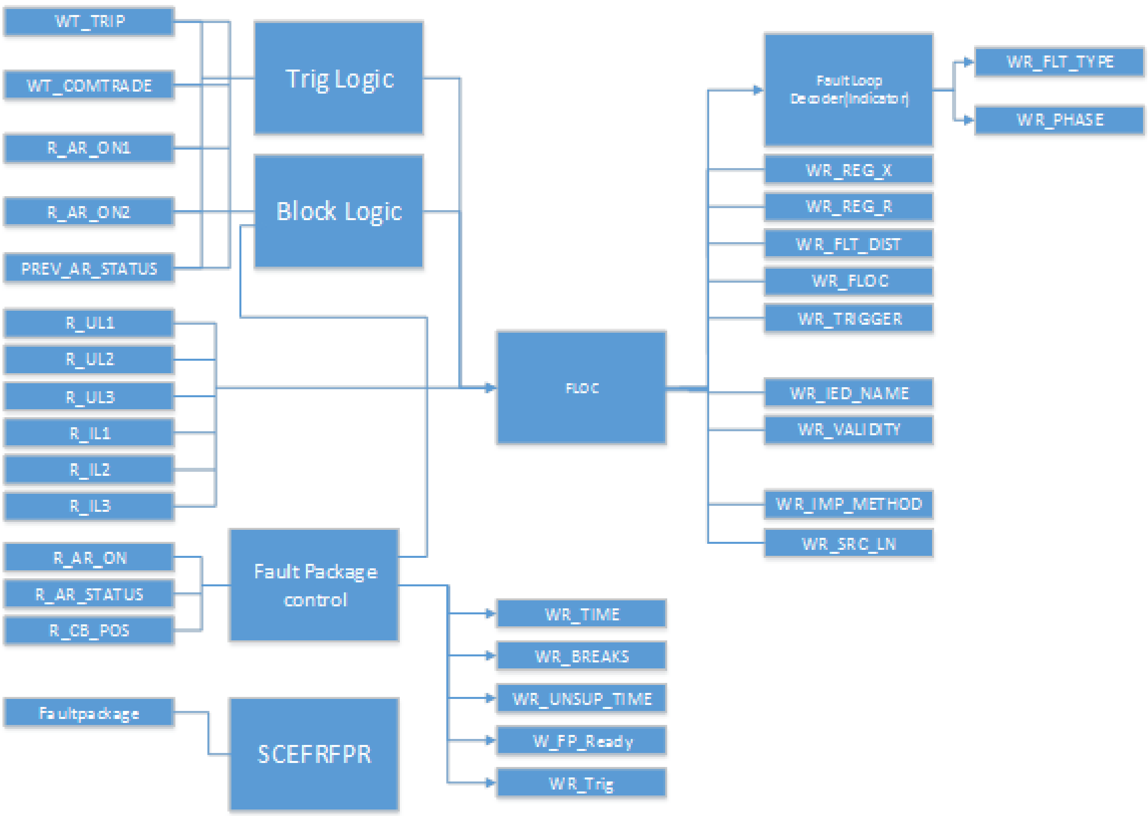
The fault distance calculation is done in two steps. The fault type is determined first using the build-in Phase Selection Logic PSL. After this, the fault distance is calculated.

The fault locator report function SCEFRFRP function provide a report recoding mechanism to create report to use in the COM600 WebHMI.

4.3. Operation Principle

The function can be enabled or disabled with the **Operation** setting. The corresponding parameter values are "On" and "Off".

The actual fault distance calculation consists of two steps. The fault type is determined first by using the built-in phase selection logic PSL. After this, the fault distance is calculated. As a fundamental operation criterion, the maximum of the phase current magnitudes must exceed a threshold value of 1 percent of the nominal phase current value of the CT primary current. When this condition is not met, all the outputs of the function are blocked.



functional_module_diagram.png

Figure 4.3-1 Functional module diagram

Fault loop indication (PSL)

The fault distance calculation is done in two steps. The fault type is determined with the inbuilt Phase Selection Logic (PSL) and then the fault distance is calculated.

As a fundamental operation criterion, it is required that the phase current and voltage magnitudes must exceed the threshold values of 2% Ir and 3% Ur, respectively.

For cases where positive-sequence components or phase-to-phase signals are used for fault distance indication, the corresponding threshold values are scaled, accordingly, to the one-third or one-to-square-root-three of the phase signal limits.

If the zero-clamping condition is not met, the output and monitored data of the function is reset.

Fault type selection

The identification of the faulty phases is compulsory for the correct operation of SCE-FRFLO. This is because only one of the impedance-measuring elements (fault loops) provides the correct result for a specific fault type. A three-phase fault is an exception and theoretically it can be calculated with any of the fault loops. The fault loop used in the fault distance calculation is indicated in the monitored data FAULT_LOOP as specified in Table 4.3-1.

Table 4.3-1 Fault types and corresponding fault loops

Fault Type	**Description**	**Output FAULT_LOOP**
A-E	Phase A-to-earth fault	1
B-E	Phase B-to-earth fault	2
C-E	Phase C-to-earth fault	3
A-B	Phase A-to-B short circuit fault	4
B-C	Phase B-to-C short circuit fault	5
C-A	Phase C-to-S short circuit fault	6
A-B-C-(E)	Three-phase short circuit	7

In case of phase-to-phase-to-earth-faults (A-B-E, B-C-E or C-A-E), the selected fault loop depends on the location of the individual earth faults. When the faults are located at the same feeder, the corresponding phase-to-phase loop (either “AB Fault” or “BC Fault” or “CA Fault”) is used for calculation. When the faults are located at different feeders, the phase-to-earth loop (either “AG Fault” or “BG Fault” or “CG Fault”) corresponding to the faulty phase at the protected feeder is used for calculation.

Identification of the faulty phase is provided by the built-in Phase Selection Logic (PSL), based on combined impedance and current criteria. Phase selection logic is virtually setting-free and has only one parameter, Z Max phase load, for discriminating a large symmetrical load from a three-phase fault. The parameter *Z Max phase load* can be calculated using the equation:

$$Z\ Max\ Phaseload = 0.8 \cdot \frac{U_{xy}^2}{S_{max}}$$

equation_1.png

Figure 4.3-2 (Equation 1)

Uxy: the nominal phase-to-phase voltage

S_{max} the maximum three-phase load

For example, if *Uxy* = 20 kV and S_{max} = 1 MVA, then *Z Max phase load* = 320.0 ohm.

Fault distance calculation

As soon as a fault condition is recognized by the phase selection logic, the fault distance calculation is started with one of the seven impedance-measuring elements, that is, the fault loops. SCEFRFLO employs independent algorithms for each fault type to achieve optimal performance.

The inherent result from the fault distance calculation is the ohmic fault loop impedance value.

$$ZFLOOP = RFLOOP + j \times XFLOOP + RF$$

equation_2.png

Figure 4.3-3 (Equation 2)

The value can be utilized as such or it can be further processed in system level fault localization applications.

Depending on the fault loop, the composition of the terms RFLOOP and XFLOOP is different.

Fault loops “AG Fault” or “BG Fault” or “CG Fault”

Fault loops “AG Fault”, “BG Fault” or “CG Fault” are used for single-phase-to-earthfaults.

When the individual earth faults are located at different feeders, they are also applied in the case of a phase-to-phase-to-earth-fault. In this case, the phase-toearth loop (either “AG Fault” or “BG Fault” or “CG Fault”) corresponding to the faulty phase at the protected feeder, is used for calculation. Figure 4.3-8 shows the measured impedances.

Fault loops “AG Fault”, “BG Fault” or “CG Fault” measure the impedance which, at the same time, are the outputs of SCEFRFLO.

$$RF = R_{Fault}$$

equation_3.png

Figure 4.3-4 (Equation 3)

$$RFLOOP = R_1 + R_N + RF$$

equation_4.png

Figure 4.3-5 (Equation 4)

$$XFLOOP = X_1 + X_N$$

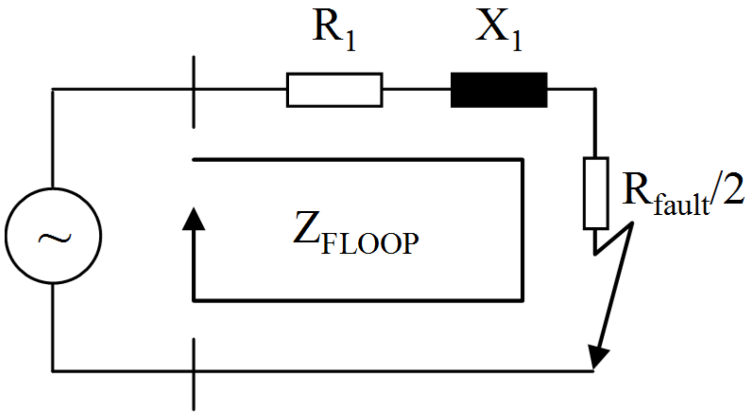
equation_5.png

Figure 4.3-6 (Equation 5)

$$XFPHASE = X_1$$

equation_6.png

Figure 4.3-7 (Equation 6)



fault_loop_impedance_for_phase-to-earth_fault_impedance_loops.png

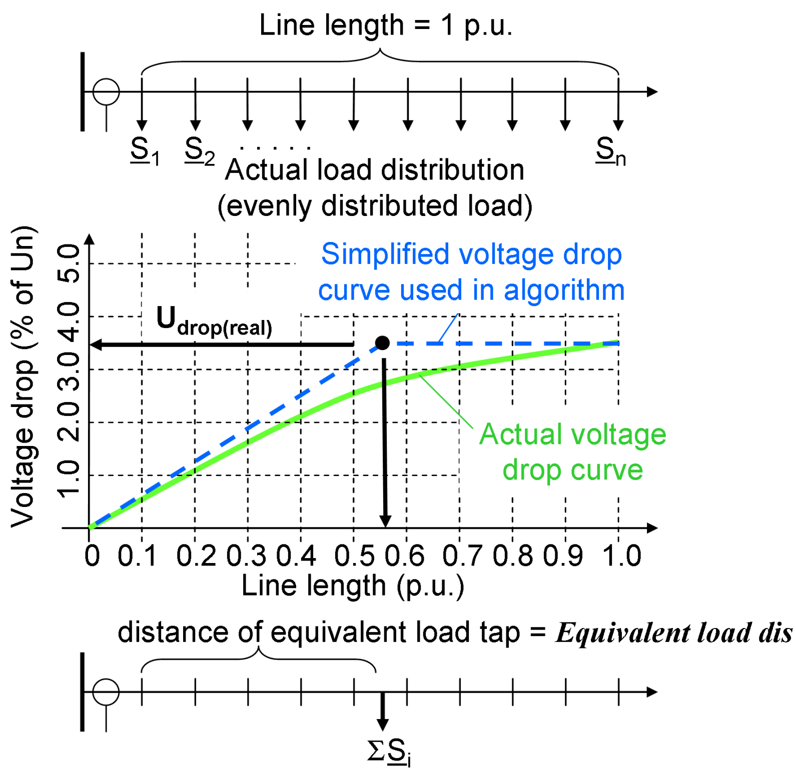
Figure 4.3-8 Fault loop impedance for phase-to-earth fault impedance loops “AG Fault”, “BG Fault” or “CG Fault”

The earth-fault distance calculation algorithm is selected by setting *EF algorithm Sel* to either “Load compensation” or “Load modelling”. For a correct operation of both the algorithms, there should not be any zero-sequence current sources, for example, earthling transformers, in front of the IED location.

“Load compensation” utilizes the symmetrical components to compensate for the effect of the load on the measured voltages and currents. In case of radial feeders, it should be selected with low-impedance/effectively earthed systems where the fault current is fed from one side only and there are no in-feeds along the protected line.

“Load modelling” takes into account the effect of the load in measured currents and voltages by load modelling. In case of radial feeders, the “Load modelling” algorithm can be applied with low-impedance/effectively earthed systems where the fault current is fed from one side only.

The "Load modelling" algorithm requires the Equivalent load Dis setting, that is, an equivalent load distance, as an additional parameter. The maximum value of the voltage drop, denoted U_{drop}(real), appears at the end of the line. The Equivalent load Dis parameter is the distance at which a single load tap corresponding to the total load of the feeder would result in a voltage drop equal to U_{drop}(real). The dashed curve shows the voltage drop profile in this case.



description_of_the_equivalent_load_distance.png

Figure 4.3-9 Description of the equivalent load distance

The value of Equivalent load Dis can be calculated based on the load flow and voltage drop calculations using equation:

$$Equivalent\ load\ Dis = \frac{U_{drop}(real)}{U_{drop}(s=1)}$$

equation_7.png

Figure 4.3-10 (Equation 7)

U_{drop} (*real*): the actual maximum voltage drop of the feeder

U_{drop} (*s*=1): the fictional voltage drop if the entire load is tapped at the end of the feeder, where *s* (proportional line length) equals unity. This value can be taken from anetwork calculation program.

The Equivalent load Dis parameter can be determined by conducting a single-phase earth-fault test (Rfault = 0 ohm) at that point of the feeder where the maximum actual voltage drop takes place. This point is typically located at the end of the main line. The calculated value of Equivalent load Dis can be obtained from the S_CALC output.

In case of evenly distributed load, Equivalent load Dis ~ 0.5. When the load is tapped at the end of the line, Equivalent load Dis = 1.0. If nothing else is known, a good initial guess for Equivalent load Dis is 0.5.

When "Load modelling" algorithm is used, the user can select with the EF algorithm current setting whether the I0 or I2-current based algorithm is used. The difference between I0 and I2 is that I2 does not require the settings Ph capacitive React and Ph leakage Ris. In case of I0, these settings are required in order to compensate for the influence of line charging capacitances. This typically improves the accuracy of a fault location estimate when fault resistance is involved in the fault.

Under certain restrictions, the *EF algorithm Sel* value “Load modelling” can also be applied to unearthed networks. In these networks, the ratio of the earth-fault current magnitude to the pre-fault load current magnitude is calculated.

Based on simulation and field tests, when Rfault = 0 ohm, the calculated

$$IFLT\_PER\_ILD = \frac{|I_{ef(Rfault=0)}|}{|I_{Load}|} \geq 1$$

equation_8.png

Figure 4.3-11 (Equation 8)

The low ratio affects also the validity estimate of calculated fault distance, which can be read from the EF_VALIDITY output. Sufficient fault current magnitude can be achieved, for example, with proper switching operations in the background network, which increases the fault current. After the switching operation, a re-energizing of the faulted line is done and a new estimate obtained. The fault resistance decreases the fault location accuracy and it should not be too large, maximum a few hundreds of ohms.

The range of the setting Equivalent load Dis is 0.01...1.00. Any value of S_CALC outside this range needs to be ignored.

Fault loops “AB Fault”, “BC Fault” or “CA Fault”

Fault loops “AB Fault”, “BC Fault” or “CA Fault” are used for phase-to-phase short circuit faults as well as in the case of a phase-to-phase-to-earth fault if the individual earth faults are located at the same feeder. Figure 4.3-15 shows the measured impedances

$$RF = Rfault/2$$

equation_9.png

Figure 4.3-12 (Equation 9)

$$RFLOOP = R1 + RF$$

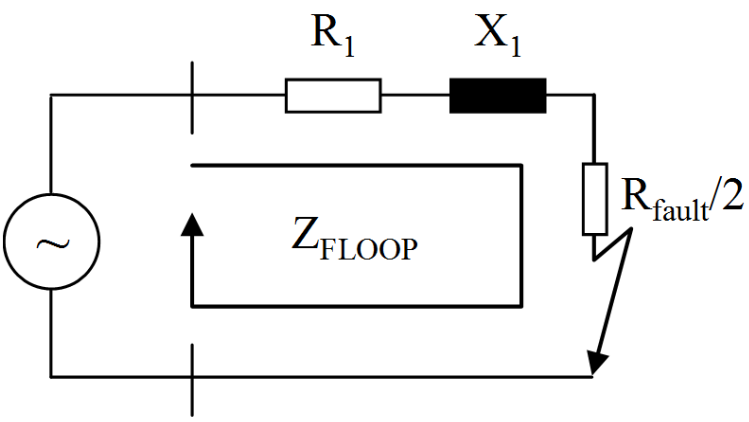
equation_10.png

Figure 4.3-13 (Equation 10)

$$XFPHASE = XFLOOP = X1$$

equation_11.png

Figure 4.3-14 (Equation 11)



fault_loop_impedance_phase-to-phase_fault_impedance_loops.png

Figure 4.3-15 Fault loop impedance for phase-to-phase fault impedance loops (either “AB Fault”, “BC Fault” or “CA Fault”)

For the fault loops 12, 23, 31, the estimated fault resistance is half the total fault resistance between the phases.

The fault distance calculation algorithm for the phase-to-phase fault impedance loops (12, 23 or 31) is defined by using setting Load Com PP loops = "Disabled"/"Enabled" setting and setting Simple mode PP loops = "Disabled"/"Enabled".

The load compensation can be enabled or disabled with the Load Com PP loops = FALSE/TRUE setting. The load compensation should be disabled only if the ratio between the fault current and load current is large or when the value of the fault distance estimate for the short circuit fault is required for each shot of an autoreclosing cycle.

The fault distance calculation is the most accurate when the calculation is made with the fault loop model. This model requires positive sequence impedances as initial data. If the data is not accessible, the calculation can be made with a simple fault loop model that does not need any impedance data. The simple fault loop model is enabled, with the value Simple mode PP loops = TRUE. When the simple model is enabled, the conversion of electrical fault distance into a physical distance is not done in the IED and the

FLT_DISTANCE output is not valid. The estimated impedances are still calculated and shown normally in their respective outputs.

Fault loop “ABC Fault”

Fault loop “ABC Fault” is used exclusively for the three-phase short circuit fault. Figure 4.3-19 shows the measured impedances.

$$RF = Rfault/2$$

equation_12.png

Figure 4.3-16 (Equation 12)

$$RFLOOP = R1 + RF$$

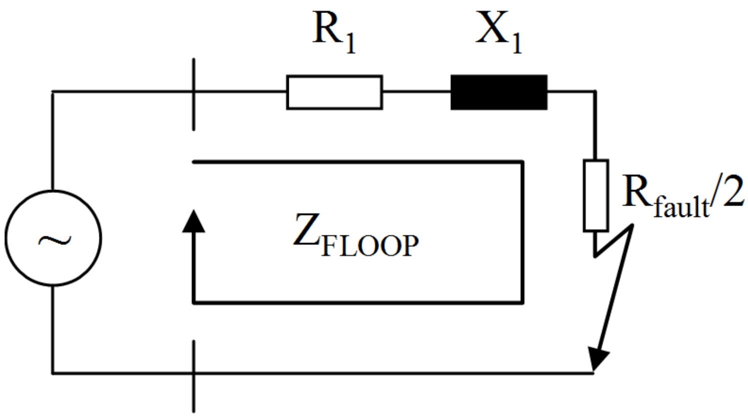
equation_13.png

Figure 4.3-17 (Equation 13)

$$XFPHASE = XFLOOP = X1$$

equation_14.png

Figure 4.3-18 (Equation 14)



fault_loop_impedance_three_phase_fault_impedance_loop.png

Figure 4.3-19 Fault loop impedance for a three-phase fault impedance loop (“ABC Fault”)

The three-phase fault distance is calculated with a special measuring element using positive-sequence quantities. This is advantageous especially in case of nontransposed (asymmetric) lines, as the influence of line parameter asymmetry is reduced. If the line is non-transposed, all the phase-to-phase loops have different fault loop reactances. The use of positive-sequence quantities results in the average value of phase-to-phase loop reactances, that is, the most representative estimate in case of three-phase faults.

The fault distance calculation algorithm for the three-phase fault impedance loop is defined by using the setting Load Com PP loops = "Disabled"/"Enabled" and setting Simple mode PP loops = "Disabled"/"Enabled" setting.

The load compensation can be enabled or disabled with the Load Com PP loops = FALSE/TRUE setting. The load compensation should be disabled only if the ratio between the fault current and load current is large or when the value of the fault distance estimate for the short circuit fault is required for each shot of an autoreclosing cycle.

The fault distance calculation is the most accurate when the calculation is made with the fault loop model. This model requires positive sequence impedances as initial data. If the data is not accessible, then the calculation can be made with a simple fault loop model that does not need any impedance data. The simple fault loop model is enabled, with the value Simple mode PP loops = TRUE. When the simple model is enabled, the conversion of electrical fault distance into a physical distance is not done in the IED and the FLT_DISTANCE output is not valid. The estimated impedances are still calculated and shown normally in their respective outputs.

The function calculates XFPHASE, which is the positive sequence fault reactance in primary ohms and is available as an output.

Table 4.3-1 Explanation of variations

Abbreviation	**Description**
RFLOOP	Estimated fault loop resistance in primary ohms
XFLOOP	Estimated fault reactance in primary ohms
XFPHASE	Positive sequence fault reactance in primary ohms
RF	Estimated fault resistance in primary ohms
R1	Positive sequence resistance from the substation to the fault location
X1	Positive sequence reactance from the substation to the fault location
RN	Earth return path resistance from the substation to the fault location = (R0 - R1)/3
XN	Earth return path reactance from the substation to the fault location = (X0 - X1)/3
R0	Zero sequence resistance from the substation to the fault location
X0	Zero sequence reactance from the substation to the fault location
Rfault	Physical fault resistance at the fault location. In case of earth faults, it includes the arc and the earthing resistance. In case of the phase-to-phase faults, it equals to the arc resistance between the phases. In case of three-phase faults, it equals to the arc resistance per phase.

Explanation of variations.png

Figure 4.3-20 Connection of a physical fault resistance is connected in different fault loops

The estimated fault point resistance (recorded data RF) for fault loops “AB Fault”, “BC Fault” or “CA Fault” is half of the total physical fault point resistance between the phases. In case of earth faults, the estimated fault point resistance includes the arc and earthing resistances. In case of a three-phase fault, the estimated fault point resistance equals the arc resistance per phase.

Steady-state asymmetry and Load compensation

In reality, power systems are never totally symmetrical. The asymmetry produces steady-state quantities in the form of zero and negative sequence voltages and currents. If not compensated, these are the error sources for the fault distance calculation, especially in the case of earth faults. In SCEFRFLO, all the fault distance calculation algorithms utilize the delta (Δ) quantities which eliminate the steady-state asymmetry. The delta quantities are also used for load compensation for short circuit faults (fault loops 12, 23, 31 and 123). The delta quantities describe the change in the measured quantities due to the fault:

Δx = xfault - xpre-fault.

The Pre fault time setting is used for generating the delta quantities. The pre-fault values are captured at least Pre fault time earlier than the actual fault moment occurs.

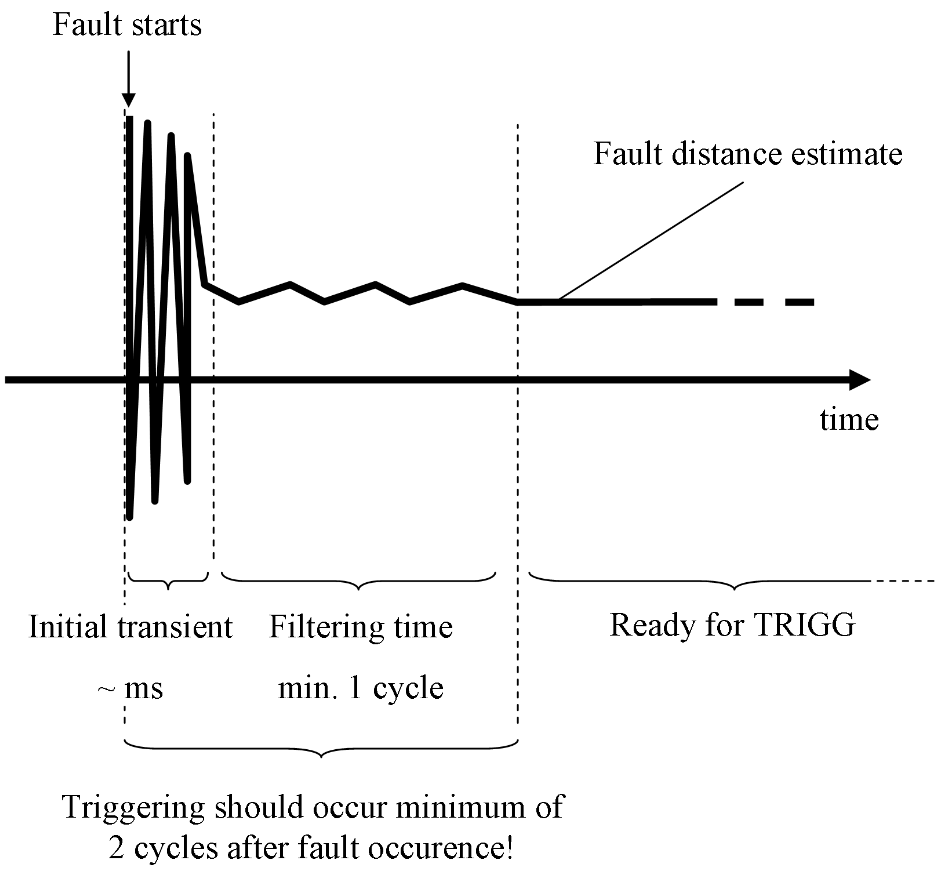
Load current is one of the main error sources for fault distance calculation. Its influence increases with higher fault resistance values. SCEFRFLO employs independent load compensation methods for each fault type to achieve optimal performance. For earth faults (fault loops either “AG Fault”, “BG Fault” or “CG Fault”), the load compensation is done automatically inside the fault distance algorithm. For short circuit faults (phase-to-phase fault impedance loops “AB Fault”, “BC Fault”, “CA Fault” and also loop “ABC Fault”), current delta quantities are used for load compensation.

Triggering FaultLocator_sc_A

The fault distance estimate is obtained when FaultLocator_sc_A is triggered.

FaultLocator_sc_A requires a minimum of two signal fundamental cycles of measuring time after a fault occurrence by omitting the signal initial transient and providing time for filtering the fault distance estimate with the principle that the more there is time for measuring, the better the fault distance estimate. Figure 4.3-21 illustrates the behavior of fault distance estimate of FaultLocator_sc_A as a function of time.

- Immediately after the fault occurrence, the estimate is affected by initial transient in voltages and currents.
- After one cycle, when the fault has occurred, the fault distance starts to converge towards the final value.
- After two cycles, when the fault has occurred, the fault distance estimate is ready and FaultLocator_sc_A can be triggered. The more there is measuring time, the better the fault distance estimate is.



behavior_of_fault_distance_estimate_time.png

Figure 4.3-21 The behavior of fault distance estimate in time

The actual trigger time is saved in the registers (recorded data). The trigger method is defined with the control parameter Calculation Trg mode with the values "External", "Internal" and "Continuous".

External

In case of external triggering, an external trigger signal should be connected to the TRIGG input. The trigger signal is typically a trip signal from a protective function. The TRIGG_OUT output signal can be monitored to see if the distance estimate is updated. The Pre fault time setting should be set at a default value of 100 ms using the external triggering. This guarantees that the load compensation uses valid data from the load conditions.

Internal

In case of internal triggering, the TRIGG input is not used for triggering. Instead, the trigger signal is created by PSL. The challenge is to time the triggering moment so that there is sufficient measuring time without the feeder breaker being operated. This is done by timing the actual triggering moment based on the Pre fault time setting.

To prove that the internal triggering has time to operate before the feeder breaker is opened, the Pre fault time setting must be set to a valuer smaller than or equal to the minimum operating time of the function used for tripping the breaker. For example, if the short circuit protection operating time delay is 0.2 s and the earthfault protection operating time delay is 0.3 s, Pre fault time should be 0.2 s. The actual triggering occurs (200 ms - 40 ms) = 160 ms after PSL has recognized the fault condition. 40 ms is reserved for the PSL function for identifying the fault type.

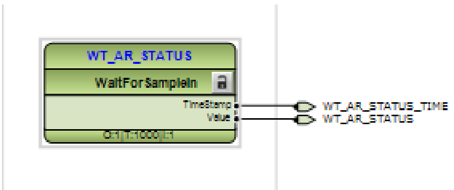
PSL is a non-directional function and therefore, internal triggering should not be used when directionality is required. The TRIGG output can be monitored to see if the distance estimate is updated.

Continuous

Continuous trigger mode can be utilized during the secondary testing of the function block. In this mode, the function outputs are continuously updated at the task time interval and can thus be monitored for testing purposes. Recorded data are updated when the internal or external triggering occurs.

Configuration example

A typical configuration example for FaultLocator_sc_A triggering is illustrated in Figure 4.3-22. The triggering logic in this example is applicable when the autoreclosing is initiated by the COMTRADE data update in the IED.



typical_configuration_for_triggering_SCEFRFLO.png

Figure 4.3-22 A typical configuration for triggering of SCEFRFLO

Another example of FaultLocator_sc_A is to trig it with generic trip signal update from the IED.

Fault Location with autoreclosing function

When Fault Location is used with the autoreclosing sequence, the distance estimate from the first trip is typically the most accurate one. The fault distance estimates from successive trips are possible but accuracy can be degraded due to inaccurate load compensation. During the autoreclosing cycle dead time, the load condition of the feeder is unsure.

In unearthed networks, the earth-fault magnitude during normal network configuration is not enough for the accurate fault location estimate. However, the accuracy of the fault location estimate can be improved by increasing the earthfault current magnitude. This can be done with the proper switching operations that enlarge the background network after the tripping of the faulty feeder. The reenergization of the feeder on to the fault gives an improved estimate about the fault distance. The switching operations that are needed can also be done during the dead time of the delayed autoreclosing sequence.

The triggering of SCEFRFLO can also be inhibited during the autoreclosing sequence. This is achieved by connecting the ACTIVE signal from the autoreclosing function which indicates that the autoreclosing sequence is in progress with the BLOCK input of SCEFRFLO. Blocking of the SCEFRFLO triggering is suggested during the autoreclosing sequence when the load compensation or steady-state asymmetry elimination is based on the delta quantities. This applies to the short circuit faults for fault loops “AB Fault” or “BC Fault” or “CA Fault” or “ABC Fault” when the setting *Load Com PP loops* equals to “Enabled” or, for earth faults, with the value *EF algorithm Sel* equal to “Load compensation”.

Result validity indicator for earth faults

Fault localization is a challenging task. There are many factors that can deteriorate the accuracy of the calculated fault distance estimate. The most important factors are:

- Fault resistance. The smaller the fault resistance, the more accurate the result is likely to be. The accuracy of the fault distance estimation deteriorates if the resistive part of the fault loop impedance becomes much larger than the reactive part due to the large fault resistance. The fault resistance is typically quite low during short circuits. However, it can be the most dominant error source in earth faults.
- Asymmetry. The asymmetry of the line parameters and the loading affects the fault distance estimation accuracy. If the asymmetry has a very high value, the accuracy of the fault distance estimation deteriorates.

- Saturation. The saturation of current or voltage transformers increases certain harmonics, especially the second, the fifth and the seventh. Saturation deteriorates the fault distance estimate.
- In unearthed networks, the ratio between the earth-fault current (Rfault = 0 ohms) and load current magnitude is critical. The higher the ratio, the better the fault distance estimate.

Furthermore, the distribution networks have specific features which further complicate and challenge fault localization algorithms. These include, for example, non-homogeneity of lines, presence of laterals and load taps. The validity of the estimated earth fault distance is judged and reported together with the fault distance estimate. The EF_VALIDITY output has various values:

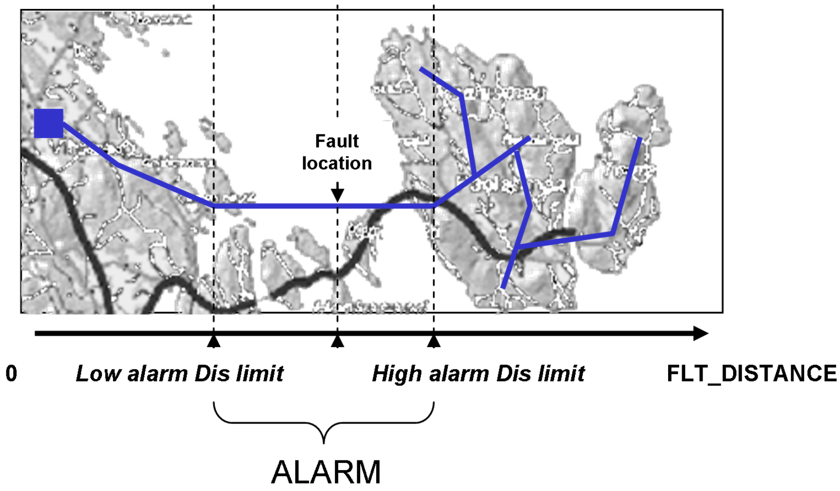
Table 4.3-1 The EF_VALIDITY output values

N/A	Indicator is not applicable (fault type is a short circuit).
High	Result is not affected by error sources
Moderate	Result is slightly affect by error sources. The additional error in the fault distance estimate can be tens of percents.
Poor	Fault distance algorithm is greatly affected by error sources and cannot function properly. In this case, the result is only trend setting. The result can only indicate, for example, whether the fault is in the beginning or in the end of the feeder section.

ALARM indication

SCEFRFLO contains an alarm output for the calculated fault distance. If the calculated fault distance FLT_DISTANCE is between the settings *Low alarm Dis limit* and *High alarm Dis limit*, the ALARM output is activated.

The ALARM output can be utilized, for example, in regions with waterways or other places where knowledge of certain fault locations is of high importance.



alarm_output_usage_with_location_between_set_limits.png

Figure 4.3-23 An example of the ALARM output usage when alarm is given with location between set limits

Impedance settings

The fault distance calculation in SCEFRFLO is based on the fault impedance loop modeling. The fault loop is parameterized with the impedance settings, for example earth fault loops (fault loops 1, 2 and 3) require both positive and zero sequence impedances as an initial data. For the short circuit fault loops (fault loops 12, 23, 31 and 123), only positive sequence impedances are needed. Even these can be omitted if the Simple mode PP loops = "Enabled". In this case, the conversion of electrical fault distance into a physical distance cannot be done in the IED and the FLT_DISTANCE output is not valid.

If the impedance settings are in use, it is important that the settings closely match the impedances through which the fault current flows. The impedance settings, for example R1 line section A, X1 line section A, R0 line section A, and X0 line section A, are given in the units of primary ohm/pu and the line section lengths in per unit (pu). Pu can be the unit that the user prefers and it allows the user to give the impedances in ohm/km and length in km, for example, (pu = km), or impedance in ohm/mile and length in mile (pu = mile). The resulting fault distance is also obtained in pu and it should match the units entered for the line section lengths.

Table 4.3-1 Positive-sequence impedance values for typical 11 kv conductors, "FLAT" tower configuration assumed

Name	R1 [Ω/km]	X1 [Ω/km]
ACSR 50 sq.mm	0.532	0.373
ACSR 500 sq.mm	0.0725	0.270

Table 4.3-2 Positive-sequence impedance values for typical 10/20 kv conductors, "Flat" tower configuration assumed

Name	R1 [Ω/km]	X1 [Ω/km]
Al/Fe 36/6 Sparrow	0.915	0.383
Al/Fe 54/9 Raven	0.578	0.368
Al/Fe 85/14 Pigeon	0.364	0.354
Al/Fe 93/39 Imatra	0.335	0.344
Al/Fe 108/23 Vaasa	0.287	0.344
Al/Fe 305/39 Duck	0.103	0.314

Table 4.3-3 Positive-sequence impedance values for typical 33kv conductors, "Flat" tower configuration assumed

Name	R1 [Ω/km]	X1 [Ω/km]
ACSR 50 sq.mm	0.529	0.444
ACSR 100 sq.mm	0.394	0.434
ACSR 500 sq.mm	0.0548	0.346

Positive-sequence impedance values

An accurate fault localization requires good setting values for line impedances. As datasheet impedance per unit values are valid only for a certain tower configuration, the values should be adjusted according to the actual installation configuration. This minimizes the fault localization errors caused by inaccurate settings.

The positive-sequence reactance per unit and per phase can be calculated with a certain approximation equation which applies to symmetrically transposed threephase aluminum overhead lines without ground wires.

$$X_1 \approx \omega_n \times 10^{-4} \left(2 \times ln \frac{a_{en}}{r} + 0.5\right) [\Omega/km]$$

equation_15.png

Figure 4.3-24 (Equation 15)

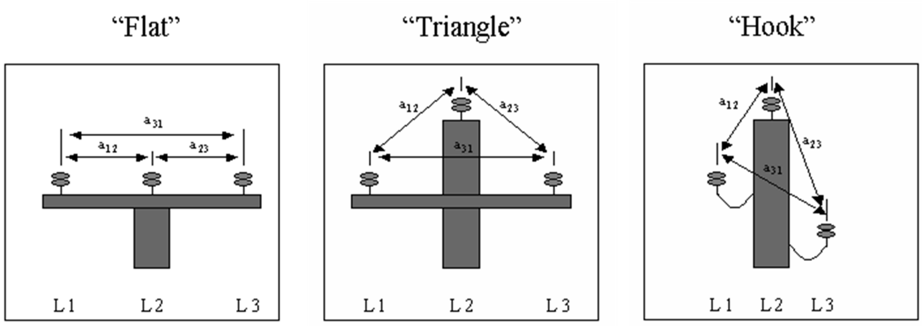
ω_n 2 × π × fn, fn = fundamental frequency [Hz]

a_{en} $\sqrt[3]{(a_{12} \times a_{23} \times a_{31})}$

the geometric average of phase distances [m]

a_{xy} distance [m] between phases x and y

r radius [m] for single conductor



typical_distribution_line_tower_configurations.png

Figure 4.3-25 Typical distribution line tower configurations

Zero-sequence impedance values

The zero-sequence impedances per unit are needed only with earth-fault localization. With the localization of two-phase or three-phase short circuit fault, positive-sequence impedances per unit are sufficient.

The positive-sequence impedance per unit values for the lines are known or can easily be obtained from datasheets. The zero-sequence values are not so easy to obtain as they depend on the actual installation conditions and configurations.

Sufficient accuracy can be obtained with rather simple calculations with certain equations (applies per phase for symmetrically transposed three-phase aluminum overhead lines without ground wires).

$$R_0[50Hz] \approx R1 + 0.14804[\Omega/km]$$

equation_16.png

Figure 4.3-26 (Equation 16)

$$R_0[60Hz] \approx R1 + 0.17765[\Omega/km]$$

equation_17.png

Figure 4.3-27 (Equation 17)

$$X_0 \approx 2\times\omega_n\times10^4\left(3\times\ln\frac{\omega}{r_{en}}+0.25\right)[\Omega/km]$$

equation_18.png

Figure 4.3-28 (Equation 18)

R1 conductor AC Resistance [/*km*]

W $658\sqrt{\frac{\rho_{earth}}{f_n}}$

ρ_{earth}

the equivalent depth [m] of the earth return path Earth resistivity

ren $\sqrt[3]{r\sqrt[3]{a_{12}^2\times a_{23}^2\times a_{31}^2}}$

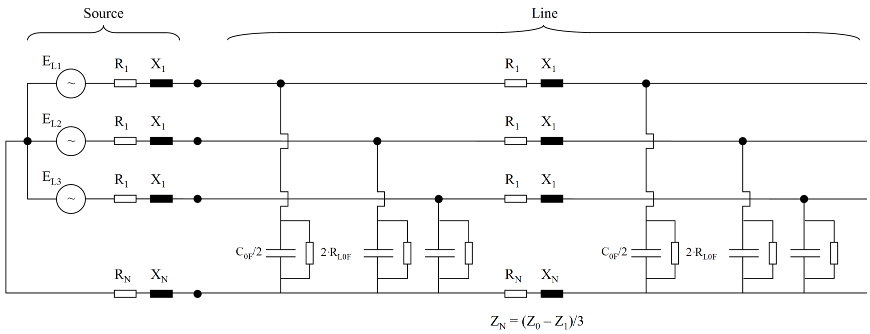
r the equivalent radius [m] for conductor bundle radius[m] for signal conductor

axy distance [m] between phase x and y

Ph leakage Ris and Ph capacitive React settings

The *Ph leakage Ris* and *Ph capacitive React* settings are used for improving fault distance estimation accuracy for earth faults. They are critical for an accurate fault location in unearthed networks. In other types of networks they are less critical.

The *Ph leakage Ris* setting represents the leakage losses (resistive losses due to insulators and so on) of the protected feeder in terms of resistance per phase. The *Ph capacitive React* setting represents the total phase-to-earth capacitive reactance of the protected feeder per phase. Based on experience, a proper estimate for *Ph leakage Ris* should be about 20…40 × *Ph capacitive React*.



equivalent_diagram_protected_feeder.png

Figure 4.3-29 Equivalent diagram of the protected feeder. RL0F = Ph leakage Ris.

The determination of the *Ph capacitive React* setting can be based either on network data or measurement.

If the total phase-to-earth capacitance (including all branches) per phase C0F of the protected feeder is known, the setting value can be calculated.

$$Ph\ capacitive\ React = \frac{1}{\omega_n \times c_{of}}$$

equation_19.png

Figure 4.3-30 (Equation 19)

In case of unearthed network, if the earth-fault current of the protected feeder Ief is known, the corresponding phase-to-earth capacitance per phase can be calculated.

$$C_{OF} = \frac{I_{ef}}{3 \times \omega_n \times U_x}$$

equation_20.png

Figure 4.3-31 (Equation 20)

Ux phase-to-earth voltage

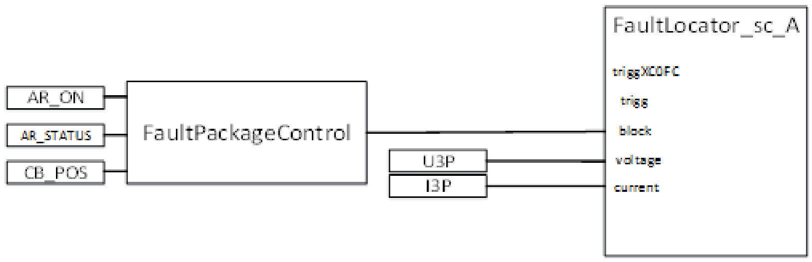
SCEFRFLO can also determine the value for the Ph capacitive React setting by measurements. The calculation of the value of Ph capacitive React setting is accomplished by conducting an earth-fault test outside the protected feeder during commissioning, for example at the substation busbar. The calculated value of the Ph capacitive React setting is obtained from the XC0F_CALC output. This value must be manually entered for the Ph capacitive React setting.

The calculated value matches the current switching state of the feeder and if the switching state of the protected feeder changes, the value is no longer valid. In this case, the setting should be updated, for example by repeating the test.

The calculation procedure of the *Ph capacitive React* setting is triggered by the binary signal connected to the TRIGG_XC0F input when earth fault is conducted.

Figure 4.3-32 shows a configuration for the Ph capacitive React calculation triggering that can be used for calculating XC0F_CALC.

- If the earth fault is detected by the residual overvoltage function (START of ROVPTOV) and fault is not seen by forward-looking earth-fault protection function (START of DEFLPDEF) that is set to direction “Reverse”, then after a set delay (TONGAPC), the XC0F_CALC output is updated. Correspondingly, if the fault direction is found to be forward, the XC0F_CALC value does not describe the protected feeder and is not useful because triggering can be done only when the fault is outside the protected feeder. Thus, the forward fault can be used for the SCEFRFLO block activation to disable wrong value calculation.
- The delay (TONGAPC) must be set longer than the start delay of the directional earth-fault function DEFLPDEF inside the terminal, but shorter than the minimum operating time of the directional earth-fault functions in the substation. For example, if the start delay is 100 ms and the shortest operating time 300 ms, a value of 300 ms can be used. Circuit breaker and disconnector status is used to verify that the entire feeder is measured.
- Additionally, circuit breaker and disconnector status is used to verify thatentire feeder is measured.

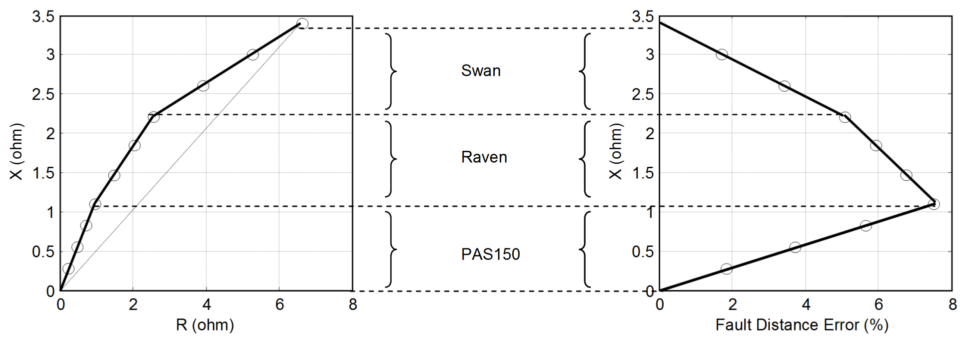


typical_configuration_for_triggering.png

Figure 4.3-32 Typical configuration for triggering

Modeling a non-homogeneous line

A distribution feeder is built with several different types of overhead lines and cables. This means that the feeder is electrically non-homogeneous. The nonhomogeneity can be illustrated by drawing the protected feeder in an RX-diagram (in the impedance plane), as shown in Figure 4.3-33. The impedance diagram is nonlinear.



impedance_diagram_example.png

Figure 4.3-33 Impedance diagram example

If the impedance of an individual line section varies, an accurate conversion of the fault loop reactance into a physical fault distance, for example into kilometres, is not possible with only one impedance setting. Therefore, SCEFRFLO allows the modeling of the line impedance variation in IED with three line sections and with independent impedance settings. This improves the accuracy of the physical fault distance conversion done in the IED, especially in cases where the line impedance non-homogeneity is severe. The number of line sections used in the conversion procedure from ohmic fault distance into physical fault distance are defined by using the Num of line sections setting.

If Num of line sections = 0, the conversion of the electrical fault distance into a physical distance is not done in the IED and the FLT_DISTANCE output is not valid. Estimated impedances are still calculated and are shown on their respective outputs. In order to guarantee accurate impedance estimation, the user should give as good values as possible for the longitudinal impedance settings R1 line section A, X1 line section A, R0 line section A, X0 line section A and the Line Len section A parameter corresponding to the total line length. Other longitudinal impedance settings are disabled (sections B and C).

If Num of line sections = 1, the longitudinal impedance settings R1 line section A, X1 line section A, R0 line section A, X0 line section A and the Line Len section A parameter are enabled for the conversion of the electrical fault distance into a physical distance. This option should be used only in the case of a homogeneous line, for example, when the protected feeder consists of only one conductor type. Also this option should be used if the user is only interested in calculated fault loop reactance XFLOOP and final fault location is done in higher system level utilizing, for example DMS-system.

If Num of line sections = 2, the longitudinal impedance settings R1 line section A, X1 line section A, R0 line section A, X0 line section A, R1 line section B, X1 line section B, R0 line section B, X0 line section B and the parameters Line Len section A, Line Len section B are enabled for the conversion of the electrical fault distance into a physical distance. This option should be used in the case of a nonhomogenous line, for example, when the protected feeder consists of two types of conductors.

If Num of line sections = 3, the longitudinal impedance settings R1 line section A, X1 line section A, R0 line section A, X0 line section A, R1 line section B, X1 line section

B, R0 line section B, X0 line section B, R1 line section C, X1 line section C, R0 line section C, X0 line section C and the parameters Line Len section A, Line Len section B, Line Len section C are enabled for the conversion of the electrical fault distance into a physical distance. This option should be used in the case of a non-homogenous line, for example, when the protected feeder consists of more than two types of conductors.

The effect of line impedance non-homogeneity in the conversion of fault loop reactance into physical fault distance is shown with an example of a 10-kilometer long feeder with three line types.

- 4 km of PAS 150 (R1 = 0.236 ohm/km, X1 = 0.276 ohm/km)
- 3 km of Al/Fe 54/9 Raven (R1 = 0.536 ohm/km, X1 = 0.369 ohm/km)
- 3 km of Al/Fe 21/4 Swan (R1 = 1.350 ohm/km, X1 = 0.398 ohm/km)

The total line impedance for the 10 km line is R1 = 6.602 ohm (0.660 ohm/km) and X1 = 3.405 ohm (0.341 ohm/km).

Figure 4.3-33 shows an example impedance diagram of the protected feeder when the line is modeled either with one or three impedance settings. The model with one impedance setting assumes homogeneous line while the model with three impedance settings gives accurate non-homogeneous line with three sections. These parameters are given in Table 4.3-1.

Table 4.3-1 Impedance diagram model parameters

Parameter	One impedance setting	Three impedance setting
R1 line section A	0.660 Ω/pu	0.236 Ω/pu
X1 line section A	0.341 Ω/pu	0.276 Ω/pu
Line Len section A	10.000 pu	4.000 pu
X1 line section B	N/A	0.369 Ω/pu
Line Len section B	0.000 pu (default)	3.000 pu
R1 line section C	N/A	1.350 Ω/pu
X1 line section C	N/A	0.398 Ω/pu
Line Len section C	0.000 pu (default)	3.000 pu

Figure 4.3-33 illustrates the conversion error as a function of physical fault location.

An error of at maximum nearly eight per cent is created by the conversion procedure when modeling non-homogenous line with only one section parameter.

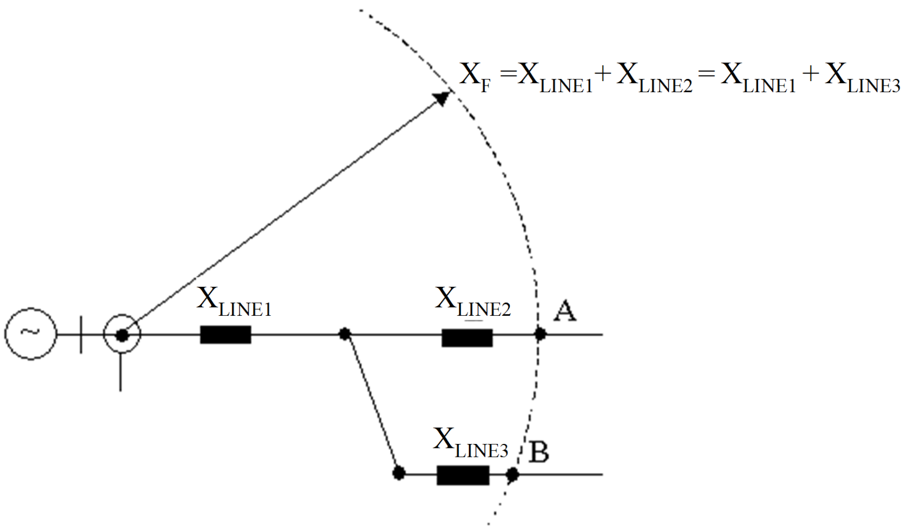
The fault location is varied from 1 km to 10 km in 1 km steps (marked with circles). As a result of a more accurate modelling, that is, with all three different line sections modeled, there is no error in conversion.

The previous example assumed a short circuit fault and thus, only positive sequence impedance settings were used. The results, however, also apply for earth faults.

Taps or spurs in the feeder

If the protected feeder consists of taps or spurs, the measured fault impedance corresponds to several physical fault locations (For example, A or B in Figure 4.3-34).

The actual fault location must be identified using additional information, for example, short circuit current indicators placed on tapping points.



fault_on_distribution_line_with_spurts.png

Figure 4.3-34 Fault on a distribution line with spurs

Fault report function SCEFRFPR

This is a fault package report creating function block, It will create a report every time a fault package is generated.

All monitored fault data will be recorded in the report including: Triggering, fault type, un-supply time, breaks, phase, fault current, load current, Resistance, capacitance, fault distance, validity, etc.

This report function will provide the report that COM600 WebHMI can handle and present to the user.

4.4. Base Values

In this function block, some of the settings are set in per unit (pu). These pu values are relational to certain base values, for example the values given in A, kV and kVA. The IED supports alternative base value groups for the phase current or voltagerelated settings, for example "Phase Grp 1", "Phase Grp 2" and "Phase Grp 3". One of the groups to be used with the Base value Sel phase setting must be selected.

4.5. Recorded Data

General

All the information required later for fault analysis is recorded when the recordingfunction of SCEFRFLO is triggered. The triggering can be either internal or external.

Table 4.5-1 Recorded data of the SCEFRFLO

Parameter name	Description
1 Recording time	Record data of bank 1 for trigger time stamp
1 FAULT_LOOP	Record data of bank 1 for fault loop
1 RF	Record data of bank 1 for fault resistance
1 RFLOOP	Record data of bank 1 for fault loop resistance
1 XFLOOP	Record data of bank 1 for fault loop reactance
1 FLT_DISTANCE	Record data of bank 1 for fault distance
1 UNSUPP_TIME	Record data of bank 1 for Unsupported time
1 FLT_PHASE	Record data of bank 1 for Fault phase
1 FLT_TYPE	Record data of bank 1 for Fault type
1 VALIDITY_CALC	Record data of bank 1 for Validity of the calculation
1 FLT_DIST	Record data of bank 1 for fault distance
1 VALIDITY	Record data of bank 1 for Validity
1 Breaks	Record data of bank 1 for Breaks
1 CB_OPEN_OR_APP_TIME	Record data of bank 1 for the CB open or Application time
1 SOURCE_LN	Record data of bank 1 for the source logic node
1 IED_NAME	Record data of bank 1 for the IED name
1 FLOC_READY_TIMESTAMP	Record data of bank 1 for the fault location ready time stamps

4.6. Application

The main objective of line protection and monitoring terminals is fast, selective and reliable operation for faults on a protected line section. Besides this, information on the distance to fault is very important for those involved in operation and maintenance.

Reliable information on the fault location greatly decreases the downtime of the protected lines and increases the total availability of a power system.

SCEFRFLO can be applied as a device level solution or as a part of a system level solution. In the device level applications, the physical fault distance (FLT_DISTANCE) is calculated in the IED based on settings. A more accurate result can be expected if the fault loop impedance (XFLOOP, RFLOOP) estimated by SCEFRFLO is utilized in the system level fault location applications.

SCEFRFLO provides the distance to the fault together with the information about the measuring loop that has been used in the calculation. Also, an estimate for the fault resistance at the fault point is calculated. In addition, both pre-fault and fault quantities of voltages and currents are available for a post-fault analysis in the recorded data. The validity of the estimated earth-fault distance is judged and reported together with the fault distance estimate.

4.7. Configuration

SCEFRFLO requires three phase currents for operation. The phase currents can be measured with conventional current transformers or Rogowski coils.

The full operation of SCEFRFLO requires that all three phase-to-earth voltages are measured. The voltages can be measured with conventional voltage transformers or voltage dividers connected between the phase and earth. Other alternative is to measure phase-to-phase voltages and residual voltage (Uo). Both alternatives are When the Phase voltage Meas setting is set to "PP without Uo" and only phase-to-phase voltages are available, only short-circuit measuring loops (fault loops 12, 23, 31, 123) can be measured accurately. In this case, the earth-fault loops (fault loops 1, 2, 3) cannot provide correct fault distance estimates and the triggering of the function is automatically disabled.

4.8. Signals

Table 4.8-1 SCEFRLOC Input Signal

Name	Type	Default	Description
R_AR_ON	BOOLEAN	False	Auto Reclose On, triggering and blocking logic for the FLOC application
PREV_AR_STATU	BOOLEAN	False	Auto Reclose Status, application blocking logic
WT_COMTRADE	BOOLEAN	False	Comrade file available, application triggering logic

Name	Type	Default	Description
WT_TRIP	BOOLEAN	False	Trip signal, application triggering logic
WT_AR_STATUS	BOOLEAN	False	AR Status, application triggering logic
R_UI1	DOUBLE	0	Phase A Voltage, fault location calculation input
R_UI2	DOUBLE	0	Phase B Voltage, fault location calculation input
R_UI3	DOUBLE	0	Phase C Voltage, fault location calculation input
R_IL1	DOUBLE	0	Phase A Current, fault location calculation input
R_IL2	DOUBLE	0	Phase B Current, fault location calculation input
R_IL3	DOUBLE	0	Phase C Current, fault location calculation input
R_CB_POS	BOOLEAN	False	CB Position, blocking logic

Table 4.8-2 SCEFRLOC Output Signal

Name	Type	Description
W_FP_Ready	BOOLEAN	Type new para here
WR_Trig	BOOLEAN	Type new para here

4.9. Settings

Table 4.9-1 SCEFRLOC settings

Parameter	Val-ues(Range)	Unit	Step	Default	Description
TripledZer-oSeq	True False	Type new para here	1	False	If set to false then the zero sequence cal-culated by symCom_A is divided by 3

Parameter	Values(Range)	Unit	Step	Default	Description
GroupDelay	Type new para here	Ms	0	1	Group delay for samples of the input signal [ms]
SamplingFrequency	Type new para here	Hz	1	1600	Sampling frequency of the input signal
Expression	1…2147483647	Type new para here	1	Type new para here	Formula used to calculate the result
DelayCycles	0…2147483647	Type new para here	1	1	The number of executions by which the Output signal is delayed with respect to the Input signal. The value of 0 means that there is no delay and the value at Output is always equal to the current value at Input
DetectRaisingEdge	False True	Type new para here	1	True	Detect changes of Input to true
DetectFallingEdge	False True	Type new para here	1	True	Detect changes of Input to false
DetectFirstOnly	False True	Type new para here	1	False	Inhibit edge detection and counting after the first detected edge of the specified kind(s)
EF algorithm	Load comp Load modelling	Type new para here	1	Load Modelling	PE-loop calculation algorithm
Equivalent load Dis	0.01…1	Type new para here	0.01	0.35	Equivalent load distance when EF algorithm = load modelling

Parameter	Values(Range)	Unit	Step	Default	Description
Ph leakage Ris	1…1000000	Ohm	1	60640	Line PhE leakage resistance in primary ohms
Ph capacitive React	1…1000000	Ohm	1	646	Line PhE capacitive reactance in primary ohms
EF algorithm current	I0 based I2 base	Type new para here	1	I0 base	Earth-fault current model
Base value Sel phase	Phase Grp 1 Phase Grp 2 Phase Grp3	Type new para here	1	Phase Grp1	Base value selector, phase / phase-to-phase
Phase voltage Meas	Accurate PP without U0	Type new para here	1	Accurate	Phase voltage measurement principle
Calculation Trg mode	External Internal Continuous	Type new para here	1	Continuous	Trigger mode for distance calculation
High alarm Dis limit	0.001…1	Pu	0.001	1.000	High alarm limit for calculated distance
Low alarm Dis limit	0.001…1	Pu	0.001	1.000	Low alarm limit for calculated distance
Z Max phase load	1…10000	Ohm	0.01	115.93	Impedance per phase of max. load, overcurr./underimp., PSL
Pre fault time	0.1…300	S	9.1	0.1	Time delay for healthy values of I and U before fault [s]
Num of line sections	0…3	Type new para here	1	1	Number of line sections
R1 line section A	0.001…1000	Ohm/pu	0.001	0.438	Positive-sequence line resistance, line section A

Parameter	Values(Range)	Unit	Step	Default	Description
X1 line section A	0.001…1000	Ohm/pu	0.001	0.329	Positive-sequence line reactance, line section A
R0 line section A	0.001…1000	Ohm/pu	0.001	0.832	Zero-sequence line resistance, line section A
X0 line section A	0.001…1000	Ohm/pu	0.001	1.749	Zero-sequence line reactance, line section A
Line Len section A	0.001…1000	Pu	0.001	27.400	Line length, section A
R1 line section B	0.001…1000	Ohm/pu	0.001	1	Positive-sequence line resistance, line section B
X1 line section B	0.001…1000	Ohm/pu	0.001	1	Positive-sequence line reactance, line section B
R0 line section B	0.001…1000	Ohm/pu	0.001	4	Zero-sequence line resistance, line section B
X0 line section B	0.001…1000	Ohm/pu	0.001	4	Zero-sequence line reactance, line section B
Line Len section B	0.001…1000	Pu	0.001	1	Line length, section B
R1 line section C	0.001…1000	Ohm/pu	0.001	1	Positive-sequence line resistance, line section C
X1 line section C	0.001…1000	Ohm/pu	0.001	1	Positive-sequence line reactance, line section C
R0 line section C	0.001…1000	Ohm/pu	0.001	4	Zero-sequence line resistance, line section C

Parameter	Values(Range)	Unit	Step	Default	Description
X0 line section C	0.001…1000	Ohm/pu	0.001	4	Zero-sequence line reactance, line section C
Line Len section C	0.001…1000	Pu	0.001	1	Line length, section C
Load Com PP loops	Disabled Enabled	Type new para here	1	Enabled	Enable load compensation for PP/3P-loops
Simple mode PP loops	Disabled Enabled	Type new para here	1	Disabled	Enable calc. without impedance settings for PP/3P-loops
Substitute-FaultType	Type new para here	Type new para here	1	2	The value for FaultType if FaultLoopValid is false
Interval	Type new para here	Ms	1	20	Interval between the executions [ms]

4.10. Monitored Data

Table 4.10-1 SCEFRLOC Monitored Data

Name	Type	Values	Unit	Description
WR_REG_X	DOUBLE	0…2147483647	Type new para here	Registered X
WR_REG_R	DOUBLE	0…2147483647	Type new para here	Registered Resistance
WR_FLT_DIST	DOUBLE	0…2147483647	Type new para here	Fault distance
WR_UNSUP_TIME	DOUBLE	0…2147483647	Type new para here	Un-supply time
WR_TRIGGER	INTEGER	0…2147483647	Type new para here	Trigger

Name	Type	Values	Unit	Description
WR_FLT_TYPE	INTEGER	0…2147483647	Type new para here	Fault type
WR_BREAKS	INTEGER	0…2147483647	Type new para here	Breaks
WR_VALIDITY	INTEGER	0…2147483647	Type new para here	Validity
WR_PHASE	INTEGER	0…2147483647	Type new para here	Fault phase
WR_IMP_METHOD	INTEGER	0…2147483647	Type new para here	Implementation method
WR_SRC_LN	STRING	0…2147483647	Type new para here	Source LN
WR_IED_NAME	STRING	0…2147483647	Type new para here	IED name
WR_TIME	TIMESTAMP	0…2147483647	Type new para here	Time stamp of fault
WR_FLOC_TIME	TIMESTAMP	0…2147483647	Type new para here	Fault locator time

5. Circuit breaker condition monitoring SSCBR

5.1. Identification

Function description	IEC 61850 Identification	IEC 60617 Identification	ANSI / IEEE C37.2 Device number
Circuit breaker condition monitoring	SSCBR	CBCM	CBCM

5.2. Functionality

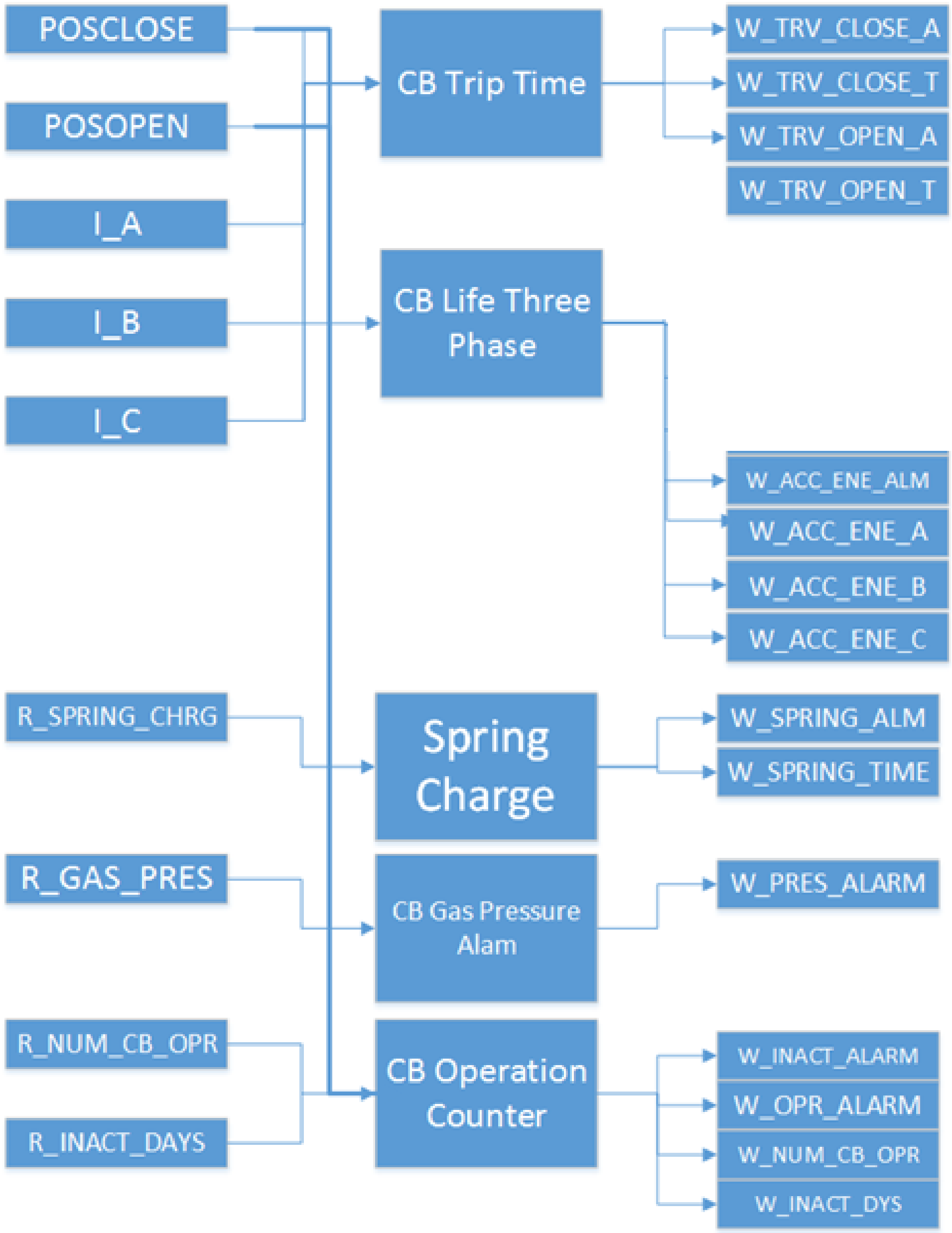
The circuit breaker condition monitoring function SSCBR is used to monitor different parameters of the circuit breaker. The breaker requires maintenance when the number of operations has reached a predefined value. The energy is calculated from the measured input currents as a sum of $I^y t$ values. Alarms are generated when the calculated values exceed the threshold settings.

The function contains a blocking functionality. It is possible to block the function outputs, if desired.

5.3. Operation Principle

The circuit breaker condition monitoring function includes different metering and monitoring sub-functions. The functions can be enabled and by blocking signal in application.

The operation of the functions can be described with a module diagram. All the modules in the diagram are explained in the next sections.



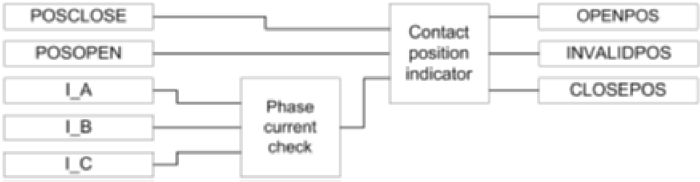
functional_module_diagram_sscbr.png

Figure 5.3-1 Functional module diagram

5.4. Circuit breaker status and breaker contact travel time

5.4.1. Circuit breaker status and breaker contact travel time

The Circuit breaker status sub-function monitors the position of the circuit breaker, that is, whether the breaker is in open, closed or invalid position. The operation of the breaker status monitoring can be described by using a module diagram. All the modules in the diagram are explained in the next sections.



functional_module_diagram_for_monitoring_circuit_breaker_status.png

Figure 5.4.1-1 Functional module diagram for monitoring circuit breaker status

Phase current check

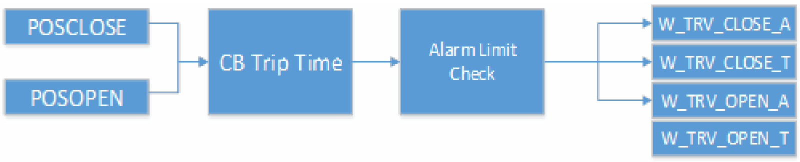
This module compares the three phase RMS currents to the setting *RMS Current Level*. If the current in a phase exceeds the set level, information about the phase is reported to the contact position indicator module.

Contact position indicator

Contact position indications are available in the main application.

5.4.2. Breaker contact travel time

The Breaker contact travel time module calculates the breaker contact travel time for the closing and opening operation. The operation of the breaker contact travel time measurement can be described with a module diagram. All the modules in the diagram are explained in the next sections.



functional_module_diagram_for_counting_circuit_breaker_operations.png

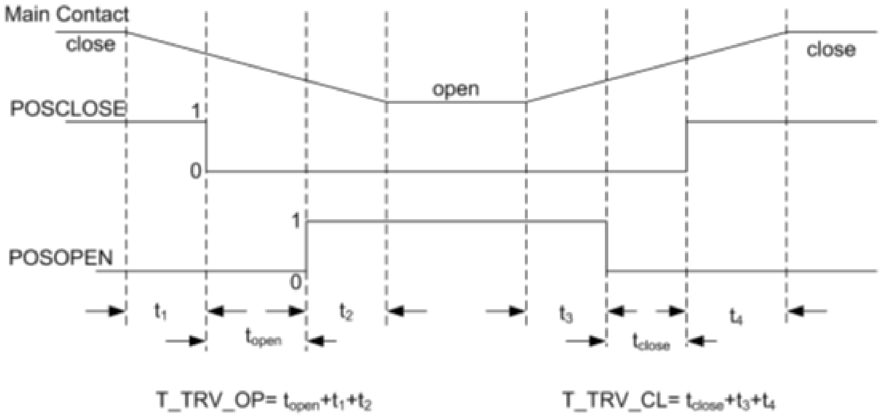
Figure 5.4.2-1 Functional module diagram for breaker contact travel time

Traveling time calculator

The travel time can be calculated using two different methods based on the setting *Travel time Clc mode*.

When the setting *Travel time Clc mode* is “From Pos to Pos”, the contact travel time of the breaker is calculated from the time between auxiliary contacts' state change. The opening travel time is measured between the opening of the POSCLOSE auxiliary contact and the closing of the POSOPEN auxiliary contact.

The travel time is also measured between the opening of the POSOPEN auxiliary contact and the closing of the POSCLOSE auxiliary contact.



travel_time_calculation.png

Figure 5.4.2-2 Travel time calculation

There is a time difference t1 between the start of the main contact opening and the opening of the POSCLOSE auxiliary contact. Similarly, there is a time gap t2 between the time when the POSOPEN auxiliary contact opens and the main contact is completely open. To incorporate the time t1 + t2, a correction factor needs to be added with topen to get the actual opening time. This factor is added with the *Opening time Cor* (= t1 + t2) setting. The closing time is calculated by adding the value set with the *Closing time Cor* (t3 + t4) setting to the measured closing time.

The last measured opening travel time T_TRV_OP and the closing travel time T_TRV_CL are available in the monitored data view on the LHMI or through tools via communications.

Alarm limit check

When the measured opening travel time is longer than the value set with the *Open alarm time* setting, the TRV_OPEN_ALARM output is activated. Respectively, when the measured closing travel time is longer than the value set with the *Close alarm time* setting, the TRV_CLOSE_ALARM output is activated.

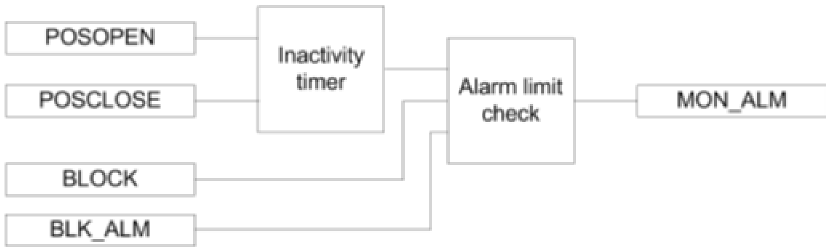
It is also possible to block the TRV_CLOSE_ALARM and TRV_OPEN_ALARM alarm signals by activating the BLOCK input.

5.5. Circuit breaker operation monitoring and operation counter

5.5.1. Circuit breaker operation monitoring and operation counter

The purpose of the circuit breaker operation monitoring subfunction is to indicate if the circuit breaker has not been operated for a long time.

The operation of the circuit breaker operation monitoring can be described with a module diagram. All the modules in the diagram are explained in the next sections.



functional_module_diagram_for_calculating_inactive_days.png

Figure 5.5.1-1 Functional module diagram for calculating inactive days and alarm for circuit breaker operation monitoring

Inactivity timer

The module calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. The calculation is done by monitoring the states of the POSOPEN and POSCLOSE auxiliary contacts.

The inactive days INA_DAYS is available in the Real time Data base.

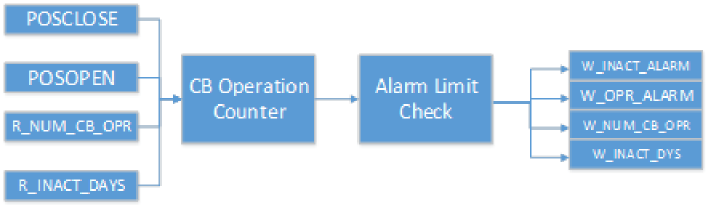
Alarm limit check

When the inactive days exceed the limit value defined with the *Inactive Alm* days setting, the MON_ALM alarm is initiated. The time in hours at which this alarm is activated can be set with the *Inactive Alm hours* parameter as coordinates of UTC. The alarm signal MON_ALM can be blocked by activating the binary input BLOCK.

5.5.2. Operation counter

The operation counter subfunction calculates the number of breaker operation cycles. The opening and closing operations are both included in one operation cycle. The operation counter value is updated after each opening operation.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.



functional_module_diagram_for_counting_circuit_breaker_operations.png

Figure 5.5.2-1 Functional module diagram for counting circuit breaker operations

Operation counter

The operation counter counts the number of operations based on the state change of the binary auxiliary contacts inputs POSCLOSE and POSOPEN.

The number of operations NO_OPR is available in the monitored data view on the LHMI or through tools via communications. The old circuit breaker operation counter value can be taken into use by writing the value to the *Counter initial Val* parameter and by setting the parameter *CB wear values* in the clear menu from WHMI or LHMI. The set values will be taken into use when trigger application is next time run.

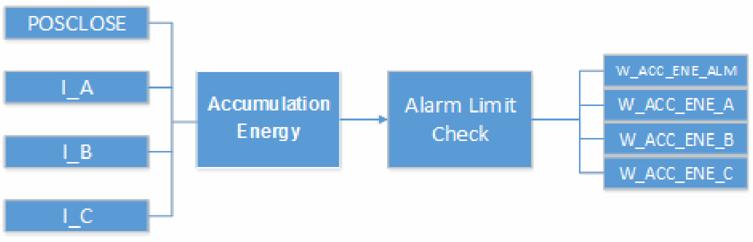
Alarm limit check

The OPR_ALM operation alarm is generated when the number of operations exceeds the value set with the *Alarm Op number* threshold setting. However, if the number of operations increases further and exceeds the limit value set with the *Lockout Op number* setting, the OPR_LO output is activated.

5.6. Accumulation of $I^y t$

Accumulation of the $I^y t$ module calculates the accumulated energy.

The operation of the module can be described with a module diagram. All the modules in the diagram are explained in the next sections.



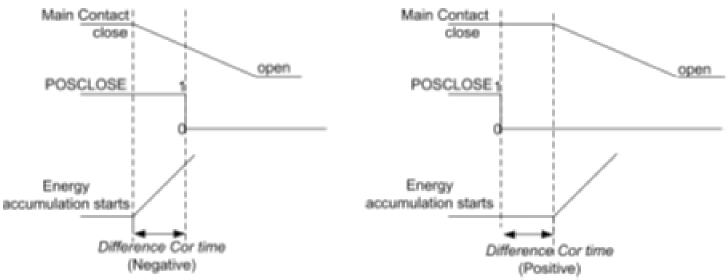
functional_module_diagram_for_circuit_breaker_gas_pressure_alarm.png

Figure 5.6-1 Functional module diagram for calculating accumulative energy and alarm

Accumulated energy calculator

This module calculates the accumulated energy $I^y t$ [$(kA)^y s$]. The factor y is set with the *Current exponent* setting.

The calculation is initiated with the POSCLOSE input opening events. It ends when the RMS current becomes lower than the *Acc stop current* setting value.



significance_of_the_difference_cor_time_setting.png

Figure 5.6-2 Significance of the Difference Cor time setting

The *Difference Cor time* setting is used instead of the auxiliary contact to accumulate the energy from the time the main contact opens. If the setting is positive, the calculation of energy starts after the auxiliary contact has opened and when the delay is equal to the value set with the *Difference Cor time* setting. When the setting is negative, the calculation starts in advance by the correction time before the auxiliary contact opens.

The accumulated energy outputs IPOW_A (_B, _C) are available in the monitored data view on the LHMI or through tools via communications. The values can be reset by setting the parameter CB *accum. currents* power setting to true in the clear menu from WHMI or LHMI. The set values will be taken into use when trigger application is next time run.

Alarm limit check

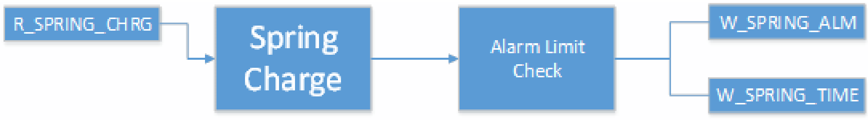
The IPOW_ALM alarm is activated when the accumulated energy exceeds the value set with the *Alm Acc currents Pwr* threshold setting. However, when the energy exceeds the limit value set with the *LO Acc currents Pwr* threshold setting, the IPOW_LO output is activated.

The IPOW_ALM and IPOW_LO outputs can be blocked by activating the binary input BLOCK.

5.7. Circuit breaker spring-charged indication

The circuit breaker spring-charged indication subfunction calculates the spring charging time.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.



functional_module_diagram_for_circuit_breaker_gas_pressure_alarm.png

Figure 5.7-1 Functional module diagram for circuit breaker gas pressure alarm

Spring charge time measurement

Two binary inputs, SPR_CHR_ST and SPR_CHR, indicate spring charging started and spring charged, respectively. The spring-charging time is calculated from the difference of these two signal timings.

The spring charging time T_SPR_CHR is available in the monitored data view.

Alarm limit check

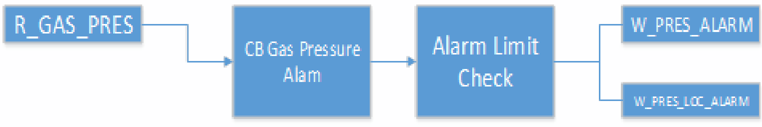
If the time taken by the spring to charge is more than the value set with the *Spring charge time* setting, the subfunction generates the SPR_CHR_ALM alarm.

It is possible to block the SPR_CHR_ALM alarm signal by activating the BLOCK binary input.

5.8. Gas pressure supervision

The gas pressure supervision subfunction monitors the gas pressure inside the arc chamber.

The operation of the subfunction can be described with a module diagram. All the modules in the diagram are explained in the next sections.



functional_module_diagram_for_circuit_breaker_gas_pressure_alarm.png

Figure 5.8-1 Functional module diagram for circuit breaker gas pressure alarm

The gas pressure is monitored through the binary input signals PRES_LO_IN and PRES_ALM_IN.

Timer 1

When the PRES_ALM_IN binary input is activated, the PRES_ALM alarm is activated after a time delay set with the *Pressure alarm time* setting. The PRES_ALM alarm can be blocked by activating the BLOCK input.

Timer 2

If the pressure drops further to a very low level, the PRES_LO_IN binary input becomes high, activating the lockout alarm PRES_LO after a time delay set with the *Pres lockout time* setting. The PRES_LO alarm can be blocked by activating the BLOCK input.

The binary input BLOCK can be used to block the function. The activation of the BLOCK input deactivates all outputs and resets internal timers. The alarm signals from the function can be blocked by activating the binary input BLK_ALM.

5.9. Application

SSCBR includes different metering and monitoring subfunctions.

Circuit breaker status

Circuit breaker status monitors the position of the circuit breaker, that is, whether the breaker is in an open, closed or intermediate position.

Circuit breaker operation monitoring

The purpose of the circuit breaker operation monitoring is to indicate that the circuit breaker has not been operated for a long time. The function calculates the number of days the circuit breaker has remained inactive, that is, has stayed in the same open or closed state. There is also the possibility to set an initial inactive day.

Breaker contact travel time

High traveling times indicate the need for the maintenance of the circuit breaker mechanism. Therefore, detecting excessive traveling time is needed. During the opening cycle operation, the main contact starts opening. The auxiliary contact A opens, the auxiliary contact B closes and the main contact reaches its opening position. During the closing cycle, the first main contact starts closing. The auxiliary contact B opens, the auxiliary contact A closes and the main contact reaches its closed position. The travel times are calculated based on the state changes of the auxiliary contacts and the adding correction factor to consider the time difference of the main contact's and the auxiliary contact's position change.

Operation counter

Routine maintenance of the breaker, such as lubricating breaker mechanism, is generally based on a number of operations. A suitable threshold setting to raise an alarm when the number of operation cycle exceeds the set limit helps preventive maintenance. This can also be used to indicate the requirement for oil sampling for dielectric testing in case of an oil circuit breaker.

The change of state can be detected from the binary input of the auxiliary contact. There is a possibility to set an initial value for the counter which can be used to initialize this functionality after a period of operation or in case of refurbished primary equipment.

Accumulation of $I^y t$

Accumulation of $I^y t$ calculates the accumulated energy $I^y t$, where the factor y is known as the current exponent. The factor y depends on the type of the circuit breaker. For oil circuit breakers, the factor y is normally 2. In case of a highvoltage system, the factor y can be 1.4...1.5.

Spring-charged indication

For normal operation of the circuit breaker, the circuit breaker spring should be charged within a specified time. Therefore, detecting long spring-charging time indicates that it is time for the circuit breaker maintenance. The last value of the spring-charging time can be used as a service value.

Gas pressure supervision

The gas pressure supervision monitors the gas pressure inside the arc chamber. When the pressure becomes too low compared to the required value, the circuit breaker operations are locked. A binary input is available based on the pressure levels in the function, and alarms are generated based on these inputs.

5.10. Signals

Table 5.10-1 SSCBR input signals

Name	Type	Default	Description
R_IL1	DOUBLE	0	Phase A Current
R_IL2	DOUBLE	0	Phase B Current
R_IL3	DOUBLE	0	Phase C Current
CB_POS	INT	0	Signal for open position of apparatus from I/O
R_GAS_PRES	BOOLEAN	0	Gas Pressure
R_SPRING_CHARG	BOOLEAN	0	Spring charge
R_INACT_DAYS	INT	0	Inactive days
R_NUM_CB_OPR	INT	0	Number of CB operation

Table 5.10-2 SSCBR Output Signals

Name	Type	Default	Description
TrvTOpAlm	BOOLEAN	0	CB open travel time exceeded set value
TrvClAlm	BOOLEAN	0	CB close travel time exceeded set value
CbOprAlm	BOOLEAN	0	Number of CB operations exceeds alarm limit
CBLifeAlarm	BOOLEAN	0	Remaining life of CB exceeded alarm limit
InActAlm	BOOLEAN	0	Inactive days exceeded set value
CBAccEneAlarm	BOOLEAN	0	Accumulated currents power (I^yt),exceeded alarm limit
SprChrAlm	BOOLEAN	0	Spring charging time has crossed the set value
PresAlam	BOOLEAN	0	Pressure below alarm level
TrvOpnTm	DOUBLE	0 = false	CB Open travel time
TrvClTm	DOUBLE	0 = false	CB Close travel time
CBAccEnePhsA	DOUBLE	0 = false	Phase A accumulated energy

Name	Type	Default	Description
CBAccEnePhsB	DOUBLE	0 = false	Phase B accumulated energy
CBAccEnePhsC	DOUBLE	0 = false	Phase C accumulated energy
SprChrTm	DOUBLE	0 = false	Spring charging time
CbOprCnt	INT	0	Number of CB operations
InActDays	INT	0	Inactive days

5.11. Settings

Table 5.11-1 SSCBR settings

Parameter	Values (Range)	Unit	Step	Default	Description
TripledZeroSeq	TRUE FALSE			False	If set to false then the zero sequence calculated by symCom_A is divided by 3
GroupDelay		ms	1	0	Group delay for samples of the input signal [ms].
SamplingFrequency		Hz	1	1600	Sampling frequency of the input signal [Hz]
Gas Pressure Alarm Time	0....60	S	1	0.1	Time delay to delay the pressure alarm (s)
Gas Pressure Lockout Time	0....60	S	1	0.1	Time delay to delay the pressure lockout (s)
Initial Value for Accumulated Energy	0....25000	Energy	1	0	Initial accumulated energy ()
Operation Coefficient	-3....-0.5	Coeff	0.5	-1.5	Directional coefficient
Rated Operating Current	0....10000	A	1	1000	Rated operation current
Rated Fault Current	0....30000	A	1	10000	Rated fault current
Number of Operations for Rated Current	0....10000	Count	1	10000	Operations number rated
Number of Operations for Rated Fault Current	0....10000	Count	1	1000	Operations number fault
Current Factor 'y'	1....2	Power factor	1	1	Current power factor

Parameter	Values (Range)	Unit	Step	Default	Description
Accumulated Energy Alarm Level	0....25000	Energy	1	2500	Accumulated energy level
Accumulated Energy Lockout Level	0.....25000	Energy	1	2500	Accumulated energy lockout level
Correction Factor for Contact Travel Time	-10....10	ms	1	5	Contact travel correction
RMS Current Level	0....199	% of the base current	1	0.1	Current RMS level
Operations Cycle	0....10000	Count	1	0	Operations cycle
Reset Accumu-lated Energy	False True	Reset	1	False	Reset accumulated energy
Monitoring Alarm Level	1....300	Days	1	1	Motoring alarm level (days)
CB Operation Number Alarm Level	0....9999	Count	1	200	Operations alarm level
CB Operation Lockout Level	0....999	Count	1	300	Operations lockout level
Reset Operation Counter	False True	Reset	1	False	Reset operation number
Reset Contact Inactivity	False True	Reset	1	False	Reset contact inactivity
Correction Factor for Open Travel Time	0....100	Ms	1	10	Correction factor open (ms)
Correction Factor for Close Travel Time	0....100	Ms	1	10	Correction factor close (ms)
Open Travel Time Alarm Level	0....300	Ms	1	40	Travel open level time (ms)
Close Travel Time Alarm Level	0....300	Ms	1	40	Travel close level time (ms)
RMS Current Level	0....100	% of base current	1	40	Current RMS level (%)

Parameter	Values (Range)	Unit	Step	Default	Description
Travel Time Calculation Mode	Open command to position change Calculation from CB Binary Signals		1	Open command to position change	Travel time calculation mode

5.12. Technical revision history

Table 5.12-1 SSCBR Technical revision history

Technical revision	Change
A	

—
ABB Distribution Solutions
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