ELIN DRS-C2BB

Busbar Differential Protection
for Single Busbars

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Author:	01.09.2005	Pairits
Approved:	01.09.2005	Schreiber
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Warning

Hazardous voltages are present in the electrical equipment during operation and standstill.

Death, severe personal injury or substantial property damage can result if proper precautions are not taken.

Please refer to plant and device manuals for safe operation of the equipment.

Qualified personnel

Only qualified personnel shall work on and in the vicinity of this equipment. The personal must be thoroughly familiar with all warnings and maintenance procedures of the manuals as well as the safety regulations.

Qualified personnel must be trained and authorized to energize, de-energize, clear ground and tag circuits and equipment in accordance with established safety practices.

Qualified personnel must be trained and instructed for switching, grounding and designating devices and systems.

Qualified personnel must be trained in rendering first aid.

General installation and safety regulations

Of particular importance are the general installation and safety regulations for work in a high-voltage environment, for example VDE, IEC; EN, DIN, or other national and international regulations. These regulations must be observed.

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1 General

The busbar differential protection ELIN DRS-C2BB is part of the DRS-Protection Family from the Model Series DRS-COMPACT. Further to the system description of the DRS-C2BB it also should be referred to the following documents:

ELIN DRS-COMPACT2A, Technical Description (DIC-018-1.00)
ELIN DRS-COMPACT2A, Local Operation via the Keypad and Display (DIC-006-1.01)

Due to the complexity of a busbar differential protective scheme (more than 50 parameters, subprograms) a parameter setting via the keypad is at present not available.
However, the general functions of the display, e.g. showing the actual measured values can be carried out.

This document outlines the features of the busbar differential protective functions whereby the knowledge about the software structure of the DRS-Family (Modular Protective Functions Library, Inputs- and Outputs- and LED Matrix) and the basic operations are not described in detail.

2 Concept

The ELIN DRS-C2BB is a centralised, digital busbar differential protection and operates according to the differential protection system with fault current bias. In addition to the bus protective function it is provided with an independent overcurrent protection which can also be applied as a backup protection for the specific line feeder.

The busbar protection DRS-C2BB is designed for a single bus system whereby the bus may be sectionalised with up to 2 bus isolators. The maximum number of feeders is limited to 10. In case of a double busbar with or without a reserve bus the digital busbar differential protection DRS-BB would be applicable.

The busbar protection DRS-C2BB is realised on the hardware platform DRS-COMPACT 2.
The DRS-COMPACT is provided with 10 current inputs (secondary nominal current 1A),
24 potential free contacts for alarms and trips and 8 binary inputs.
Communication with the control equipment can be made parallel hard wired via potential free contacts or with the serial interface according to the IEC 60870-5-103 protocol (optional 104).

The bus protective function evaluates 3 independent bus sections which may be connected via 2 bus section isolators and the 10 current inputs can be allocated to any of the 3 sections.
This way a DRS-C2BB can provide differential protection per phase for up to 10 feeders.
By this for traction systems 2 devices are necessary, i.e. one 19” rack with 6UH.
The output contacts of both DRS-C2BB are connected in parallel to the protection cubicle terminals. Communication between the two relays is not provided. For traction with a single busbar one DRS-C2BB can provide protection for up to 5 feeders provided that no section isolator is required, i.e. 5 current inputs are allocated to the first phase and the other current inputs are connected to the second phase.

The relay contains following protective functions from the Protective Function Library:

- Bus bar differential protection
- 10 overcurrent functions (1- phase, 2- stage) for each feeder
- Signal functions

The overcurrent function is a standard single phase two stage definite time overcurrent protection using the nominal frequency of the Fourier Analysis to compute the operating criteria. Details can be obtained from the "Protective Functions Library".
The signal functions are binary functions which will forward the function inputs onto real or virtual outputs (also inverted and/or with time delay). In the DRS-C2BB they can be applied for section isolator position, i.e. section isolator "Open" corresponds to "Not Closed" or as a transfer function for external inputs as an annunciation according to IEC60870-5-103.

The bus protective function is operating with it's own and independent task having a sampling rate of 1ms. The other protective functions are processed by the general task with a sampling rate of 12 per period, i.e. 5ms at 16.7Hz.

All features of the DRS-Family are also available for the busbar protection DRS-C2BB such as self-monitoring, display of the actual measured values, fault recording and event records. A series of menus as well as the fully graphical PC User Operating Program DRS-WIN provide a User-friendly access to the setting parameters, measured values and disturbance records.

3 Function Principles

3.1 Functions Overview

The busbar protection DRS-C2BB is operating according to the current differential principle with through-fault current bias. Three independent sections can be evaluated and to increase reliability against false operation for each feeder a check zone and a fast overcurrent interlock is included into the scheme. Different CT ratios can be matched by software for each feeder thereby eliminating the necessity of applying equal CT ratios or interposing CT's and the well-proven method of CT saturation detection is taken from the busbar protection DRS-BB to prevent false tripping by external faults causing CT saturation.

The allocation of the feeders to the bus sections have to be individually configured for the busbar differential protective scheme for a specific plant (plant layout) since a default structure of the bus configuration is set. But the allocation of the feeders to the different bus sections can easily be altered by the Customer.

3.2 Build-up of the Sections (Plant Layout)

The busbar protection DRS-C2BB is designed for a fixed plant structure also known as plant layout and implemented into the function which cannot be altered. Fig. 1 shows the basic arrangement of the busbar.

The bus function consists of 3 independent sections and the maximum number of 10 feeders and the mask parameters can be allocated to the individual bus sections whereby these bus sections can be connected via 2 section isolators.

The allocation to the feeders is basically according to system requirements but the bus layout cannot be changed. Bus section 1 and bus section 2 must only be connected with the bus isolator BC1 and section 2 and 3 only via the bus isolator BC2. The open or closed state of bus isolators are determined via 2 isolator auxiliary contacts for the Open or Closed state. For details please refer to Item 3.10.

Fig. 1 shows an example whereby the isolators and circuit breakers are shown as circles and squares respectively:
A single bus system consists of 3 sections, i.e. section 1 to 3 which are connected by bus isolators BC1 and BC2. In the following example feeders 1, 2, 5, 6 and 7 are allocated to bus section 1, the feeder 3 to bus section 2 and the feeders 4, 8, 9 and 10 to bus section 3.

An input of the feeder isolators is not considered to reduce external cabling. When the setting values of the protective function are exceeded selective tripping of the faulty bus section will be initiated.

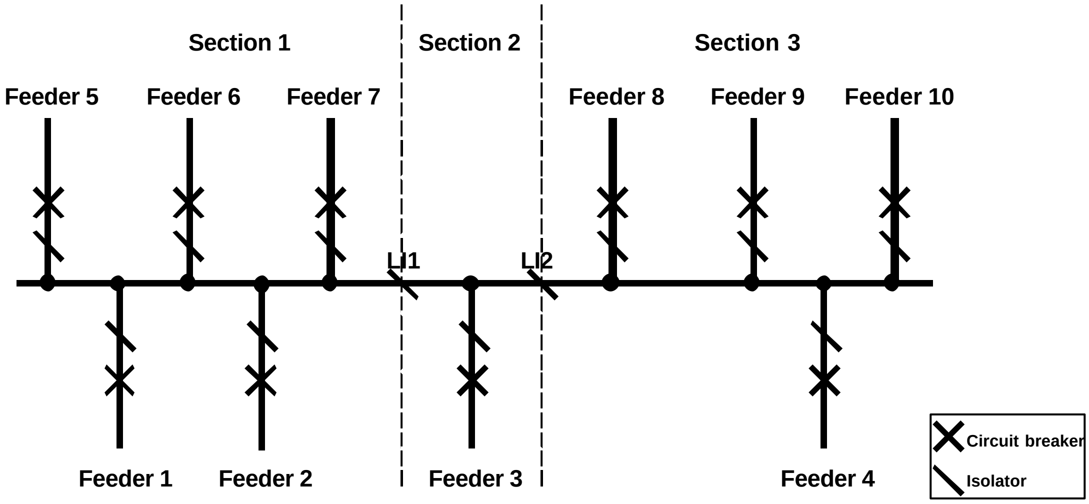

Fig. 1: Bus Layout

In addition to the 3 bus differential protective sections also a check zone feature can be configured to increase supply reliability since the sum of the currents of the whole plant is considered.
The parameter settings are carried out the same way as by the bus section functions via the masked parameters. When the interlock of the check zone is set to “Yes“ also the check zone will be evaluating the differential current according to the set parameter mask and should there be any incoming signals of a bus section isolator not plausible a false bus trip will be prevented.

Fig. 1 shows the maximum upgrading (3 bus sections with 2 bus section isolators). By the flexible allocation to the bus sections also busbars can be protected which represent a partial structure of the station layout:

- Single bus without bus section isolator: All feeders are allocated to one bus, e.g. section 1.
- Single bus with 1 bus section isolator: The feeders will be allocated to bus section 1 and 2 according to the above single line diagram.

3.3 Maintenance Selector Switch

During plant maintenance or extensions feeder circuits can be switched to “Maintenance“ to continue work with the plant still in service. Selecting a feeder to “Maintenance“ it will not be included into the computation of the current sum. However, it has to be ensured that this feeder circuit was completely taken out of service before commencing work.

CAUTION: When switching to the “Maintenance“ position of a feeder circuit included into the busbar protective function being still in primary service conditions a trip of this section may be initiated!

There are 2 kinds of “Maintenance” conditions which can be configured via the “Maintenance” parameter settings: ‘Static’ and ‘Dynamic’.

Maintenance 'Static':
With the mask parameter settings 'Feeder Maintenance' the feeders being not in service can be selected which then will not be included into the current sum check.

Maintenance 'Dynamic':
In the input matrix each feeder can be identified by a binary input, e.g. maintenance feeder n. In case of the maintenance parameters are configured to ‘Dynamic’ the auxiliary inputs are evaluated. When selected to maintenance the input is a logic 1 and the corresponding feeder is considered to be under maintenance conditions.
For the allocation it has to be considered that the DRS-COMPACT is provided with 8 binary inputs and therefore for 10 feeders it will not be possible to provide for each feeder a separate external maintenance control selector switch. However, an input can be allocated to several feeder circuits.

3.4 CT Ratio (Primary CT Rating) and Current Direction

The busbar protection is operating according to the differential current principle whereby all current values which are summed up have to be compensated.
Compensation is obtained via following two parameter settings which have to be configured for each individual feeder circuit.

Primary CT current rating:
With the primary CT rating compensation different CT ratios can be accommodated thereby eliminating the use of equal CT ratios and/or interposing CT’s in the switchgear.

The determination of the primary CT rating is according to following procedures:

The highest CT primary rating of a feeder is set to a value of 1 and feeders with a lesser primary current are set correspondingly smaller than 1, i.e. feeders with a smaller current rating are set in relation to the maximum primary feeder current.

e.g.: In a switch gear with CT ratios of F1 = 1000/1A, F2 = 500/1A and F3 = 200/1A, F1 will be configured with the primary CT rating factor of 1.00. For the feeder F2 the primary CT ratio factor is calculated 500A/1000A = 0.50 and by feeder F3 the primary compensation factor is 200A/1000A = 0.20.

Current Direction:

It is important that for the busbar differential protection the switchgear CT mounting positions and the direction of the secondary CT current connections for each feeder circuit are correctly wired to determine the exact current sum.

Generally in most switch gears and substations the CT's are mounted in the same direction whereby in generating stations the generator-transformer CT's may be mounted in the opposite direction to the line feeders.

The parameter setting 'Current Direction' will match the CT direction of the plant having a value of 1 or 2. When all CT's are mounted in the same direction a 'Current Direction' of 1 is applicable for all feeder circuits. However, when some feeders of a plant are having opposite directions one direction has to be defined as 'Current Direction 1'.

As an example following procedure can be applied:

Direction = 1 when the CT neutral is in opposite direction to the busbar.
Direction = 2 when the CT neutral is in the direction towards the busbar.

3.5 CT Saturation Detection

The most important feature of a busbar differential protection is the stability for external system faults even if one CT is being saturated. As soon as CT saturation is detected all trips are blocked but for a reliable operation for internal faults a saturation-free transfer during the first 5ms has to be guaranteed.

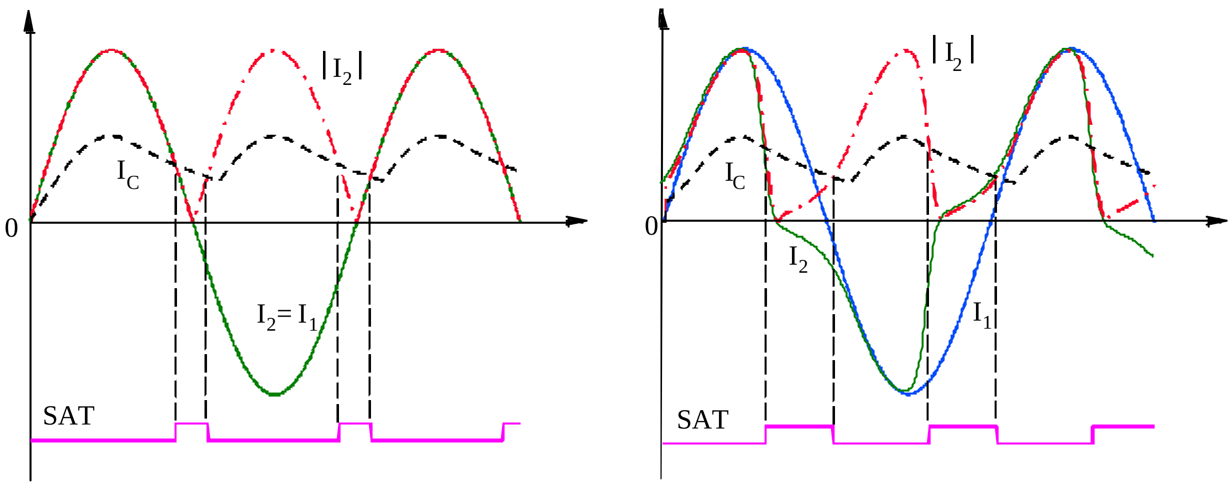

Fig. 2: Saturation Algorithm

The principle of the algorithm is displayed in Fig. 2. On the left side a sinusoidal progression of the CT current is shown, i.e. the primary current I1 and the secondary current I2 are in union. The rectified signal is filtered and processed the same way as a condenser discharge (Ic). By the comparison of the two values Ic>|I2| the signal "SAT" is derived as a binary time sequence.
The right part of Fig. 2 shows a saturated current progression (I2≠I1) and the time where the "SAT" signal is produced is considerably larger. Since the saturation signal is evaluated by each sample protection blocking is taking place always in the saturated portion of the fault current progression, respectively near the zero current instant.

3.6 Overcurrent Interlock Criteria

To increase the safety against mal-operation an additional fast current interlock function besides the differential current and the check zone feature is provided and only then when all 3 criteria are in unison a busbar differential trip will be initiated.

The fast current interlock requires an overcurrent condition in at least one feeder of the respective bus section to enable tripping of the busbar protection in this section.
The overcurrent algorithm is applying a combination of the instantaneous- and differential current measuring method to ensure fast operation of the busbar protection for internal faults.

If required this interlock can be de-activated via software, i.e. for consumer feeders which cannot contribute to the short circuit current.

Further, an interrogation request can be configured, namely I> before trip, so that a busbar protection trip will only be initiated in the presence of overcurrent conditions.

3.7 Bus Section Functions (Tripping Characteristic)

3.7.1 General

Each bus section function represents a bus differential protection for the respective bus section. All feeder currents not being in maintenance selection are being summed up. When one of the section isolators are closed both section functions are evaluating the current sum of the feeders, i.e. according to Fig. 1 section 1 and section 2 are considering the sum of the currents for feeders 1, 2, 3, 5, 6 and 7.

Two differential stages are provided: Stage 1 is used for the main bus differential protection which is a differential protection with a bias characteristic. Stage 2 is a sensitive stage for compensated network systems which is only evaluating via the Fourier Analyses the basic harmonic and is being time delayed.

When the setting value of the section function is exceeded and the check zone and the current interlock are allowing a trip the corresponding function outputs will be activated and distributed to the corresponding trip relays.
Via the fast stage 1 the tripping command may be too short to ensure tripping of the circuit breaker and for this purpose a minimum trip time can be adjusted.

3.7.2 Measuring System Stage 1

For the computation of the tripping criterion the currents of each feeder being not in the maintenance condition are summed up.

For the currents following bias differential algorithm is applicable:

$$\left|\sum_{r=1}^{n} i_r\right| \geq \mathrm{I}_{\mathrm{Stufe\ 1}} \quad \text{und} \quad \left|\sum_{r=1}^{n} i_r\right| \geq \mathrm{K}.\sum_{r=1}^{n} |i_r|$$

Whereby 'i' ist the current in feeder r, 'n' is the number of feeders of the bus section zone and $I_{Stage\ 1}$ the zone differential setting of stage 1 and K the zone bias slope. Fig.3 is showing this characteristic graphically.

The bias differential algorithm provides stabilising during heavy through fault conditions. For the computation of the bias algorithm the sum of the absolute values of the feeder currents is used.

When the setting value is exceeded during a few consecutive cycles a trip signal will be initiated but in case of a saturation signal the respective cycle is considered to be not valid and will be ignored.

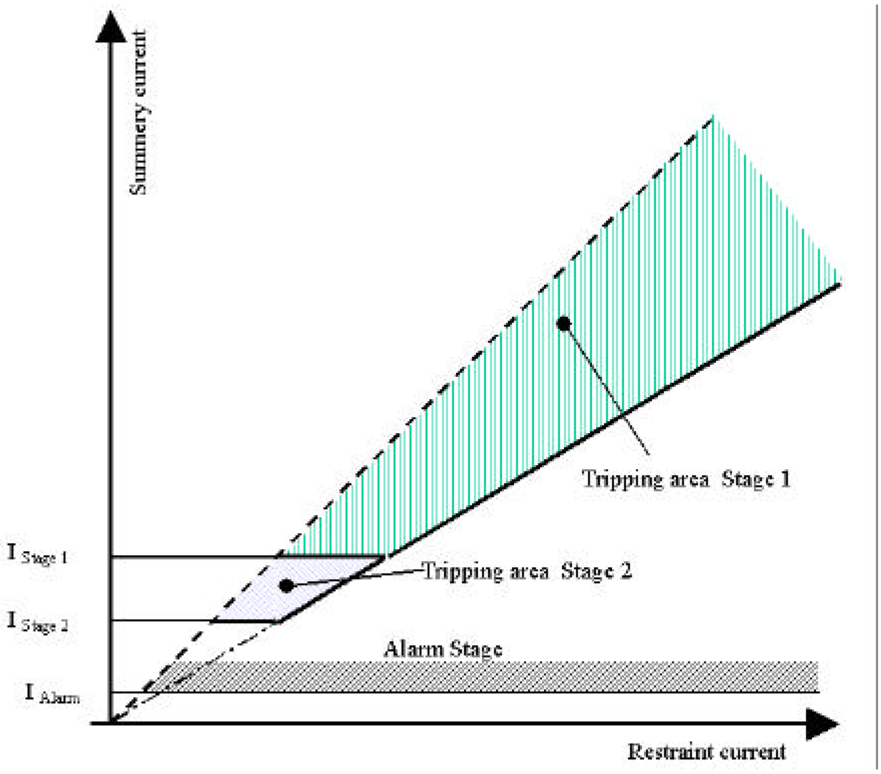

Fig. 3: Tripping Characteristic

3.7.3 Measuring System Stage 2

This sensitive stage is for the application by compensated and Peterson-Coil system. It is provided with a Fourier filter to extract higher harmonic frequencies above the basic frequency and has additionally a time delay stage.

$$\left|\sum_{r=1}^{n} i_r\right| \geq \mathrm{I}_{\mathrm{Stufe\ 2}} \quad \text{und} \quad \left|\sum_{r=1}^{n} i_r\right| \geq \mathrm{K}.\sum_{r=1}^{n} |i_r|$$

The variables correspond to stage 1; $I_{Stage\ 2}$ to the zone differential setting stage 2.

3.8 Check Zone

The check zone is a bus differential protection over the whole switchgear which is independent of the bus section isolator positions. A special section function summarising all plant feeder currents thereby providing a trip interlock for each particular bus section when the operating value is exceeding the set value.

For a busbar differential protection DRS-C2BB with a single bus system in some applications the use of a check zone may not be an advantage and therefore this feature can be disabled via the parameter setting 'Check Zone Enabled'.

Two differential stages are provided: Stage 1 is used fort he main busbar protection having a bias restraint characteristic whereas the sensitive stage 2 is applicable for compensated power systems which is only evaluating the basic harmonic with the Fourier Analysis having a time delay stage.

3.8.1 Check Zonen Summation – Stage 1

All feeder currents not being selected to the maintenance state are phase-wise evaluated for the current sum of the check zone.

For the currents following bias differential algorithm is applicable:

$$\left|\sum_{r=1}^{n} i_r\right| \geq \mathrm{I}_{\mathrm{Stufe\ 1}} \quad \text{und} \quad \left|\sum_{r=1}^{n} i_r\right| \geq \mathrm{K}.\left|i_{max}\right|$$

In this formula 'i' is the current in feeder r, 'n' the number of feeders being within the check zone , I_{Stage1} is differential current setting for stage 1 of the check zone, K the bias slope of the check zone and Imax represents the largest feeder current.

The function of the check zone measuring system is similar to those of the section functions whereby the only difference is that the highest absolute value the largest CT current is applied for the bias and not the sum of the absolute values. The reason for this is that the sum of the normal load currents of the individual zones which are not influenced by a bus section fault may lead to an excessive high level of stabilising.

The operating characteristic is basically the same as fort the bus section protective functions illustrated in Fig. 3.

3.8.2 Check Zone Stage 2

This sensitive stage is applied for compensated or Peterson-Coil network systems and is provided with Fourier Filter to suppress frequencies above the basic harmonic. Stage 2 has an additional configurable time delay.

The bias algorithm is according to following formula:

$$\left|\sum_{r=1}^{n} i_r\right| \geq \mathrm{I}_{\mathrm{Stufe2}} \quad \text{und} \quad \left|\sum_{r=1}^{n} i_r\right| \geq \mathrm{K}.\left|i_{max}\right|$$

Whereby I_{Stage2} represents the check zone differential current setting for stage 2.

3.9 Alarm Stage

This stage is used for a phase-wise monitoring of the CT currents with a sensitive parameter setting. The characteristic has no bias and is provided with an adjustable time delay. During external system faults there may be an initiation of this feature due to unbalance currents

and CT errors but because of the time delay no false trips can occur. The time delay should be set above the tripping time of the main protection.
In case of operation of the alarm stage the bus protection trip should be inhibited and the bus protective functions shall be set according to their functionality, e.g. parameter setting blocking by alarm stage.

3.10 Bus Isolator

As outlined in Item 3.2 the busbar protection DRS-C2BB consists of 3 selective sections which can be connected via the bus isolators. These positions of the of the bus isolatotors have to be configured into the busbar differential scheme to ensure correct allocation to the feeder currents for each section. For this function two direct auxiliary contacts for each isolator with following characteristic are required:

- 1 Auxiliary contact 'Open' when the bus isolator is in the open position
- 1 Auxiliary contact 'Closed' when the bus isolator is in the closed position

The way of operation is illustrated in Fig. 4 whereby the isolator position is derived from the normally closed contact and position discrepancy monitoring is carried out via the normally open contact.

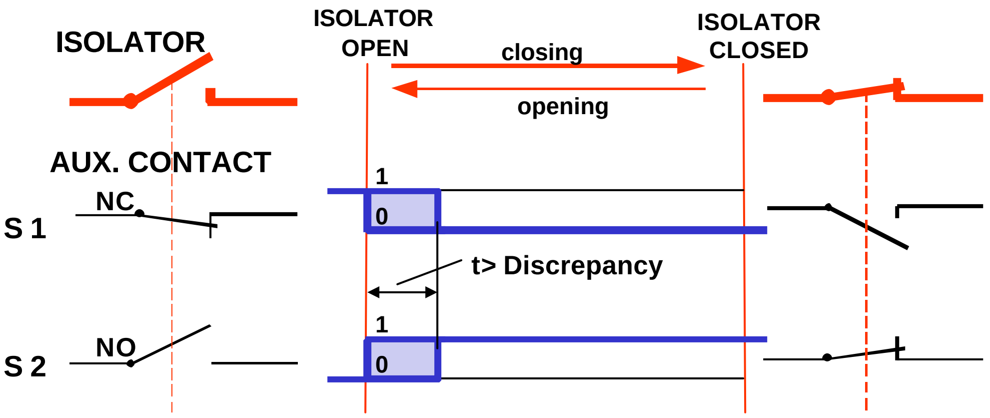

Fig. 4: Isolator Axiliary Contacts

Since the isolator distance is reached when the isolator is completely open for reasons of safety the auxiliary contact operation should happen near the open position of the bus isolator thereby ensuring that for the busbar protection the isolator is considered to be ‘Closed’ as soon as the open position has been left.

3.10.1 Position Discrepancy

According to Fig. 4 that except during the transfer time "t> Discrepancy" the auxiliary contacts S1 or S2 always have a logic 1 and the other one a logic 0. This way each of the two bus isolators is monitored by an incident detector via an EX-OR circuit and a time delay stage for position discrepancy.

In case of discrepancy the bus isolator is considered to be ’Closed’ and the protective function will also set the corresponding ‘Isolator Position Discrepancy’ output which can be configured either as an indication or an alarm via the User Software.

Should it be desired that by bus isolator discrepancy conditions the protective functions shall be blocked this can be achieved by the parameter 'Block by Discrepancy' setting.

3.10.2 Failure of the Auxiliary Input Supply Voltage

A failure of the input supply voltage will result into a position discrepancy, i.e. S1=0 & S2=0.

When the input supply voltage of the bus isolators is connected to a binary input a memory of the isolator position before supply failure can be configured.

4 Setting Parameters

4.1 General Setting Parameters (Valid for the Complete Bus Protective Function)

4.1.1 Station Layout and General Parameters

SETTING VALUE	RANGE	DEFAULT	NOTE
Section 1 Feeders	Yes (☑), No (☐)	No (☐)	
Section 2 Feeders	Yes (☑), No (☐)	No (☐)	
Section 3 Feeders	Yes (☑), No (☐)	No (☐)	
Check Zone Feeders	Yes (☑), No (☐)	No (☐)	
Maintenance Feeders	Yes (☑), No (☐)	No (☐)	
Maintenance inquiry	STATIC, DYNAMIC	STATIC	
O/C Interlock Active	Yes (☑), No (☐)	Yes (☑)	
Inquiry O/C Before Trip	Yes (☑), No (☐)	No (☐)	
Interlock by Check Zone	Yes, No	Yes	
Trip Signal Extention	0.050 to 1.000 s in Steps of 0.05s	0.500s	

4.1.2 CheckZone - Parameter

SETTING VALUE	RANGE	DEFAULT	NOTE
Setting Value Alarm	0.10 to 1.00 A in 0.01 A Steps	0.20 A	
Time Delay Alarm	0.00 to 10.00 s in 0.01s Steps	5.00 s	
Setting Value Stage 1	0.20 to 10.00 A in 0.05 A Steps	2.00 A	
Bias Slope	0 to 80 % in 1 % Steps	70.00 %	
Setting Value Stage 2	0.20 to 5.00 A in 0.05 A Steps	2.00 A	
Time Delay Stage 2	0.00 to 10.00 s in 0.01s Steps	5.00 s	

Stage 1: Fast stage according to the instantaneous value method
Stage 2: Time delayed stage according to FFT

The bias slope is equal for both stages.

4.1.3 Section Parameter Settings (For All 3 Sections)

SETTING VALUE	RANGE	DEFAULT	NOTE
Setting Value Alarm	0.10 to 1.00 A in 0.01 A Stufen	0.20 A	
Time Delay Alarm	0.00 bis 10.00 s in 0.01s Stufen	5.00 s	
Setting Value Stage 1	0.20 bis 10.00 A in 0.05 A Stufen	2.00 A	
Bias Slope	0 bis 80 % in 1 % Stufen	70.00 %	
Setting Value Stage 2	0.20 bis 5.00 A in 0.05 A Stufen	2.00 A	
Time Delay Stage 2	0.00 bis 10.00 s in 0.01s Stufen	5.00 s	

Stage 1: Fast stage according to the instantaneous value method
Stage 2: Time delayed stage according to FFT

The bias slope is equal for both stages.

4.1.4 Blocking Function

SETTING VALUE	RANGE	DEFAULT	NOTE
Block by Alarm Stage	YES, NO	NO	
Block by Isolator Discrepancy	YES, NO	NO	

4.1.5 Bus Section Isolator Setting Parameters

SETTING VALUE	RANGE	DEFAULT	NOTE
t>Discrepancy	0.1 to 200s in 0.1 Steps	5.00 s	
Memorise Isolator Position	YES, NO	NO	

4.2 Feeder Specific Parameter Settings

SETTING VALUE	RANGE	DEFAULT	NOTE
Primary CT Factor	0.050 to 1.000 in 0.005 Steps	1.000	
O/C Interlock	0.20 to 25.00 A in 0.05 A Steps	1.50 A	
Current Direction	Direction 1, Direction 2	Direction 1	

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Our address:

VA TECH SAT GmbH & Co
PRT
Ruthnergasse 1
A-1210 VIENNA
AUSTRIA

Phone: ++43 1 29 129 Ext. 4417
Fax: ++43 1 29 129 Ext. 4488

E-mail: martin.hantsch@sat-automation.com
http://www.sat-automation.com/

To

VA TECH SAT GmbH & Co
PRT / attn. Mr. Hantsch
Ruthnergasse 1
A-1210 VIENNA

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