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Capacitor unbalance protection for blocks in double star connection

PROTECTA HUNGARY

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User’s manual version information

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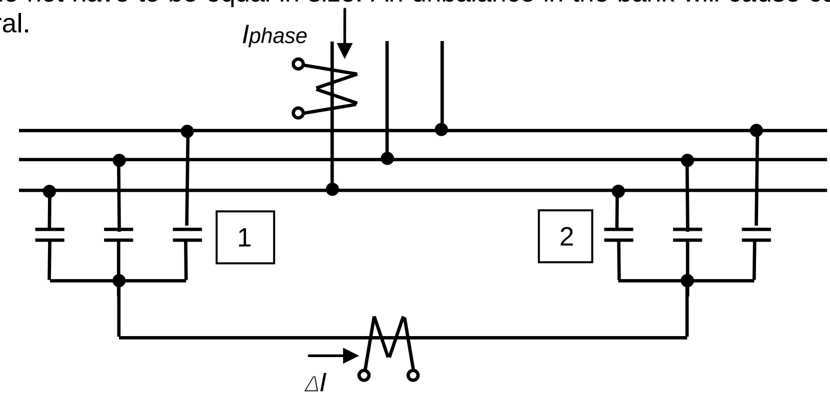
Capacitor unbalance protection function for blocks in double star connection

This version of the capacitor unbalance protection can be applied if the capacitors are arranged in two parallel stars (ungrounded) with a current transformer between the neutrals. The stars do not have to be equal in size. An unbalance in the bank will cause current to flow in the neutral.



The shunt capacitor banks are usually constructed of capacitor units, and the units contain capacitor elements.

There are constructions of the bank where fuses are connected inside a capacitor unit, in series with an element or a group of elements. The fuse is connected in series with the element that the fuse is designed to isolate if the element becomes faulty. After the breakdown of an element, the fuse connected to it will blow and isolate it from the remaining part of the capacitor, which allows the unit to continue in service. The blowing of one or more fuses decreases the capacitance value and additionally it will cause voltage changes within the bank.

If no internal fuses are applied then the breakdown of an element will short-circuit a “layer” of capacitors. The capacitance value increases and additionally it will also cause voltage changes within the bank.

Each time an internal capacitor element fails, a slight change of voltage distribution and current flow within the capacitor bank is encountered. The magnitude of these changes depends upon the number of failed elements and their location within the bank.

The main purpose of the capacitor unbalance protection is to give an alarm or to disconnect the entire capacitor bank when unbalances across healthy capacitors, adjacent to a failed capacitor, are excessive. Normally not more than 10 % unbalance should be allowed (unbalance limit according to (IEC 60871-1 Shunt capacitors for a.c. power systems having a rated voltage above 1000 V - Part 1: General).

If an externally fused capacitor is disconnected by its fuse, a larger voltage and current change is obtained than if single elements are disconnected by internal fuses.

This kind of protection prevents steady-state overvoltage and accelerated aging of the capacitor elements.

Another function of the unbalance protection is to remove the bank from service for a fault not isolated by a fuse or to protect banks that are not internally or externally fused. Unbalance protection is not a replacement for short-circuit protection.

This protection scheme may be used for both internal and external fuses and also in capacitor configurations without fuses. As the sensitivity performance is good, the method is especially useful for internal fuses. The current transformer between the neutral points should be rated for full system voltage.

The related standard permits a considerable amount of asymmetry, which can be up to 10%, consequently in healthy state a relatively high current can flow between the star points. At commissioning the unbalance protection function stores the vector position and the value of the “natural” unbalance current as the reference current $\Delta Iref$ and additionally those of one phase current $Iphase_{ref}$

The reference current is corrected according to the actually measured phase current *Iphase* and the stored $Iphase_{ref}$ reference phase current

$$\mathbf{\Delta} Iref_{corr} = \Delta Iref \frac{Iphase}{Iphase_{ref}}$$

where all current values are complex Fourier base harmonic vectors:

$\Delta Iref$	reference current measured between the neutral points at commissioning,
$\Delta Iref_{corr}$	corrected reference current,
Iphase	measured phase current,
$Iphase_{ref}$	phase current measured at commissioning.

If there are no changes inside the capacitor then no change can be detected in the actually measured unbalance current related to the corrected reference current.

Accordingly the energizing quantity for evaluation is the difference of the measured current between the neutral points and the corrected reference current:

$$G = dI = \Delta I - \mathbf{\Delta} Iref_{corr}$$

where all current values are complex Fourier base harmonic vectors:

ΔI	current measured between the neutral points,
$\Delta Iref_{corr}$	corrected reference current (see above).

NOTE: This approach using a single phase current supposes that the asymmetry of the network itself does not change, or the changes are cleared with high speed by other protection functions. If considerable steady-state changes in the symmetry of the network are expected, then the measurement and correction based a single phase current is not sufficient. In this case please consult Protecta Co. Ltd. for solution.

Calibration of the protection is the task of the commissioning to store the reference values for the neutral point current $\Delta Iref$, and that of the phase current $Iphase_{ref}$ in the memory.

For this purpose the function block has a dedicated binary input: *Calibr*. This input must be activated for the calibration. For the physical means for activation see the description of the configuration. This input may be programmed by the user using the graphic logic editor.

The calibration at the moment of activation can be performed only if the conditions for calibration are fulfilled. The conditions for calibration are:

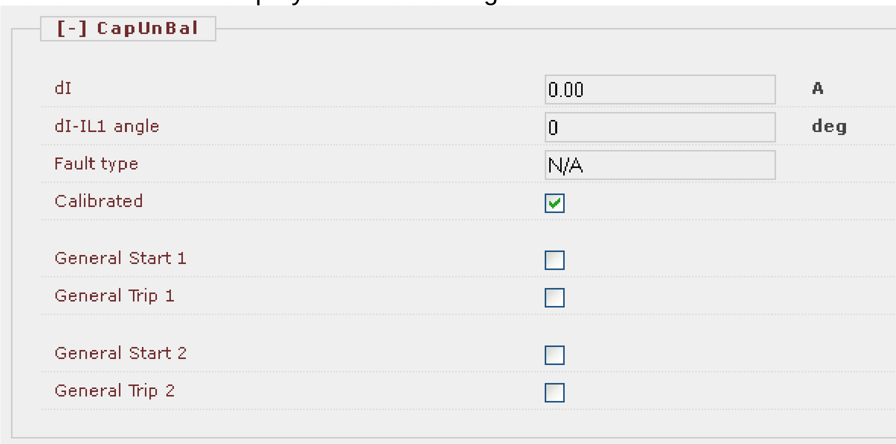
- The phase current has to be less than 2*In of the current input,
- The phase current has to be above 70% of the rated capacitor current,
- The neutral current has to be less than the value set by the dedicated parameter.

The calibrated state is indicated by the dedicated binary output of the function *Calibrated*.

The calibration values are stored in non-volatile memory, separately for each parameter set.

The *Reset* binary input resets the calibrated state.

Among the “on-line” information the function continuously displays the magnitude and the angle of the ΔI current measured between the neutral points. At the moment of calibration this vector resets to zero vector (see Figure below, dI=ΔI). At the same time the “Calibrated” field on the screen displays a check-mark. If however after calibration any changes happen within the capacitor bank then the displayed values change.



The capacitor unbalance protection function is configured with two independent stages.

For the first stage definite time characteristic and several types of inverse characteristics can be selected.

The second stage is definite time characteristic.

The inverse time operating characteristics are defined by the formula below:

$$t(G) = TMS\left[\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha} - 1} + c\right] \quad \text{when } G > G_S$$

where

t(G)(seconds) theoretical operate time with constant value of G,
k, c constants characterizing the selected curve (in seconds),
α constants characterizing the selected curve (no dimension),
G measured value of the characteristic quantity, Fourier base harmonic value,
G_S preset starting value of the characteristic quantity,
TMS preset time multiplier (no dimension).

The constant values k, c and α of the standard dependent time characteristics, see below.

	IEC ref	Title	k_r	c	α
1	A	IEC Inv	0,14	0	0,02
2	B	IEC VeryInv	13,5	0	1
3	C	IEC ExtInv	80	0	2
4		IEC LongInv	120	0	1
5		ANSI Inv	0,0086	0,0185	0,02
6	D	ANSI ModInv	0,0515	0,1140	0,02
7	E	ANSI VeryInv	19,61	0,491	2
8	F	ANSI ExtInv	28,2	0,1217	2
9		ANSI LongInv	0,086	0,185	0,02
10		ANSI LongVeryInv	28,55	0,712	2
11		ANSI LongExtInv	64,07	0,250	2

The end of the effective range of the inverse time characteristics (G_D) is:

$$G_D = 20 * G_S$$

Above this value the theoretical operating time is definite:

$$t(G) = TMS\left[\frac{k}{\left(\frac{G_D}{G_S}\right)^{\alpha} - 1} + c\right] \text{ when } G > G_D = 20 * G_S$$

Additionally a minimum time delay can be defined by parameter setting. This delay is valid if it is longer than t(G), defined by the formula above.

The inverse characteristic is valid above G_T =1,1* G_s. Above this value the function is guaranteed to operate.

Resetting characteristics of the inverse time delay is as follows.

- For IEC type characteristics the resetting is after a fix time delay defined by the parameter CapUnB1_Reset_TPar_ (Reset Time),
- for ANSI types however according to the formula below:

$$t_r(G) = TMS\left[\frac{k_r}{1-\left(\frac{G}{G_S}\right)^{\alpha}}\right] \text{ when } G < G_S$$

where

t_r(G)(seconds)	theoretical reset time with constant value of G,
k_r	constants characterizing the selected curve (in seconds),
α	constants characterizing the selected curve (no dimension),
G	measured value of the characteristic quantity, Fourier base harmonic of the phase currents,
G_S	preset starting value of the characteristic quantity (parameter: CapUnB1_StCurr1_IPar_, Start current 1),
TMS	preset time multiplier (no dimension).

The resetting constants of the standard dependent time characteristics are shown below.

	IEC ref	**Title**	**k_r**	**α**
1	A	IEC Inv	Resetting after fix time delay, according to preset parameter CapUnB1_Reset_TPar_ “Reset Time”	
2	B	IEC VeryInv		
3	C	IEC ExtInv		
4		IEC LongInv		
5		ANSI Inv	0,46	2
6	D	ANSI ModInv	4,85	2
7	E	ANSI VeryInv	21,6	2
8	F	ANSI ExtInv	29,1	2
9		ANSI LongInv	4,6	2
10		ANSI LongVeryInv	13,46	2
11		ANSI LongExtInv	30	2

Fault location

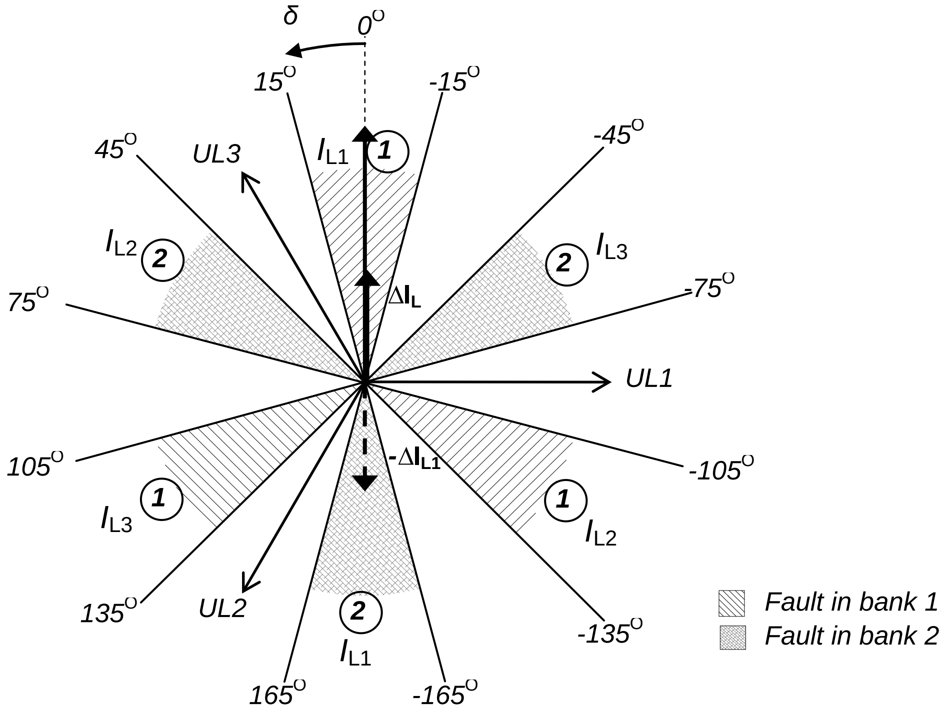
The vector measurement enables identification of the faulty capacitor unit. The positive directions of the currents *Iphase* and Δ*I* are as indicated in Figure above.

If the capacitor elements are not fused then the breakdown of a capacitor element will short-circuit a “layer” of capacitors. The resultant capacitance, consequently the capacitive current increases, as in the following explanation.

If a fault inside unit 1 in the phase L1 is considered, it increases the capacitance value. This event can be modelled by an additional capacitor connected parallel to the capacitor in unit 1 phase L1. It is obvious that this additional current is in phase of the current of the original phase capacitor "*IL1*". Consequently the ΔI current measured in the neutral point is in phase with the current of the original phase capacitor. To permit some asymmetry changes in the network and some measuring error, this current is inside the shaded area between -15 ° and +15 °. The on-line measurement will display the increased "*dI*" value with "*dI-IL1 angle*" in this range. The related event indicates "L1-1".

Similarly if an additional capacitor is added to phase L2, then the ΔI current measured in the neutral point is in phase with the current IL2. The phase angle related to phase IL1 is -120°, and it is in the range of -105 ° and -135 °. The related event indicates "L2-1".

If for example the added capacitor is in unit 2 in phase L2 then the vector is in the range of +45 ° and +75°. The related event indicates "L2-2".



If however the capacitor elements are individually fused then the breakdown of a capacitor element is disconnected from the "layer" of capacitors. The resultant capacitance decreases, and the result is opposite to the explanation above.

For correct evaluation the information is needed: whether internal fuses are applied or not. This is to be set by the Boolean parameter "Internal fuse".

The event list related to the capacitor faults can contain the following messages:

Message	Explanation
L1-1	Fault in phase L1, unit 1
L2-1	Fault in phase L2, unit 1
L3-1	Fault in phase L3, unit 1
L1-2	Fault in phase L1, unit 2
L2-2	Fault in phase L2, unit 2
L3-2	Fault in phase L3, unit 2

NOTE: The fault location is active in "*Calibrated*" state only. The event is registered at the moment of trip command generation.

Technical data

Function	Value	Accuracy
Pick-up starting accuracy	$20 \le G_S \le 1000$	< 5 %
Pickup time	< 40 ms	
Angle accuracy		<1 degree*
Reset ratio	0,9	
Reset time Dependent time char. Definite time char.	approx 60 ms	< 2% or ±35 ms, whichever is greater
Operate time accuracy		±5% or ±15 ms, whichever is greater

** Valid if the negative sequence component of the network voltage is < 5%*

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Enabling or disabling the capacitor unbalance protection function			
CapUnB1_Oper1_EPar_	Operation Stage 1	Off,DefinitTime,IEC Inv,IEC VeryInv,IEC ExtInv,IEC LongInv,ANSI Inv,ANSI ModInv,ANSI VeryInv,ANSI ExtInv,ANSI LongInv,ANSI LongVeryInv,ANSI LongExtInv	Off
CapUnB1_Oper2_EPar_	Operation Stage 2	Off,On	Off

Boolean parameters

Parameter name	Title	Default	Explanation
CapUnB_IntFuse_BPar_	Internal fuse	0	0 means no internal fuse 1 means capacitor units with internal fuse

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Current setting for the capacitor unbalance protection function, first stage						
CapUnB1_StCurr1_IPar_	Start Current 1	%	10	100	1	10
Current setting for the capacitor unbalance protection function, second stage						
CapUnB1_StCurr2_IPar_	Start Current 2	%	5	100	1	10
Nominal current of the capacitor, as percent of the rated input current						
CapUnB1_NomCurr_IPar_	Inom capacitor	%	15	120	1	100
ΔI setting, at calibration the current between the neutral points must be below this level						
CapUnB1_dIMax_IPar_	dI maxcalib	%	5	50	1	10

Float point parameter

Parameter name	Title	Dim.	Min	Max	Default
Time multiplier setting for the inverse type characteristics, first stage					
CapUnB1_Multip_FPar_	Time Multiplier	sec	0.05	999	1.0

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimum time delay for the inverse type characteristics (valid, if this characteristic is selected), first stage						
CapUnB1_MinDel_TPar_	Min Time Delay	msec	0	60000	1	100
Definite time delay for the first stage (valid, if this characteristic is selected)						
CapUnB1_DefDel_TPar_	Definite Time Delay	msec	0	60000	1	1000
Reset time setting, first stage						
CapUnB1_Reset_TPar_	Reset Time	msec	0	60000	1	100
Definite time delay for the second stage						
CapUnB1_Delay2_TPar_	Delay Stage 2	msec	0	60000	1	1000

Binary output status signals

Binary output signals	Signal title	Explanation
CapUnB1_GenSt1_GrI_	General Start 1	General start signal for stage 1
CapUnB1_GenTr1_GrI_	General Trip 1	General trip command for stage 1
CapUnB1_GenSt2_GrI_	General Start 2	General start signal for stage 2
CapUnB1_GenTr2_GrI_	General Trip 2	General trip command for stage 2
CapUnB1_Calib_GrI_	Calibrated	True, if the function has been calibrated

Binary input status signals

The conditions of the binary input signals are defined by the user, applying the graphic logic editor.

Binary input signals	Signal title	Explanation
CapUnB1_Reset_GrO_	Reset	Resetting the calibrated state
CapUnB1_Calibr_GrO_	Calibr	Binary input for calibration
CapUnB1_Blk_GrO_	Blk	Blocking input