

Directional Phase Overcurrent Protection ANSI 67 with 7SA522 and 7SA6

1. Introduction

The implementation of a directional overcurrent stage (ANSI 67) in the distance protection relays 7SA522 and 7SA6 is possible via a simple coupling of the distance protection directional stage (in this case Zone 5) with one of the overcurrent stages (in this example stage $I>$) in the relay.

The distance protection and the directional overcurrent protection use the same measured signals, phase current and phase voltage, but the impedance measurement achieves both higher sensitivity and higher selectivity.

This document illustrates how easily the ANSI 67 function can be implemented in the 7SA522 and 7SA6 by using the CFC logic.

2. General parameters for implementation of directional overcurrent (ANSI 67)

The settings of the relay can be applied as required by the application as usual. For the ANSI 67 function at least the functions 0112 Phase Distance, 0113 Earth Distance and 0126 Backup Overcurrent must be activated in the relay configuration (Fig. 2):

Setting parameter of 67	Designation	Example Value (secondary 1 A)
Pick-up threshold	$I_{67} >$ pick-up	2.5 A
Time delay	Time 67	0.5 s

Table 1 Parameters for directional overcurrent I_{67}

Setting block: Relay configuration

The distance protection must be enabled (quadrilateral or MHO) for phase faults: Parameter 0112. Backup overcurrent must be enabled (time overcurrent IEC or ANSI): Parameter 0126



Fig. 1 SIPROTEC line protection 7SA522 and 7SA6

Functional Scope		
Available functions:		
No.	Function	Scope
0103	Setting Group Change Option	Disabled
0110	Trip mode	1-/3pole
0112	Phase Distance	Quadrilateral
0113	Earth Distance	Quadrilateral
0120	Power Swing detection	Disabled
0121	Teleprotection for Distance prot.	Disabled
0122	DTT Direct Transfer Trip	Disabled
0124	Instantaneous HighSpeed SOTF Overcurrent	Disabled
0125	Weak Infeed (Trip and/or Echo)	Disabled
0126	Backup overcurrent	Time Overcurrent Curve IEC
0131	Earth fault overcurrent	Disabled
0132	Teleprotection for Earth fault overcurr.	Disabled

Fig. 2 Setting of functional scope

Matrix: Masking I/O (configuration matrix)

Assign the signal “3719 Distance forward” in the “Distance General” block to destination CFC.

	Information		L	Type	Source				Destination						
	Number	Display text			BI	F	S	C	BO	LE	Buffer	O	S	T	CM
Dis. General	03713	Dis. Loop L1E <->		OUT								00			
	03714	Dis. Loop L2E <->		OUT								00			
	03715	Dis. Loop L3E <->		OUT								00			
	03716	Dis. Loop L12 <->		OUT								00			
	03717	Dis. Loop L23 <->		OUT								00			
	03718	Dis. Loop L31 <->		OUT								00			
	03719	Dis. forward		OUT										X	
	03720	Dis. reverse		OUT										X	

Fig. 3 Masking of dist. signals in configuration matrix

Select that stage in the backup overcurrent that must be directional (ANSI 67). For this stage assign the corresponding blocking input signal to source CFC. Therefore either:

- 7104 >Block O/C I>> or
 7105 >Block O/C I> (used in this example) or
 7106 >Block O/C I_p

Multiple assignment is also possible.

	Information		L	Type	Source				Destination						
	Number	Display text			BI	F	S	C	BO	LE	Buffer	O	S	T	CM
Dis. Quadrl	07104	>BLOCK O/C I>>		SP								00		X	
	07105	>BLOCK O/C I>		SP								00		X	
	07106	>BLOCK O/C I _p		SP								00		X	
	07110	>O/C InstTRIP		SP								00	00	X	
	07130	>BLOCK I-STUB		SP								00		X	
	07131	>I-STUB ENABLE		SP								00	00	X	
	07151	O/C OFF		OUT								00		X	
	07152	O/C BI OFF		OUT								00	00	X	

Fig. 4 Masking of overcurrent signals in configuration matrix

3. Special setting for the distance protection

The distance protection sensitivity must be greater than or equal to that of the required directional overcurrent protection. This does not present any problems, as the directional overcurrent protection will be set less sensitive than the maximum load current while the distance protection is set more sensitive than the smallest fault current.

In the relevant setting group (e.g. Setting Group A) the following distance protection settings must be checked:

Distance protection, general settings - Settings Group A		
General Earth faults Time Delays		
Settings:		
No.	Settings	Value
1201	Distance protection is	ON
1202	Phase Current threshold for dist. meas.	0,10 A
1211	Angle of inclination, distance charact.	85 °
1208	Series compensated line	NO
1232	Instantaneous trip after SwitchOnToFault	Inactive
1241	R load, minimum Load Impedance (ph-e)	∞ Ohm
1242	PHI load, maximum Load Angle (ph-e)	45 °
1243	R load, minimum Load Impedance (ph-ph)	∞ Ohm
1244	PHI load, maximum Load Angle (ph-ph)	45 °
1357	Z1B enabled before 1st AR (int. or ext.)	YES

Fig. 5 Distance protection function general setting

1201 Distance protection is ON

1202 Phase current threshold for distance measurement $\leq I_{67>}$ pick-up (Table 1)

To calculate the minimum reach setting of the distance protection, the overcurrent characteristic is shown in the impedance plane below in Fig. 6:

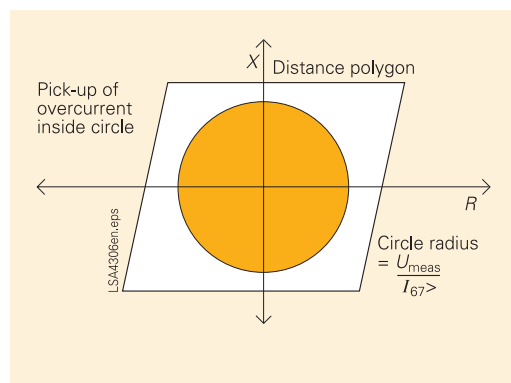


Fig. 6 Pick-up characteristic of overcurrent protection in impedance plane

From Fig. 6 it is apparent, that the largest circle radius must be determined to set the minimum impedance reach so that a direction decision is available when the overcurrent stage picks up. The maximum circle radius is obtained when the measured fault voltage together with fault current at pick-up threshold occurs. If the maximum operating voltage (unfaulted) is used, a large safety factor is already incorporated as the fault voltage will always be less than this.

$$\text{Circle_radius} = \frac{U_{\text{operating max}}}{\sqrt{3} \cdot (I_{67>} \text{ pick-up})}$$

In this example the rated secondary VT voltage is 100 V. The maximum operating voltage is 110% of rated, so the following circle radius can be calculated:

$$\text{Circle_radius} = \frac{100 \cdot 1.1}{\sqrt{3} \cdot 2.5}$$

$$\text{Circle_radius} = 25.4 \, \Omega$$

The setting 1243 R load, minimum load impedance (ph-ph) must be greater than the calculated circle radius. In practice, this is no problem because this setting is calculated with a similar equation using the maximum load current instead of the overcurrent pick-up ($I_{67>}$ pick-up) which must be greater than the maximum load current. Therefore, this setting when applied is by nature greater than the circle radius calculated here.

At least one of the set distance protection zones with forward or non-directional reach must have a reach greater than the circle radius. In this example the Zone 5 has the largest reach, and it is set non-directional. In this case the following must be checked:

1341 Operating mode Zone 5 is non-directional

1342 $R(Z5)$ resistance for ph-ph faults \geq Circle radius (25.4 Ω)

1343 $X+(Z5)$ reactance for forward direction \geq Circle radius (25.4 Ω)

If none of the applied zones has a sufficiently large reach, a special zone must be selected for this purpose. This zone must then be set as non-directional (for MHO set forward) with an X and R reach equal to the calculated circle radius (25.4 Ω in this example). The time delay of this zone can be set to infinity (∞) to avoid tripping by the distance protection in this zone if required.

No.	Settings	Value
1341	Operating mode Z5	Non-Directional
1342	$R(Z5)$, Resistance for ph-ph-faults	25,400 Ohm
1343	$X(Z5)+$, Reactance for Forward direction	25,400 Ohm
1344	$RE(Z5)$, Resistance for ph-e faults	21,000 Ohm
1345	TS delay	oo sec
1346	$X(Z5)-$, Reactance for Reverse direction	20,000 Ohm

Fig. 7 Zone settings of non-directional zone

■ 4. Setting the backup overcurrent stage for ANSI 67

The backup overcurrent must be operated as backup protection so that it is always active:

2601 Operating mode ON: always active

In the backup overcurrent protection the following settings must be applied to the stage that is intended for the ANSI 67 function. In this example stage $I>$ will be used:

2620 $I_{ph}>$ pick-up value
set equal to required $I_{67}>$ pick-up (in this example 2.5 A)

2621 T $I_{ph}>$ time delay
set equal to the desired 67 time delay (in this example 0.5 s)

2622 $3I_0>$ pick-up value
disabled by setting to infinity (∞)

No.	Settings	Value
2620	$I_{ph}>$ Pickup	2.5 A
2621	T $I_{ph}>$ Time delay	0,50 sec
2622	$3I_0>$ Pickup	oo A
2623	T $3I_0>$ Time delay	2,00 sec
2624	Instantaneous trip via Teleprot./BI	NO
2625	Instantaneous trip after SwitchOnToFault	NO

Fig. 8 Settings for backup overcurrent function ($I>$ in this example)

■ 5. Setting up the CFC logic

In the CFC logic, the absence of a forward detection by the distance protection (in this case Zone 5) will be used to block the backup overcurrent stage (in this example stage $I<$).

In the fast PLC, insert a negator and route the signal "Dis forward" to its input. Route the negator output to the relevant blocking input to the backup overcurrent stage.

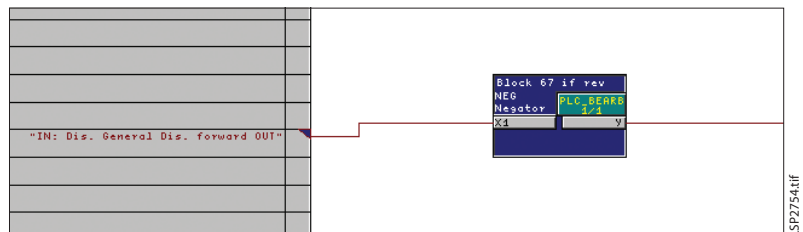


Fig. 9 Input signal allocation in the CFC logic

■ 6. Testing the ANSI 67 function

To test the directional overcurrent, a forward and a reverse fault condition were simulated with the Omicron® state sequencer. For both faults, the fault current level was set to 10 % above pick-up of the ANSI 67 function, 2.75 A. The angle between current and voltage for the forward fault was 0° and for the reverse fault 180° .

The fault recordings and trip log for these two cases are shown on the following page:

The trip log (Fig. 10) shows the trip signal by the backup O/C I> stage after 510 ms.

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Trip Log - 000002 / 12.07.2004 16:05:03.111 - Test / Testbox / 7SA522 OC67 V4.3/7SA522				
Number	Indication	Value	Date and time	
00301	Power System fault	2 - ON	12.07.2004 16:05:03.111	
00302	Fault Event	2 - ON	12.07.2004 16:05:03.111	
03693	Distance Pickup L123	ON	0 ms	
03704	Distance Loop L12 selected forward	ON	0 ms	
03705	Distance Loop L23 selected forward	ON	0 ms	
03706	Distance Loop L31 selected forward	ON	0 ms	
07162	Backup O/C PICKUP L1	ON	10 ms	
07163	Backup O/C PICKUP L2	ON	10 ms	
07164	Backup O/C PICKUP L3	ON	10 ms	
07184	Backup O/C Pickup L123	ON	10 ms	
07192	Backup O/C Pickup I>	ON	10 ms	
07215	Backup O/C TRIP Phases L123	ON	510 ms	
07222	Backup O/C TRIP I>	ON	510 ms	
00533	Primary fault current IL1	2,75 kA	514 ms	
00534	Primary fault current IL2	2,75 kA	514 ms	
00535	Primary fault current IL3	2,75 kA	514 ms	
03805	Distance TRIP command Phases L123	ON	900 ms	
07161	Backup O/C PICKED UP	OFF	989 ms	
03671	Distance PICKED UP	OFF	999 ms	
03704	Distance Loop L12 selected forward	OFF	1000 ms	
03705	Distance Loop L23 selected forward	OFF	1000 ms	
03706	Distance Loop L31 selected forward	OFF	1000 ms	
00511	Relay GENERAL TRIP command	OFF	1000 ms	
01128	Fault Locator Loop L3L1	ON	894 ms	
01117	Flt Locator: secondary RESISTANCE	21,84 Ohm	894 ms	
01118	Flt Locator: secondary REACTANCE	0,07 Ohm	894 ms	
01114	Flt Locator: primary RESISTANCE	87,36 Ohm	894 ms	
01115	Flt Locator: primary REACTANCE	0,27 Ohm	894 ms	
01119	Flt Locator: Distance to fault	0,5 km	894 ms	
01120	Flt Locator: Distance [%] to fault	0,5 %	894 ms	

Fig. 10 Trip log for forward fault

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Trip Log - 000003 / 12.07.2004 16:06:00.775 - Test / Testbox / 7SA522 OC67 V4.3/7SA522				
Number	Indication	Value	Date and time	Initiator
00301	Power System fault	3 - ON	12.07.2004 16:06:00.775	
00302	Fault Event	3 - ON	12.07.2004 16:06:00.775	
03693	Distance Pickup L123	ON	0 ms	
03710	Distance Loop L12 selected reverse	ON	0 ms	
03711	Distance Loop L23 selected reverse	ON	0 ms	
03712	Distance Loop L31 selected reverse	ON	0 ms	
03805	Distance TRIP command Phases L123	ON	900 ms	
00533	Primary fault current IL1	2,75 kA	904 ms	
00534	Primary fault current IL2	2,75 kA	905 ms	
00535	Primary fault current IL3	2,75 kA	905 ms	
03671	Distance PICKED UP	OFF	1000 ms	
03710	Distance Loop L12 selected reverse	OFF	1000 ms	
03711	Distance Loop L23 selected reverse	OFF	1000 ms	
03712	Distance Loop L31 selected reverse	OFF	1000 ms	
00511	Relay GENERAL TRIP command	OFF	1001 ms	
01128	Fault Locator Loop L3L1	ON	894 ms	
01117	Flt Locator: secondary RESISTANCE	-21,82 Ohm	894 ms	
01118	Flt Locator: secondary REACTANCE	-0,07 Ohm	894 ms	
01114	Flt Locator: primary RESISTANCE	-87,28 Ohm	894 ms	
01115	Flt Locator: primary REACTANCE	-0,28 Ohm	894 ms	
01119	Flt Locator: Distance to fault	-0,5 km	894 ms	
01120	Flt Locator: Distance [%] to fault	-0,5 %	894 ms	

Fig. 11 Trip log of reverse fault

7. Summary

The implementation of a directional overcurrent stage (ANSI 67) in the distance protection relays 7SA522 and 7SA6 is possible via a simple coupling of the distance protection directional release with one of the overcurrent stages in the relay. If one of the other backup overcurrent stages is required as an emergency protection in the event that the distance protection is blocked due to fuse

failure, a similar logic may be implemented whereby the blocking signal is derived from the Fuse Fail alarm (170).