

Testing protection functions in Distributed Energy Resources (DER)

Example of how to test common relay protection in DER with SVERKER 900

Tests included: Pickup and Timing

Protection type to be tested	Protection setting
Vector shift	6 Degree
ROCOF	0,2Hz/s
Under voltage	95% & 90% of 63,5V
Over voltage	105% & 110% of 63,5V
Under frequency	48Hz & 46Hz
Over frequency	52Hz & 54Hz

Preparations: Make one test in “Ramp Instrument” with settings for pickup tests, save test in one test file called pickup tests. Changes in “Stop value” and “Ramp speed” are made depending on test.

Settings for timing tests are made in “Sequence Instrument” and explained below.

(Each test must be saved separately and then opened in same instrument.)
(BI must be set for each instrument used.)

Tests made in ramp instrument, manually changes are needed.

	Pickup test files		
	Ramp speed	Stop value	
	Phase L1/L2/L3	Phase L1/L2/L3	
Vector shift	0,2 Δ °/s	10°/250°/130°	Leading angle
	-0,2 Δ °/s	350°/230°/110°	Lagging angle
ROCOF	0,21 Δ Hz/s	51Hz/49Hz	Incr./Decr.
ROCOF (timing)	0,25 Δ Hz/s	51Hz/49Hz	Incr./Decr.
Voltage	0,20 Δ V/s	55V/75V	Under/Over.
Frequency	0,20 Δ Hz/s	45Hz/55Hz	Under

Tests made in sequence instrument.

	Timing & Stability test files		
	Pre fault value	Fault value	
	Phase L1/L2/L3	Phase L1/L2/L3	
Vector shift	0°/240°/120°	10°/250°/130°	Leading angle
	0°/240°/120°	350°/240°/120°	Lagging angle
Voltage	63,5V	58V/55V	Under voltage
	63,5V	68V/72V	Over voltage
Frequency	50Hz	47Hz/45Hz	Under

Testing protection functions

Pickup tests

Vector shift leading angle (3phase)

Same start value is used for all tests in "Ramping" instrument

Make one pickup test for leading angle in the ramp instrument.

Start value

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	63.50 V	0.0 °	50.000 Hz
U2	63.50 V	240.0 °	50.000 Hz
U3	63.50 V	120.0 °	50.000 Hz

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Ramp speed

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	0.00 ΔV/s	0.2 Δ°/s	0.000 ΔHz/s
U2	0.00 ΔV/s	0.2 Δ°/s	0.000 ΔHz/s
U3	0.00 ΔV/s	0.2 Δ°/s	0.000 ΔHz/s

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Stop value

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	-----	10.0 °	-----
U2	-----	250.0 °	-----
U3	-----	130.0 °	-----

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Result

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	63.50 V	6.3 °	50.000 Hz
U2	63.50 V	246.3 °	50.000 Hz
U3	63.50 V	126.3 °	50.000 Hz

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Vector shift lagging angle

Use same test as for leading angle but change ramp speed and stop value.

Ramp speed

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	0.00 ΔV/s	-0.2 Δ°/s	0.000 ΔHz/s
U2	0.00 ΔV/s	-0.2 Δ°/s	0.000 ΔHz/s
U3	0.00 ΔV/s	-0.2 Δ°/s	0.000 ΔHz/s

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Stop value

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	-----	350.0 °	-----
U2	-----	230.0 °	-----
U3	-----	110.0 °	-----

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

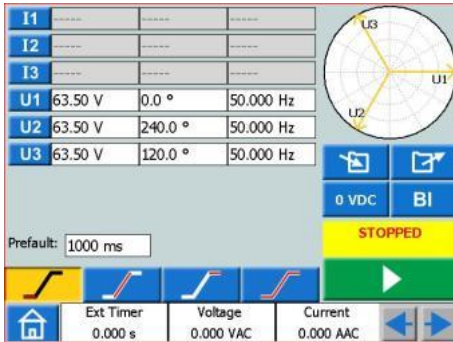
Testing protection functions

ROCOF increasing Hz (3-phase)

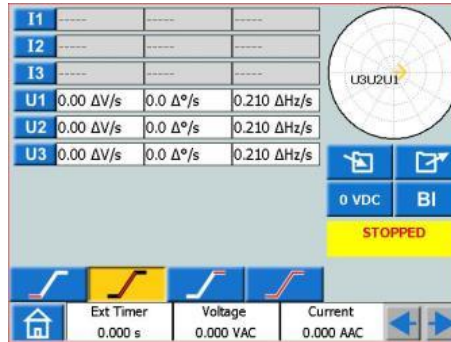
Block under voltage protection when testing ROCOF.

Make one pickup test for increasing frequency in the ramp instrument.

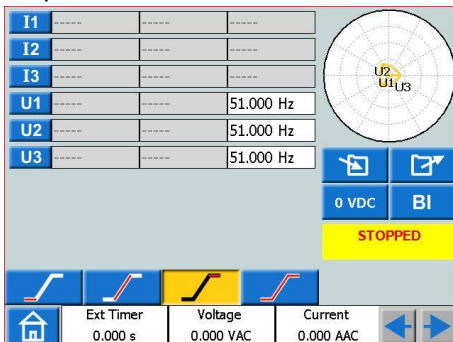
Start value



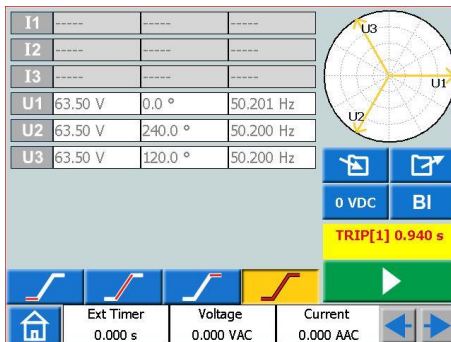
Ramp speed



Stop value



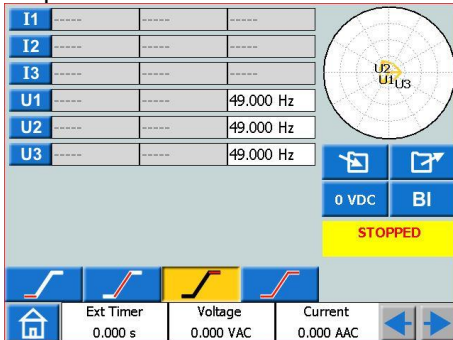
Result



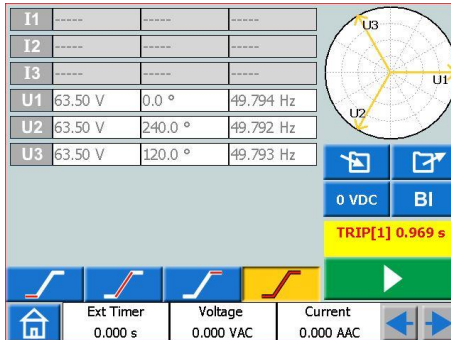
ROCOF decreasing Hz

Use same test for decreasing frequency but change stop value.

Stop value



Result

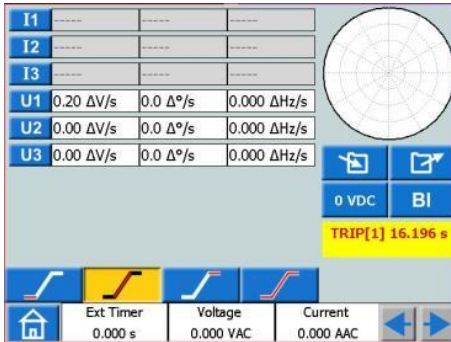


Testing protection functions

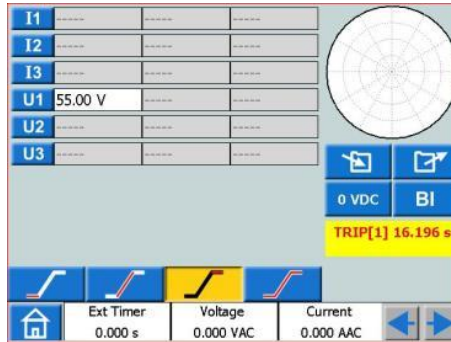
Under voltage

Make one pickup test for phase U1 and use same test for U2 and U3 with the same ramp speed and stop value.

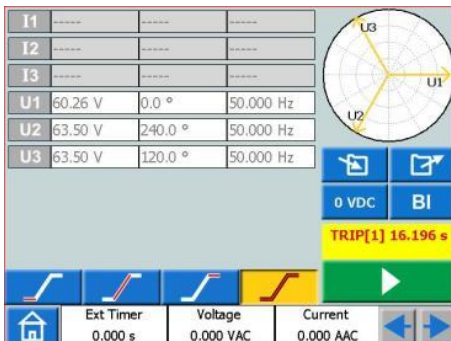
Ramp speed



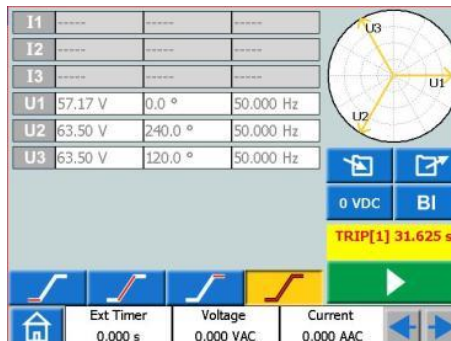
Stop value



Level 1 result



Level 2 result

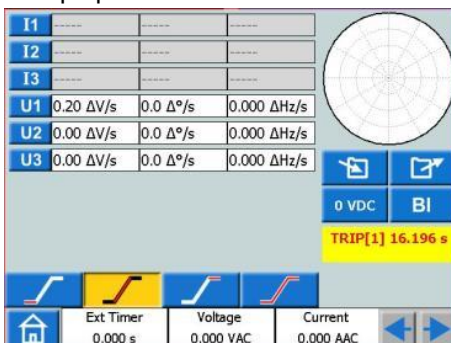


(Block level 1 in protection when checking level 2)

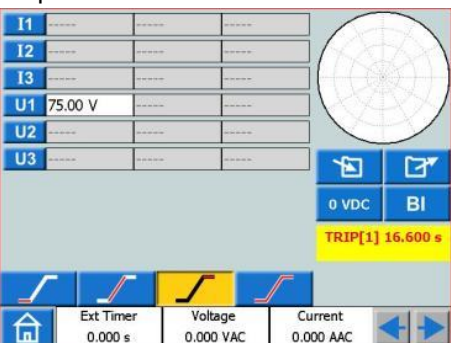
Over voltage

Use the same test as for under voltage and change stop value for phase U1, U2 and U3.

Ramp speed

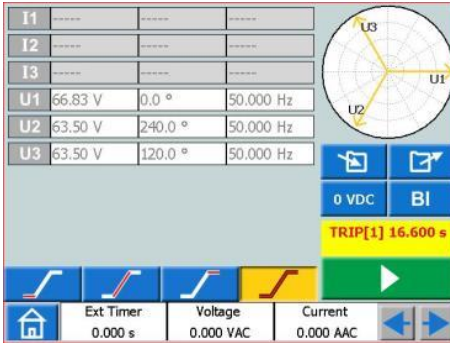


Stop value

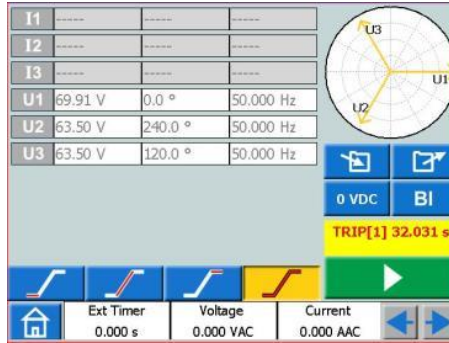


Testing protection functions

Level 1 Result



Level 2 Result

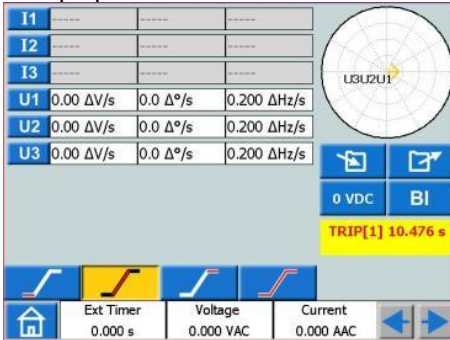


(Block level 1 in protection when checking level 2)

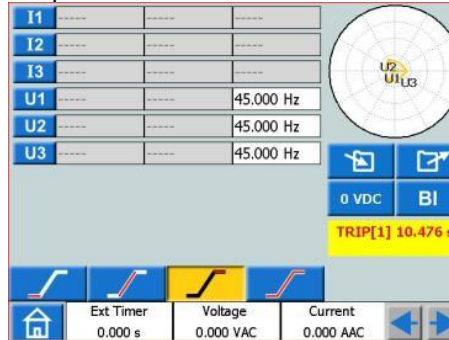
Under frequency (3-phase)

Make one pickup test.

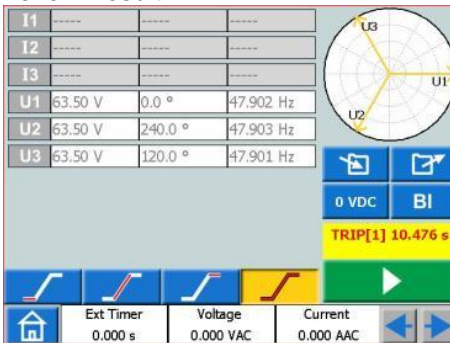
Ramp speed



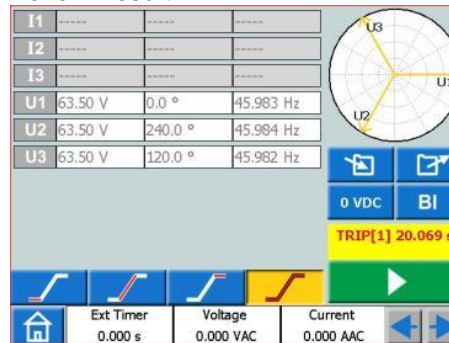
Stop value



Level 1 result



Level 2 result



(Block level 1 in protection when checking level 2)

Testing protection functions

Over frequency

Use same test as for under freq. but change stop value. The ramp speed is the same.

Ramp speed

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	0.00 ΔV/s	0.0 Δ°/s	0.200 ΔHz/s
U2	0.00 ΔV/s	0.0 Δ°/s	0.200 ΔHz/s
U3	0.00 ΔV/s	0.0 Δ°/s	0.200 ΔHz/s

TRIP[1] 10.476 s

Stop value

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	-----	-----	55.000 Hz
U2	-----	-----	55.000 Hz
U3	-----	-----	55.000 Hz

TRIP[1] 10.531 s

Level 1 result

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	63.50 V	0.0 °	52.109 Hz
U2	63.50 V	240.0 °	52.109 Hz
U3	63.50 V	120.0 °	52.110 Hz

TRIP[1] 10.531 s

Level 2 result

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	63.50 V	0.0 °	54.031 Hz
U2	63.50 V	240.0 °	54.031 Hz
U3	63.50 V	120.0 °	54.032 Hz

TRIP[1] 20.141 s

(Block level 1 in protection when checking level 2)

Timing tests

Vectorshift leading angle/lagging angle (3-phase) Over/Under frequency (3-phase)
Make one time test in the sequencer instrument.

Pre-fault

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	63.50 V	0.0 °	50.000 Hz
U2	63.50 V	240.0 °	50.000 Hz
U3	63.50 V	120.0 °	50.000 Hz

Prefault 1(13) 1000 ms

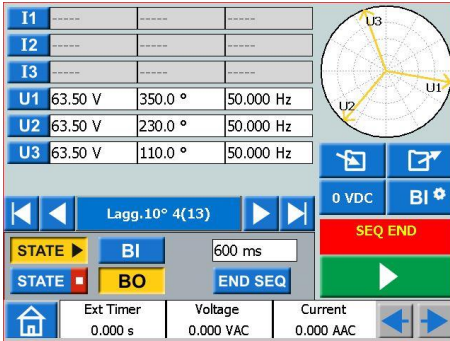
Vector shift leading angle 10 degree

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	63.50 V	10.0 °	50.000 Hz
U2	63.50 V	250.0 °	50.000 Hz
U3	63.50 V	130.0 °	50.000 Hz

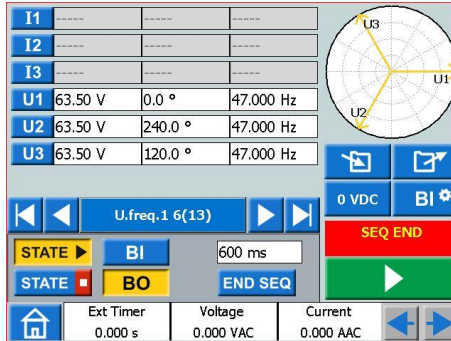
Lead10° 2(13) 600 ms

Testing protection functions

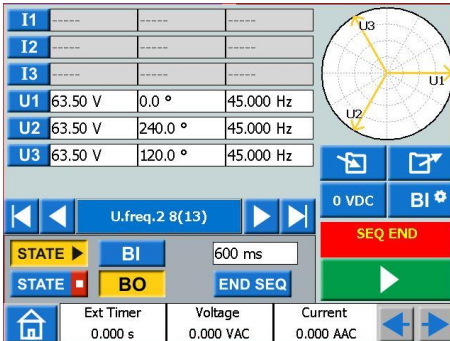
Vector shift lagging angle 10 degree



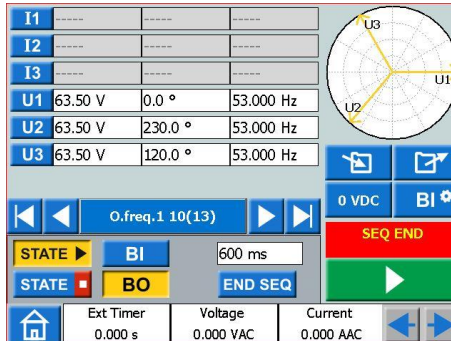
Under frequency level 1



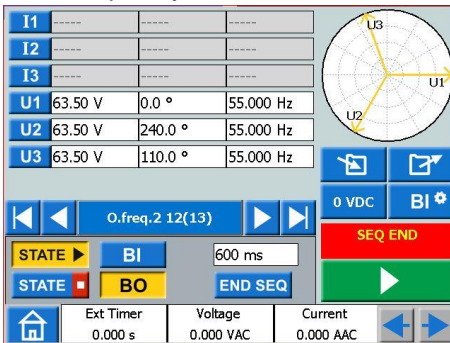
Under frequency level 2



Over frequency level 1



Over frequency level 2



Copy state 1(Pre-fault) into state 3, 5, 7, 9, 11 and 13. Set state 13 to “END SEQ”

Result

#	U1: V	°	Hz	U2: V	°	Hz	U3: V	°	Hz	BI	Time...	BO
1	63.50	0.0	50.0...	63.50	240.0	50.0...	63.50	120.0	50.0...	2	1000	0
2	63.50	10.0	50.0...	63.50	250.0	50.0...	63.50	130.0	50.0...	2	337	1
3	63.50	0.0	50.0...	63.50	240.0	50.0...	63.50	120.0	50.0...	2	1000	0
4	63.50	350.0	50.0...	63.50	230.0	50.0...	63.50	110.0	50.0...	2	329	1
5	63.50	0.0	50.0...	63.50	240.0	50.0...	63.50	120.0	50.0...	1	1000	0
6	63.50	0.0	47.0...	63.50	240.0	47.0...	63.50	120.0	47.0...	1	504	1
7	63.50	0.0	50.0...	63.50	240.0	50.0...	63.50	120.0	50.0...	1	1000	0
8	63.50	0.0	45.0...	63.50	240.0	45.0...	63.50	120.0	45.0...	1	110	1
9	63.50	0.0	50.0...	63.50	240.0	50.0...	63.50	120.0	50.0...	1	1000	0
10	63.50	0.0	53.0...	63.50	230.0	53.0...	63.50	120.0	53.0...	1	529	1
11	63.50	0.0	50.0...	63.50	240.0	50.0...	63.50	120.0	50.0...	1	1000	0
12	63.50	0.0	55.0...	63.50	240.0	55.0...	63.50	110.0	55.0...	1	124	1

Testing protection functions

ROCOF increasing Hz

Use same test as in pickup tests and change ramp speed.

Ramp speed

I1			
I2			
I3			
U1	0.00 ΔV/s	0.0 Δ°/s	0.250 ΔHz/s
U2	0.00 ΔV/s	0.0 Δ°/s	0.250 ΔHz/s
U3	0.00 ΔV/s	0.0 Δ°/s	0.250 ΔHz/s

0 VDC BI

STOPPED

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Result

I1			
I2			
I3			
U1	63.50 V	0.0 °	50.130 Hz
U2	63.50 V	240.0 °	50.131 Hz
U3	63.50 V	120.0 °	50.131 Hz

0 VDC BI

TRIP[1] 0.508 s

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

ROCOF decreasing Hz

Use same test as for increasing and change stop value to same as pick up test.

Ramp speed

I1			
I2			
I3			
U1	0.00 ΔV/s	0.0 Δ°/s	0.250 ΔHz/s
U2	0.00 ΔV/s	0.0 Δ°/s	0.250 ΔHz/s
U3	0.00 ΔV/s	0.0 Δ°/s	0.250 ΔHz/s

0 VDC BI

STOPPED

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Result

I1			
I2			
I3			
U1	63.50 V	0.0 °	49.867 Hz
U2	63.50 V	240.0 °	49.866 Hz
U3	63.50 V	120.0 °	49.867 Hz

0 VDC BI

TRIP[1] 0.518 s

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Under voltage

Make the time test in the sequencer instrument.

Pre-fault

I1			
I2			
I3			
U1	63.50 V	0.0 °	50.000 Hz
U2	63.50 V	240.0 °	50.000 Hz
U3	63.50 V	120.0 °	50.000 Hz

0 VDC BI

SEQ END

STATE BI 1000 ms

STATE BO END SEQ

Ext Timer 0.000 s Voltage 0.000 VAC Current 0.000 AAC

Level 1

I1			
I2			
I3			
U1	58.00 V	0.0 °	50.000 Hz
U2	63.50 V	240.0 °	50.000 Hz
U3	63.50 V	120.0 °	50.000 Hz

0 VDC BI

SEQ END

STATE BI 1000 ms

STATE BO END SEQ

Ext Timer 0.000 s Voltage 0.00 VDC Current 0.000 AAC

Testing protection functions

Level 2

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	55.00 V	0.0 °	50.000 Hz
U2	63.50 V	240.0 °	50.000 Hz
U3	63.50 V	120.0 °	50.000 Hz

Copy state 1 into state 3, 5, 7, 9 and 11 (pre-fault)
 Copy state 2 into state 6 and 10 change to phase U2
 Copy state 4 into state 8 and 12 change to phase U3

Over voltage

Use the same sequence as in under voltage but change voltage level.

Level 1

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	68.00 V	0.0 °	50.000 Hz
U2	63.50 V	240.0 °	50.000 Hz
U3	63.50 V	120.0 °	50.000 Hz

Level 2

I1	-----	-----	-----
I2	-----	-----	-----
I3	-----	-----	-----
U1	72.00 V	0.0 °	50.000 Hz
U2	63.50 V	240.0 °	50.000 Hz
U3	63.50 V	120.0 °	50.000 Hz

Result under voltage

#	U1:V	U2:V	U3:V	BI	Time...
1	63.50	63.50	63.50		1000
2	58.00	63.50	63.50	1	503
3	63.50	63.50	63.50		1000
4	55.00	63.50	63.50	1	110
5	63.50	63.50	63.50		1000
6	63.50	58.00	63.50	1	515
7	63.50	63.50	63.50		1000
8	63.50	55.00	63.50	1	110
9	63.50	63.50	63.50		1000
10	63.50	63.50	58.00	1	515
11	63.50	63.50	63.50		1000
12	63.50	63.50	55.00	1	110
Σt-S1					6863

Condensed

Result over voltage

#	U1:V	U2:V	U3:V	BI	Time...
1	63.50	63.50	63.50		1000
2	68.00	63.50	63.50	1	517
3	63.50	63.50	63.50		1000
4	72.00	63.50	63.50	1	110
5	63.50	63.50	63.50		1000
6	63.50	68.00	63.50	1	515
7	63.50	63.50	63.50		1000
8	63.50	72.00	63.50	1	110
9	63.50	63.50	63.50		1000
10	63.50	63.50	68.00	1	516
11	63.50	63.50	63.50		1000
12	63.50	63.50	72.00	1	111
Σt-S1					6879

Condensed