

How to test 47 Phase unbalance protection in SEPAM relays:

The use 47 Ansi code is protection against phase unbalance caused by:

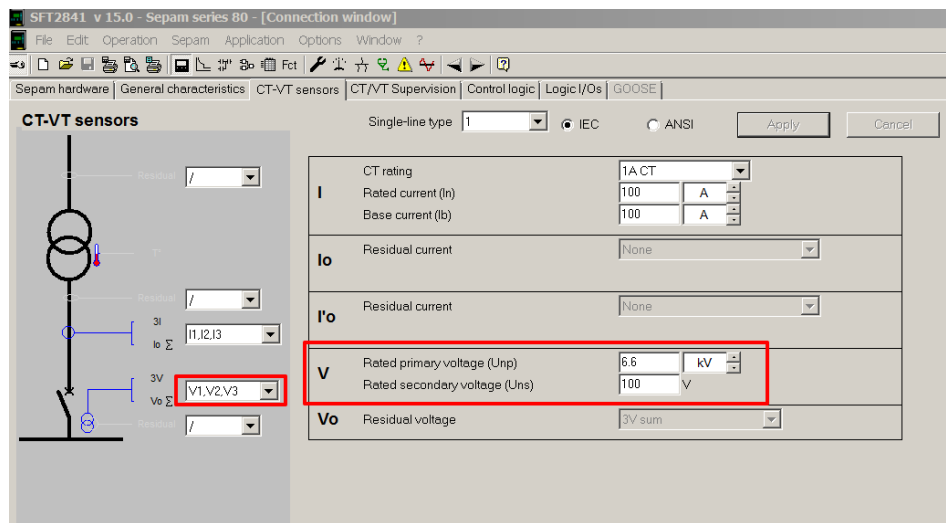
1. Phase inversion (phase rotation)
2. Unbalanced power supply
3. Distant fault

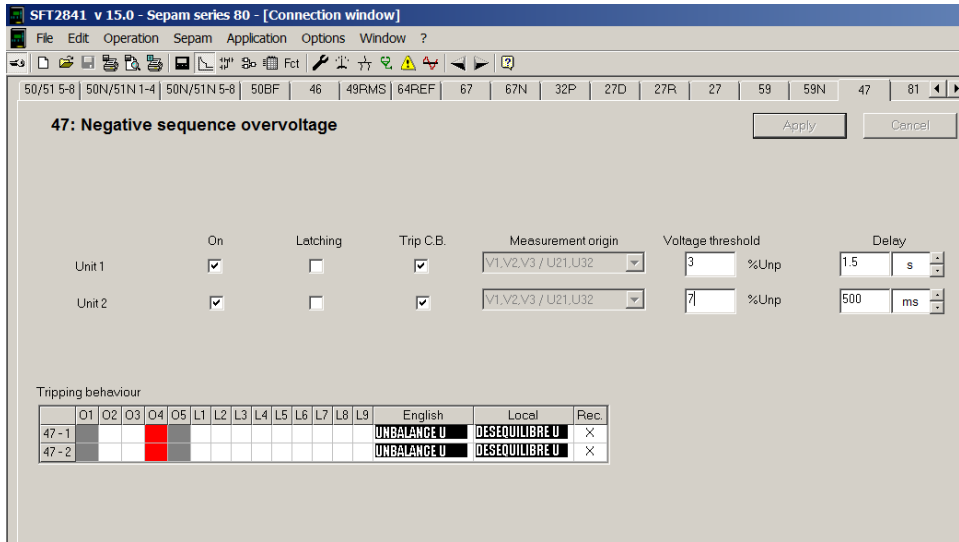
Scenario No.1: Test the first issue in order to trip in phase rotation condition (worst unbalance condition). It is easy to test this scenario: you can inject V1, V2, and V3 in a normal phase angle with nominal values but swap V1 and V2, or any other pair of voltages, at relay terminals.

Let's assume you set voltage sensors and 47 protection on Sepam as below:

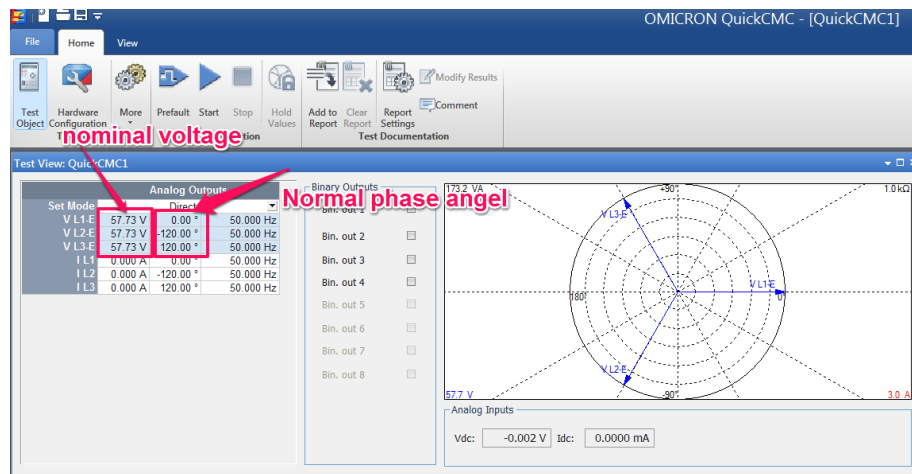
VT: $6600/\sqrt{3}$ V / $100/\sqrt{3}$ V

Settings: Unit 1 at 3% Unp with tripping time 1.5 sec
Unit 2 at 7% UNp with tripping time 0.5 sec





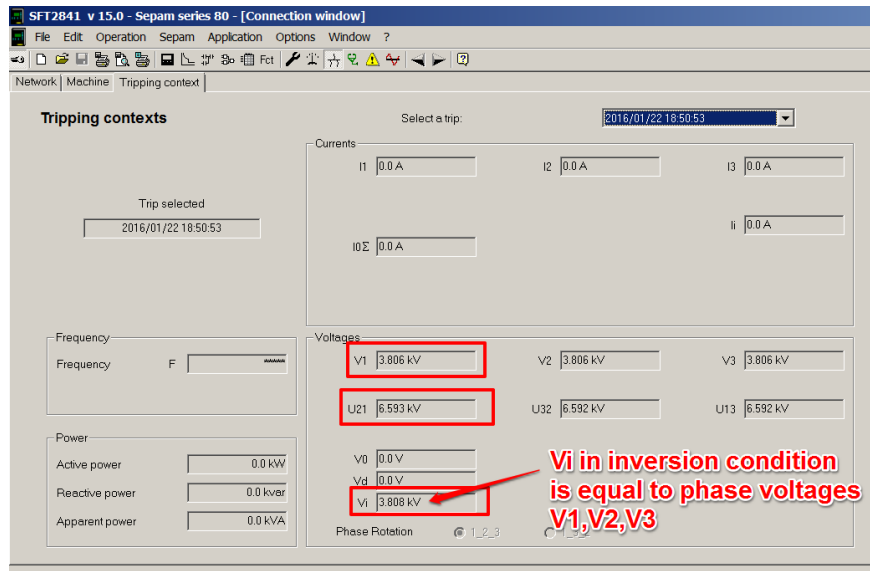
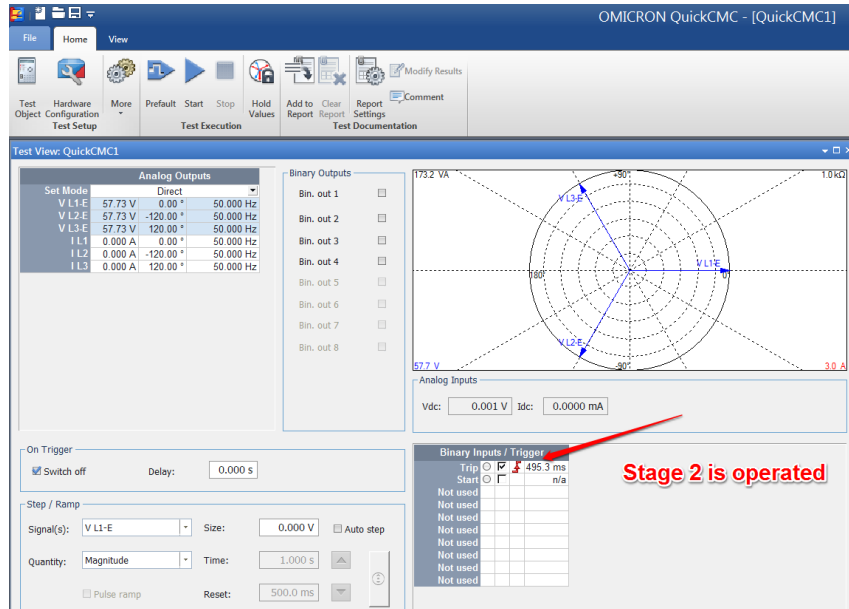
Then you inject nominal voltage and normal phase angle for each phase as below:



Before injecting voltage please do not to forget to swap the wiring between Omicron (or any other test set) and relay; as an illustration swap V1 and V2. In other words, you need to connect voltage output channel No. 1 of Omicron to voltage input channel No.2 of relay and vice versa.

Here below you see the Sepam setting for negative sequence overvoltage 47 protection function: I would like to grab your attention into the fact that in Sepam relays all voltage settings are done according to Unp voltage reference. So it is very important issue while you're setting any voltage protection function. As an illustration, if you set voltage threshold to 3%, the tripping negative sequence value would be $3\% \times 6.6 \text{ kV} = 198 \text{ V}$ and for threshold of 7%, it would be $7\% \times 6.6 \text{ kV} = 462 \text{ V}$. In next test scenario it is explained how to test this threshold as well.

Here after you'll find the tripping report from Omicron test set and tripping contexts report extracted from Sepam.

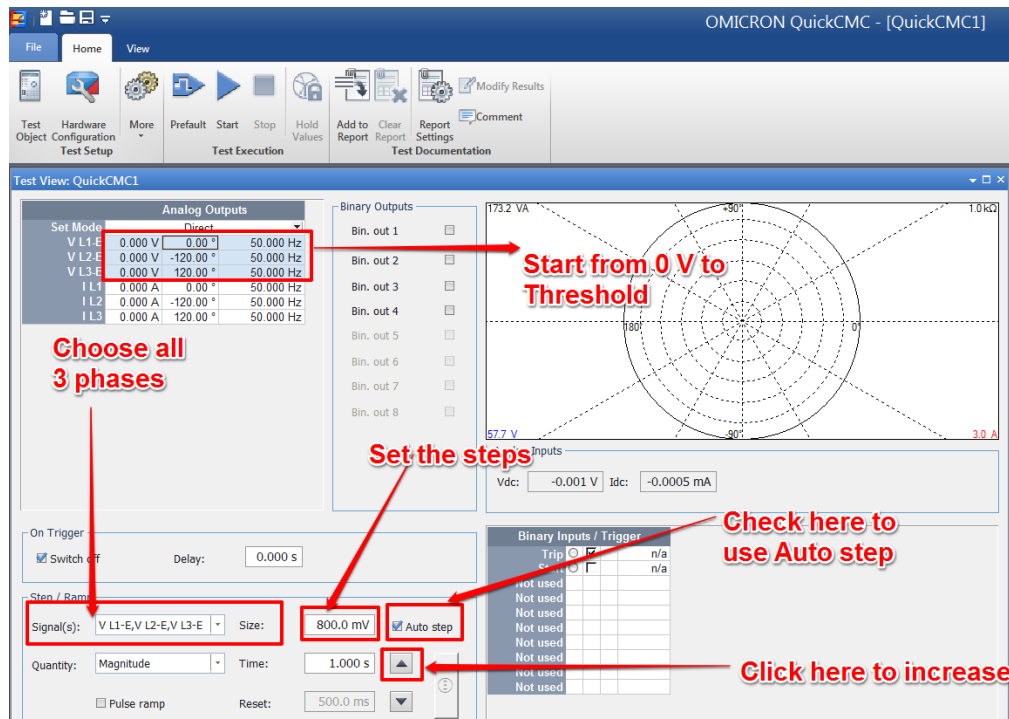


In this case, where we swapped the wiring between two phases, worst condition of unbalanced system is created. As you can see, the V_i (negative sequence voltage) reported by Sepam is the maximum value which is equal to phase voltage ($6.6 \text{ kV} / 1.732 = 3.81 \text{ kV}$)

Scenario No.2: Test the unbalance phase voltage caused by any unbalance situation of power supply or any distant fault. So for these types of issue you can test the threshold of function. There are two ways to test the threshold.

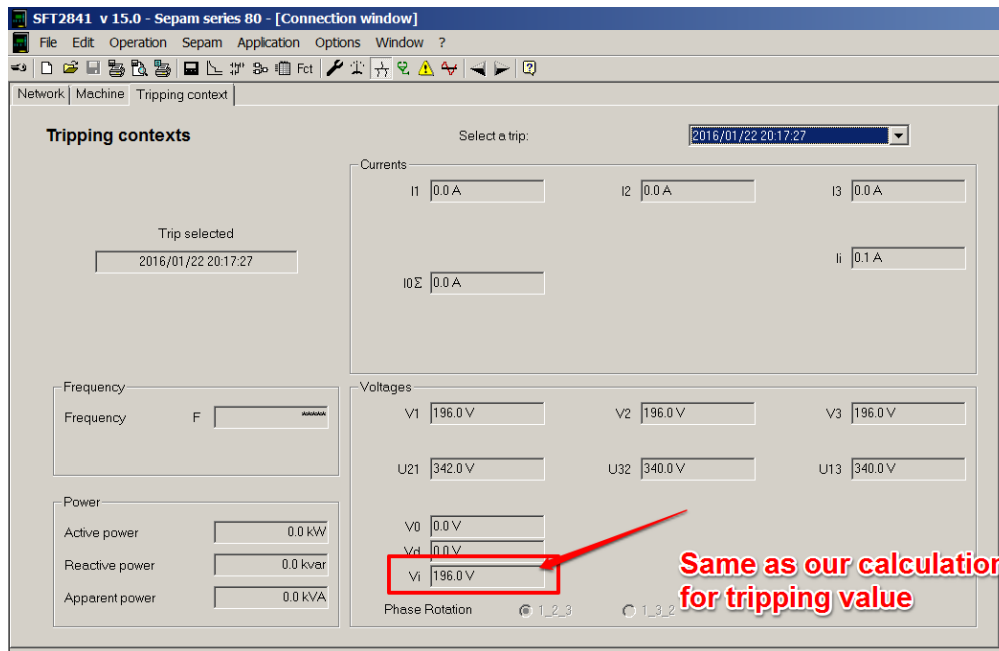
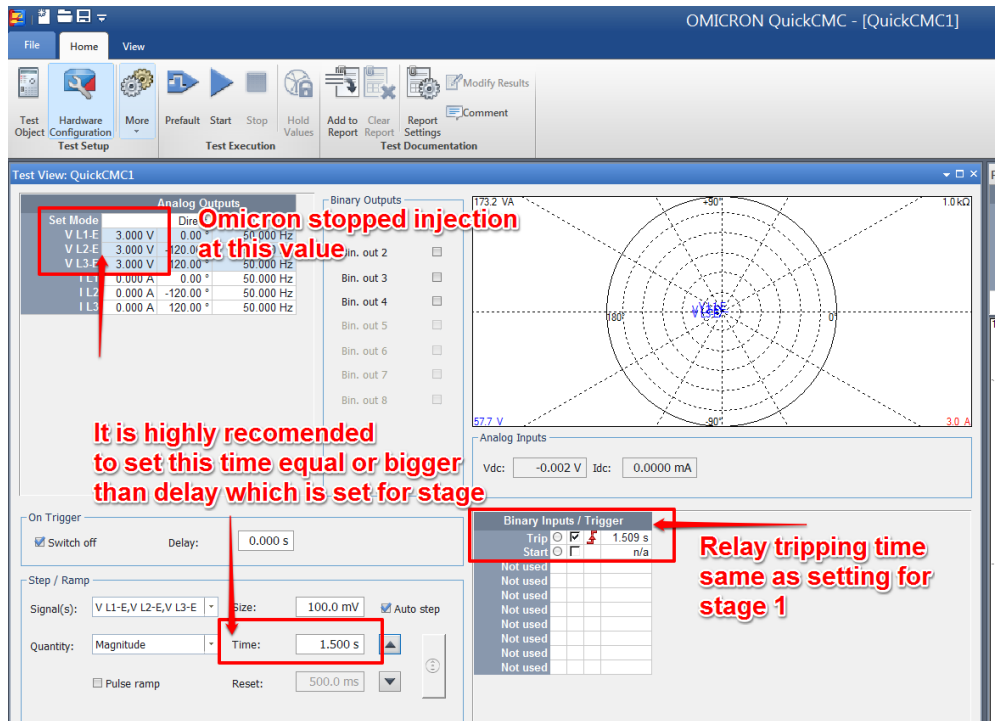
Scenario No.2 First Way:

One way is to keep your wiring same as scenario one, swapped two voltages, and gradually increase the voltage in all three phases at the same time from 0 V to reach the threshold. So threshold for 3% is 198 V and for 7% is 462 V and we can read the Sepam Negative sequence voltage (V_i) measured values in Ulf measurements screen of SFT2841 during the test. But for secondary injection, we start from 0 V and gradually increase voltage to 3% of secondary voltage ($3\% \cdot 100 \text{ V} = 3 \text{ V}$) and also to 7% ($7\% \cdot 100 \text{ V} = 7 \text{ V}$). These are the values that should be set on Omicron. Moreover there is an easy way on Omicron in order to gradually increase the voltage. In next page you can see the screen shot of this tool and its setting.

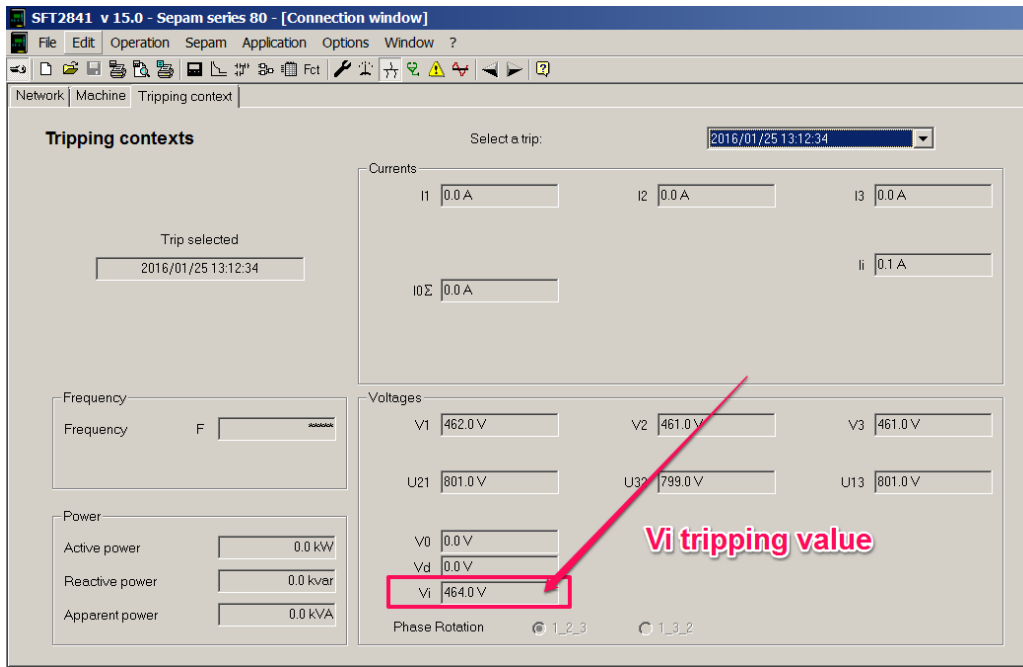
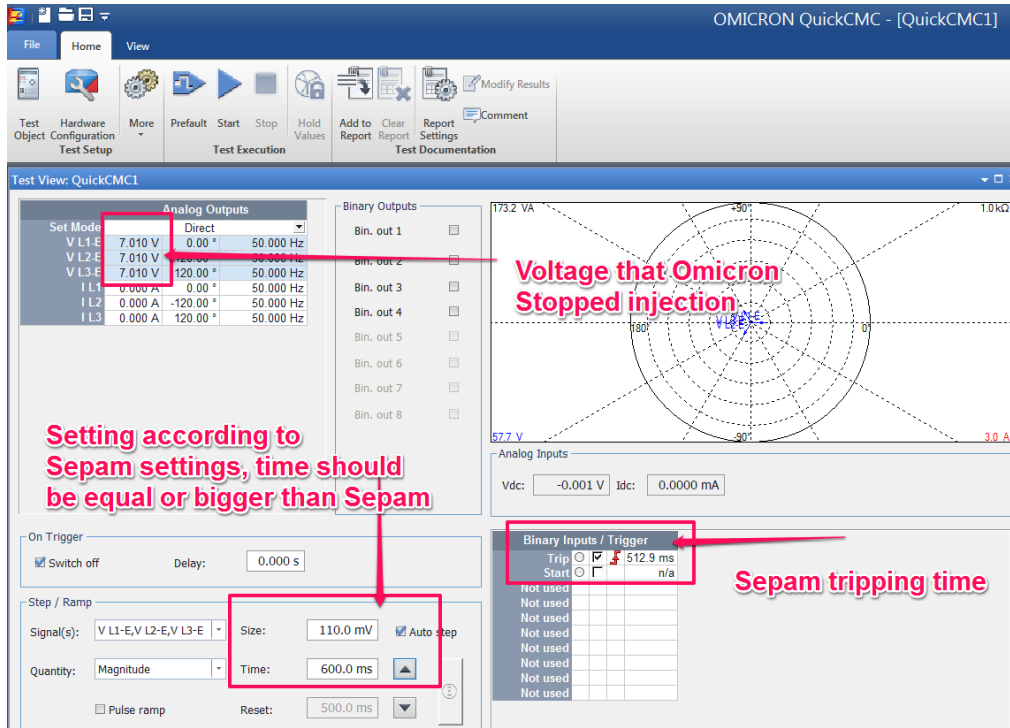


You can do two tests:

1. Start from 0 to 3% , Sepam should trip at 1.5 second, and measured value for V_i in tripping contexts should be 198 V (tripping value).



2. Start from 6.9% to reach over 7% (steps in 110 mV and time changes in 600 ms same as Sepam setting for stage 2). In order not to have any interaction between two Unit stages, it is recommended to inhibit Unit 1. Here after you see the Omicron report and Sepam tripping context. Relay tripped in 512ms and near to 464 V.



Scenario No.2 second Way:

This time you can wire the test set and relay connection normally, connecting voltage output channel No. 1 of Omicron to voltage input channel No.1 of relay (V1 of Omicron to V1 of relay and so on). In fact this case is the actual condition while we have got an unbalance condition during normal service. So maybe some customer ask to test 47 function without any changes on wiring.

To create the unbalance condition, this time we inject nominal value on all channels, and then start to reduce (or increase) the voltage just on one phase. In order to trip we need to reduce voltage as bellow:

$$U_{ns} / \sqrt{3} - [(3 * 3\%) * \sqrt{3} * U_{ns} / \sqrt{3}] = 57.73 - [0.09 * 100] = 48.73 \text{ V}$$

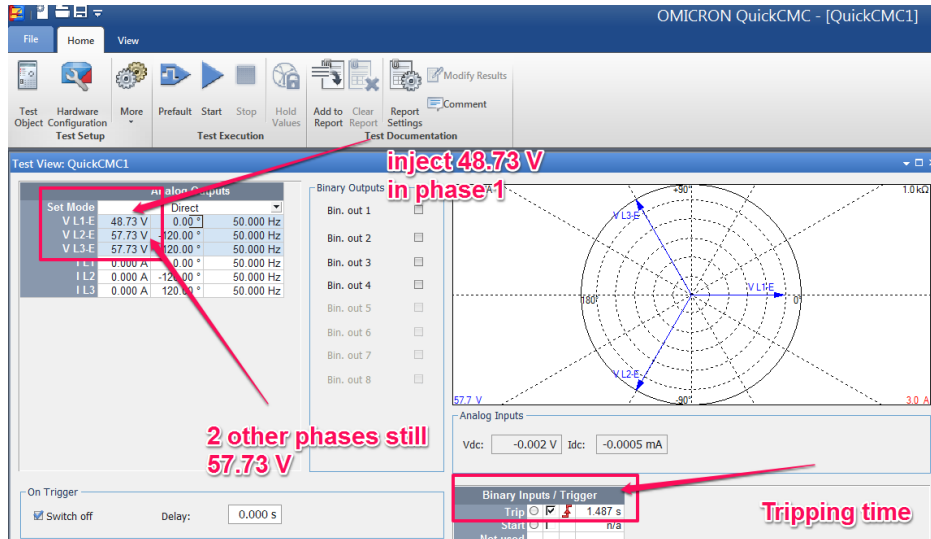
Where: U_{ns} is Secondary nominal voltage of VT: 100 V

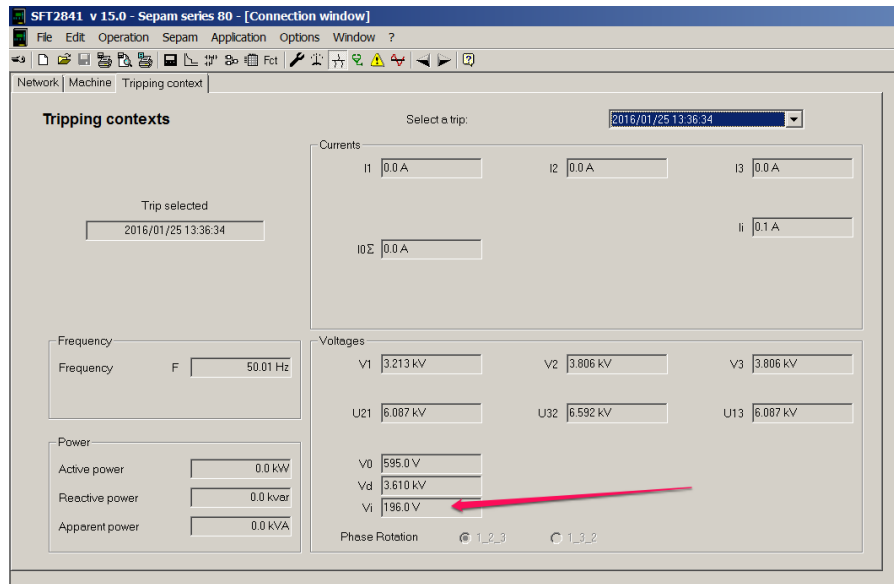
3% is the first stage setting of protection

3 is the factor while we change the voltage just in one phase (and not all phases)

It means that if you inject 48.73 V to the relay, it will create 3% unbalance condition, and relay will trip in 1.5 seconds and will report approximately 198 V in tripping contexts.

Note that the increasing ratio uses the same formulae with + instead of -. If you inject 66.73 V, it will also create 3% unbalance condition.





The same test could be done for second stage:

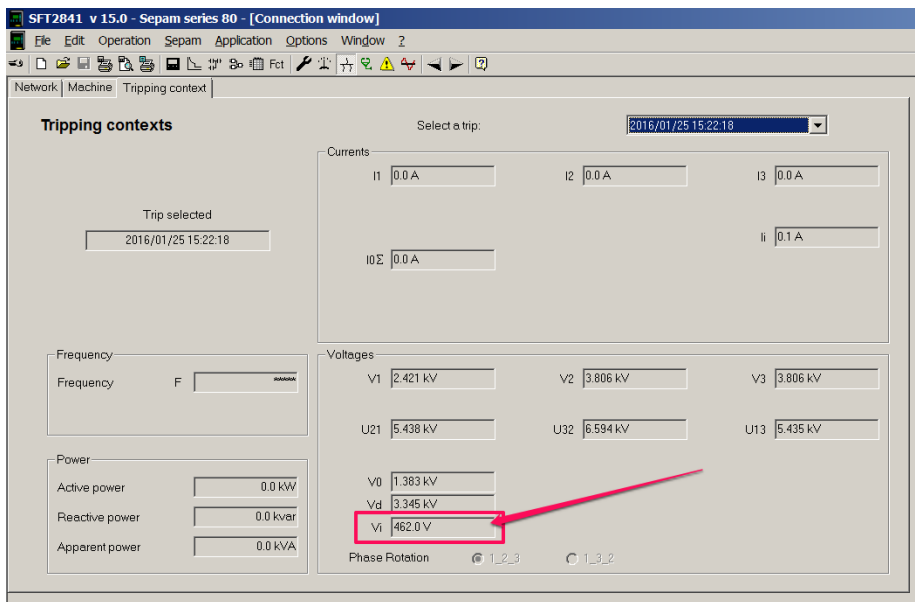
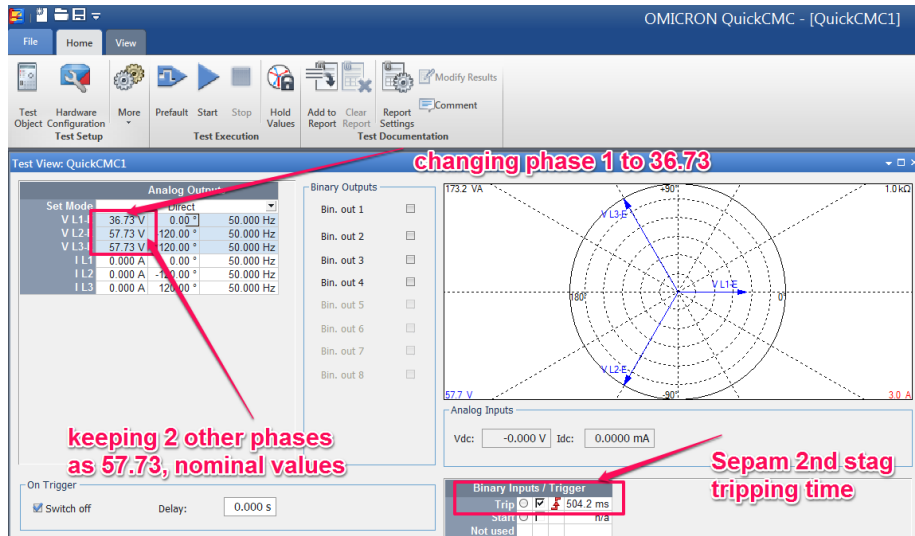
$$U_{ns} / \sqrt{3} - [(3 * 7\%) * \sqrt{3} * U_{ns} / \sqrt{3}] = 57.73 - [0.21 * 100] = 36.73 \text{ V}$$

Where: U_{ns} is Secondary nominal voltage of VT : 100 V

7% is the second stage setting of protection

3 is the factor while we change the voltage just in one phase (and not all phases)

It means that if you inject 36.73 V to the relay, it will create 7% unbalance condition, and relay will trip in 0.5 second and will report approximately 462 V in tripping contexts.



Two important recommendations before testing:

1. We grab your attention on the fact that knowing the measurement range of Negative Sequence Voltage is important while you are testing. Please check the table extracted from Sepam catalogue.

$$0.05 * V_{np} < \text{measurement range of } V_i < 1.2 * V_{np}$$

Where V_{np} is Primary phase to neutral voltage (= $U_{np} / \sqrt{3}$)

In our test the low range would be: $0.05 * (6600 / 1.732) = 190.75 \text{ V}$

In our test the high range would be: $1.2 * (6600 / 1.732) = 4572.75 \text{ V}$

Negative sequence voltage

Operation

This function calculates the value of the main negative sequence voltage V_i :

■ from the 3 main phase-to-neutral voltages:

□ phase rotation direction 1-2-3: $\vec{V}_i = \frac{1}{3} \times (\vec{V}_1 + a^2\vec{V}_2 + a\vec{V}_3)$

□ phase rotation direction 1-3-2: $\vec{V}_i = \frac{1}{3} \times (\vec{V}_1 + a\vec{V}_2 + a^2\vec{V}_3)$

■ or from the 2 main phase-to-phase voltages:

□ phase rotation direction 1-2-3: $\vec{V}_i = \frac{1}{3} \times (\vec{U}_{21} - a\vec{U}_{32})$

□ phase rotation direction 1-3-2: $\vec{V}_i = \frac{1}{3} \times (\vec{U}_{21} - a^2\vec{U}_{32})$

with $a = e^{j\frac{2\pi}{3}}$


The additional negative sequence voltage V_i is calculated in the same way:

■ from the 3 additional phase-to-neutral voltages $V'1$, $V'2$ and $V'3$

■ or from the 2 additional phase-to-phase voltages $U'21$ and $U'32$.

Readout

The measurements may be accessed via:

- the Sepam display via the  key
- the display of a PC with the SFT2841 software
- the communication link.

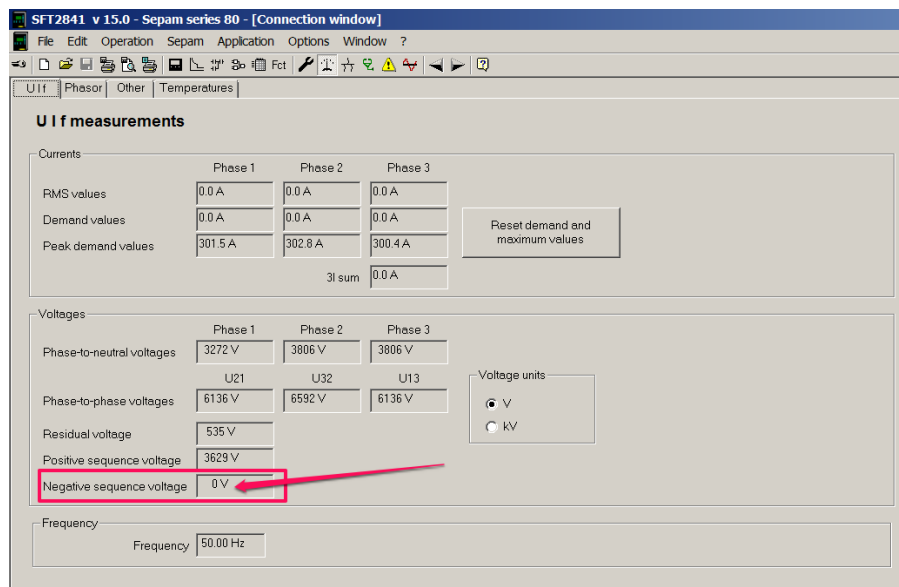
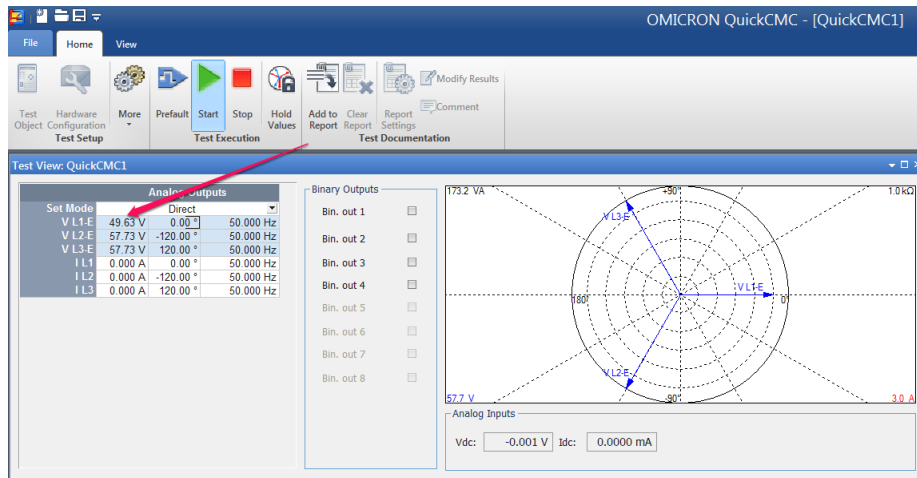
Characteristics

Measurement range	0.05 to 1.2 V_{np} ⁽¹⁾
Units	V or kV
Resolution	1 V
Accuracy	±2 % at V_{np}
Display format	3 significant digits
Refresh interval	1 second (typical)
<i>(1) V_{np}: primary rated phase-to-neutral voltage ($V_{np} = U_{np}/\sqrt{3}$).</i>	

To make it simpler: if you inject less than $(0.05 / 1.732 = 2.8\%)$ of unbalance condition then Sepam won't display any V_i value. Let's take an example and calculate for 2.7%:

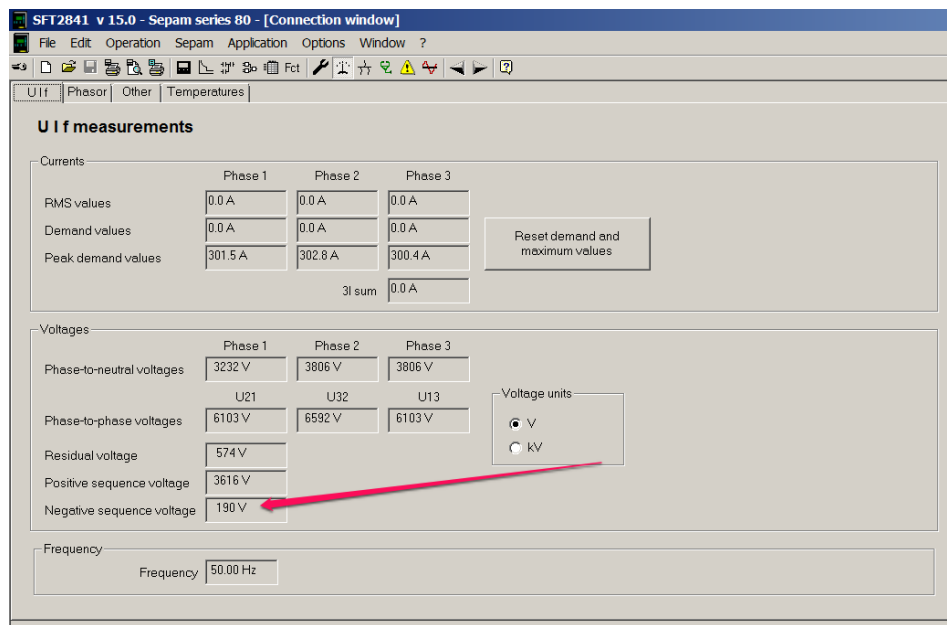
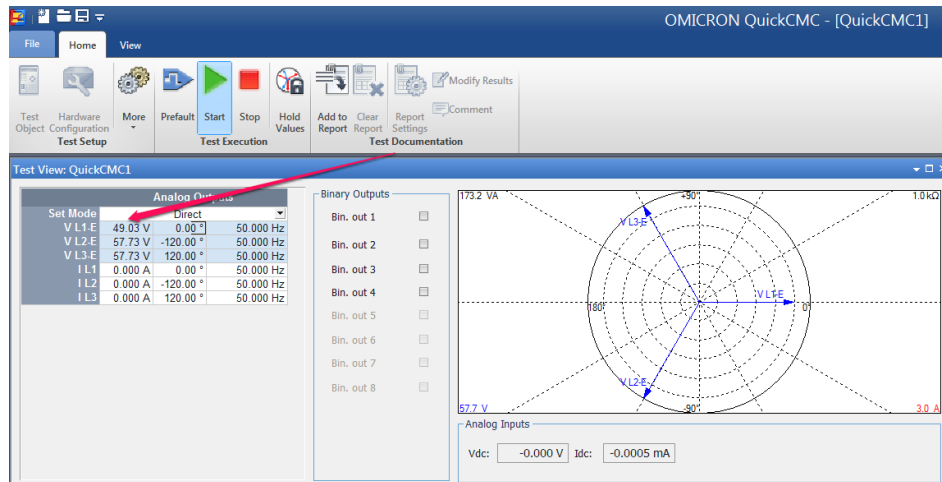
$$U_{ns} / \sqrt{3} - [(3 * 2.7\%) * \sqrt{3} * U_{ns} / \sqrt{3}] = 57.73 - [0.081 * 100] = 49.63 \text{ V}$$

If I inject 49.63 V on phase 1, and keep two other phases as 57.73 V, Sepam will not display any V_i on the measurement menu.



But if we inject 2.9% unbalance condition:

$Uns / \sqrt{3} - [(3 * 2.9\%) * \sqrt{3} * Uns / \sqrt{3}] = 57.73 - [0.087 * 100] = 49.03 \text{ V}$, we will now read 190V.



2. While you are testing 2nd scenario's first way, and increasing step by step all phases to make unbalance condition, it is important to consider the Sepam tripping time also. It is recommended to set time of step changing equal or even bigger than Sepam tripping time. This point is explained above.

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