# Testing impedance measurement based protection schemes

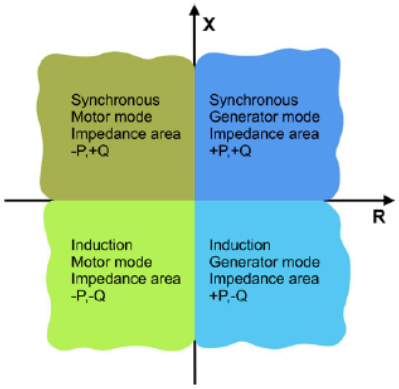
The impedance measurement schemes are widely used for protection of different assets within electric power systems. Relay protection devices utilizing such schemes are benefiting from continuous monitoring of both voltage and current quantities within the protected circuit and the calculated impedance value is employed to determine whether the circuit is operating in a normal condition or not.

**Important**
**Read and comply with the safety instructions in the User's manual.**

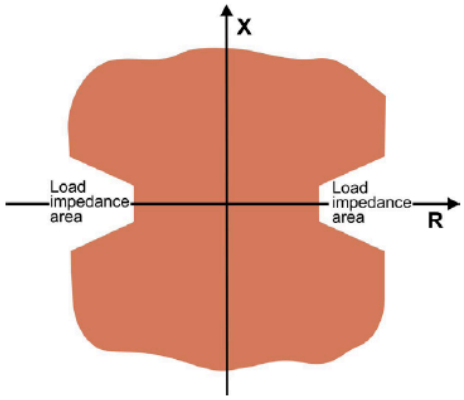
## Test procedures

- Testing field failure/loss of excitation protection (ANSI 40)
- Testing under impedance back up protection (ANSI 21B)
- Testing line distance protection (ANSI 21)

Depending on applications, as shown for examples in following figures, testing the behaviour of protection for measured impedance in different quadrants of R-X plane is of interest.




*R-X plain for typical machine protection applications*




*R-X plain for typical distance protection and under impedance applications*

The impedance instrument in SVERKER 900 is a powerful tool for simulating impedances in all four quadrants of the R-X plain and enables you to test a

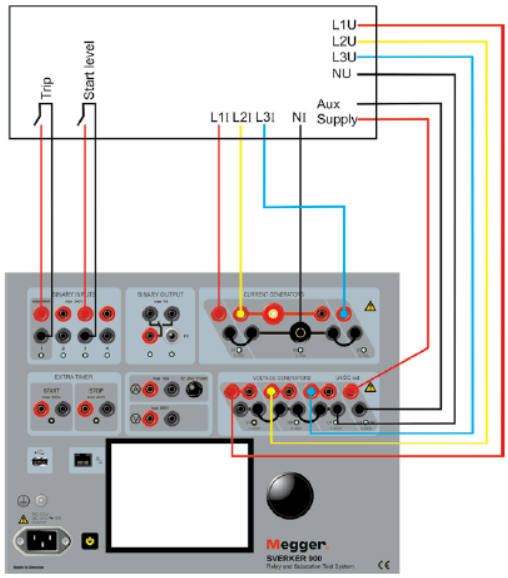
## Testing impedance measurement based protection schemes

majority of impedance based protections. (see section 4.5 in the SVERKER 900 User's manual.

### Connecting

1] Connect the SVERKER 900 according to the figure below, using the aux supply if needed.

2] Select the Binary Input for trip and the start level, (see the section "Binary Inputs" in the SVERKER 900 User's manual).




## Testing field failure/loss of excitation protection (ANSI 40)

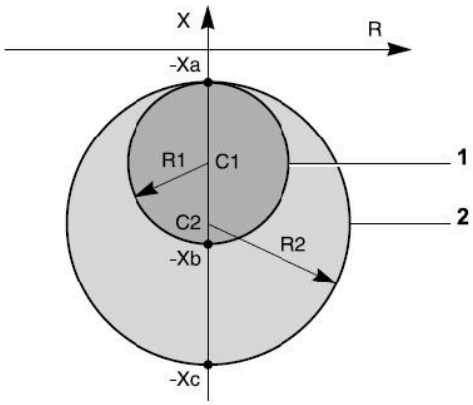
In synchronous machine operation loss of excitation is a common fault for reasons such as short circuit of the field windings, unexpected opening of a field breaker, etc. In any of these cases a machine starts drawing reactive power from the network and operates as a induction motor or generator.

Impedance measurement based field failure protections are effectively used to monitor synchronous motor/generator terminal impedances. In these schemes operating zones are normally located in the third and fourth quadrants since the measured terminal impedance at these quadrants represent a change of operating mode of the machine at field failures.

This protection scheme normally consists of more than one operating zone with respective timers to provide different tripping times for different load conditions. Moreover off set circular mho shapes are the most common characteristics.

### Settings

In this example the field failure protection (Sepam G87) with two offset mho zones as shown below is tested.




Settings are dependent on the power generator used. The manufacturer recommends the following settings for a 3.15 MVA generator.

Xa = 1.321 Ω
Xb = 13.907 Ω with time delay T1= 70 ms
Xc = 30.646 Ω with time delay T2 = 500 ms

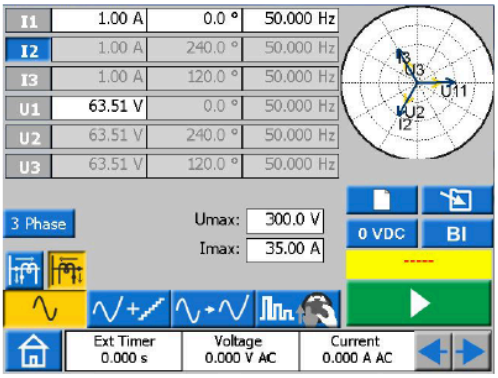
Where
Rated primary voltage Unp = 6.3 kV
Rated secondary voltage Uns = 110 V

## Testing impedance measurement based protection schemes

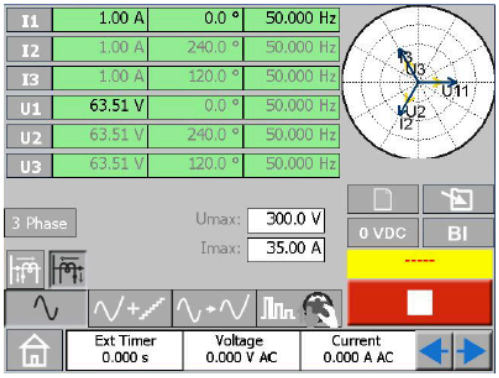
CT ratio: 100/1 A
Xd = 233%
X'd = 21%

### Wiring check and stability test

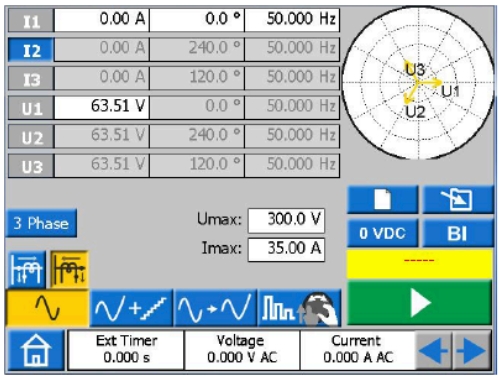
1] In "Prefault" view, select the correct CT direction (for this example to the test object) and set nominal secondary voltage and current as shown below.




2] Press the start button and read the corresponding measured voltage and current values from the relay.
If the wirings are correct and correct CT direction is selected the relay shall not trip and remain stable.

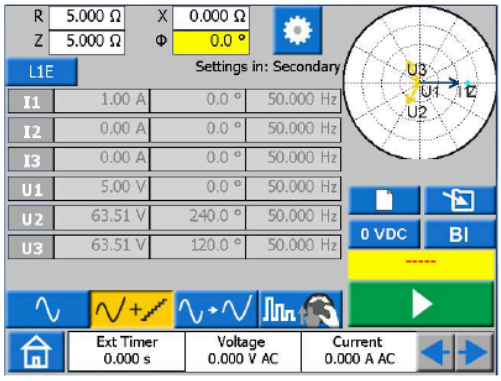


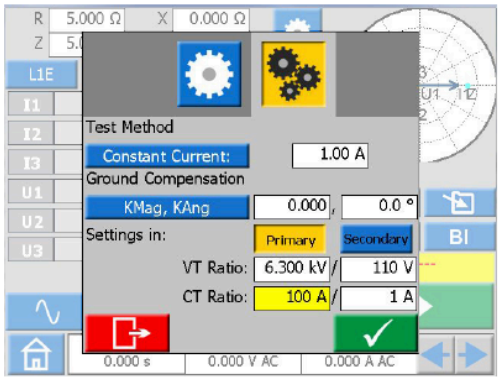

3] Before going forward with other tests remember to set back the current to zero in order to simulate no load condition as prefault state trough out your tests.




### Pick up test

1] In "Fault + Manual pickup search" view, set the VT and CT ratios under configuration menu if required.
In this example the characteristic is given in primary ohms therefore VT and CT ratios are set as shown below.

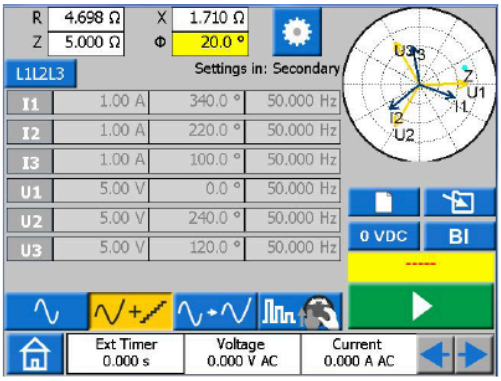


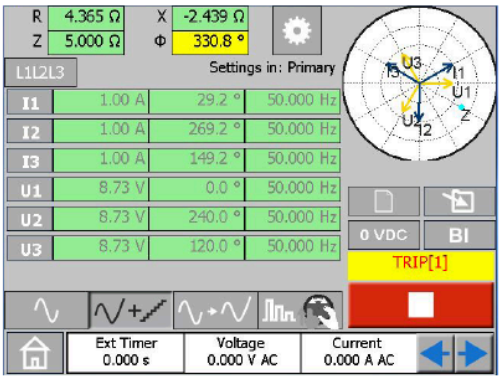

2] Next step is to select three phase fault type and place the test point outside the operating characteristic of the relay by setting the

## Testing impedance measurement based protection schemes

corresponding R-X or Z-Φ values in order to start searching for pick up.



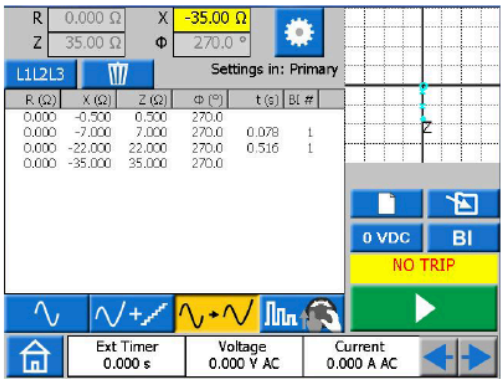

**3]** To manually search for pick-up, press the start button and move the test point toward the operating characteristic area by simply selecting one of the impedance settings and rotating the knob to change the selected value.
In this example the test point is moved from first quadrant to forth quadrant by changing Φ value. As it can be seen below, as the test point is entering the operating characteristic of the relay a trip signal is registered.




## Timing test

In Prefault-Fault view the trip time for test points of interest can be verified.

**1]** Start the test with the same last test point from pick up test or set a new test point and continue verifying trip times.
In this example moving on X axis and using few test points, trip times for zone 1 and zone 2 are verified as shown below.




**2]** Same procedure can be followed on any directions or areas of impedance plane to verify trip times.

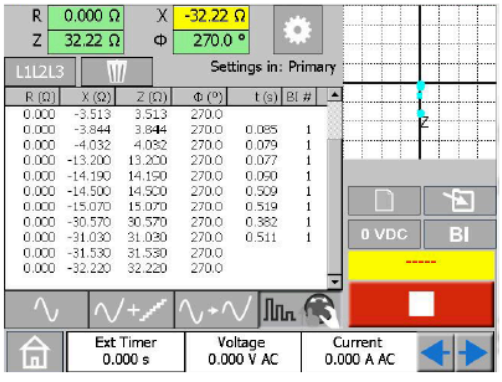
## Reach test

In "Manual binary search" view operating characteristic of the relay can be effectively verified.

**1]** Press the start button to generate with pre-fault settings while placing the test point. Select one of the impedance settings and rotate the knob for desired placement.

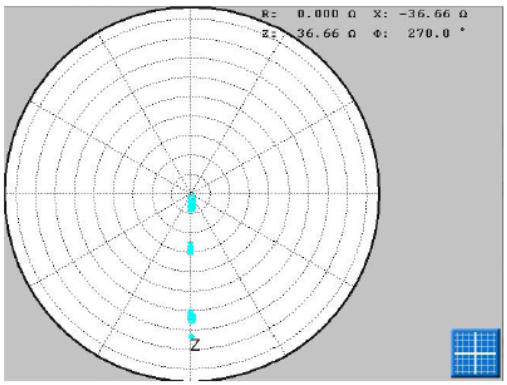
**2]** When you are ready press the knob to apply the fault settings and observe the registered trip time in the table.

**3]** Move the test point using the knob without stopping the test and press the knob to apply the new fault settings and to register new test result in the table, respectively.




In this example reach of zone 1 and zone 2 are found on X axis using few test points as shown above. For larger graphical view tap on the graph. You can also Toggle between Polar and Cartesian view as shown below.

## Testing impedance measurement based protection schemes




# Testing under impedance back up protection (ANSI 21B)

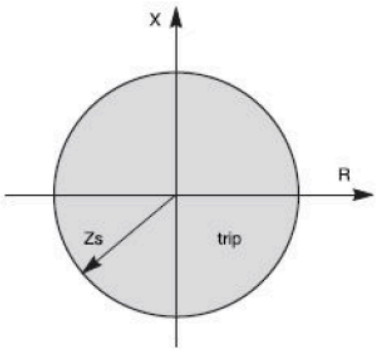
It is common to use under impedance protection to detect not cleared faults in the network. The most common application is backup phase to phase short circuit protection for generator/generator-transformer unit.

This protection scheme is normally consists of one operating zone with a timer to perform as a backup protection. Moreover circular mho shapes are the most common characteristics.

In normal operation condition the measured impedance seen by the relay is located outside of the operating zone and when a fault occurs the measured impedance falls into the operating zone. If the main protection does not operate within the predefined time, this protection will operate as backup and clear the fault.

## Settings

In this example the under impedance back up protection (Sepam G87) with circular operating characteristic as shown below is tested.




Settings are dependent on the power generator used. The manufacturer recommends 30% of the rated generator impedance setting for the same 3.15 MVA generator.

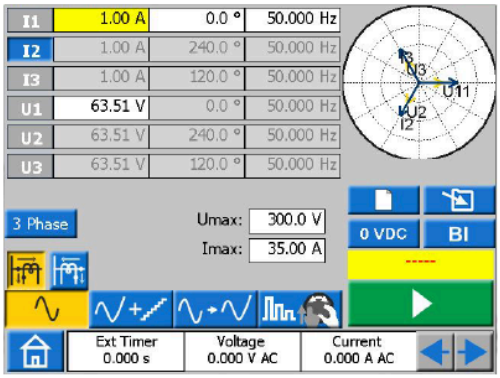
Zs = 0.30 x Zn = 3.77 Ω with time delay T= 900 ms

Where
Rated primary voltage Unp = 6.3 kV
Rated secondary voltage Uns = 110 V
CT ratio: 100/1 A
Zn= 12.59 Ω

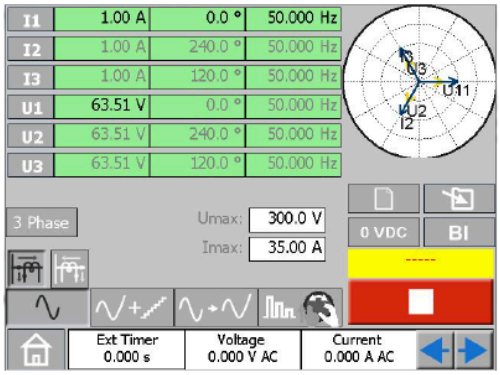
## Testing impedance measurement based protection schemes

### Wiring check and stability test

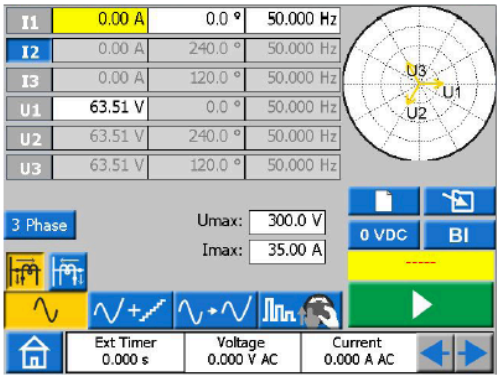
1] In "Prefault" view select the correct CT direction and set nominal secondary voltage and current as shown below.




2] Press the start button and read the corresponding measured voltage and current values from the relay.
If the wirings are correct and correct CT direction is selected the relay shall not trip and remains stable.

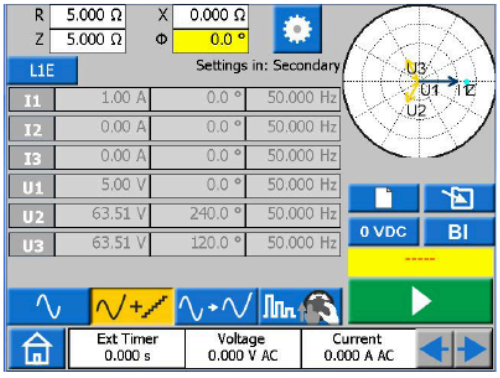


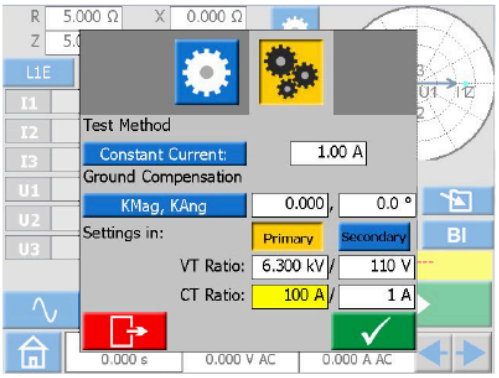

3] Before moving forward with other tests remember to set back the current to zero in order to simulate no load condition as pre-fault state trough out your tests.




### Pick up test

1] In "Fault + Manual pickup search" view, set the VT and CT ratios under configuration menu if required.
In this example the characteristic is given in primary ohms therefore VT and CT ratios are set as shown below..

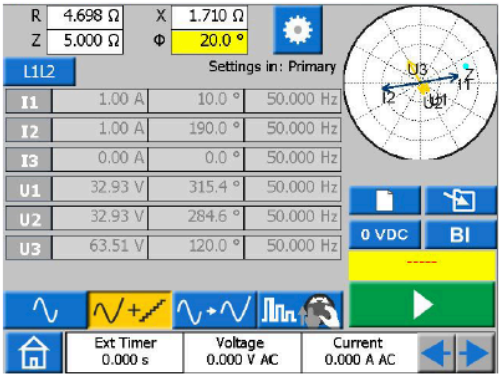


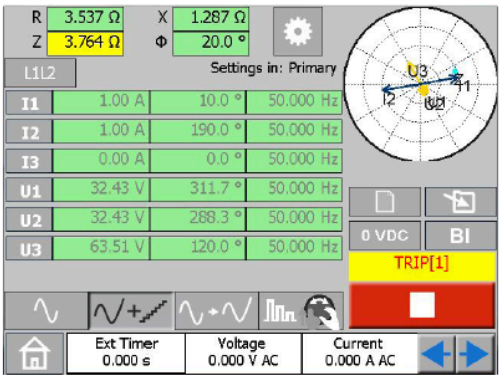

2] Next step is to select two phase fault type to simulate phase to phase short circuit and place the test point outside the operating characteristic area of the relay by setting the

## Testing impedance measurement based protection schemes

corresponding R-X or Z-Φ values in order to start searching for pick up.



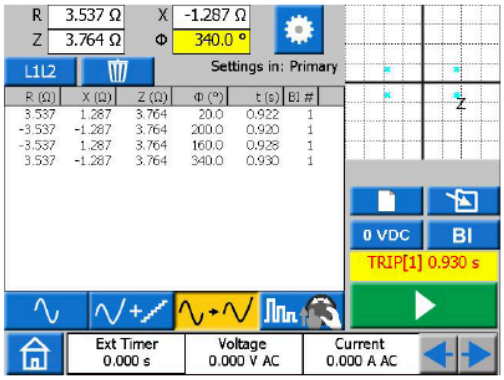

**3]** To manually search for pick-up, press the start button and move the test point toward the operating characteristic area by simply selecting one of the impedance settings and rotating the knob to change the selected value. In this example the test point is moved along constant angle Φ=20° by changing Z value. As it can be seen in below, as the test point is entering the operating characteristic area of the relay a trip signal is registered.



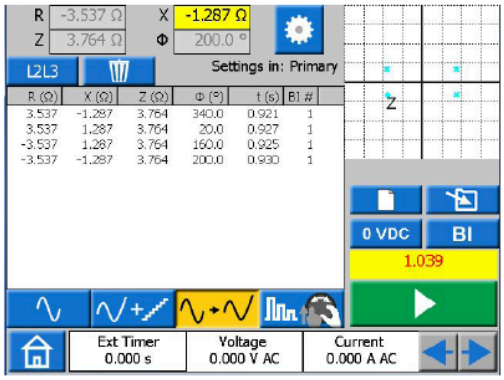

### Timing test

In Prefault-Fault view the trip time for test points of interest can be verified.

**1]** Start the test with the same last test point from pick up test or set a new test point and continue verifying trip times.
In this example four test points for verifying trip time in different quadrants are used as shown below.




**2]** Same procedure can be followed on any directions or areas of impedance plane to verify trip times.
Moreover, phase to phase faults for other combination of phases can be tested in the same way simply by selecting desired type of fault and collecting the test results for corresponding fault type as shown in following example for L2L3 faults.




### Reach test

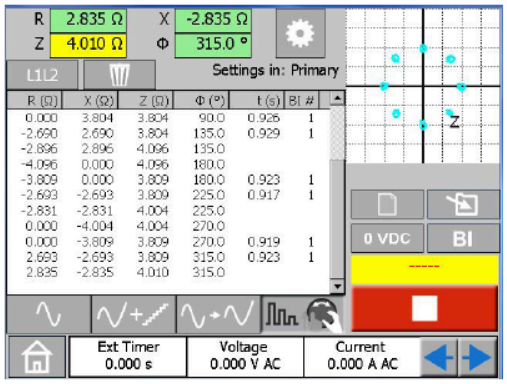
In "Manual binary search" view operating characteristic of the relay can be effectively verified.

**1]** Press the start button to generate with pre-fault settings while placing the test point. Select one of the impedance settings and rotate the knob for desired placement.

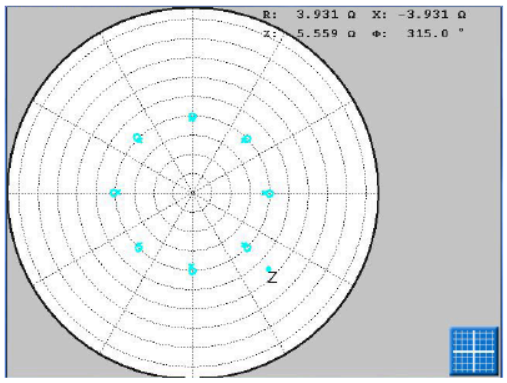
**2]** When you are ready press the knob to apply the fault settings and observe the registered trip time in the table. Move the test point using the knob without stopping the test and press the knob to apply the new fault settings and to register new test result in the table, respectively.

Megger

## Testing impedance measurement based protection schemes




In this example reach of this circular operating zone is found for angel intervals of 45° with reference to origin using few test points as shown above. For larger graphical view tap on the graph. You can also Toggle between Polar and Cartesian view as shown below.




Same procedure can be followed on any directions or areas of impedance plane to verify operating characteristic of the relay. Moreover, phase to phase faults for other combination of phases can be tested in the same way simply by selecting desired type of fault and collecting the test results for corresponding fault type.

# Testing line distance protection (ANSI 21)

In today networks more and more over headlines and cables are protected by line distance relays. This protection scheme is normally consists of more than one operating zone to perform also as a backup protection for the adjacent lines.

In normal operation condition the measured impedance seen by the relay is located outside of operating zones and when fault occurs the measured impedance moves inside impedance plane and may or may not enter and stays inside the predefined operating zones. Individual timer for operation of each zone is usually available.

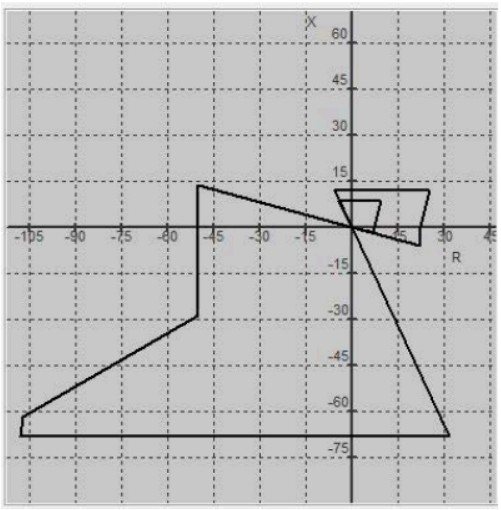
Operating characteristics of line distance relays can have different shapes based on technologies and methods provided by different vendors. (e.g. Mho, Quadrilateral, Lenz and etc.)

## Settings

Settings of distance protection are dependent on network configuration and have also different variants for different relay manufacturers which are out of scope of this application note.

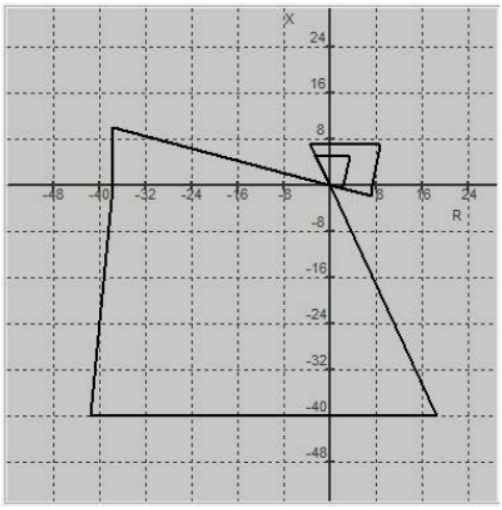
In this example the distance protection (ABB REL670) with 3 zones of quadrilateral characteristic for phase to ground faults and phase to phase faults as shown below is tested. The characteristics are presented in secondary ohms for:

Rated secondary voltage Uns = 110 V
Rated secondary current Ins= 1 A




Quadrilateral characteristic for phase to ground faults

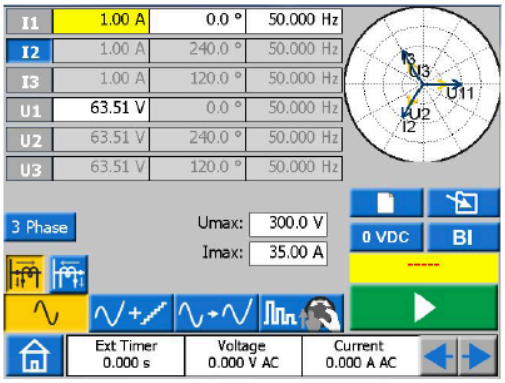
## Testing impedance measurement based protection schemes



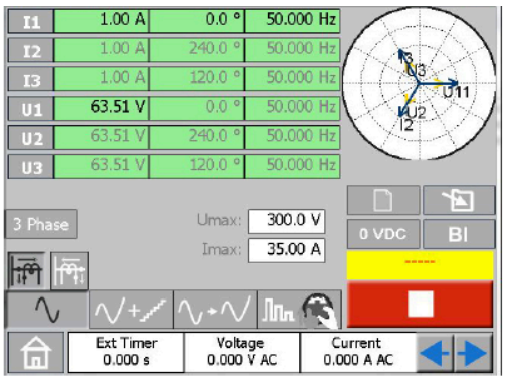

Quadrilateral characteristic for phase to phase faults

### Wiring check and stability test

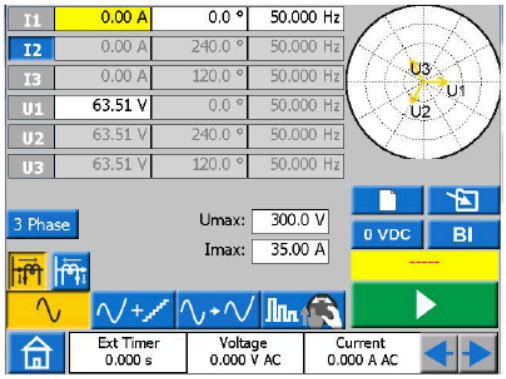
**1]** In "Prefault" view select the correct CT direction and set nominal secondary voltage and current as shown below.




**2]** Press the start button and read the corresponding measured voltage and current values from the relay.
If the wirings are correct and correct CT direction is selected the relay shall not operate and remains stable.




**3]** Before moving forward with other tests remember to set back the current to zero in order to simulate no load condition as pre-fault state trough out your tests.

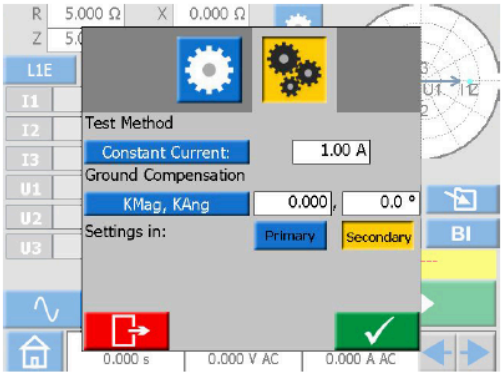



### Pick up test

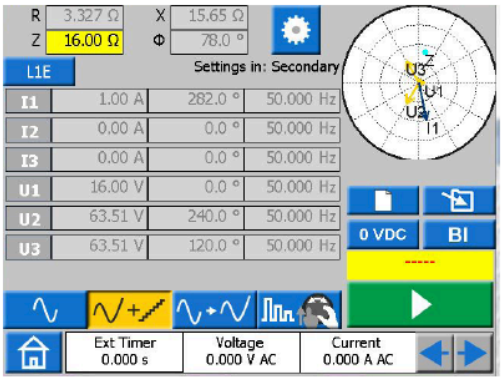
**1]** In "Fault + Manual pickup search" view set the ground compensation factors and VT and CT ratios under configuration menu if required.

In this example the characteristics are given in secondary ohms and phase to ground characteristics are defined in ohm per loop. As shown below the default settings can be used directly.

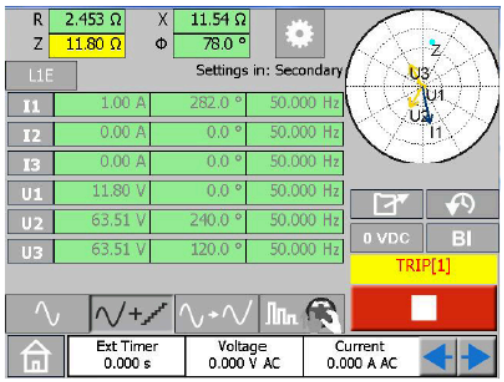
## Testing impedance measurement based protection schemes




**2]** Next step is to select fault type and place the test point outside the operating characteristic area of the relay by setting the corresponding R-X or Z-Φ values in order to start searching for pick up.



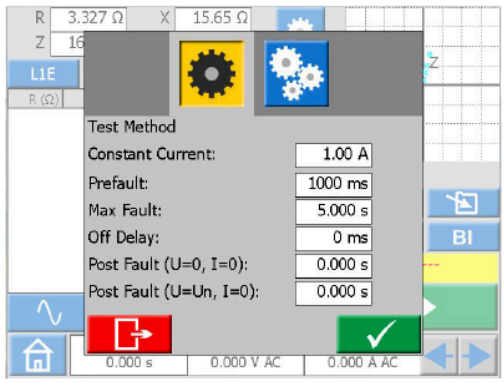

**3]** To manually search for pick-up, press the start button and move the test point toward the operating characteristic area by simply selecting one of the impedance settings and rotating the knob to change the selected value.
In this example the test point is moved along line angel Φ=78° by changing Z value. As it can be seen in below, as the test point is entering the operating characteristic area of the relay a trip signal is registered.




## Timing test

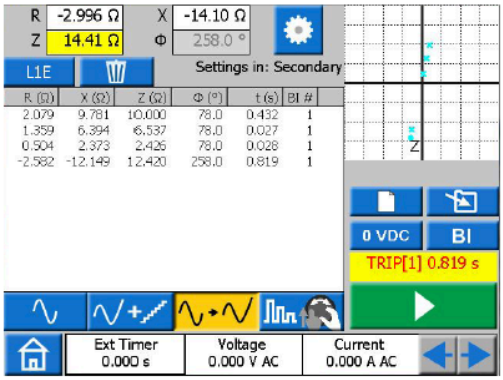
In Prefault-Fault view the trip time for test points of interest can be verified.

**1]** Under configuration menu set timer for Prefault and fault state. If applicable set Off Delay and Post Fault timers to verify the behaviour of the relay after operation. As shown below the default settings can be used directly.

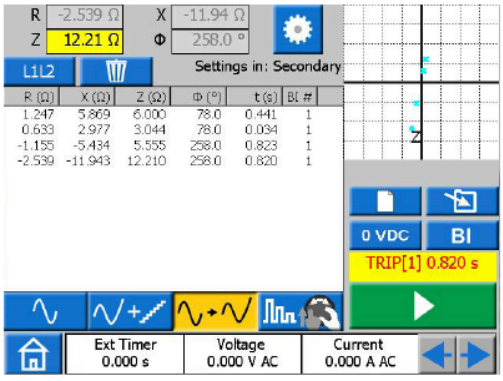



**2]** Start the test with the same last test point from pick up test or set a new test point and continue verifying trip times.
In this example moving along line angel Φ=78° and using few test points, trip times for zone 1, zone 2 and zone 3 are verified as shown below.

## Testing impedance measurement based protection schemes




**3]** Same procedure can be followed on any directions or areas of impedance plane to verify trip times.
Moreover, test for other type of faults can be tested in the same way simply by selecting desired type of fault and collecting the test results for corresponding fault type as shown in following example for L1L2 faults.

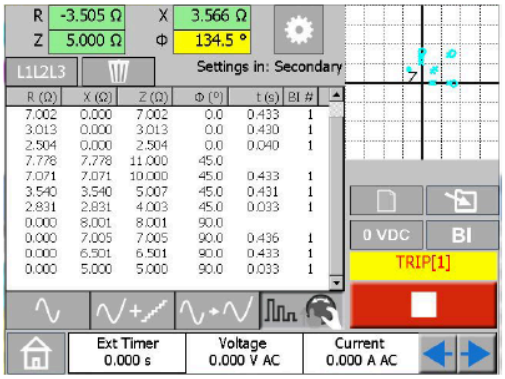



## Reach test

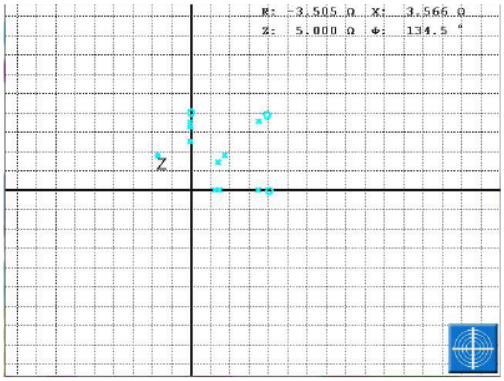
In "Manual binary search" view operating characteristic of the relay can be effectively verified.

**1]** Press the start button to generate with pre-fault settings while placing the test point. Select one of the impedance settings and rotate the knob for desired placement.

**2]** When you are ready press the knob to apply the fault settings and observe the registered trip time in the table. Move the test point using the knob without stopping the test and press the knob to apply the new fault settings and to register new test result in the table, respectively.




In this example reach of zone 1 and zone 2 are found for angel intervals of 45° with reference to origin using few test points as shown above. For larger graphical view tap on the graph.



**3]** Same procedure can be followed on any directions or areas of impedance plane to verify operating characteristic of the relay. Moreover, test for other type of faults can be performed in the same way simply by selecting desired type of fault and collecting the test results for corresponding fault type.