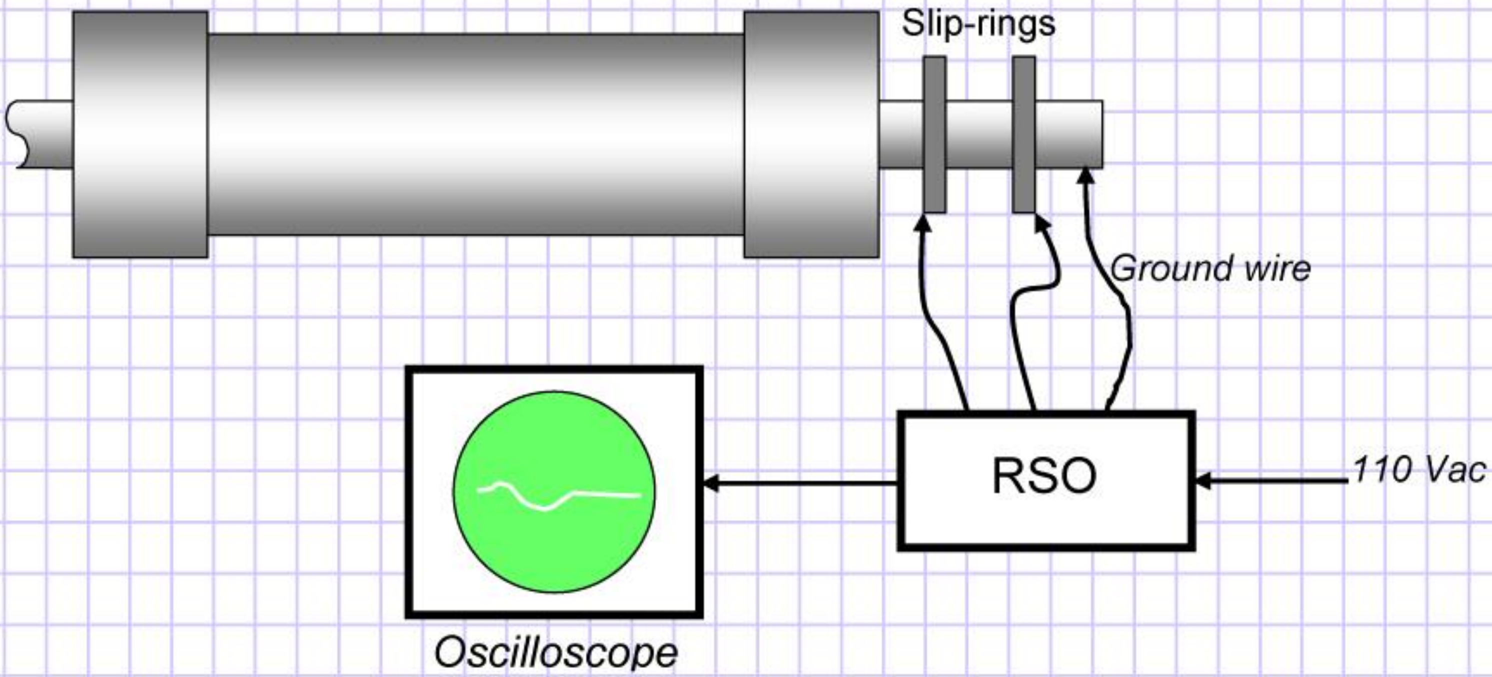
Shorted Turn Analyzer Instruction Manual



Version 1.1

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Introduction

Shorted turns in generator cylindrical rotor field windings can contribute to vibration problems due to rotor thermal bending from the uneven heating associated with non-symmetrical dc current flow and watt losses in the windings. Shorted turns can also cause unbalanced magnetic flux in the air gap that can also aggravate vibration problems.

Since vibration signature analyses for rotor shorted turn problems is not always an exact science, it is desirable to have confirming data from other testing before proceeding with very costly disassemblies and repairs of large machines. Additional tests for confirming the existence of shorted turns in generator rotor field windings are commonly performed before committing to expensive repairs. At this time, the following three test procedures are generally used in the industry to help verify whether or not generator field windings have shorted turns:

1. **Thermal Stability Testing** - involves changing generator-operating parameters (watts, vars, and cooling) and recording and analyzing the impact on rotor vibration signatures.

2. **Flux Probe Analysis** - utilizes an installed air gap probe to measure and analyze the magnetic flux from each rotor slot as it passes by the location of the sensor. Some generators are permanently equipped with flux probes and many are not. Installing the probe normally requires a unit outage, especially with hydrogen-cooled machines.

3. **RSO (Repetitive Surge Oscilloscope) Testing** – which is the applied principal for the **"Sumatron Generator Rotor Shorted Turn Analyzer"** will be discussed in more detail in the following text:

It should be noted that the foregoing testing (vibration analyses, thermal stability, flux probe analyses, and RSO testing by themselves does not provide absolute certainty that there is a shorted turn problem in the generator rotor. However, when confirmed by other testing the probability of the field winding being the cause of the vibration problem increases significantly. Shorted turn anomalies can be masked if they are near the center of the winding or otherwise balanced, if there are multiple shorted turns, if they are intermittent, if there are grounds, and if there are other contributors to the overall machine vibration levels.

RSO testing has some advantages over other testing in that it can be used periodically during rewinds to verify that windings are free of shorts and on both at rest and spinning de-energized rotor windings.

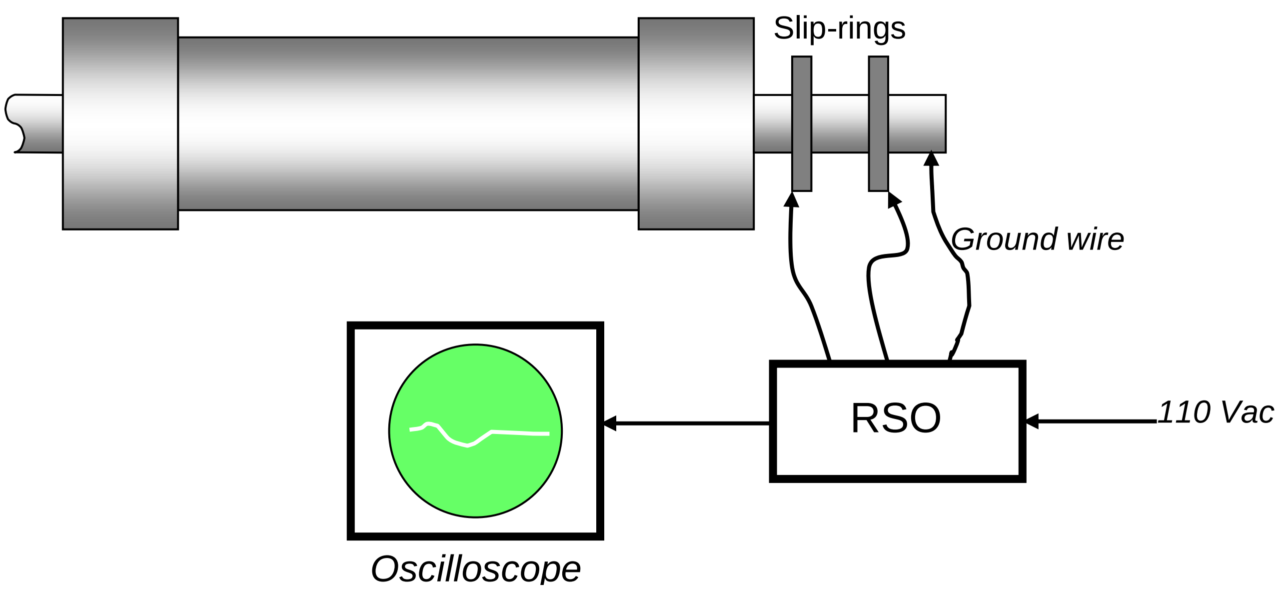
Theory of Operation

The "Generator Rotor Shorted Turn Analyzer" or ("RSO" Repetitive Surge Oscilloscope) produces a succession of step-shaped low voltage pulses. The pulses are introduced simultaneously to the dc rotor winding ("field winding") from both ends. The resulting reflected signals can be viewed on a dual channel oscilloscope screen as two separate waveforms, or after one of them is inverted, and both summed as a single trace.

If no discontinuities are present in the winding (due to grounds or shorted-turns), both traces will be nearly identical and if inverted and summed, a single trace will be displayed as a horizontal straight line, with a minor blip at the origin and an almost imperceptible ripple. Any significant discontinuity arising from a fault will be shown as an irregularity on the summed trace. By estimating the location of the anomaly on the screen, an inference can be made as to the approximate location of the fault. For instance, large irregularities near the origin of the trace are attributed to faults close to either end of the winding.

The injected pulses have amplitudes of between 8 to 12 volts. Thus, it is possible to carry out tests on a rotor without undue safety concerns.

The best interpretations are obtained when the results are compared to other tests. It is therefore suggested that for reference, results of tests performed with this instrument be recorded and saved for future use. This is important both for benchmarking a specific unit and for comparison with results obtained on other rotors. In this manner a database can be compiled for future reference. Figure 1 below shows the typical connection arrangement:



The foregoing figure shows the connection to a field winding with an external excitation source. In the case of self-excited rotors or brush-less excitation systems, the connections are made to the leads leading from the diode-wheel to the winding. The leads between the diode wheel and rotor winding must be disconnected before proceeding with the test. All connections “away” from the rotor must be open. Otherwise, the RSO will be measuring not only the field winding, but also everything that is connected in parallel with it.

Figure 2 below shows a typical inverted summed trace indicating that no shorted-turns are present in the rotor under test:

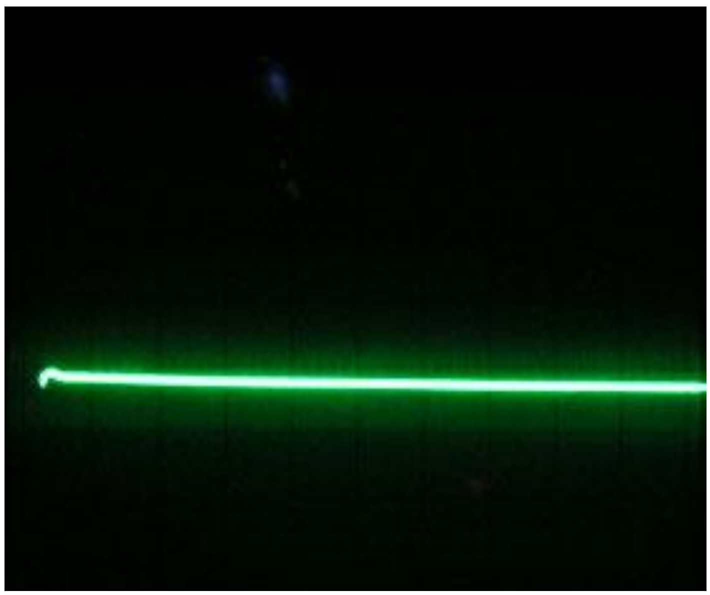
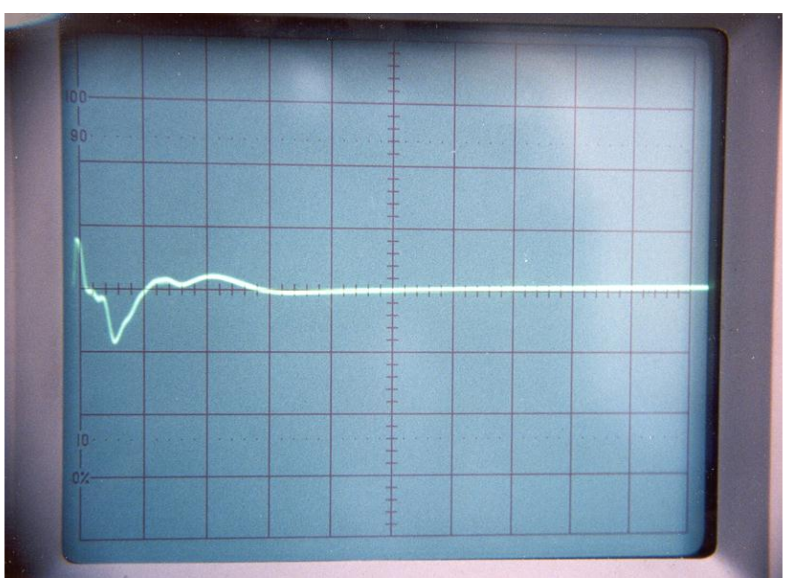


Figure 3 shows an actual winding trace indicating the presence of one or more shorted-turns:



Equipment Required

1. Generator Rotor Shorted Turns Analyzer (RSO).

2. Oscilloscope (*see "Note" below*).

3. Camera to take pictures of the traces. Alternatively, a digital scope with the capability to store traces that can be down loaded for display and analysis.

4. Interconnecting test leads (supplied with the RSO)

<u>Note</u>: There are numerous types of oscilloscopes in existence. Almost any analog or digital oscilloscope will be acceptable for this application as long as it:

1. Can measure <u>two independent traces</u>.

2. Has an <u>inversion function</u> allowing one trace to be inverted.

3. Has a <u>summation function</u> allowing both traces to be added.

4. Has a bandwidth of at least <u>20 megahertz</u>.

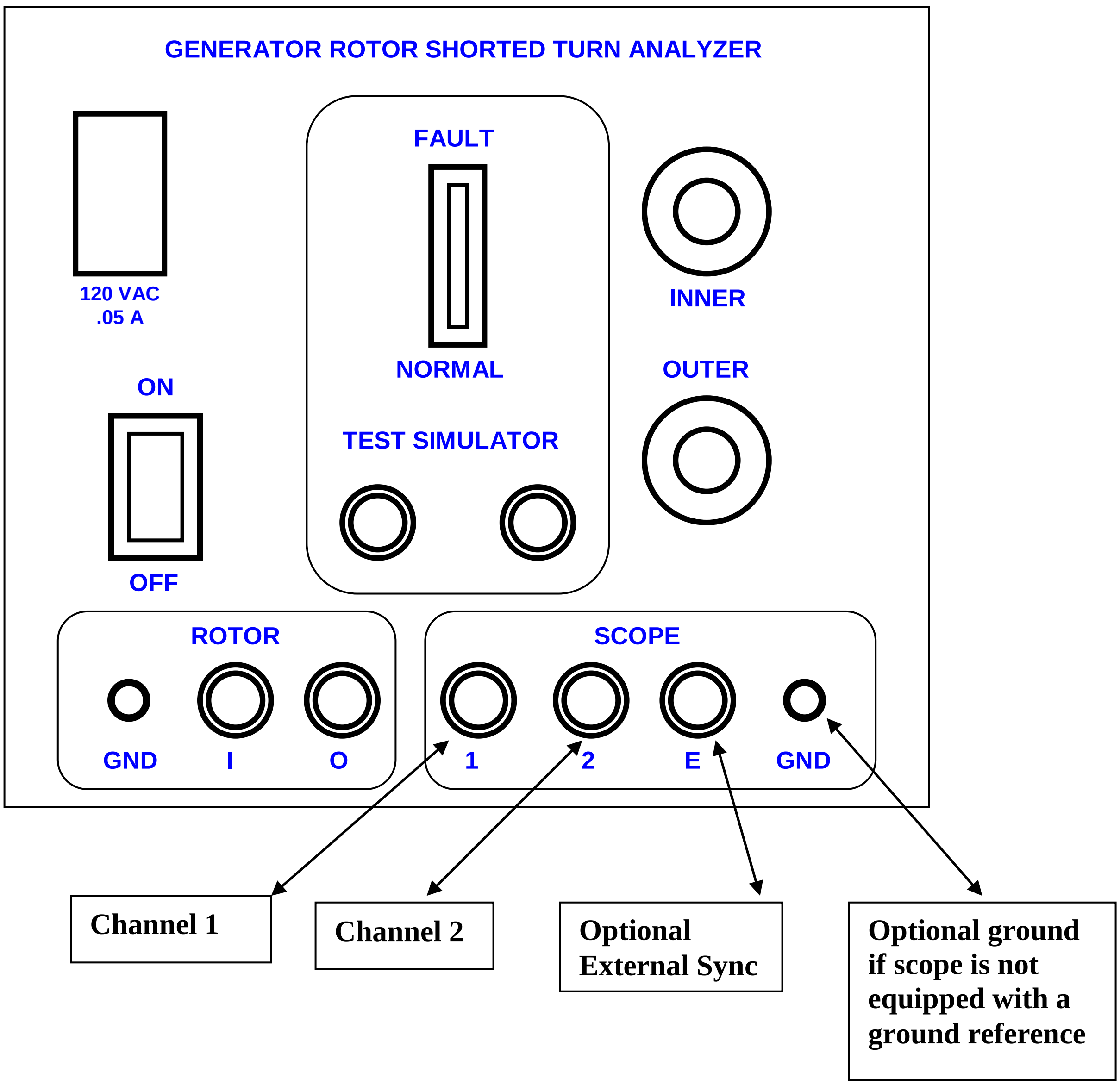
5. Has a voltage resolution of at <u>least 0.5 volts per division</u>.

Precaution: with digital scopes, the input channels may saturate at 0.5 volts per division and result in erroneous measurements. Accordingly, only the math or summed channel should be reduced to 0.5 volts per division and not the input channels. When selecting a digital scope, ensure that increasing the sensitivity or reducing the volts/div of the math channel does not impact the input channels.

Instrument Settings

1. Turn both the **Inner** and **Outer** potentiometers to their fully counter-clockwise positions.

2. Connect the test leads to the oscilloscope as shown in figure 4 below:



3. Power-up the instrument and the oscilloscope.

Oscilloscope Settings

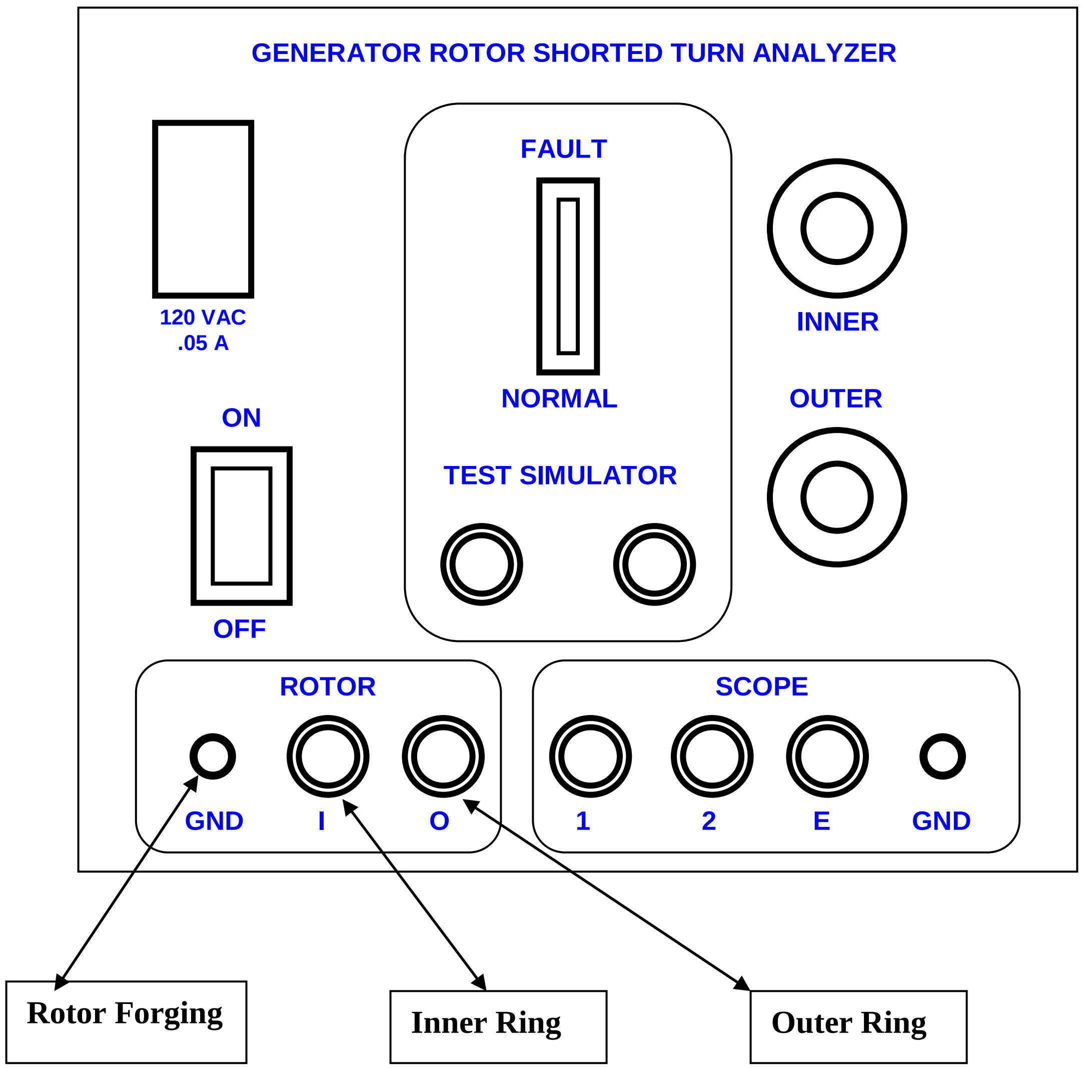
The particular settings for the scope depend on the model used. Some scopes will use the nomenclature presented below and others will be labeled in a different manner. However, in general, it is better to start with both traces in "normal" view, and if possible, triggered from an external source. The following settings can be applied on most oscilloscopes:

1. Set the Source for the trigger to **EXT.**
2. Set the Trigger Mode to **AUTO**.
3. Set the Trigger Coupling to **AC**.
4. Set the INVERT button to **OFF** or non-invert.
5. Set the CH1/CH2 button to **CH1**.
6. Set the MONO/DUAL button to **DUAL**.
7. Set the ALT/CHOP/ADD button to **ALT.**
8. Set both AC/GND/DC knobs to the **AC** position.
9. Set all VARIABLE knobs to **CALIBRATE**.
10. Turn both channels to **2 VOLTS/DIV.**
11. Set the TIME/DIV knob to **5 MICRO-SEC/DIV.**

Adjust the **TRIGGER** until two traces are displayed. Both traces should be nearly identical (of about 8 to 12 volts amplitude). Any minor difference between trace amplitudes should be completely canceled with the **VARIABLE** knobs.

Rotor Connections

Connect the Generator Rotor Shorted Turn Analyzer instrument to the rotor slip-rings (collector rings) or leads, if these are disconnected from the slip-rings during repairs, testing or manufacturing as shown in figure 5 below. The BNC cables to the rotor should be of equal length. The instrument banana jack ground must be connected to the rotor body or forging since the tests are made in relationship to ground. Make sure the inner “I” BNC jack is connected to the inner ring, and the outer “O” BNC jack to the outer ring. The Inner ring is the one closes to the forging, and the outer is the ring away from the forging. In rotors without slip-rings, identify the leads connected to the inner “I” and outer “O” instrument jacks. This will aid in identifying the location of the fault.



Final Calibration Procedure

1. Disconnect the cable from the outer **"O"** BNC jack and adjust the **INNER** potentiometer until the trace on Channel 1 is about one half the amplitude of that on Channel 2.

2. Reconnect the cable to the outer **"O"** BNC jack and adjust the **OUTER** potentiometer until the two traces are of equal magnitude, from ground level to the positive peak. Change both channel settings to **1.0 volt per division** to make the adjustment more sensitive.

   Note: for units equipped with counter knobs, our suggestion is to not use the counter brake. If you decide on using the brake, please use one hand to hold the counter to prevent turning or loosening the potentiometer when setting or releasing the brake. Otherwise, you may need to disassemble the instrument to retighten the potentiometers.

3. Invert one of the channels in the scope (some scopes allow only one of the channels to be inverted; others allow any one or both). Set the **ALT/CHOP/ADD** button to **<u>ADD</u>**, and the **MONO/DUAL** button to **<u>MONO</u>**.

4. Position the resulting trace in the <u>middle</u> of the screen with the help of the respective **POSITION** knob.

5. Set both channels to **0.5 volts per division** and photograph the resulting trace for determination of winding condition, or if a *storage* function exists in the scope, store the traces to be downloaded at a convenient time.

Please see the next section on "Instrument Diagnostics" for a sequence of oscilloscope photographs that illustrate the calibration procedure.

Instrument Diagnostics

The Generator Rotor Shorted-Turns Analyzer has a built-in test simulator circuit. This has been included to prove that the instrument is functioning properly, for training, and to also prove that the test leads are intact.

To use the "Test Simulator", follow this procedure:

1. Plug the outputs of the "Rotor" section (bottom left on instrument's panel) to the Test Simulator" binding post banana jacks located in the "Test Simulator" Section (center of instrument panel). Use the short banana jack cables and BNC adapter provided for this purpose. An external ground connection is not necessary, since an internal ground is provided.

2. Complete the "**Final Calibration Procedure**" explained previously, with the exception that the connection is made to the "Test Simulator" circuit instead of a generator rotor. During the calibration, the "Test Switch" should be set to the "Normal" position. Two identical traces (or one straight line) should be obtained on the scope's screen.

3. After performing the calibration, set the "Test Switch" to the "Fault" position. The two traces should now be different (or the otherwise straight line will now show a "blip" at the front-end of the waveform), mimicking a faulty winding.

The following photographs show the calibration procedure using the test simulator circuit:

Figure 6 below shows both traces (2.0 volts per division) before the test leads are connected to the "Test Simulator" circuit.

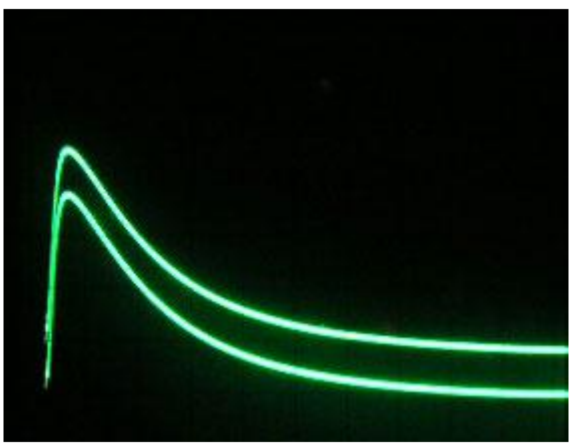


Figure 7 below shows both waveforms after connection to the “Test Simulator” circuit. In this case, the inner (I) BNC is connected to the black binding post and the outer (O) BNC is connected to the red binding post.

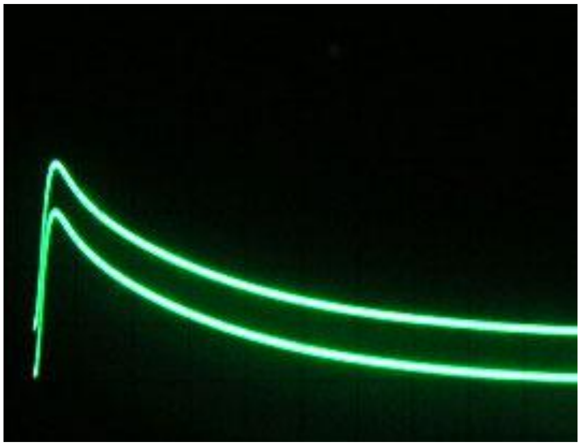


Figure 8 below shows both traces after the red binding post lead is disconnected and the Inner potentiometer is rotated clockwise to reduce the channel 1 amplitude by approximately one half.

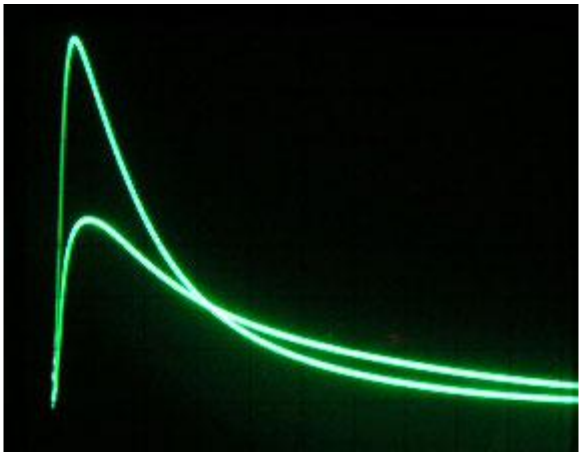


Figure 9 below shows both waveforms superimposed after the red binding post lead is reconnected and the Outer potentiometer is rotated clockwise to reduce the amplitude of channel 2 until it matches channel 1.

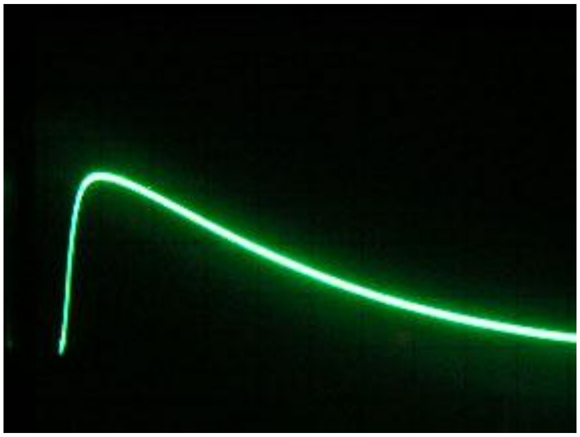


Figure 10 below shows a single trace that was formed when channel 2 was inverted and then added to channel 1. The test switch is in the normal position and the straight line with a minor blip at the origin indicates that the winding does not have shorted turns.

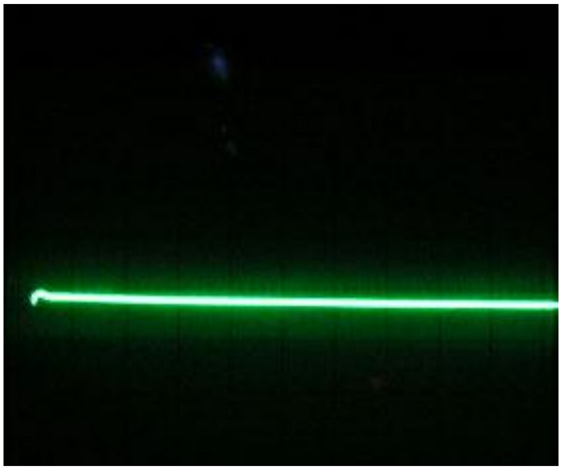
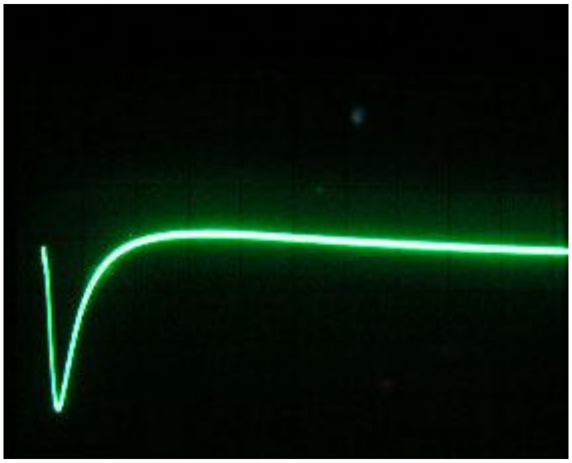


Figure 11 below shows the inverted summed single trace with the test switch closed to the fault position. In this case, the relatively large negative going blip indicates a shorted turn near the start of the simulator circuitry. If channel 1 had been inverted instead of channel 2, the fault blip would have been positive going instead of negative.



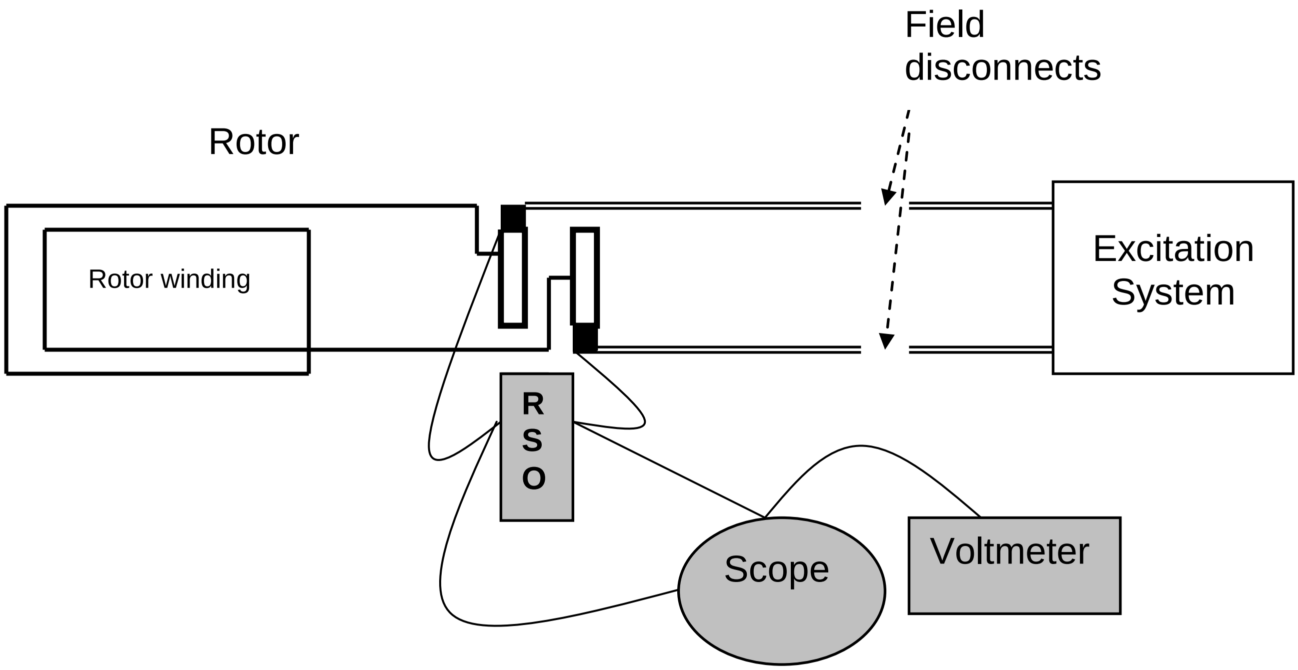
The foregoing tests prove that the instrument is functioning properly. If the actual test leads were used to connect from the instrument rotor BNC jacks to the test circuit binding posts, the integrity of those leads would be proven as well.

Repeat the same sequence (figures 6 - 10), when testing an actual generator rotor field winding.

PERFORMING A SPINNING TEST

The spinning test is mainly carried out for the purpose of ascertaining if the rotor winding has shorted turns that tend to appear or disappear when the rotor goes from full speed to rest (or vice-versa). Obviously this test can only be performed on a rotor with an external source of excitation, given that the connections to the winding are made via the slip-rings. The ground connection to the rotor is made indirectly via the grounding-brush (sweeping against the rotor's shaft).

Figure 5 shows a typical arrangement for the test. In order to eliminate any route for the injected waves other than the rotor winding, the excitation must be disconnected from the slip-rings. This can be achieved either by opening the leads/busses at a point close to the brush-rigging, or by lifting the brushes and placing instead a set of brushes insulated from the rest of the brush-rigging, but connected to the Shorted Turn Instrument.



Repair

The unit is equipped with an internal 1.0 amp fuse. If scope traces are not displayed and the "Power Switch" does not illuminate when closed to the "ON" position even though the power cord is plugged into a 115 VAC outlet that is verified to be energized, the instrument panel should be removed (after unplugging the power cord) to access and prove the integrity of the fuse. The panel wiring connections to the circuit board terminals should also be verified tight when the panel is removed. For all other problems, the instrument should be returned to the factory for repair.

Warranty

Sumatron warrants the instrument to be free of defects in material and workmanship for a duration period of 18 months from the date of shipment. Sumatron will either replace or repair the instrument free of charge during the warranty period. Any other obligation or liabilities on the part of Sumatron is expressly excluded. Sumatron shall in no event be liable for special or consequential damages.

For repair, ship to:

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