ROTOR RSO REFLECTOMETERS

TYPE TDR100/200

APPLICATION NOTE 2

INTERPRETING AND ACTING ON THE RESULTS OBTAINED FROM RSO TESTS

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SUMMARY

This brief document explains how to interpret the results from RSO (Recurrent Surge Oscillograph) tests carried out using the Rowtest TDR100/200 series Rotor Reflectometers. Further more detailed information can be found in the references quoted at the end of this note.

DISCLAIMER

The information given here is offered in good faith and is for advisory purposes only. All users of the equipment must use their own professional experience and judgement or seek other expert advice before making any decisions following an RSO test. Rowtest and its associate companies will not be held responsible for any actions taken which are based on the results obtained using its equipment.

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INTERPRETING AND ACTING ON THE RESULTS FROM RSO TESTS

1. OVERVIEW

The Recurrent Surge Oscillograph (**RSO**) test is used to detect and locate the position of winding faults in large turbogenerator alternator rotors. The test is very sensitive and can detect earth faults, inter-turn faults and high-resistance joints. Detailed information about the test is given in the references listed at the end of this document, which provides advice on interpreting the results obtained from the RSO test.

The RSO test is based on applying (typically) 12V pulses between the ends of the rotor windings and the rotor body (ground) and produces pairs of of waveforms, which are viewed and compared to detect and locate any winding faults. These waveform pairs should be identical for a fault-free rotor winding. Typical RSO waveforms are shown in figure 1 below for a fault-free rotor winding.

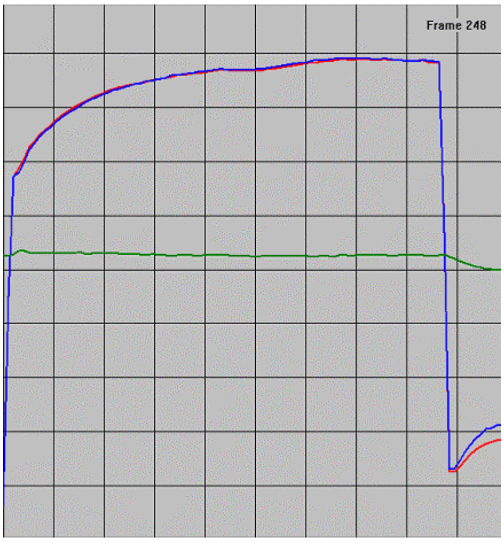

Figure 1(a) Input end waveforms

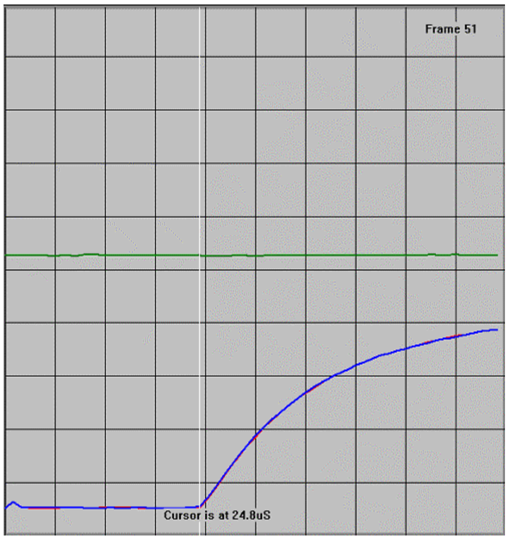

Figure 1(b) Output end waveforms

Figure 1. Typical RSO test results for a 660 mw 2-pole rotor winding

The test pulses are applied at each end of the rotor winding (designated red and blue for convenience) in turn and the resulting RSO waveforms are viewed at both the input and output ends of the rotor winding

Figure 1(a) shows the RSO waveforms at the input ends of the rotor windings. There are two superimposed waveforms (red and blue) corresponding to the pulses injected at each end of the winding. These waveforms are compared and used to view and detect any winding faults.

Figure 1(b) shows the waveforms at the output ends of the winding. The output end waveforms are used to measure the time which the applied pulse takes to travel from one end of the winding to the other end for fault location purposes.

The results which should be obtained for a healthy rotor winding are shown in figure 1 above. The end1 (red) and end 2 (blue) waveforms should be identical and the (green) waveform, which displays the difference between the red and blue end waveforms, should be a horizontal straight line for a fault-free rotor winding.

If there is a fault in the rotor winding, the red and blue end waveforms will not be identical and examples of typical RSO test results for rotor windings which contain an inter-turn, earth fault and a high-resistance joint are shown in figure 2 below.

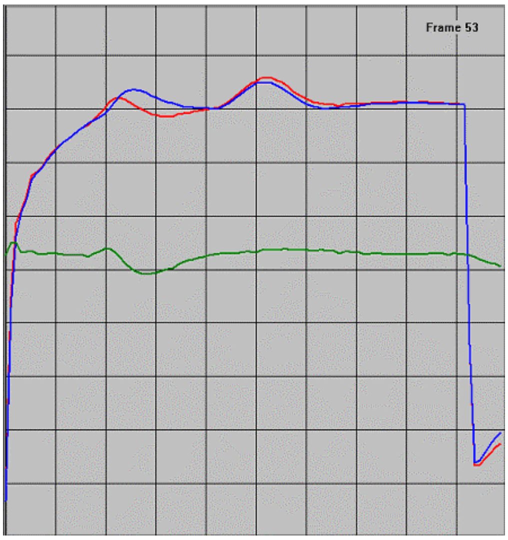

Figure 2(a) Input end waveforms for a shorted turn

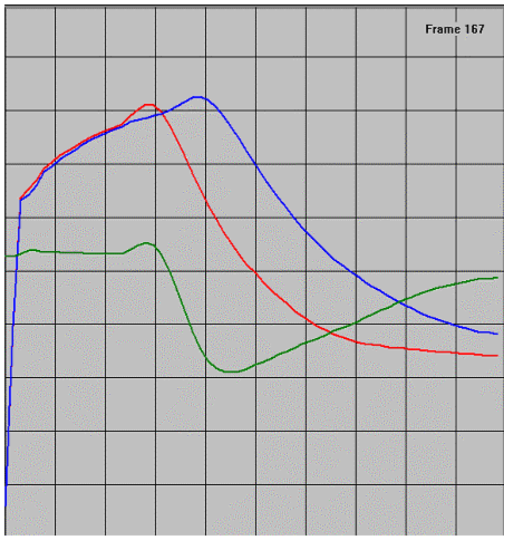

Figure 2(b) Input end waveforms for an earth fault

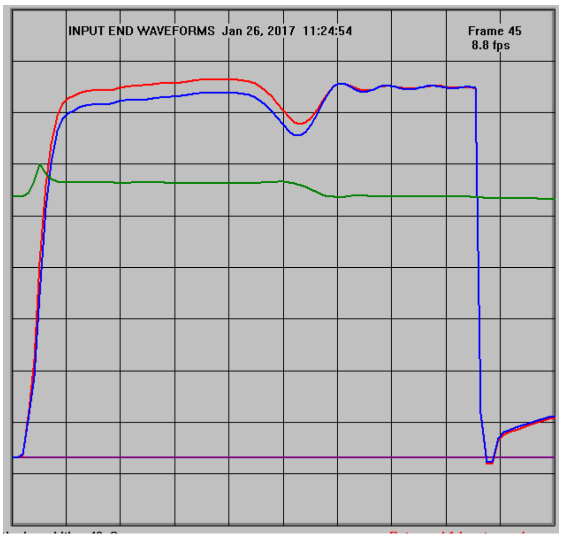

Figure 2(c) Input end waveforms for a simulated high-resistance joint

Figure 2. Typical RSO test results for a 660 mw 2-pole rotor winding containing an interturn fault (a), earth fault (b), and a high-resistance joint at the red end (c).

2. TEST CONDITIONS

For complete confidence in the integrity of a rotor winding, the RSO test should ideally be carried out with the rotor both at rest and at speed, because even if no winding faults are found on a stationary rotor, faults may still develop at speed. It is therefore prudent to test all rotors at speed as well as at rest if possible, to ensure the rotor is completely free from winding faults.

In a perfect world, the RSO test waveforms will indicate that the rotor winding is fault-free (identical red and blue traces). However if this is not the case, careful consideration needs to be given to what, if any remedial action is taken.

In general, the outcome will depend on whether the test has been carried out in a manufacturer or repairer's works or whether the test is conducted in a Power Generation plant.

The RSO test is particularly valuable when carried out in the premises of a manufacturer or repairer because any winding faults that are found can be quickly located and remedied. In fact, many Plant Operators insist on witnessing RSO tests at manufacturers' premises before agreeing to take delivery of new or repaired rotors.

In contrast, if a winding fault is detected on a rotor in service at a Power Utility company, the choices are more complex, because of the cost of lost generation as well as the cost and complexity of any repair work.

3. A NOTE ON SHORTED TURNS

The RSO test is very sensitive and will detect shorts between turns which do not carry any significant current.

The winding resistance for a large generator rotor is around 0.1 Ohms (100m Ω). As the rotor winding typically contains around 150 turns, the resistance around a single turn will be less than 1m Ω. Consequently, a short between turns of 1Ω will only carry 0.1% of the rated current. As typical large rotor currents are around 3000A, this will result in a current of only 3A through the short. If the short resistance value is 10 Ω, this current reduces to 0.3A.

The power (heat) dissipated at the short is calculated using $P = I^2 \times R$ where I is the current through the short and R is the short resistance.

For a 1Ω/3A short, the power dissipated will be 9 watts, and this amount of heat may be significant enough to burn the insulation.

For a 10Ω/0.3A short, the power dissipated will be 0.9 watts, which is unlikely to cause any problems on a large rotor winding.

If a shorted turn is detected by an RSO test, further tests will normally be required to determine whether the short is severe enough to carry significant current. A suitable method is to use a magnetic flux probe (search coil) which will only detect current-carrying shorted turns.

4. RECOMMENDED ACTIONS FOR PLANT OPERATORS *

When the RSO test was first used routinely in the UK (from around 1980 onwards), many rotors were found to have winding faults, and these included some brand new rotors. However as manufacturers started to use the RSO test themselves, the number of new rotors delivered with winding faults rapidly reduced to zero. In current practice, it is reasonable for plant operators to expect that any new rotor will be delivered free from any winding faults.

However, the situation for rotors currently in service is more complicated if the RSO test indicates winding faults. Symptoms which can be caused by shorted turns in large generators include increased vibration levels, thermal damage to the winding insulation and the need for increased excitation current for a given power output. If inter-turn faults detected by an RSO test are not causing any obvious operational problems, many plant operators will decide to continue to run the generator, while monitoring it regularly to determine whether the fault is stable or whether it is changing and/or worsening.

If operational problems are being experienced, a flux-probe (search coil waveform) test can be carried out if a suitable search coil has been previously installed in the generator air-gap. This will determine whether the winding fault is current-carrying.

Comparison of the RSO waveforms between results obtained for similar rotors at the same generation site can also be helpful in making decisions for further action.

If an earth fault is detected by the RSO test, it is likely that this will have already been detected by other on-line monitoring equipment. Most plant operators are reluctant to run a large generator with a single earth fault, as major damage can occur if a second earth fault occurs, as this may short out much of the rotor winding.

5. REFERENCES

Additional information on testing generator rotors can be found in the following documents:

1. **Turbo-Generator Winding Fault Detection by a Recurrent Surge Method**, Grant, A.E., UK Central Electricity Generating Board Technical Disclosure Bulletin 201, 1973.

2. **Rotor winding short detection**, Wood, J.W. and Hindmarch, R.T., IEE Proceedings, Vol 133, Pt. B, No. 3, May 1986, pp 181-190.

3. **GE Generator Rotor Design, Operational Issue, and Refurbishment Options**, Ronald J. Zawoysky, Karl C. Tornroos, GER 4212, 08/01, GE Power Systems. Schenectady, NY

4. **Generator Field Winding Shorted Turn Detection Technology**, Donald R. Albright, David J. Albright And James D. Albright, Generatortech, Inc.

5. **Rotor RSO Reflectometer type TDR200 Instruction Manuals, Operation in Analogue mode/ Operation in Digital mode**, Rowtest Ltd. 2016

* See **Disclaimer** on front sheet.