ROTOR REFLECTOMETER TYPE TDR200

INTRODUCTORY NOTES

***** PLEASE READ THIS DOCUMENT FIRST *****

May 2021

ROWTEST LTD

Wilmslow, UK

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SAFETY WARNING

The use of the TDR200 equipment on a rotor installed in an operational generator must be carried out with the explicit permission and under the supervision of the local plant operator. All local safety rules and procedures must be complied with.

In particular, the equipment must only be connected to the generator rotor after the field supply has been disconnected and isolated in accordance with local safety regulations. Failure to comply with this instruction will damage the equipment and may endanger both the the plant and the operator.

CE **This Equipment complies with the following EEC Directives:**

2006/95/EEC Low voltage directive
2004/108/EEC EMC directive

SOME IMPORTANT NOTES ABOUT YOUR CONTROL PC

1. WINDOWS 10

Your **TDR200 Control PC** uses the latest Microsoft Operating system (**Windows 10**) and has been set up and optimised to control the **TDR200 Rotor Reflectometer**. It is not intended to be used as a general-purpose PC and should be used only for controlling the **TDR200 unit**.

Experience to-date has shown that **updates** to the **MS Windows 10 operating system** can make major changes to the **PC settings.** If a Windows update does occur, it can completely disable the PC for a considerable period (an hour or more in some cases) until the update has completed.

Unfortunately, unlike previous Microsoft operating systems, **it is not possible to turn off the automatic update operation in Windows 10**, as these updates are **delivered automatically via any live internet connection.**

Consequently, we suggest that this PC is **never connected to the internet**, to prevent any **operating system updates** from corrupting the **TDR200 control software**.

Please use USB memory sticks etc. to transfer files to or from this PC.

2. WINDOWS 10 RECOVERY DRIVE

We have also supplied a Windows 10 USB Recovery drive. This bootable device contains software which is is unique to your Laptop and can be used to re-install the Windows 10 operating system in the event of major PC/software failure.

We suggest that this device is stored safely away from the PC and only used by an IT technician who is familiar with the Windows 10 recovery procedure.

1. OVERVIEW

The **TDR200 Rotor Reflectometer** is used to test large **electricity generators** to detect faults, such as **shorts between turns or to ground** in the **rotor (field) winding**. It uses the **RSO test (Recurrent Surge Oscilloscope**) test method and is an enhanced version of the original **TDR100** model which has been used for carrying out these tests for over 30 years.

The **RSO test method** is based on **injecting low-voltage pulses** through impedance-matching resistors **between each end of the rotor winding and ground** and comparing the resulting **waveforms at each end of the winding**. These should be identical for a good rotor winding, but will differ if a winding fault is present. A full decription of the **RSO test method** is given in **section 1** of the **TDR100 Instruction Manual (Operation in Analogue mode)**.

The TDR200 RSO Rotor Reflectometer measurement system

The **TDR200** unit contains a rechargable battery giving at least 8 hours of continuous operation of the unit between charges.

2. OPERATING MODES

The **TDR200** unit can be used in either of two alternative operating modes:

1. In **Digital mode** where the waveforms are displayed on a **Control PC**. This is the default mode of operation

2. In an optional **Analogue mode**, where the waveforms can be displayed on an **oscilloscope** (not supplied)**.**

In both operating modes, the **RSO waveforms at each end** of the rotor winding are displayed **continuously and simultaneously**, which permits faults to be identified quickly and unambiguously. In **digital mode**, the **RSO waveforms** are captured directly to a notebook PC, where they can be saved as either **bit-map image** or **text files**.

The operation of the equipment can be demonstrated with **simulated inter-turn and ground faults** applied to a **demonstration delay line,** which is supplied with the equipment.

The use of the **TDR200 Rotor Reflectometer** in **digital mode** is described in the **TDR200 Operation in Digital mode user guide**.

The use of the **TDR200 Rotor Reflectometer** in **analogue mode** is described in the **TDR100 Instruction Manual (Operation in analogue mode).** This manual also describes the **basic principles of the RSO test** and contains examples of fault waveforms and other background information.

3. DOCUMENTATION

The documentation pack supplied with the equipment includes the following items:

3.1 This **Introductory Note,** which includes a **Test Certificate** and two brief **Application Notes**.

3.2 The **TDR200 Instruction Manual (Operation in analogue mode).**

3.3 The **TDR200 Operation in Digital Mode UserGuid**e.

3.4 A CD containing documentation and software installation files, together with other support information, including some relevant technical reports and Powerpoint presentations.

New users should read **section 1 (Introduction)** of the **TDR100 Instruction Manual** to gain an understanding of the **RSO test method,** followed by **sections 1 (Introduction) and 2 (Quickstart)** of the **TDR200 Operation in Digital Mode UserGuide**, which explains how to use the equipment in **digital mode** under PC control.

There is also a set of **6 NUMBERED POWERPOINT PRESENTATIONS** which give some useful information about the construction and testing of cylindrical generator rotors.

4. CONTROL PC.

Your **TDR200** Reflectometer system has been supplied with an HP **notebook PC** running the **Windows 10** operating system and pre-installed **TDRPlot** software. As far as possible, Windows 10 has been configured to ressemble Windows 7 for ease of use.

5. SOFTWARE DETAILS

Full details of the software operation are given in the **TDR200 Operation in Digital Mode UserGuide,** including a **Quickstart** section**.**

To run the software, set up the measurement system as described in the **Quickstart** section and then click on the 

shortcut icon on the **PC Desktop** to run the **TDRPlot** software.

All data files generated by the software are in the **Data files folder,** which can be found by double-clicking on the 

shortcut icon on the **PC Desktop**.

This software can also be installed on further PCs if required (subject to obtaining a valid **user-code** from PTL/Rowtest) by following the instructions given in the **TDR200 Operation in Digital Mode UserGuide.**

6. HINTS AND TIPS

We have included a number of comments in this section which do not yet appear in the manuals.

6.1 COMPENSATING THE PC DISPLAY FOR VARIATIONS IN BATTERY VOLTAGE.

The amplitude of the excitation signal applied to the rotor varies with the state of charge of the internal 12V battery and may affect the position of the RSO traces on the PC screen.

If necessary, compensate for this effect by changing the **Vertical scaling factor** in the PC **Control Window**. Suitable scaling factor values are 1.5 for a fully-charged battery and 1.6 for a partially-discharged battery.

Small variations in the vertical position of the RSO waveforms can also be made by adjusting the **R1 Input end impedance matching control** on the **front panel** of the **TDR200** unit.

6.2. DEALING WITH ELECTRICAL NOISE AND INTERFERENCE

It is likely that the **TDR200 equipment** will be operated in areas where there is a high level of electrical noise and interference, which can adversely affect the operation of many types of sensitive electronic measurement equipment.

The most likely effect of high noise levels is disruption to the running of the **TDRPlot software**. If this occurs, the simplest solution is to exit and restart the software.

One common path for electrical noise to enter the equipment is via the mains supply. If interference problems are encountered, it may be possible to eliminate them by running both the **Laptop PC** and **TDR200** unit on **battery power only**.

6.3 BRUSH CONTACT PROBLEMS WHEN TESTING A ROTOR AT SPEED

It is important to maintain good contact with the rotor slip rings and the rotor shaft earth when testing a rotor at speed. However, this can sometimes be difficult to achieve, resulting in noisy RSO waveforms. One method for overcoming this problem, using averaging, is described in section 7.7 of the **Operation in Digital Mode** Instruction manual. A second option is to operate the Reflectometer in analogue mode as described in section 6.3.1.

6.3.1 Operation in analogue mode to overcome brush contact problems

Although for most test conditions, the **TDR200** is intended for use under **PC-control**, there is one situation where **analogue mode** may be useful. This occurs when testing a rotor at speed if brush contact problems occur, resulting in noisy or erratic RSO waveforms.

If the **TDR200** unit is operated in **analogue** mode with an **oscilloscope**, it is possible to manually control the pulse injection period, using the front panel **frequency control,** so that the pulses are always injected at the same point on each slipring. In some cases, it may be possible to reduce the effects of brush noise by careful adjustment of the frequency control.

Operation of the **TDR200** in **analogue** mode with an **oscilloscope** is described in detail in the **TDR100/200 Operation in Analogue Mode** Instruction manual.

6.4 MODE SWITCH SETTING

For operation in **Digital (PC) Mode**, the **Output Mode** switch on the front panel of the **TDR200** unit must be set to the **AUTO** position. No waveforms will be visible in the PC plotting window if this switch is set to either of the **END1** or **END2** positions.

7. ADDITIONAL INFORMATION

7.1 LIST OF EQUIPMENT SUPPLIED

Appendix 1 contains a list of all of the equipment supplied with your **TDR200** measurement system.

7.2 TEST CERTIFICATE

Appendix 2 contains the **test certificate** for your **TDR200 Rotor Reflectometer system**. It shows the RSO waveforms obtained using the supplied delay line under a number of standard test configurations.

7.3 APPLICATION NOTES

We have included 2 Application Notes at the end of this document which give further information about optimising the measurement parameters and also guidance on interpreting RSO waveforms.

8. THE NEXT STEPS

1. Please read all of the supplied documentation, which should give you a good understanding of the **RSO measurement method**.

2. Once you have done this, try using the **TDR200** Unit with the **demonstration delay line** as described in the **TDR200 Operation in Digital Mode UserGuide (Quickstart section)** to familiarise yourself with the **RSO measurement method**.

3. View and read the **Powerpoint** presentations and **technical papers** included on the CD.

In case of any problems or queries, please contact us by email at

enquiries@rowtest.com.

Rowtest Ltd. May 2021

APPENDIX 1

DETAILS OF TDR200 ROTOR REFLECTOMETER MEASUREMENT SYSTEM

ITEMS SUPPLIED

1 x TDR200 Rotor RSO Reflectometer s/n XXX in padded case

1 x EU-type IEC mains lead for above

1 x Demonstration delay line s/n XXX

1 x 1m delay line connection lead

2 x short 2mm delay line patch leads

1 x rotor connection module with 5m lead s/n XXX

3 x Contact magnets with keepers

3 x individual 5m connecting leads (R,G,B) with crocodile clips

2 x coaxial oscilloscope leads for use with optional oscilloscope

2 x Instruction manuals.

1 x Introductory Notes

1 x HP Notebook PC in carrying case

1 x Power supply for above

1 x EU-type IEC mains lead for above

1 x USB printer lead

1 x Software and documentation CD

1 x USB Recovery drive

APPENDIX 2

TEST/CALIBRATION CERTIFICATE

Equipment type: Rotor Reflectometer measurement system type **TDR200**

Serial number: XXX

Date of Manufacture: May 2021

This is to certify that the product was manufactured and tested in England as specified by Rowtest Ltd

CALIBRATION

The RSO test does not carry out an absolute measurement, as it relies on comparing 2 nominally-identical waveforms. Consequently, conventional calibration techniques cannot be applied.

Instead, the supplied **DL100 Delay line** unit, acts as a **dual calibration/test device.**

The following sheets of this test/calibration certificate show the two **RSO waveforms** obtained using the suppplied **TDR200** unit together with its **DL100 Delay line** under standard test conditions.

To check that the **TDR200** unit is working correctly, use it with the delay line and compare the waveforms obtained with those in this test certificate. If these 2 sets of waveforms are identical, the equipment is working correctly.

Declaration of Origin

The exporter of the product covered by this document, (Customs Authorisation No. GB 16102/13) declares that this product is of United Kingdom preferential origin.

Signed:

M. Byars.

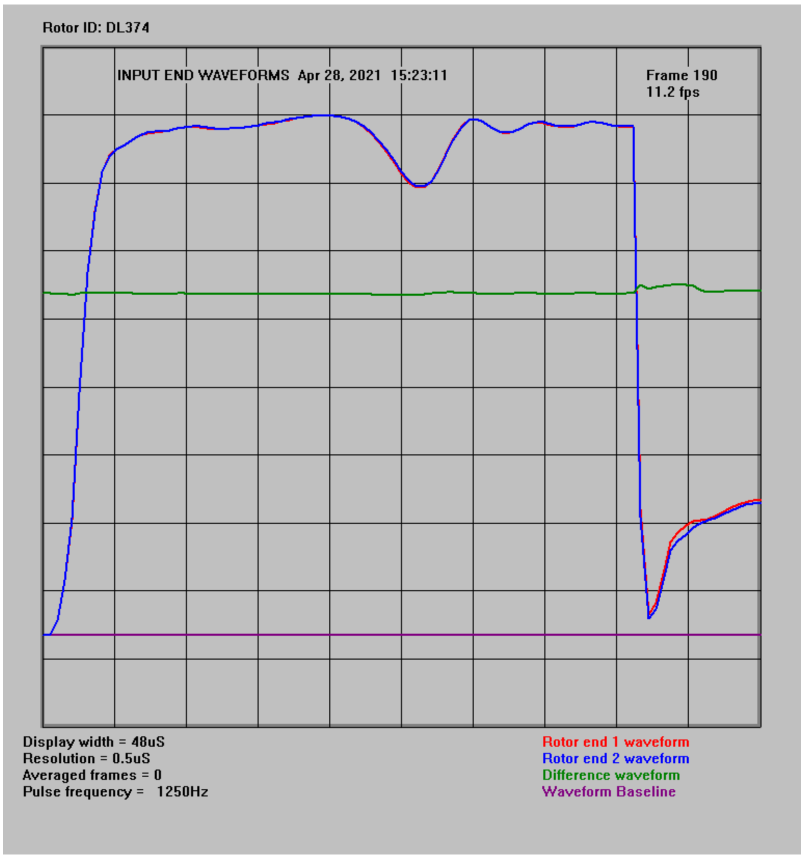
M. Byars (Director)

Rowtest Ltd.

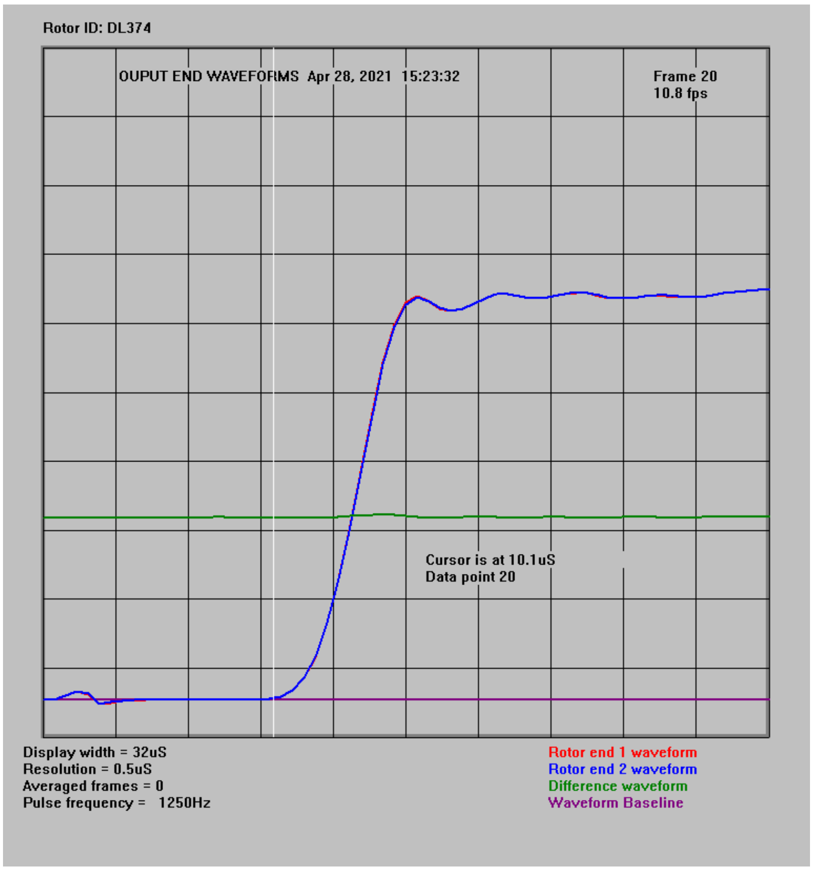
Wilmslow, UK.

Date: 2-5-2021

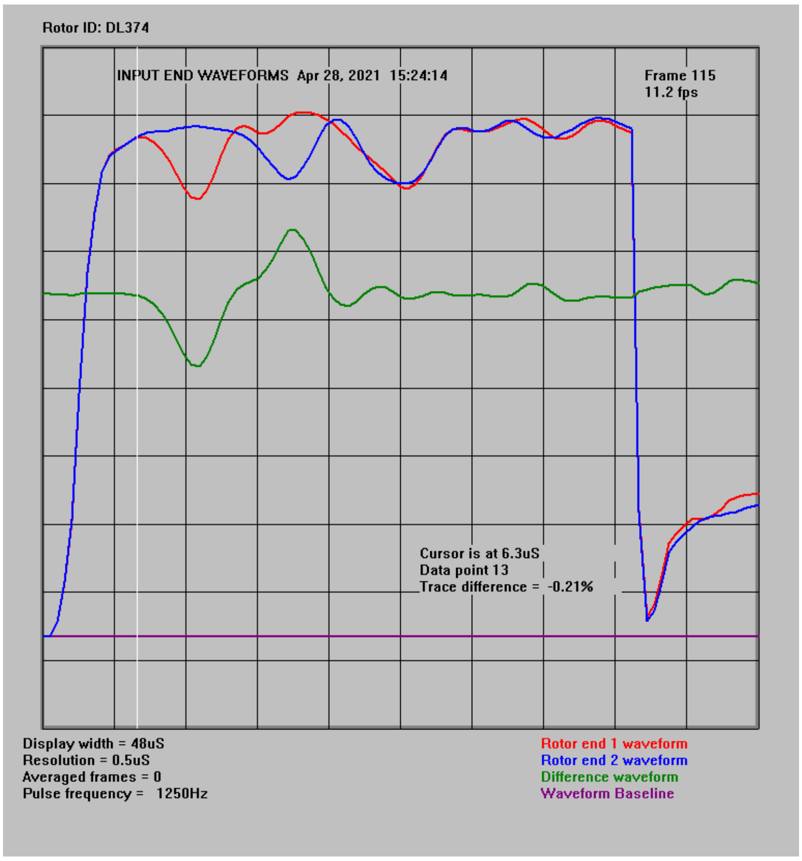
TDR200/XXX TEST WAVEFORMS WITH DELAY LINE S/N XXX



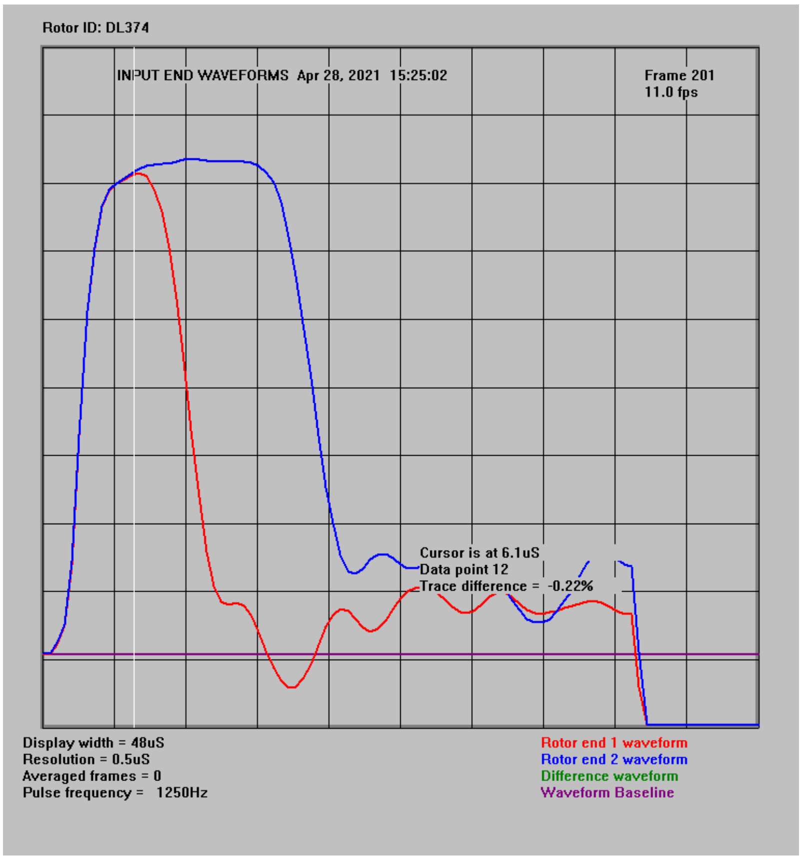
No Fault. Input ends



No Fault. Output ends



Simulated shorted coil (4-5)



Simulated earth fault (4 - G)

ROTOR RSO REFLECTOMETERS

TYPE TDR100/200

APPLICATION NOTE 1

SETTING THE RSO MEASUREMENT PARAMETERS.

Issue 2. February 2017

SUMMARY

In normal use, it is almost impossible to incorrectly set the **TDR100/200 Rotor Reflectometer hardware and software controls** so that **two non-identical RSO waveforms** are generated for a **fault-free rotor winding**. However, it is preferable to set these controls in a standard way, as this allows measurements carried out on similar rotor windings at different times to be easily compared. Users should first read the full set-up instructions in the **TDR 100/200 Instruction manuals** and then follow the instructions given here to optimise the settings of these measurement controls and parameters.

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1. OVERVIEW

When carrying out **RSO measurements** on an unknown rotor winding, it is important to measure the **characteristic impedance** of the **rotor winding** and also the **single-pass transit time** (**SPT**). Once these values are known, the **RSO waveforms** can be displayed and viewed in a standardised format which facilitates comparison with results obtained for other similar rotors. This note describes how this is done.

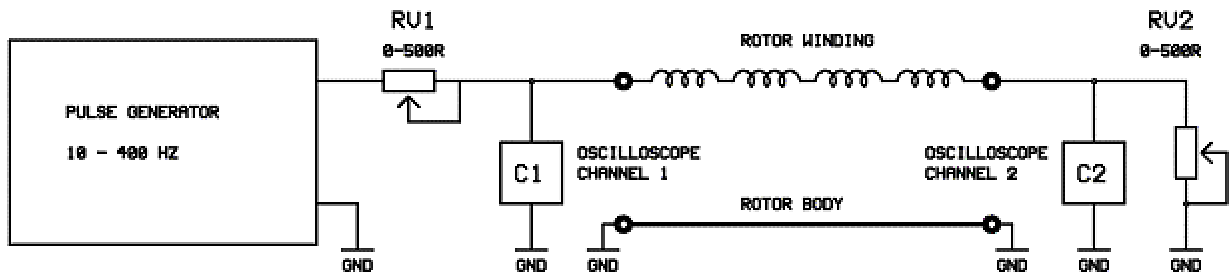


Figure 1.1 Basic RSO measurement circuit

2. MEASURING THE ROTOR CHARACTERISTIC IMPEDANCE

The approximate **rotor characteristic impedance** value can be measured as follows:

On the **PC screen**, set the **Control window Measurement Channel** to monitor the **Input ends** of the winding.

With the **Vertical scaling factor** in the **Control window** set to a value of **1.6**, adjust the **R1** (input impedance) control on the **TDR200 front panel** so that the pulse displayed in the **Plot window** is approximately 80% of the **Plot window height**, as shown in figure 2.1. **This value of R1** is the approximate **characteristic impedance of the rotor winding** in Ohms.

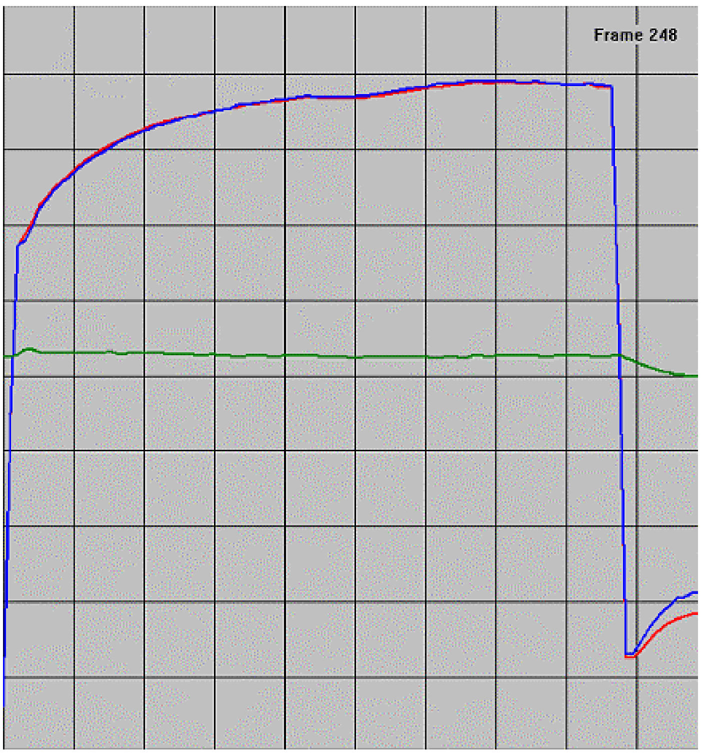


Figure 2.1 Plot window showing Input end waveforms with R1 adjusted correctly

3. MEASURING THE SINGLE-PASS TRANSIT TIME.

On the PC, set the **Control window Measurement Channel** to monitor the **Output ends** of the winding.

Adjust the **Control panel Plot window width** and also the **Pulse width controls** on the front panel of the **TDR200** unit until a waveform similar to that shown in figure 3.1 is obtained.

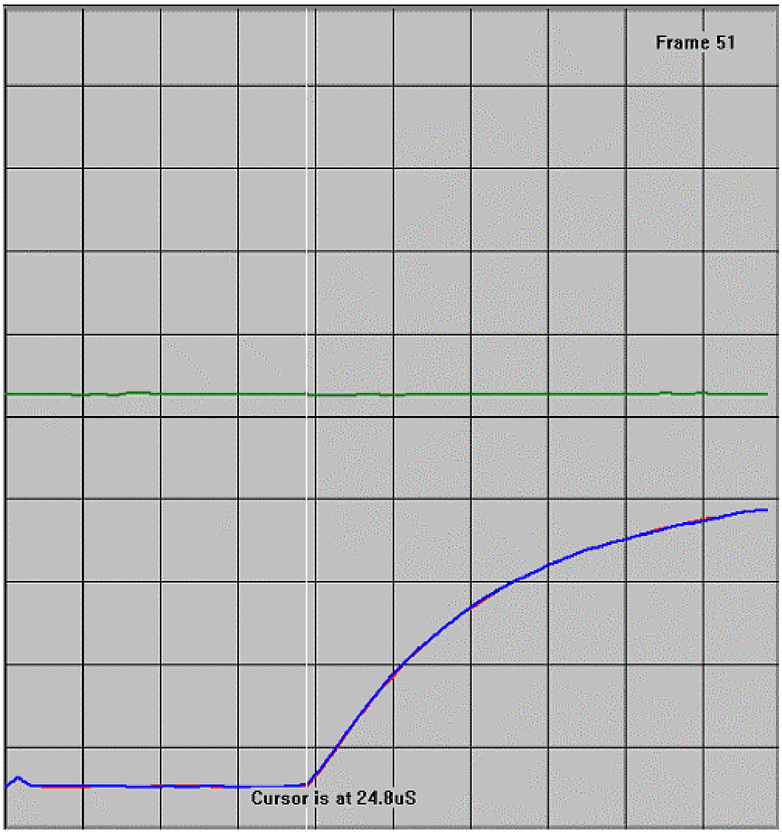


Figure 3.1 Plot window (output ends)

Click on the **Pause button** in the **Plot window**, which will stop the scanning. Now click the **mouse pointer** at the point near the start of the output waveforms (where the waveform starts to increase). This will generate a white time cursor line as shown in figure 3.1 and the **time at the cursor position** will be is displayed.

Note the time displayed for the cursor (in this case, 24.8uS). This is the time in microseconds for the pulse to pass through the rotor winding from one end to the other and is known as the **Single-pass transit time** (**SPT**).

4. SETTING THE VALUE OF R2.

The next step is to measure and set the correct value for the terminating impedance **R2**. This should be similar to that of the input impedance, **R1**. However, it is possible to measure it accurately as described next.

Reset the **Control window Measurement Channel** to monitor the **Input ends** of the winding.

Set the **Display width** in the **Plot window** to be approximately 2 x **SPT** + 16 uS. So in the above case, where SPT is 24.8uS, this figure becomes 65.6 uS. The nearest settable value to this figure is 64 uS, so this value should be used.

On the **TDR200 front panel**, set the value of **R2 = 0.5 * R1** and set the **PC** to display the input end waveforms. (Note that **R1 and R2** are shown as **RV1** and **RV2** in figure 1.1.)

If necessary, adjust the **pulse width controls** on the **TDR200** unit until the waveforms are similar to those shown in figure 4.1(a) below.

Next reset the value **of R2 = 2 * R1** and display the input end waveforms. These should be similar to those shown in figure 4.1(b) below.

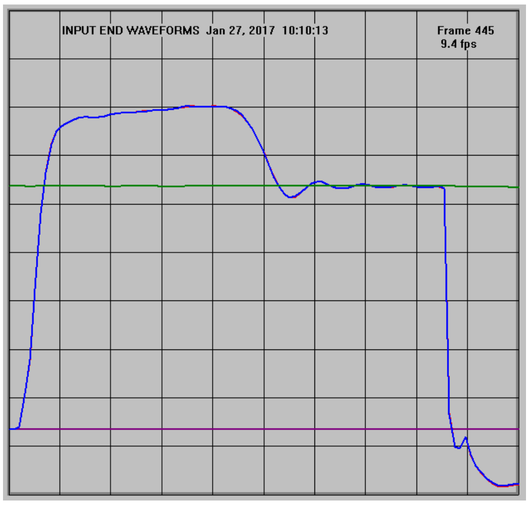


Figure 4.1 (a) Typical input end waveforms with R2 set to half R1 value.

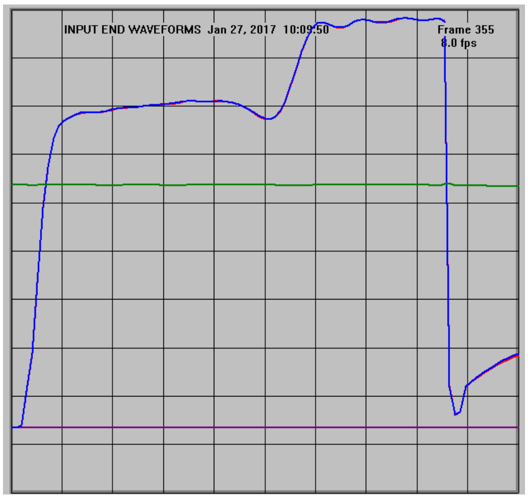


Figure 4.1(b) Typical input end waveforms with R2 set to 2 x R1 value.

Notice that there is now a **reflected signal** which occurs approximately **2 x SPT** after the start of the input pulse.

If **R2 is set to be > R1**, the reflected signal is **positive** and adds to the input waveform.

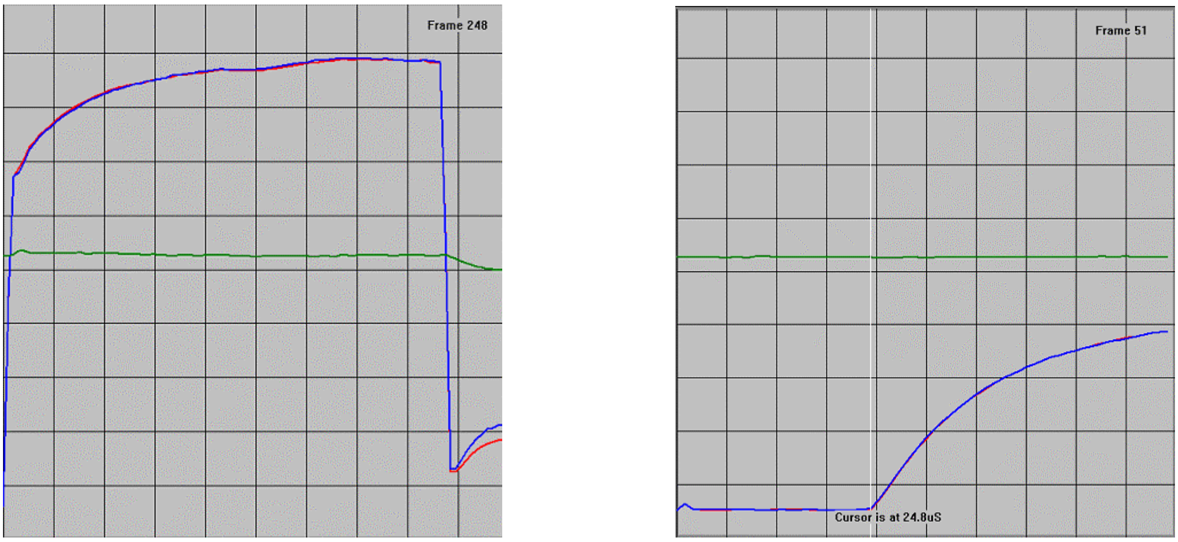
If **R2 is set to be < R1**, the reflected signal is **negative** and subtracts from the input waveform.

Now adjust **R2** so that there is no reflected signal after **2 x SPT**. This is the correct setting for **R2**. The waveforms should now resemble those shown in figure 5.1.

Finally, adjust the setting of **R1** so that it is the same as **R2** if necessary to finish the measurement set-up.

5. SUMMARY

If the **Control window** and **TDR200** controls have been set correctly, the waveforms at the input and output ends of the rotor winding should now be similar to those shown in figure 5.1 below.



(a) Input end waveforms **(b) Output end waveforms**

Figure 5.1 Correct RSO waveforms for a fault-free rotor winding.

ROTOR RSO REFLECTOMETERS

TYPE TDR100/200

APPLICATION NOTE 2

INTERPRETING AND ACTING ON THE RESULTS OBTAINED FROM RSO TESTS

Issue 1. January 2017

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.

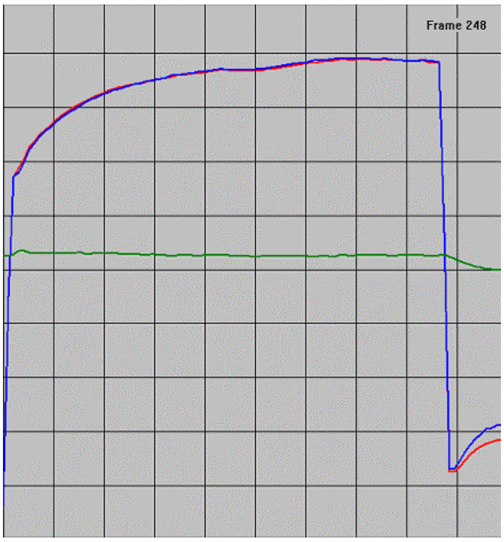

Figure 1(a) Input end waveforms

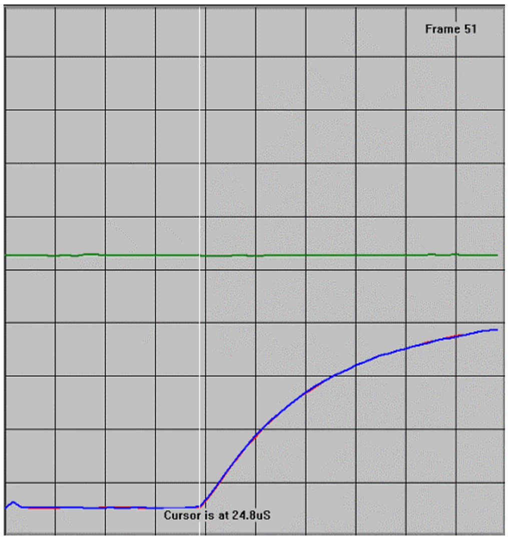

Figure 1(b) Output end waveforms

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.

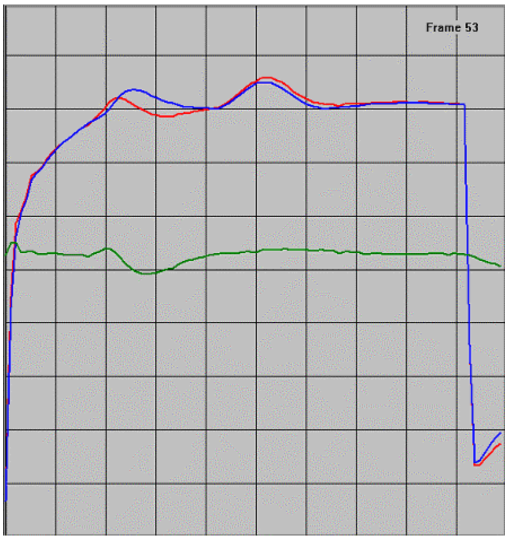

Figure 2(a) Input end waveforms for a shorted turn

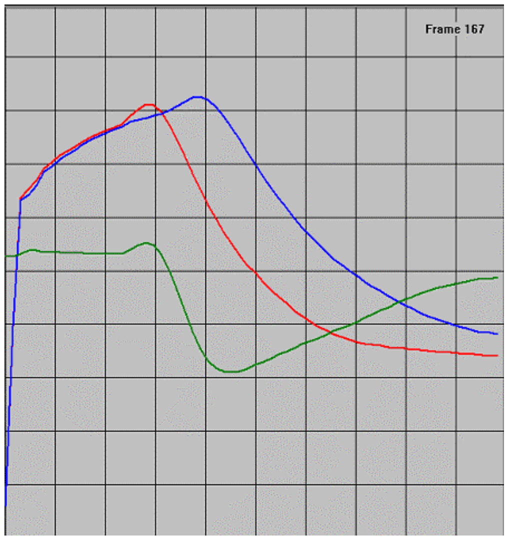

Figure 2(b) Input end waveforms for an earth fault

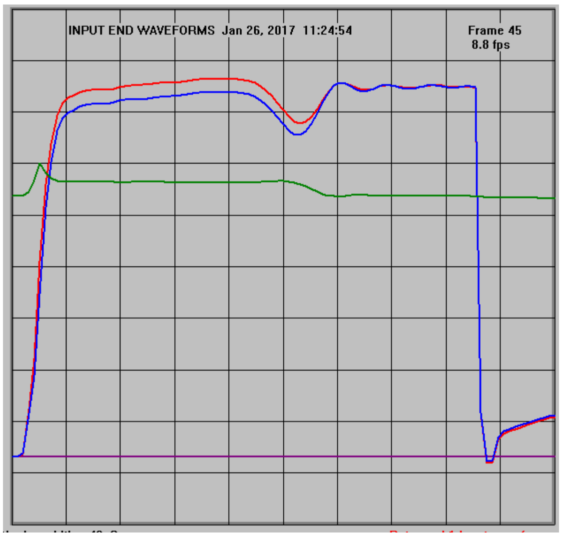

Figure 2(c) Input end waveforms for a simulated high-resistance joint

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.