ROTOR REFLECTOMETER

TYPE TDR100RB

INSTRUCTION MANUAL

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CONTENTS

WARNING

THIS EQUIPMENT MUST ONLY BE CONNECTED TO THE GENERATOR AFTER THE FIELD SUPPLY HAS BEEN DISCONNECTED. FAILURE TO COMPLY WITH THIS COULD RESULT IN DAMAGE TO THE EQUIPMENT AND POSSIBLE DANGER TO THE OPERATOR.

ENSURE MAINS SELECTOR SWITCH ON REAR PANEL IS SET CORRECTLY BEFORE SWITCH ON.

1. OPERATING INSTRUCTIONS

There are several modes in which the Reflectometer may be used:

a) Testing of stationary rotor in generator.

b) Testing of rotor at speed in generator.

c) Testing of rotor when removed from generator.

The most straightforward case is when the rotor is at rest in the generator and the test method for this will be described in detail. The other test modes are based on this technique with suitable modifications. The measurement system is shown in Figs. 1 and 2 and assumes the use of a two channel oscilloscope, although a single channel instrument will suffice if this is not available.

A Method for Testing a Rotor at Rest while Installed in the Generator

1. Isolate the generator stator winding and open the switch.

2. Either isolate the field brushgear from the field supply (both sets of brushes), or remove all of the brushes from each brushgear cage, ensuring that none of the brushes touch the slip rings. For a brushless generator, isolate the generator field winding from the rotating rectifier unit (both leads).

3. Clean an area of rotor shaft adjacent to the slip rings with emery cloth, followed by a degreasing solvent and wipe off with a clean rag. Attach one of the terminal magnets provided to the shaft at this point and connect the green lead supplied to the screw stud on this magnet.

4. Attach the red and blue leads provided to each end of the rotor field winding as follows:

    i) If it has been possible to isolate the brushgear cages from the field supply, then simply connect these leads to each brushgear cage assembly (clip the crocodile clip on to one of the brush braids).

    ii) If the brushes have been removed, clean a small area on each slip ring with degreasing solvent and attach the two remaining magnets to the slip rings. Attach the red and blue leads to the terminal studs on these magnets using the crocodile clips.

    iii) For the case of a brushless generator, clip the red and blue leads directly to the up shaft field winding leads after the isolating links have been removed.

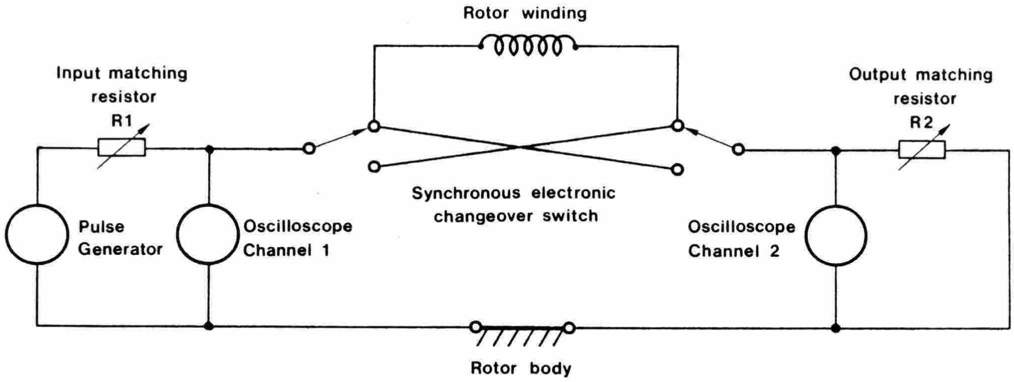


FIG.1. Rotor TDR Measurement System.

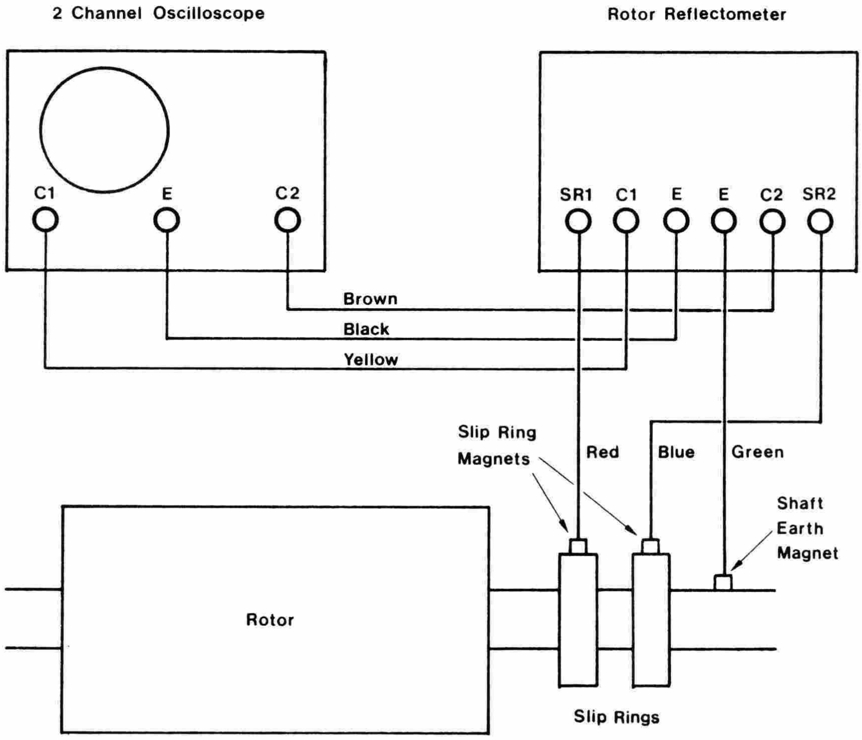


FIG.2. Rotor Reflectometer Connection Diagram.

5. Measure the rotor winding resistance between the remote ends of the red and blue leads using a multimeter. This should be typically less than one ohm, including the resistance of the leads. If the measured resistance is greater than one ohm, check the contact resistance between the clip ends of the red and blue leads and the field winding. If magnets are being used, remove them and reclean the slip ring and magnet faces if necessary. Record the measured winding resistance.

6. Check the contact resistance of the earth magnet to the rotor shaft by measuring the resistance between the remote end of the green lead and a point on the rotor shaft near the magnet. If the resistance exceeds one ohm, reclean the shaft and the magnet face and repeat until a low contact resistance is obtained.

7. Measure the insulation resistance of the rotor between one slip ring (red or blue) and the rotor earth lead (green). A healthy rotor will have an insulation resistance in excess of 1MΩ, although if the winding is damp, this may be reduced to 10KΩ or less. Record the insulation resistance.

8. Connect the plug ends of the red and blue leads to the Reflectometer unit slip ring terminals and connect the green lead to the green earth terminal on the Reflectometer.

9. Connect the short black plug lead from the oscilloscope earth terminal to the black earth terminal on the Reflectometer. Connect the short yellow plug lead between the oscilloscope channel 1 vertical input and the ‘OSCILLOSCOPE INPUT END’ terminal on the Reflectometer. If a two-channel oscilloscope is available, connect the short white plug lead between the second oscilloscope channel vertical input and the ‘OSCILLOSCOPE OUTPUT END’ terminal on the Reflectometer.

10. Set the controls on the Reflectometer initially as follows:

    R1 = R2 = 100Ω

PULSE FREQUENCY	:	Fully clockwise
PULSE WIDTH SWITCH	:	Centre position
PULSE WIDTH POTENTIOMETER	:	Mid scale

11. Set the oscilloscope controls initially as follows:

DISPLAY	:	Channel 1
VERTICAL SENSITIVITY	:	2V/CM (Both channels)
TRIGGER CONTROLS		
- MODE	:	Normal
- SOURCE	:	Channel 1
- LEVEL	:	Positive
- SLOPE	:	Positive
- COUPLING	:	D.C.
- TIME BASE	:	20 µsec/CM

CHECK MAINS SELECTOR ON REFLECTOMETER BEFORE SWITCH ON.

12. Switch on the oscilloscope and the Reflectometer. Adjust the oscilloscope trace position and triggering controls until a stable voltage step is displayed on the oscilloscope screen. This is the waveform at the input ends of the rotor winding and should resemble one of the traces shown in Fig. 3 (a) to (c).

13. Switch the oscilloscope to display channel 2 or, if a single channel oscilloscope only is available, connect the oscilloscope input lead to the 'OSCILLOSCOPE OUTPUT END' terminal of the Reflectometer. Adjust the oscilloscope controls until a trace similar to that shown in Fig. 3 (d) is obtained. This trace shows the voltage step received at each remote end of the rotor winding. Adjust the oscilloscope timebase switch (and, if necessary, the Reflectometer pulse width controls) until the single pass transit time [t_1 in Fig. 3 (d)] occupies less than half of the trace width. Record this transit time in micro-seconds.

14. Switch the oscilloscope back to display channel 1 and adjust the pulse width controls on the Reflectometer unit so that the trailing edge of the voltage step can be seen at the far right of the trace as shown in Figs. 3 (a) to (c). This is a convenient way of displaying the zero voltage level. Now adjust R2 so that there is no reflected signal from the ends of the winding. Fig. 3 shows three cases:

    a) R2 matched (no reflection)

    b) R2 too large (positive reflection)

    c) R2 too small (negative reflection)

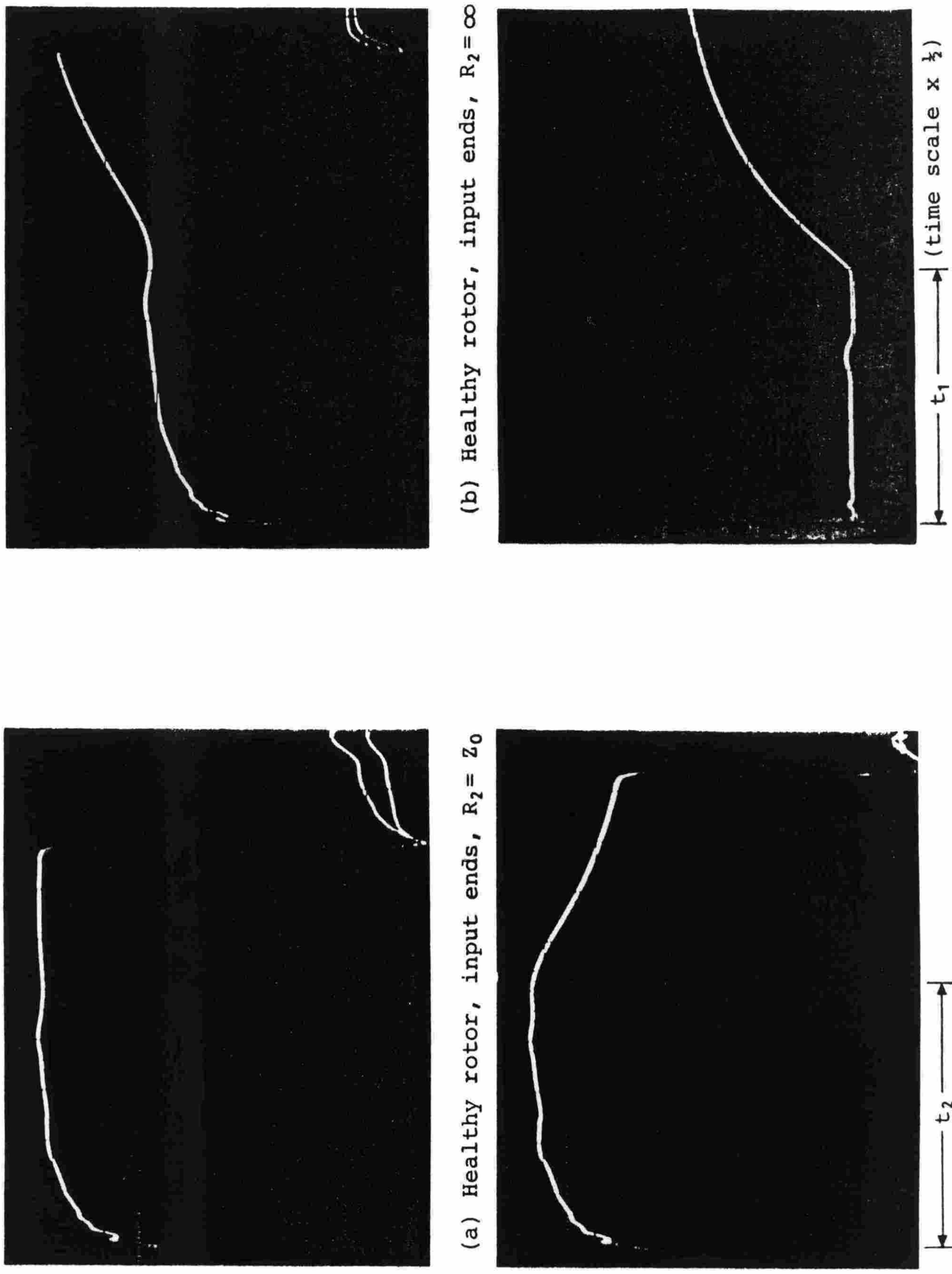
    The reflection is seen at the input ends t_2 seconds after the start of the voltage step where t_2 is approximately twice the single pass transit time (t_1).

15. Having matched the output ends correctly, note the value of R2 (adding 500Ω if necessary), which is the characteristic wave impedance of the rotor winding. Now set R1 = R2 to complete the matching at the input ends. This eliminates the possibility of multiple reflections from one end of the rotor to the other. It may now be necessary to adjust the oscilloscope vertical sensitivity controls to optimise the trace size relative to that of the oscilloscope screen.

16. If the rotor winding is perfect, two perfectly superimposed traces will be displayed on the screen. If this occurs then the rotor winding can be safely assumed to be fault-free. To verify the existence of the two traces, push one of the trace identifier buttons, when one of the traces should be displayed vertically towards the zero voltage level, showing the two traces. If only one trace is displayed check PULSE OUTPUT switch is in AUTO position.

17. If two perfectly superimposed traces are not obtained, there may be a fault in the rotor winding. Section 2 explains in detail the trace shapes to be expected for various types of faults.

<u>FIG.3. Typical traces for a fault-free rotor winding</u>



(a) Healthy rotor, input ends, $R_2 = Z_0$

(b) Healthy rotor, input ends, $R_2 = \infty$

(c) Healthy rotor, input ends, $R_2 = 0$

(d) Healthy rotor, output ends, $R_2 = Z_0$ (time scale x ½)

Note: Z_0 is the characteristic impedance of the rotor winding.

B Method for Testing Rotor at Speed

1. The Reflectometer may be used to test an unexcited rotor at speed. This is particularly useful for detecting and locating faults that are speed-dependent. The most useful information is obtained if the test is conducted either while the rotor is being run up to speed from rest, or while it is run down to rest from synchronous speed. The method is essentially the same as for testing a stationary rotor except of course that it is necessary to make contact with moving slip rings and shaft earth connections.

2. If the brushgear cages can be isolated from the field supply, then connections can be made to the slip rings via the brushgear. However, in most cases it is not possible to isolate the cages. In these circumstances it is necessary to remove all of the brushes from the cage and install some insulated brushes that have been previously prepared. In anticipation of the test, three brushes per slip ring should be removed from the cages and marked so that they may be reinserted in the positions from which they have been removed. The brushes should be machined undersize, and strips of Tufnol or other suitable insulating material glued to the faces of the brushes using an epoxy resin adhesive. The insulated brushes should then be re-machined down to the correct size for reinsertion.

   It should be stressed that it is necessary to use brushes that have been in service in the machine and which have been passing current. Experience has shown that the technique does not work if new brushes are used, a very poor contact being obtained in these circumstances. The insulated brushes are installed in the machine prior to the test, and the brushes in each cage are commoned taking care not to let the brush braids touch the cage assembly. Connections are then made from these insulated brushes to the Reflectometer.

3. It is necessary to make a separate earth connection to the rotor shaft. The most effective method appears to be to clean an area of the shaft and to hold a short length of heavy duty stranded earthing cable against the shaft. This may be done by stripping off the last few centimetres of insulation from the cable and taping the cable to a short length of dowel so that the temporary earth brush may be held safely in contact with the shaft. It has been found by experience that it is not satisfactory to use an existing shaft earth brush for this test because of the large amount of electrical noise generated by these devices.

4. With the modifications mentioned above, the test may be carried out as the rotor speed is increased or decreased. The equipment should be set to monitor the traces at the input ends of the rotor and should be watched carefully for any changes in one trace which will indicate a speed dependent fault.

C Method for Testing Rotor when Removed from Generator

1. The test method is basically the same as that outlined in Section A. However, with the rotor removed from the machine, further tests may be possible.

2. If the rotor end bells are removed, the shape of the traces obtained may differ considerably from that for a rotor with the end bells in-situ. Moreover, because the windings can expand radially in the absence of the end bell, two slightly different traces may be obtained for a rotor that is known to be fault-free, because the expansion of the end region windings may not be uniform. In general, the effect of removing the end bells increases the characteristic impedance of the rotor considerably.

3. If a winding fault has been detected in the rotor, and the end bells have been removed, it is possible to find the approximate location of the fault by putting a similar fault onto the other half winding of the rotor and moving the position of this deliberate fault until two identical traces are obtained. This may be done by using insulated probes.

   If an earth fault is suspected, then one of the probes should be earthed to the rotor body using a short flexible lead, and the end winding should be probed until the application of this fault causes similar traces to appear. The faulted coil may be found by touching the probe onto the outer turn of each coil in the end region of the winding. When the coil which causes the traces to almost coincide has been located, the faulted turn may be located by moving the probe radially down this coil in the end winding region and making contact with the sides of the conductors, which are not usually insulated. When the turn has been located which causes the traces to coincide (or nearly so) its coil number and turn number (found by counting turns down from the outside of the winding) should be noted. The fault lies in the equivalent coil in the other half winding.

4. It is possible to use this same technique without removing the end bells if the rotor contains radial cooling holes that run next to the conductor slots. In this case, the winding may be probed directly.

5. The position of an inter-turn fault may be located by using two probes connected via a length of flexible lead. In this case, adjacent turns of the opposite half-winding are shorted together to locate the fault.

2. INTERPRETATION OF RESULTS

A Fault-free, Healthy Rotor Winding

Fig. 3 shows the results to be expected when a healthy rotor is tested.

Fig. 3 (d) shows the voltage step received at the far end of the rotor, and t_1 is the time for it to propagate through the rotor. This is termed the single pass transit time and is typically 50-100µS.

Fig. 3 (a) shows the traces at the input ends of the rotor and displays two perfectly superimposed traces (except in the region after the end of the voltage step, which is of no relevance to the test). This indicates a healthy rotor winding.

Fig. 3 (c) shows the input end traces when the output ends are terminated in a near short circuit (R2 = O). The top of the voltage step is seen to start to decrease in amplitude after a time t_2 seconds, which is the time for the pulse to pass through the winding once and then back again.

Similarly Fig. 3 (b) shows the input end traces when the output ends are terminated in an open circuit. In this case, the top of the voltage step starts to increase after t_2 seconds.

It will be seen that the input and output matching resistors have no effect on the individual traces apart from changing their shape. It is not possible to produce two different traces for a healthy rotor by maladjustment of the Reflectometer or oscilloscope controls and hence the possibility of misinterpreting traces caused by operator error is greatly reduced. Always check for two traces by pressing the trace identify switches.

B Trace indicates a Faulty Winding

There are several basic modes of failure of a rotor winding:

a) Fault between winding and rotor body (earth fault)

A full or partial fault may occur between the winding and the rotor body. An example of the type of trace obtained in this case is shown in Fig. 4 (a). The voltage step which is injected from the end nearest the fault is seen to increase to a peak at the fault and then to decay rapidly. The voltage step injected from the end furthest from the fault increases and decays some time later, as the voltage step injected from the remote end takes a longer time to reach the position of the fault. It should be noted that the sharpness and rate of decay of the second peak is considerably less than that for the first peak. This is an example of the general rule that the resolution of the measurement for this test is greatest near the point of injection of the voltage step (i.e. at the slip rings) and decreases as the position of the fault moves further into the winding.

The approximate location of the fault may be found by comparing the time from the start of the voltage step to the peak of the trace with that to the end of the winding when R2 is set equal to zero as shown in Fig. 3 (c). This must have been done prior to the fault occurring and highlights the need to record the traces of 3 (a) and 3 (b) for the rotor while it is in a fault-free state (ideally when it is first commissioned) to act as a reference 'fingerprint' for future use.

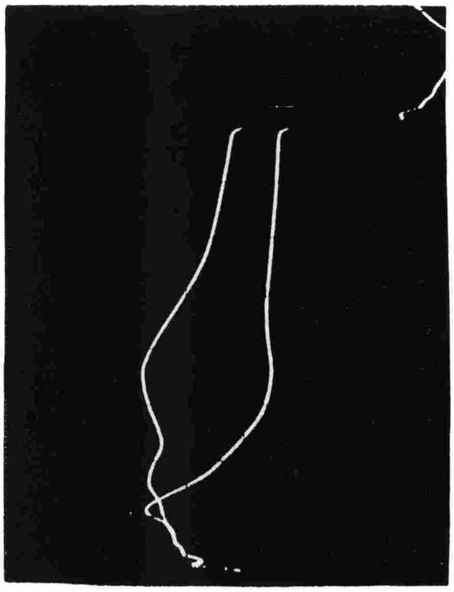
b) Interturn Fault

Fig. 4 (b) shows the type of trace obtained when a short circuit between adjacent turns occurs. The trace corresponding to the end nearest the fault increases slightly then decreases and finally increases to meet up again with the trace injected from the other slip ring end. The faulty trace is that which gives rise to the lower part of the first major loop shown in Fig. 4 (b). The approximate location of the fault may be found by similar means to that described for the earth fault case. It should be noted that the test is particularly sensitive and will detect a relatively high (a few ohms) interturn fault that may, in practice, not carry current in an operational state. Further tests involving measuring the voltage drop across adjacent turns by passing a large direct current through the total winding must be carried out to determine whether the fault is current-carrying or not.

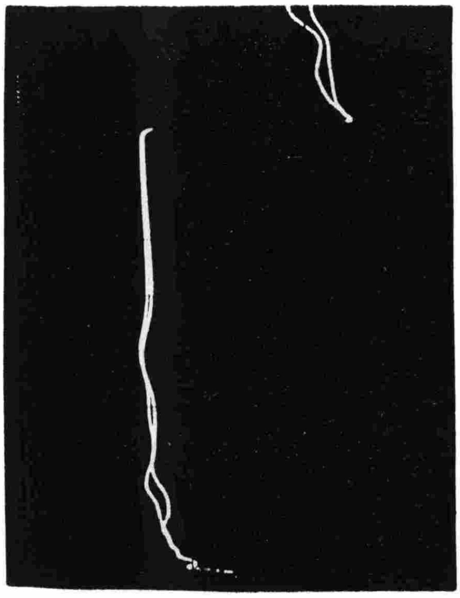
c) High resistance joint in rotor

The effect of a high resistance joint on the winding is shown in Fig. 4 (c). The apparent characteristic impedance of the end of the winding nearest the fault is increased relative to that of the other end of the winding. Hence the upper trace shown in Fig. 4 (c) corresponds to the end of the winding nearest the fault. It is possible that the fault may be caused by a high resistance joint at one slip ring. In this case, the fault may be confirmed by placing a variable 0 - 500Ω resistor in series with the lead to the other slip ring and adjusting this variable resistor. If it is possible to make the traces coincide by these means, then the fault occurs very close to the first slip ring.

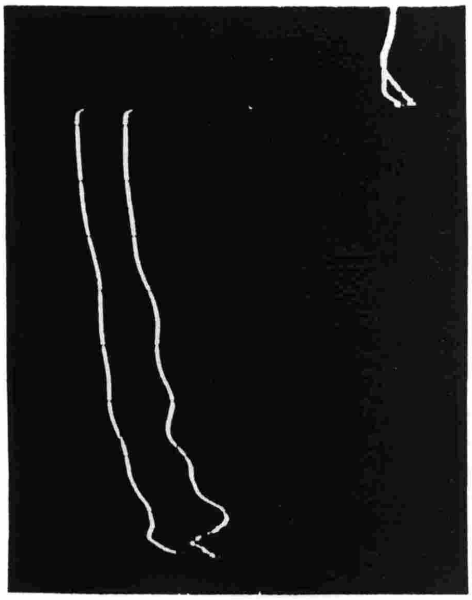
FIG.4. Typical traces for common types of winding faults



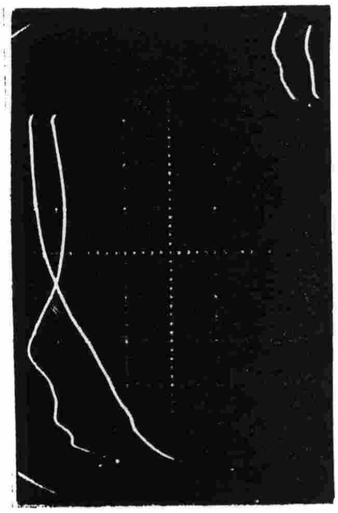
(a) Short circuit to rotor body at end of 5th slot coil (16 coils in winding).



(b) Short circuit between outer two turns in 5th slot coil.



(c) High resistance joint (32Ω) near one end of winding.



(d) Short circuit between up-shaft lead and 5th slot coil. Example of major inter-winding fault.

d) <u>Interwinding fault</u>

It is possible for faults to occur between rotor slot coils and the upshaft leads which connect the slip rings to the ends of the rotor winding. Fig. 4 (d) shows an example of a fault of this type, in which the upshaft lead had shorted to the fifth coil in the winding, effectively shorting out the first five coils in a total winding of sixteen coils. The lower trace corresponds to the slip ring nearest the shorted coils.

e) <u>Other causes of non-identical traces</u>

Apart from these common faults, there are circumstances where, in applying the test, problems occur which may indicate that a good rotor is faulty. These may be caused by:

i) Poor contact between the slip rings and the test leads. If this occurs, the traces will resemble Fig. 4 (c), the difference between the traces being dependent on the magnitude of the contact resistance. If this occurs, re-check the contact between the test leads and the slip rings before assuming that the rotor winding is faulty.

ii) Poor contact between the earth lead and the rotor shaft. Again, the cure is to re-check the contact resistance.

iii) The characteristic impedance of both rotor half windings are not identical. On the face of it, this seems most improbable. However, it may be caused by a previous repair to one half winding using insulation different from that used during manufacture. Moreover, when the end bells are removed, the end windings expand radially in a non-uniform manner, causing the impedances to differ. Consequently, two slightly different traces are nearly always obtained when one or both end bells are removed.

3. PRINCIPLE OF OPERATION

Electrical faults in generator rotors fall into two main categories, faults from the winding to the rotor body ('earth faults') and faults between parts of the winding ('inter-winding faults'). The existence of an earth fault is detectable with a simple multimeter. A single earth fault on a rotor is frequently tolerated and many generators run in this condition. The existence of an inter-winding fault is not easily detected by simple electrical methods. However, a rotor with a serious inter-turn fault will frequently display excessive mechanical vibration and may have to be taken out of service because of this.

The rotor Reflectometer uses a technique known as time domain reflectometry. The application of this technique to testing rotors is known as the RSO (recurrent surge oscillograph) method by power engineers in the U.K.

The method involves applying a D.C. voltage step between one end of the rotor winding and the rotor body. The transmitted wave at the far end of the winding and the reflected wave at the input end of the winding are monitored using two oscilloscope channels. If the voltage step is applied from each end of the rotor winding alternately, then two oscilloscope traces will be obtained which may be superimposed on the oscilloscope screen. A healthy rotor winding will have two identical traces. A rotor with a fault will have differing traces and the positions of the fault may be deduced by scaling in the time domain.

The basic Reflectometer system is shown in Fig. 1. A pulse generator supplying a 12V pulse of variable length at a repetition rate of up to 500Hz is connected via a 500Ω variable resistor to an electronic changeover switch synchronised to the pulse repetition rate. The changeover switch enables the rotor to be excited from each end of the winding in turn, alternate pulses exciting the rotor from opposite ends. The rotor is terminated in a second variable resistor R2 via the changeover switch. The pulse generator, synchronous changeover switching network, matching resistors and terminals are all contained within the Reflectometer unit. Two oscilloscope channels monitor the voltage at the input end of the rotor (channel C1) and at the output end (channel C2). The values of R1 and R2 are chosen to match, approximately, the characteristic wave impedance of the rotor winding, to eliminate reflections of the pulse at each end of the rotor.

The pulse repetition rate and pulse length are adjustable by means of three controls on the front panel of the Reflectometer. The synchronous changeover switch first excites the rotor at end 1 and the pulse propagates along the rotor winding, emerges at end 2 and is absorbed by R2. The switch then operates and the next pulse excites the winding at end 2, propagates through the winding to end 1 and is again absorbed in R2. The changeover switch returns to the first condition and the sequence is repeated continuously. Hence successive pulses from the pulse generator excite the rotor from each end in turn and energy is always supplied via R1 and absorbed by R2. The changeover switch is arranged to operate approximately half way in time between successive pulses so that the operation of the changeover switch does not adversely affect the leading edge of the pulse. A single channel oscilloscope connected between S1a and earth as shown will therefore display two traces corresponding to the signals applied to each end of the rotor.

The voltage waveforms at the input and output ends for a typical sound rotor are shown in Fig. 3. Simplified idealised versions of these traces are shown in Fig. 5 (a). A sound rotor will appear to be symmetrical with respect to either slip ring and therefore, the two traces that either C1 or C2 monitor will be identical and will be superimposed on the oscilloscope screen. The pulse will take a finite amount of time (the transit time) to travel from input end of the rotor to the output end. As a result, the traces monitored by C2 will display zero voltage for this period (the transit time) and the transit time may therefore be measured directly from the C2 traces.

When an earth fault occurs part way along the winding, the traces that occur are shown in idealised form in Fig. 5 (b) and, as measured, in Fig. 4 (a). At the short circuit to earth, the input pulse is reflected with reverse polarity and when it returns to the input end, a decrease in voltage is observed. Assuming that the fault is not exactly in the centre of the winding, the reflection will occur at different positions for the two traces. The traces will therefore diverge as shown in Fig. 4 (a). The trace that is deflected corresponds to the end nearest to the fault. A rough estimate of the position of the fault may be found by noting the time to the fault by noting the time to the fault as indicated by the input trace (t_2 seconds).

By linear scaling, the fault will be approximately $\frac{t2}{2t_1} \times 100\%$ of the winding from one end. The apparent propagation velocity of the pulse through the rotor winding is not uniform and care must therefore be exercised in locating faults by this method.

The best method for locating the position of the fault is outlined in Section 1 (c). This involves removing the rotor from the generator and probing the winding in the end region or down the radial cooling holes if these exist. The detection and location of interwinding faults may be carried out in a similar manner.

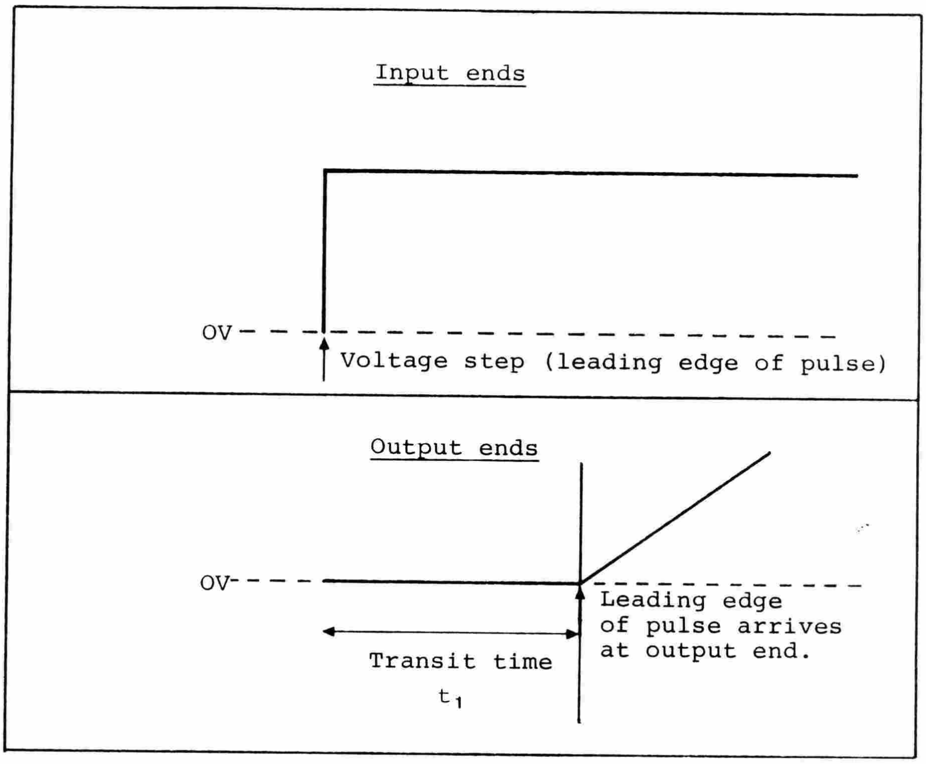


FIG.5(a). Idealised traces for a perfect rotor

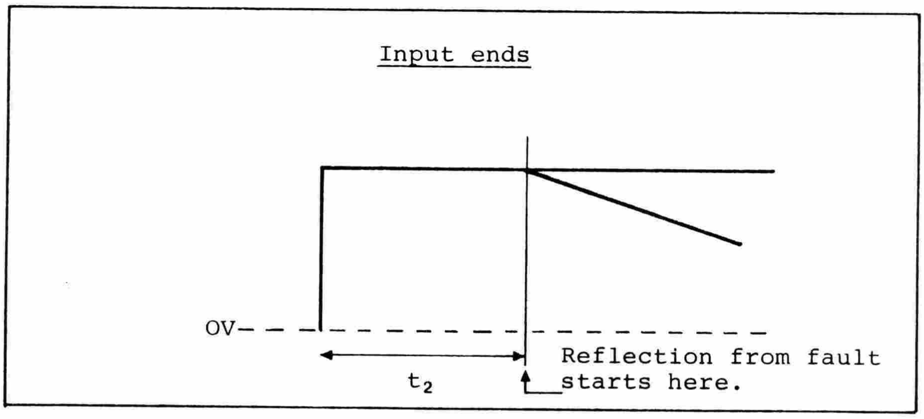


FIG.5(b). Idealised traces for a rotor with an earth fault

4. REFLECTOMETER DELAY LINE TEST UNIT

The purpose of the delay line unit is to check that the Reflectometer is operating correctly and it is also an aid to demonstrating and understanding the test method.

The unit consists of a 10 section lumped component delay line. The characteristic impedance of the delay line is 100Ω and the propagation time for a single pass through the unit is 11μS. The junctions between each section of the delay line are connected to a series of 2mm sockets, enabling external connection to these points. The input and output ends of the unit are connected to 4mm sockets.

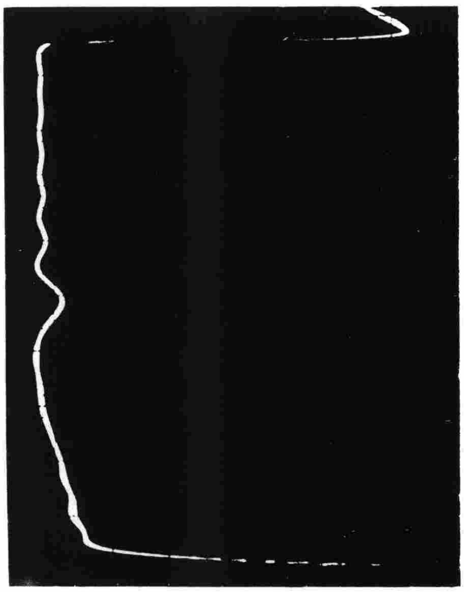
In use, the input and output sockets (red and blue) are connected to the rotor slip ring terminals on the Reflectometer, together with a single lead from the Reflectometer earth terminal to one of the common (black) 4mm sockets on the delay line. The oscilloscope controls should be set up as described in Section 1 of this manual. Set the oscilloscope vertical sensitivity to 1V/cm, the horizontal sensitivity to 5μS/cm and both Reflectometer matching resistors to 100Ω.

With the oscilloscope monitoring the input ends of the delay line, adjust the pulse width so that the display resembles that shown in Fig. 6 (a). The effect of mismatching the output ends of the delay line may now be demonstrated by changing the output matching resistor, R2 on the Reflectometer. Fig. 6 (c) shows the traces obtained when R2=0. The double pass transit time is seen to be 22μS and Fig. 6 (d) shows the traces obtained with R2=500Ω. The effect of a simulated earth fault may be demonstrated by shorting one of the delay line junctions to earth. Fig. 7 (a) shows the result of shorting junction 4 to earth. Similarly the effect of a shorted turn may be demonstrated by shorting out one or more delay line sections as shown in Fig. 7 (b).

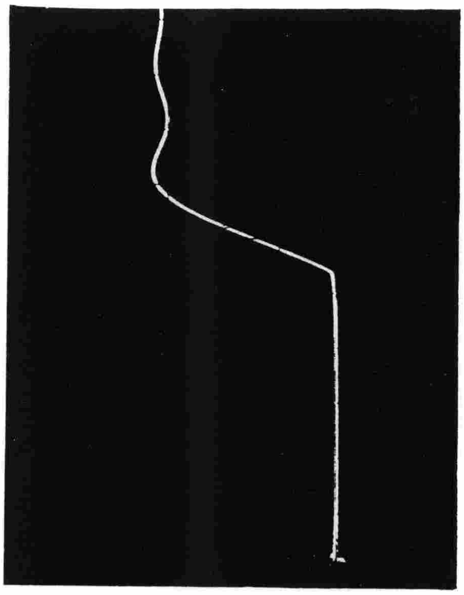
NOTE

The impedance and single pass transit time of the unit supplied may differ from the figures quoted above.

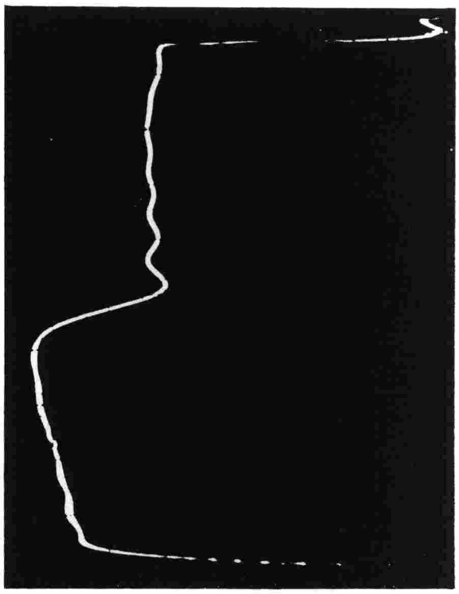
FIG.6 Typical traces with no faults applied.



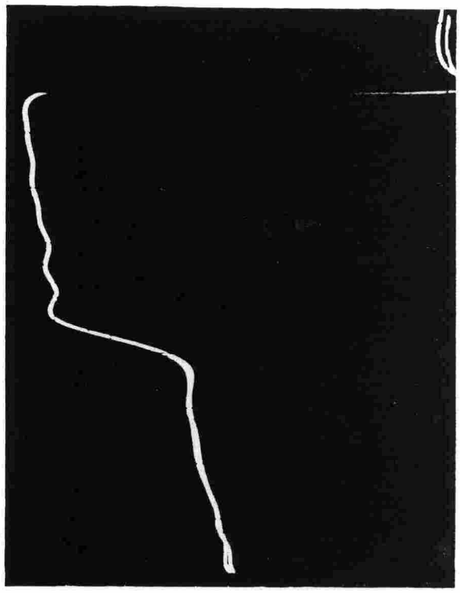
(a) Waveform at input ends of delay line



(b) Waveform at output ends of delay line

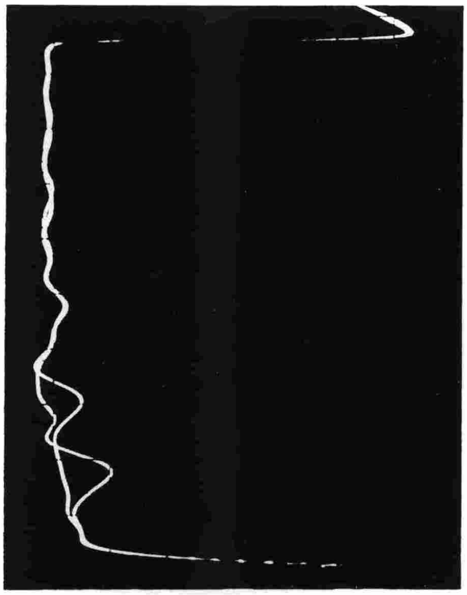


(c) Waveform at input ends, R2=0

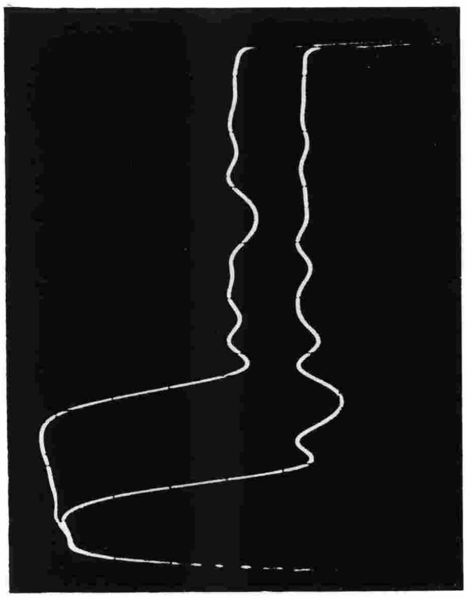


(d) Waveform at input ends, R2=500Ω

FIG.7 Typical traces with faults applied.



(b) Waveform at input ends.
Short circuit between '4' and '5'



(a) Waveform at input ends.
Short circuit to earth at '4'

5. LIST OF EQUIPMENT SUPPLIED

1	Rotor Reflectometer unit
3	Terminal magnets
3	Long crocodile clip/4mm plug leads (red, blue, green)
3	Short 4mm plug leads (yellow, black, white)
2	BNC/4mm plug adaptors
1	Mains lead
1	DL100 Delay Line (inc. leads)
1	Manual

APPENDIX A

Two additional facilities are now included in the Rotor Reflectometer as follows:

1) The Input Matching Resistors now have increased range and can be set to between 0-500Ω or 500-1000Ω. If the toggle switch is down when correctly matched add 500Ω to the dial reading to obtain the value of R2.

2) A three position rotary switch is included to provide the additional facility of injecting pulses into slip ring 1 or slip ring 2 only.

   Position 'RSR1' - pulses are injected into slip ring 1 only.

   Position 'RSR2' - pulses are injected into slip ring 2 only.

   Position 'AUTO' - normal operating mode.

NOTE

For normal rotor testing ensure that the switch is in the 'AUTO' position as the single trace produced when the switch is in the 'RSR1' of 'RSR2' position will not indicate a winding fault.

When in the 'AUTO' position always check that two traces are present by using the 'Trace Identify' buttons. If only one trace is shown when one button is pressed, check and adjust the triggering of the oscilloscope (particularly when using a storage oscilloscope).

APPENDIX B

TDR100RB

The TDR100RB is similar in operation to the TDR100. The only difference is that the TDR100RB contains a maintenance free 12 volt rechargeable Nickel Cadmium battery pack giving over 15 hours continuous use under average operating conditions.

To recharge the battery, connect the Reflectometer to a suitable 240V or 110V 50Hz mains supply via the rear mounted socket. The 'CHARGE' indicator on the front panel will light showing that the unit is on charge.

With the front panel 'SUPPLY' switch set to the 'OFF' position the battery can be fully charged from a fully discharged state in 16 hours.

ENSURE THAT THE 240V/110V SWITCH SITUATED ON THE REAR PANEL IS SET TO THE CORRECT POSITION BEFORE CONNECTING THE SUPPLY.