

Utilization of Repetitive Surge Oscillograph (RSO) in the Detection of Rotor Shorted-Turns in Large Turbine-Driven Generators

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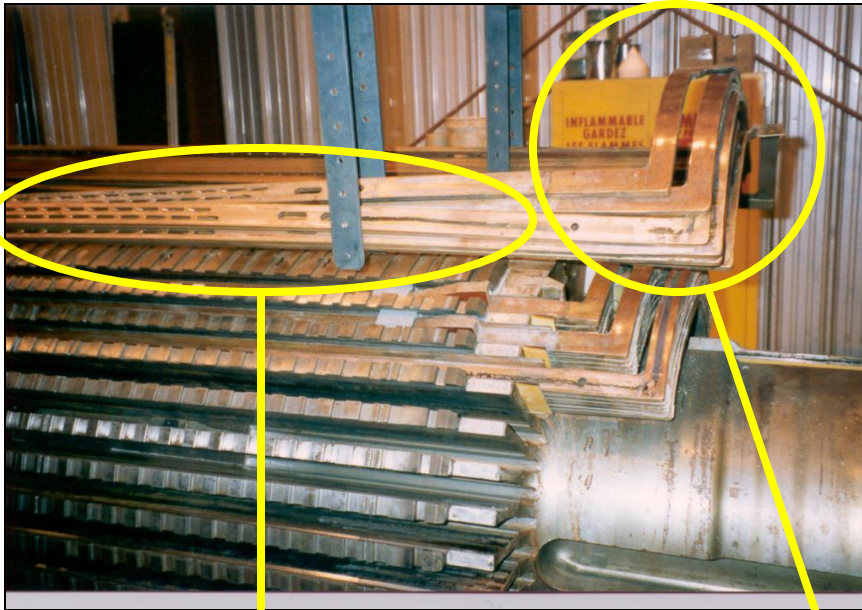
Purpose of this presentation:

The implementation of the RSO testing-technique has been gathering momentum in the USA during the last few years.

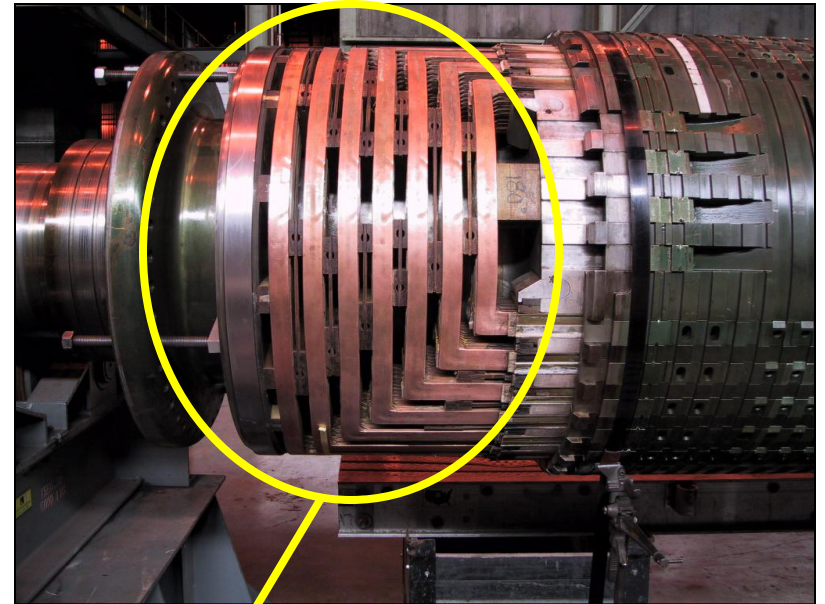
With its extended use, questions about its implementation (such as safety to the windings and extent of application) have multiplied.

The intention of the authors of the paper is to provide answers to these questions, based on their experience with the technique.

Typical cylindrical (turbo-generator) rotor winding



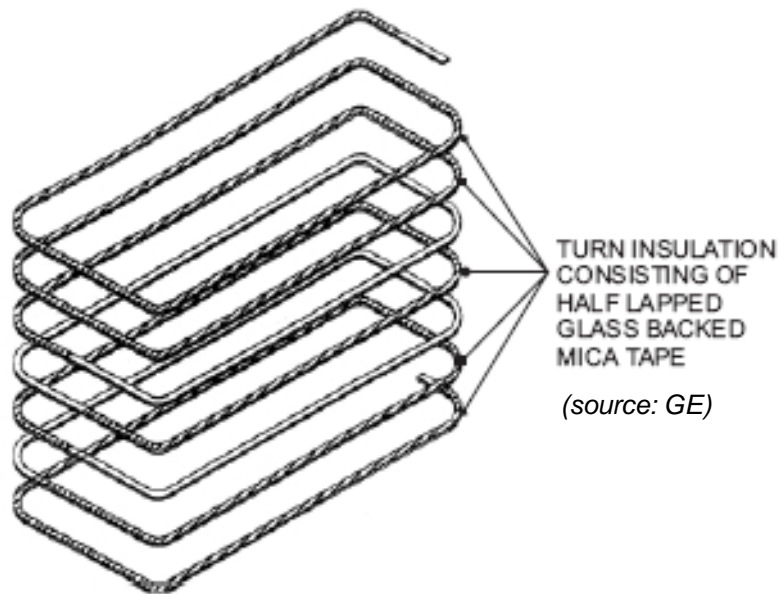
**SLOT AREA
OF THE
COIL**



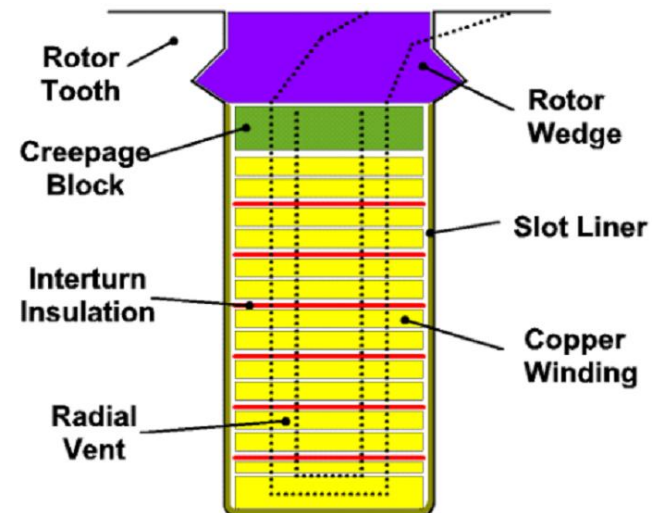
**END-
WINDING**

Typical winding construction

Interturn insulation typically made of Nomex paper or resin/epoxy-impregnated glass laminate material, half-lapped glass backed mica tape (old systems), or similar insulating material. Typical thickness of the turn insulation is 10 to 15 mils.



FULL TURN INSULATION



STRIP TURN INSULATION

Typical operating conditions

- Temperatures of up to 155 °C (class B rise).
- Interturn voltages of several volts.
- Strong mechanical pressure.
- Tearing forces due to unequal elongation between copper, insulation.
- Tearing forces due to relative movement during acceleration, deceleration, heating and cooling.
- Vibration.

What's a shorted turn?

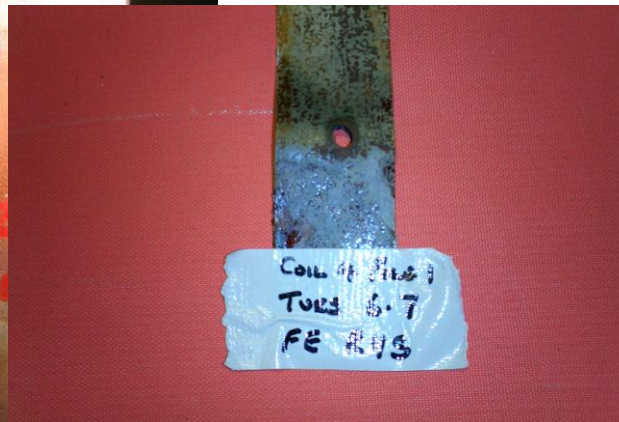
Breach of insulation between two (or more) adjacent turns in the coil of a rotor winding.



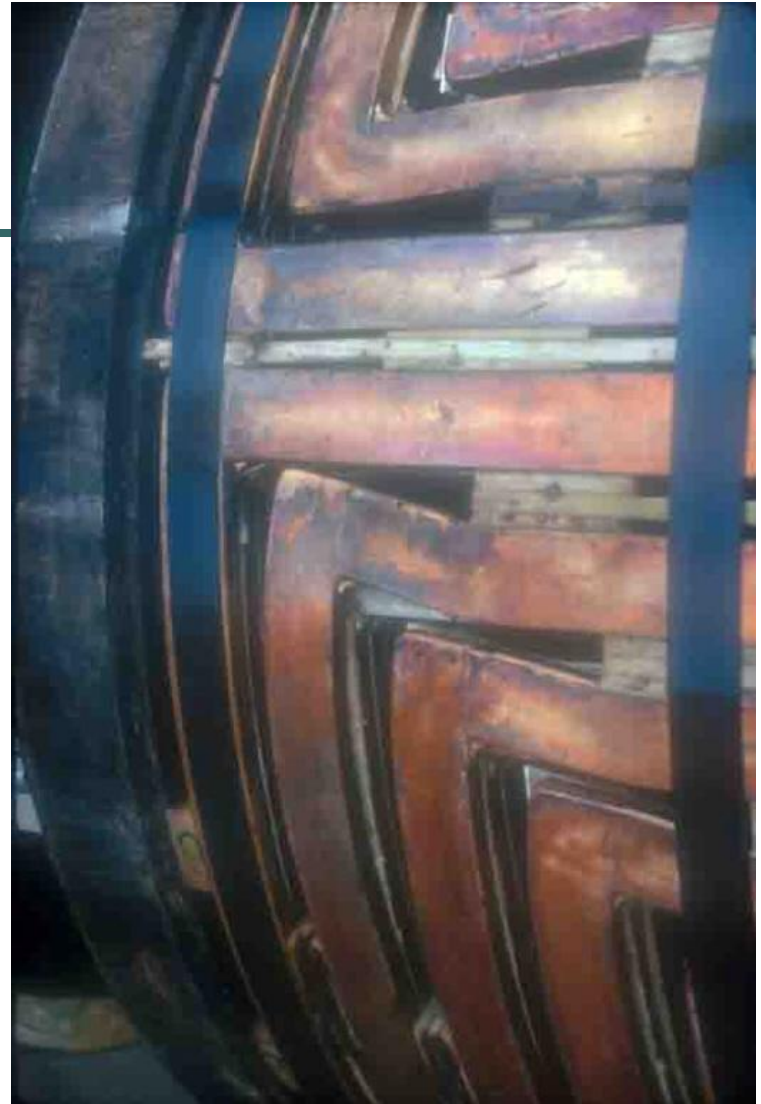
In overhang area



In slot area



Example of shorted turns due to cyclic loading of a generator coupled with an ineffective blocking of the end-windings



Reasons why shorted turns occur

Manufacturing causes:

- Coil blocking
 - Allows too much movement/distortion between turns in the overhangs
- Clean conditions not maintained
- Type of insulation (e.g.: glass epoxy, Nomex) & thickness
- Coil construction
 - Consolidated vs. not consolidated
- Poor workmanship & QA

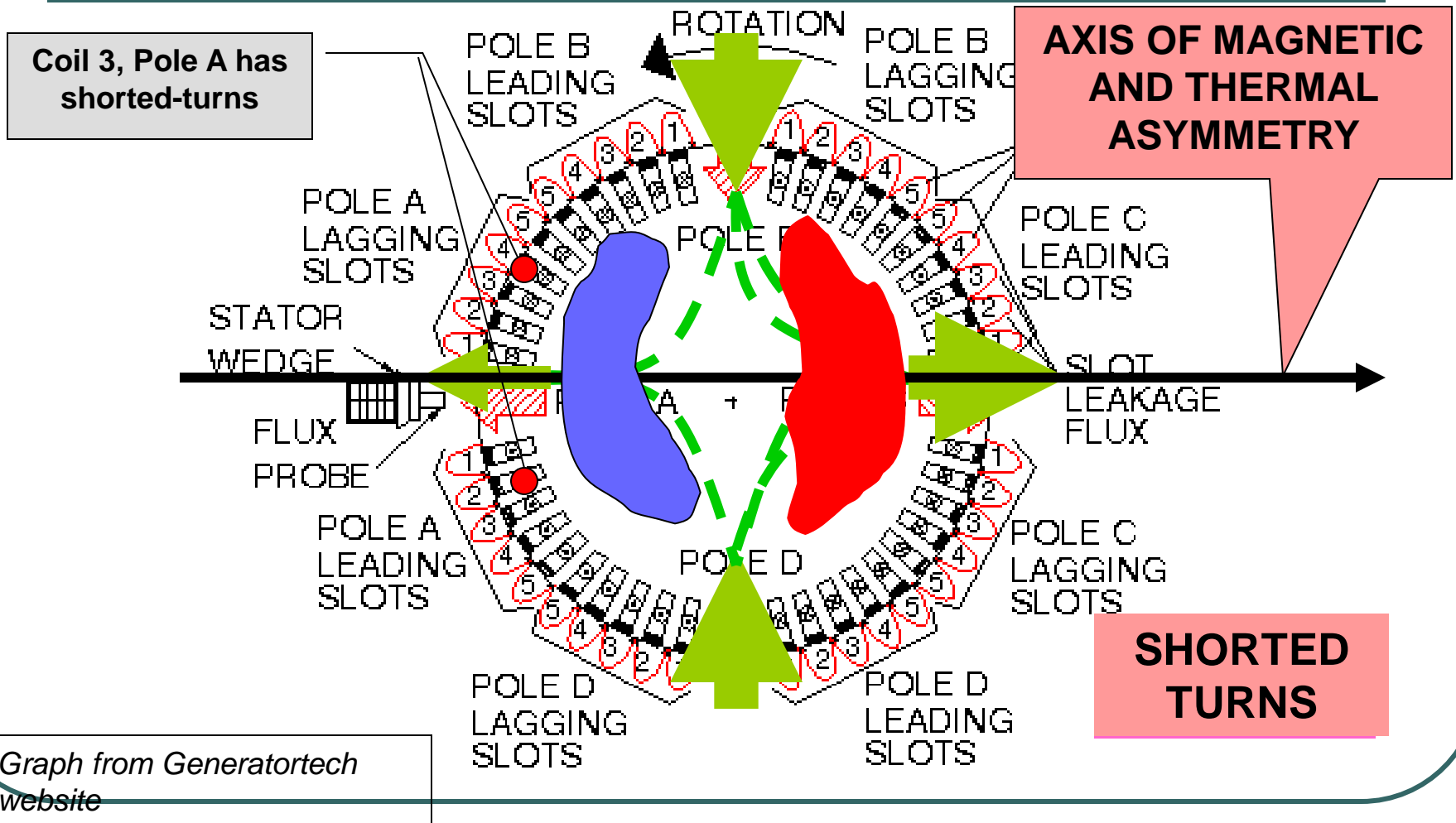
Operational causes:

- Copper dusting (many hours on turning-gear)
- Double shifting
- Poor FME during open-machine outages
- Poor maintenance
 - E.g.: no rotor cleaning from carbon dust in air-cooled machines
- Severe Grid disturbances
- Overload/Loss of Cooling events
- Aging
- Etceteras.....

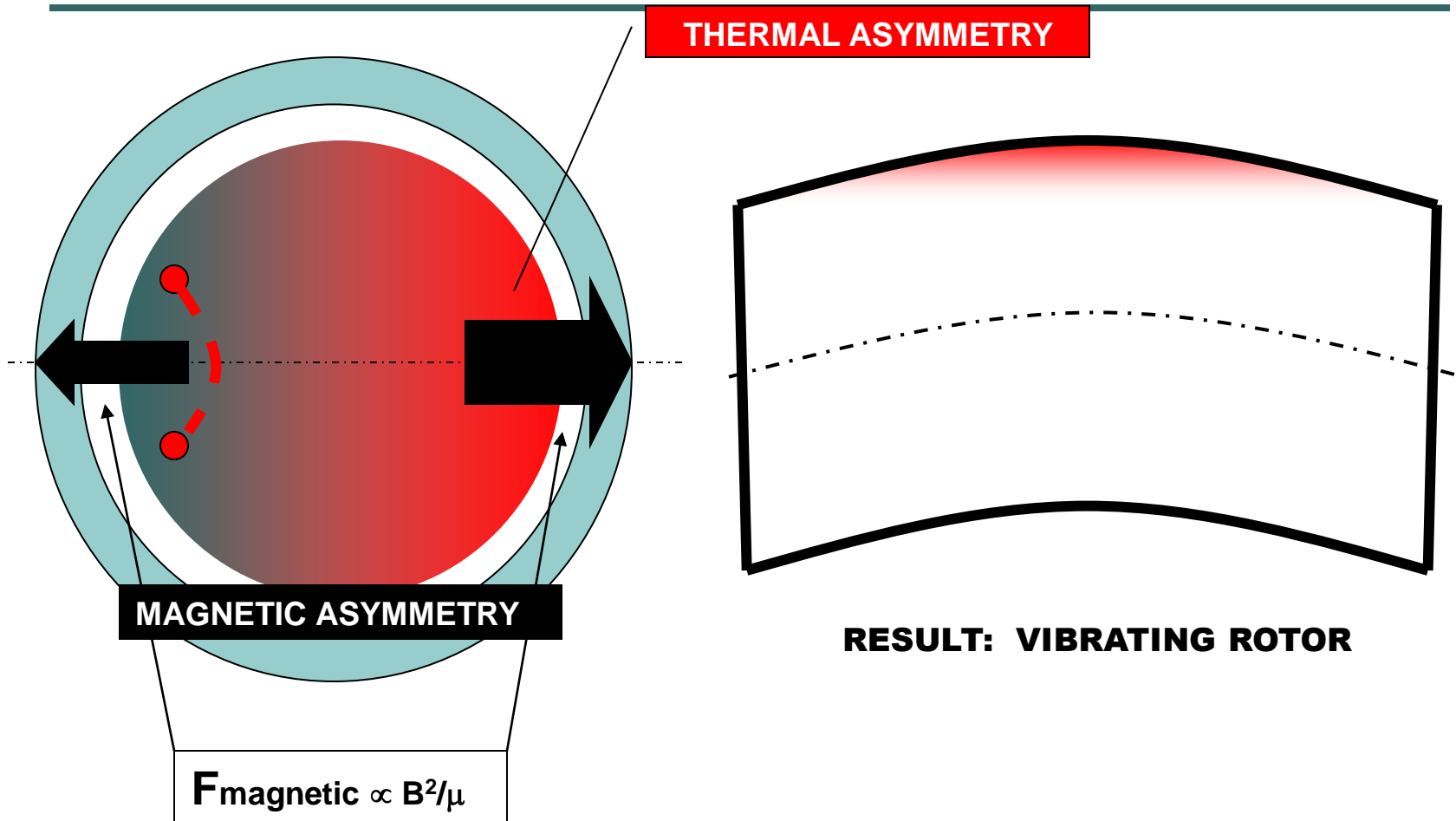
How do shorted-turns make themselves noticeable?

- Mostly by increased vibrations
- Vibrations sensitive to field current (VAR) changes
- Sometimes by reduced excitation capability
- Often they DON'T cause any obvious performance changes and are only found by monitoring (e.g.: flux probe and shaft voltages) and/or by testing (RSO, Open Circuit voltage, impedance, pole-drop, etceteras)

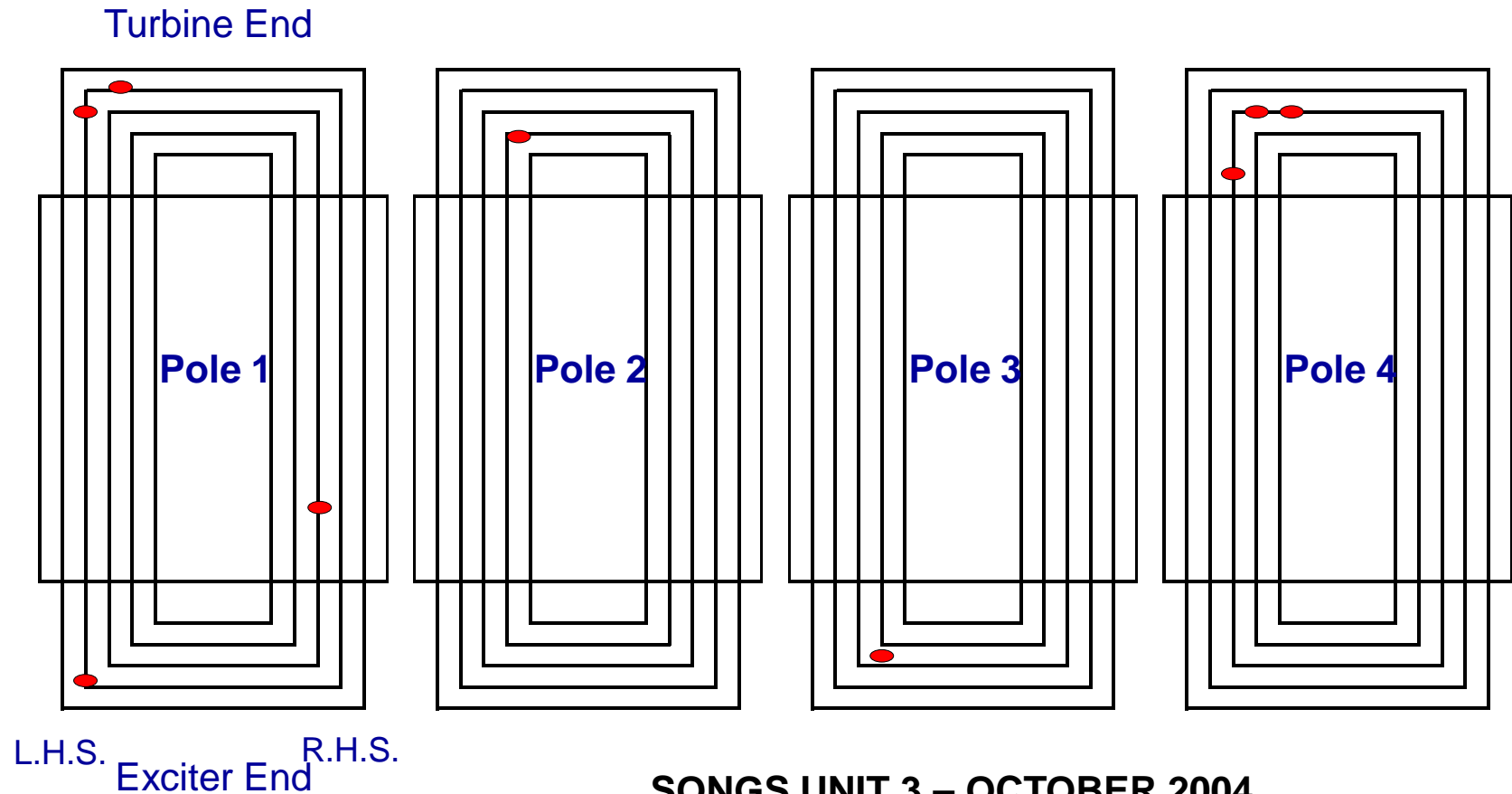
How shorted-turns cause vibrations?



Resulting bow and magnetic pull:



Where are shorted turns more prone to occur?



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How bad are shorted-turns?

- Perhaps close to 50% of all units in operation have at least one shorted turn.
- Some may remain stable (no additional shorts) for many years.
- Some may continue to develop shorts and may eventually create a ground fault.
- Some may have MANY shorts without any severe impact on operation.
- Some may severely impact operation after only developing a few shorts.
- Two-pole and four-pole units exhibit significant different behaviors due to shorted-turns.
- Bottom Line: How bad it is and what needs to be done depends on the machine construction, history, OEM recommendations based on similar units' history, Grid requirements, rating, age, etceteras.

What monitoring equipment and/or tests are available for finding shorted-turns?

- RFM (rotor flux monitor) – Requires unit on line and readings taken at various load points. Can be used to determine pole-coil location of the short.
- Shaft-voltages – Requires unit running. Difficult interpretation of readings.
- RSO (*repetitive surge oscillosgraph* or *recurrent surge oscillogram*) – Unit at rest or spinning without load and excitation removed.
- O.C. Voltage Characteristics – Taken with unit at full speed and open breaker. Requires benchmark curve.
- Rotor impedance vs. rpm.
- “C-Core” test – Requires rotor out of bore.
- Pole-Drop measurements – Rotor out. Maybe retaining rings off.

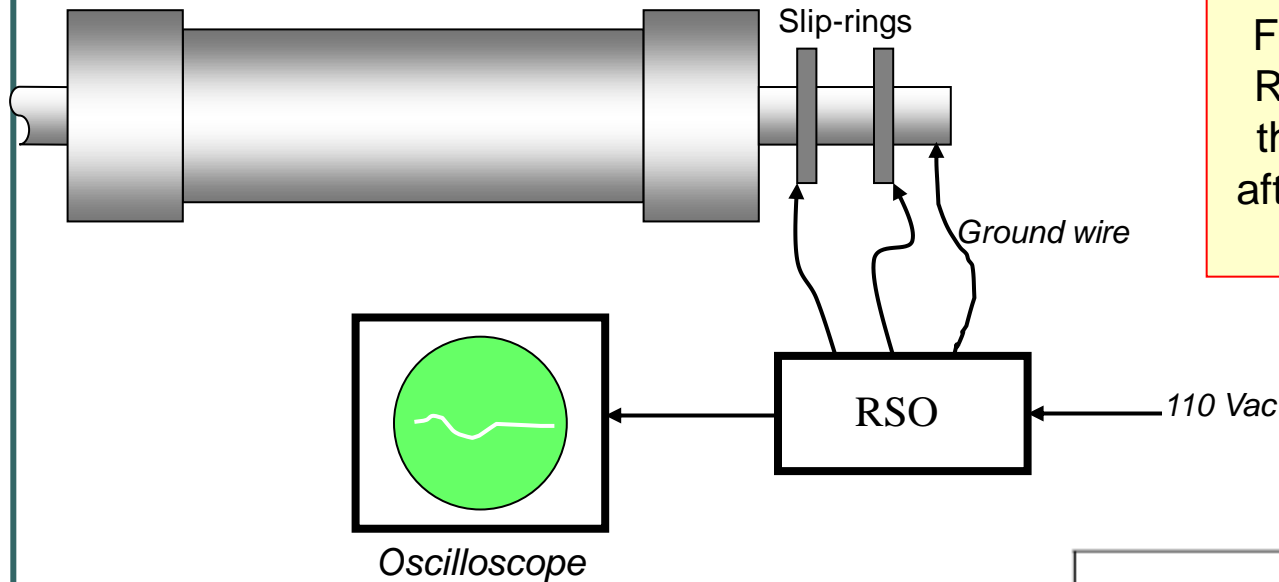
What is the RSO?

- It is a testing technique used to detect shorted-turns by inserting a high-frequency, low-voltage waveform at both ends of the field winding, and visually evaluating the differences in the returning signals.
- The RSO can be used with the rotor inside or outside the stator.
- The RSO can be used while working on the rotor, due to the low voltage operation.
- The RSO is safe to the interturn insulation due to its low voltage operation.
- The RSO can ONLY be applied to cylindrical fields (turbo-generators), due to the inherent high symmetry of the winding.

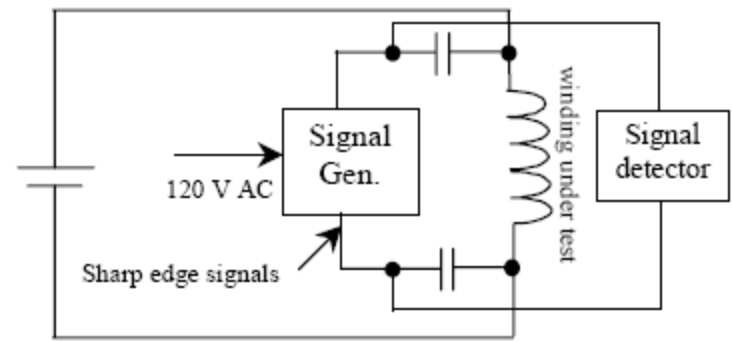
How the RSO works?

- The principle of operation is based on the fact large turbo-generator field windings have high symmetrical geometries.
- Under the relatively high frequencies of the injected signals the winding behaves as a distributed impedance, and thus, any asymmetry due to shorted-turns, grounds and very large malformations of the conductors will result in changes on the waveform of the signals.
- The frequency of the waveform and its periodicity are chosen by the various RSO manufactures in such a manner that the equipment is sensitive to shorted-turns for all large rotors.

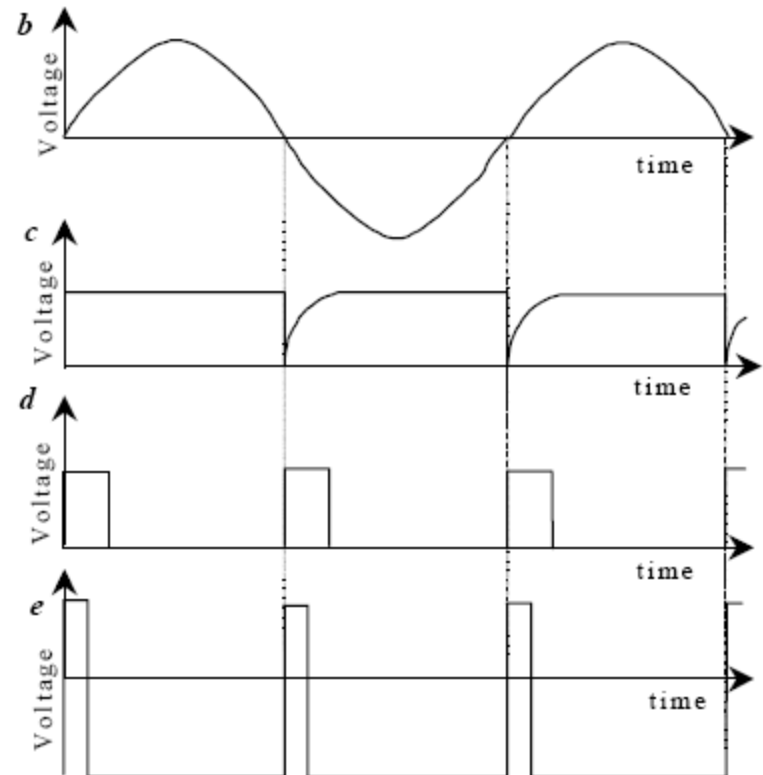
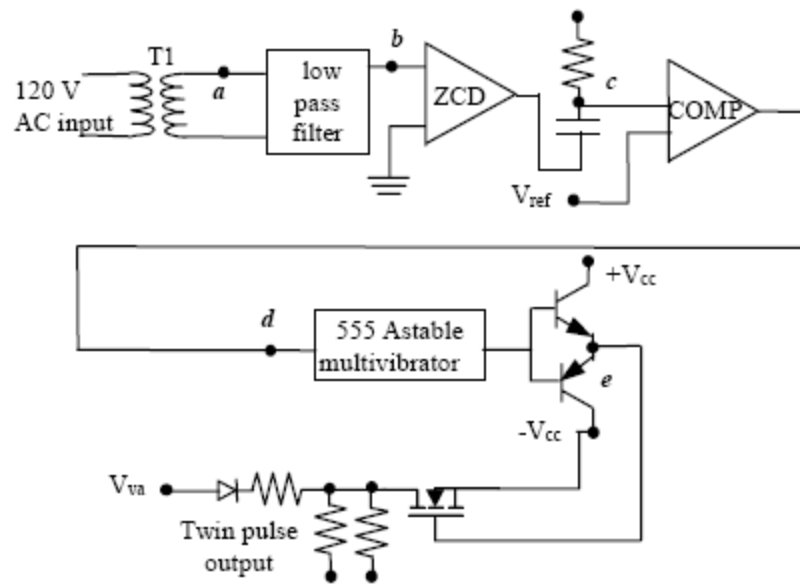
Typical circuit arrangement



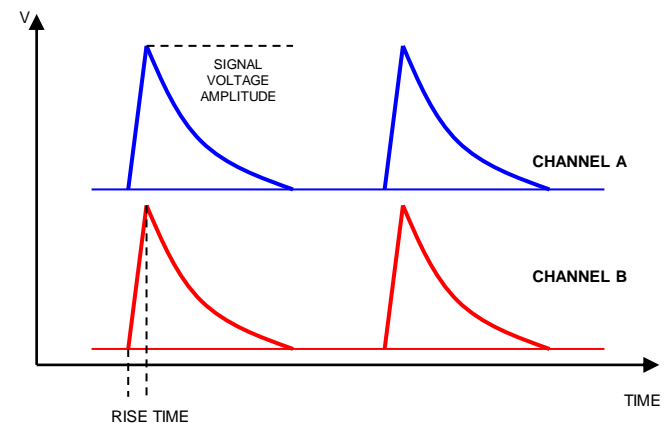
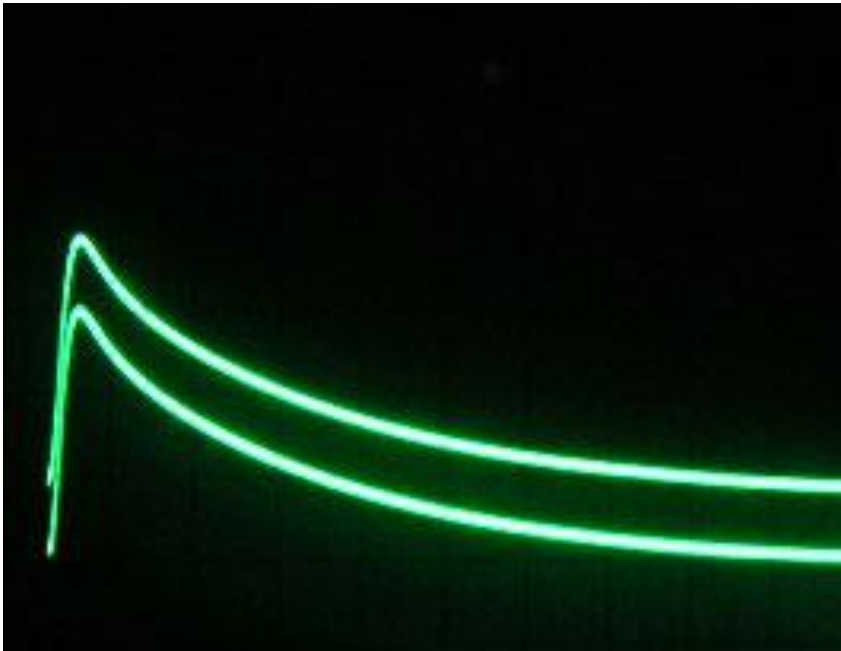
For brushless machines, the RSO wires are connected to the ends of the field winding after this is disconnected from the diode wheel.



Basic design



Typical waveform of the signals generated by the RSO



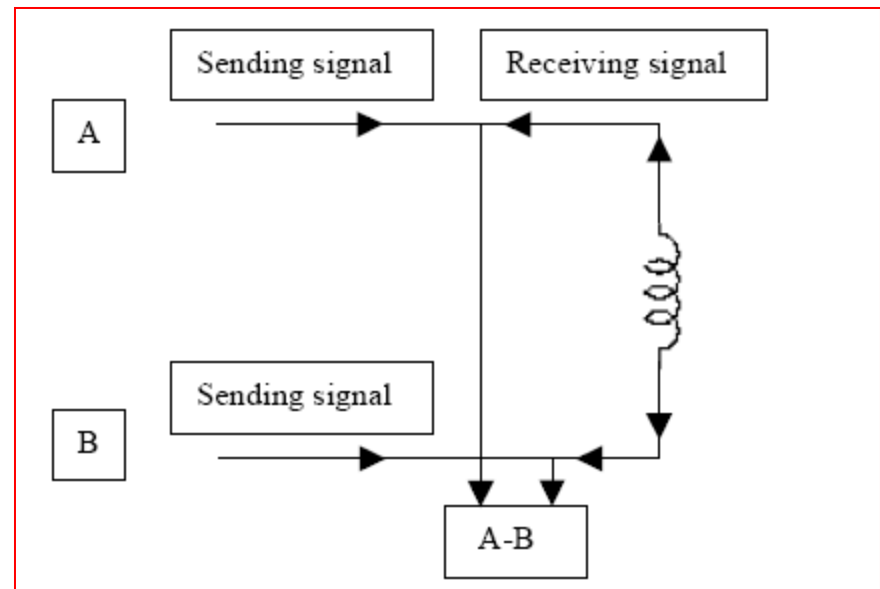
Typical rise-time: a few μs
Typical voltage: 5-12 volts

Reading the signals

- Although both resulting signals can be compared, it is easier to sum them up after one channel is inverted, and looking at the resultant:

- Straight line: no shorts
- A distorted line: shorts are present

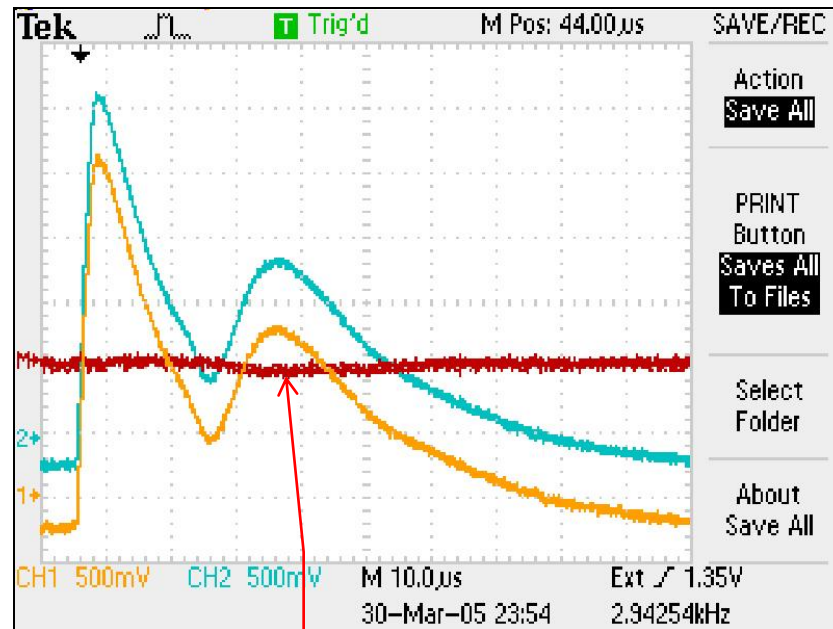
(A Megger test is required previous to the RSO test to ascertain no grounds are present in the winding)



TEST IN PROGRESS



Real example

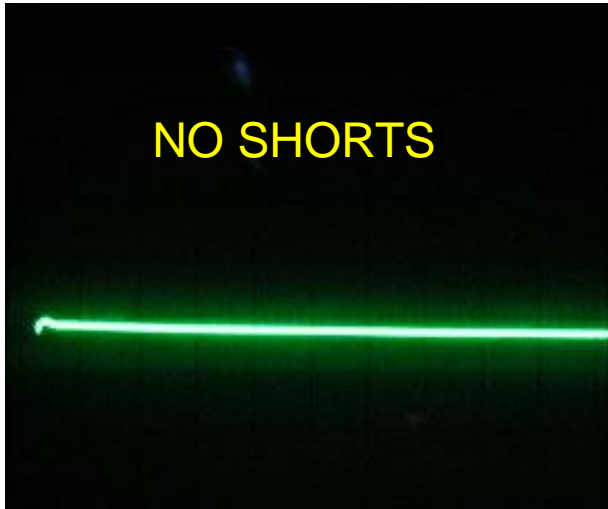


Channel A plus
inverted Channel B

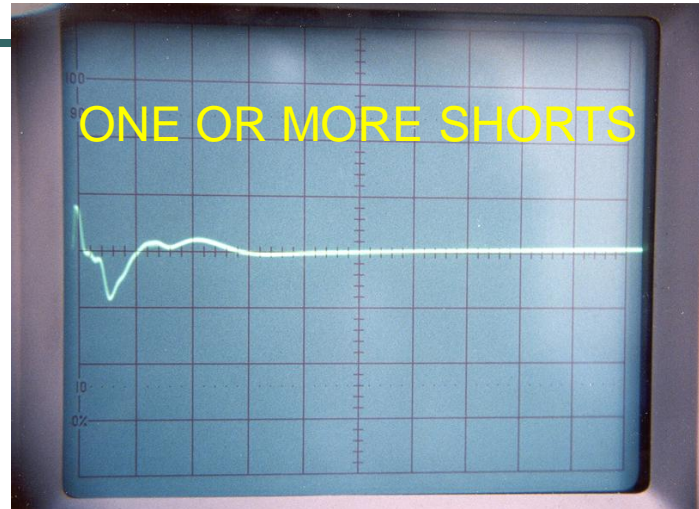
Examples of real traces

With experience, depending on the location of the “kinks” on the line, rough localization of the shorts (coil and pole) is possible

NO SHORTS



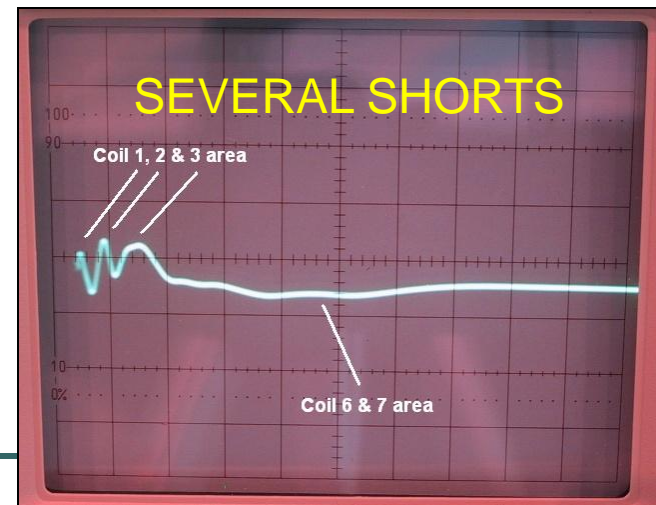
ONE OR MORE SHORTS



ONE SHORT



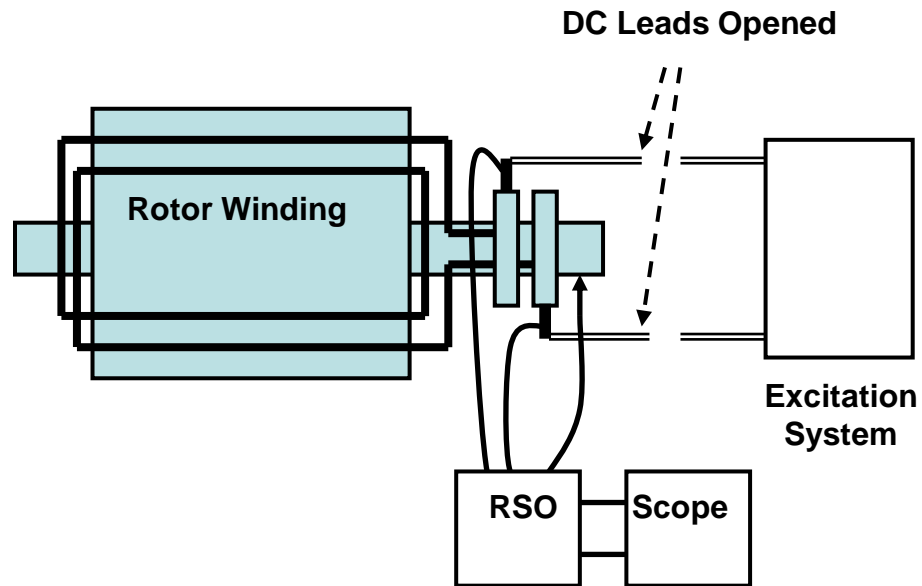
SEVERAL SHORTS



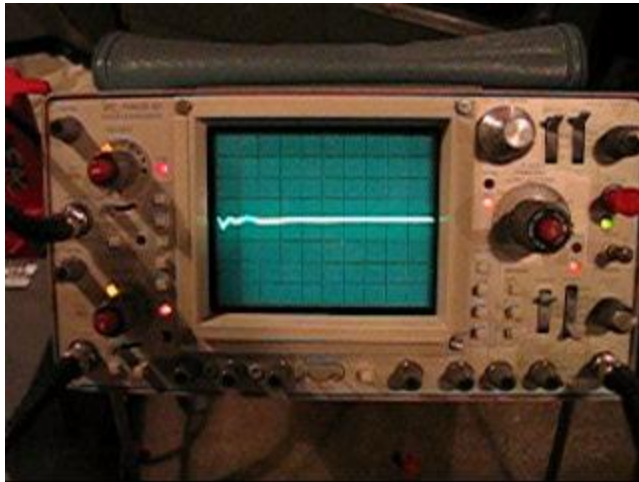
Speed (pressure) dependency of shorted-turns

- A significant proportion of shorted-turns are pressure dependent. The pressure is a function of the position of the rotor when idle, or speed, when rotating.
- Therefore, “spinning RSO” tests can be done with the unit at speed (during acceleration/deceleration and at full speed), to “catch” shorted turns that “disappear” when the rotor is standing still.
- When the rotor is idle, RSO readings should be taken with the rotor rotated at several angles.

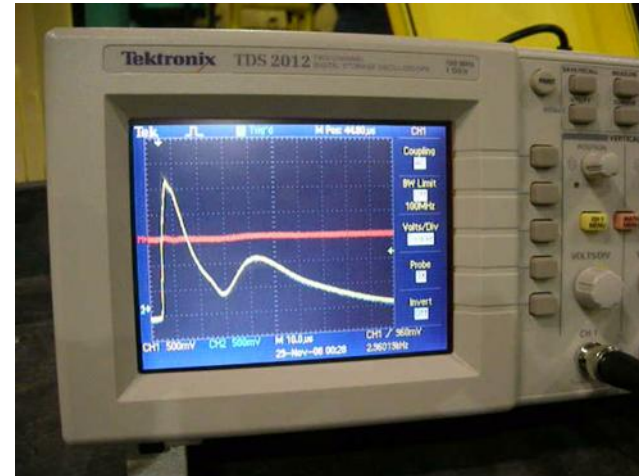
Typical arrangement for a spinning RSO



Readings taken with the unit spinning



AT TURNING GEAR



AT FULL SPEED

THANK YOU!!

QUESTIONS?