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Why Endwinding Vibration Monitoring?

A recent study of generator loss data over the last 10 years shows that the claim amount per loss caused by stator endwinding vibration is almost 50% of the total paid out for all causes!!

Introduction

Figure 1 – Failed phase connection [1]

The stator endwinding is the winding extending beyond the stator core. Due to design requirements the endwinding from the slot exit can be quite long (sometimes greater than 2m), especially on 2-pole machines. This results in a cantilever effect when operational forces are applied to the windings. The primary forces are due to the electromagnetism effect of 2 parallel current carrying conductors at line frequency resulting in a force at twice line frequency (100/120Hz). On some machines the centrifugal forces (at once turning speed) are coupled to the stator including the endwindings (50/60Hz for 2-pole synchronous machines, 25/30Hz for 4-pole, etc). Both, the turning speed and the electromagnetic forces are predominantly in the radial direction (between the rotor and the stator and between the top and bottom bars). However there is also a significant force in the tangential direction (circumferential around the endwinding basket between two adjacent bars).

Air Cooled Steam or Gas Turbine Driven Generators >100MW

Recently, over the last decade, there has been a reduction of the capability of stator endwinding support system, probably to reduce manufacturing cost. Machines are no longer rigidly supported enough to absorb the operational forces particularly in the endwinding, resulting in premature winding failure. This is particularly the case for 100-300 MW air cooled machines made since about 2000.

Other Generators

Generally hydrogen cooled machines are larger and have a more conservative design, i.e. the endwindings are more often suitably supported, but another consideration is age. Over time, support materials loosen resulting in more winding movement which may lead to endwinding vibration related failures which will affect all machines. The industry is trending towards longer periods between outages and there is no way of identifying this loosening of support materials without continuously monitoring the vibration.

Study Findings

A machine that is vibrating excessively will result in insulation fretting or dusting between two components that should otherwise be stationary. This excessive motion can be limited by re-tightening periodically, but if this repair is not performed the copper conductor can eventually open under load [2]. This can be a very expensive failure and take months to repair, maybe even requiring a rewind. A recent study by a global insurance company [3] of generator loss data over the last 10 years shows that while the number of losses related to endwinding vibration issues are small (<10%) the claim amount per loss is staggering (almost 50% of the total paid out for all causes!!). Their conclusion was that endwinding vibration has the highest total loss and average loss mitigation value for generator failures and that installing endwinding vibration monitors is the most cost effective monitoring technology for units with potential issues.

Online Monitoring

Once a machine with endwinding vibration issues has been identified the owner has 2 options. One is to take more outages to perform visual inspections/bump testing and repair the endwinding support structure as necessary, but this adds downtime cost and puts the machine at risk. Alternatively, a more cost effective approach is to monitor continuously with IRIS Power EVAs and EVTracII or GuardII continuous monitor. Of course, the best method is to use both the offline inspections/bump tests with online monitoring for a better understanding of stator endwinding behavior.

- Minimum installation: *6 sensors on the connection end*
- Installation on critical machines: *12 sensors (6 on each end)*
- Dual and single axis sensors available
- Single axis sensor: *stator core reference recommended*
- Bump test service: *identify optimal locations for installation*

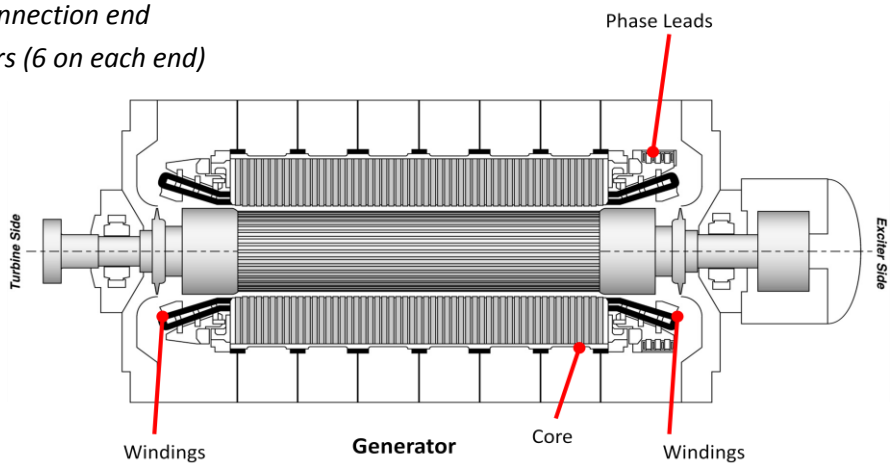

Figure 2 – Typical Endwinding Vibration Accelerometer Installation Locations

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March 19, 2014

References

[1] C. V. Maughan, "Stator Endwinding Vibration Detection," in *IRMC*, New Orleans, 2009.

[2] J. Kapler, J. Letal, M. Sasic and G. C. Stone, "Recent Endwinding Vibration Problems in Air-Cooled Turbine Generators," in *CIGRE*, Paris, 2014.

[3] S. Purushothaman, "Prioritize Condition Monitoring for Turbine Generators based on Loss Exposure," in *EPRI Fleet-Wide & Generator On-Line Monitoring Interest Group Meetings*, Chicago, 2013.