New Online Motor Stator Insulation Monitor (MSIM) for 3500 System

Many of our customers employ medium and large AC motors (such as the representative example in Figure 1) as prime movers for their process machinery, driving large compressors, pumps, blowers and fans. Traditionally, many of these motors have been mechanically protected and managed using Bently Nevada 3500 vibration and condition monitoring systems. The majority of motors in this class employ fluid film bearings.

The Problem

The 3500 System is effective for vibration monitoring of motor rotor and bearing faults, but another common problem with motors is the degradation of stator winding insulation. Stator problems, combined with bearing problems (detected by vibration), constitute over 75% of motor failures. The need to address the stator failure mode is obvious, yet there are few, if any online systems which meet that need. Existing condition monitoring techniques for this class of motors fall into one of two categories – offline or online monitoring.

Offline Monitoring

This type of testing is done with the motor shut down, cooled down, and de-terminated, using portable test equipment. Tests in this category include the following examples:

- Capacitance and dissipation factor (C & DF) testing, which are both conducted at ambient temperature.
- Megohmmeter (“megger”) for Insulation Resistance (IR) and polarization Index (PI), AC and DC high-potential (“hi-pot”), Partial Discharge (PD), Power Factor or Dissipation Factor (tip-up) and other electrical tests designed to assess the condition of the stator insulation system.
- Partial Discharge Analysis: This measurement looks for indications of tiny arcs that occur within voids and gaps in the winding insulation as it deteriorates over time. Both permanently-installed and portable versions of PD instruments are used.

Other techniques can be used to complement the above tests for more effective diagnostics and health assessment.
Online Monitoring

This type of monitoring is done with the motor energized and running, usually at a significant fraction of full load. Online monitoring can be performed with permanently installed instrumentation, or with portable test equipment.

- Ground/phase fault relays: These are classic machine protection relays, which were originally electromechanical devices, and evolved into solid-state analog, then digital devices. Protective relays are permanently installed to provide real-time automatic protective measures for detected electrical faults. Modern digital relays can also provide some condition monitoring data via digital network communications.

- Partial Discharge Analysis (PDA): This measurement looks for indications of tiny arcs that occur within voids and gaps in the winding insulation as it deteriorates over time. Both permanently-installed and portable versions of PD instruments are used.

- Temperature, moisture and other parameters can also be continuously monitored.

Tradeoffs

Offline testing is time consuming, relatively expensive, and requires the process equipment to be removed from service while the tests are conducted. For these reasons, tests are performed infrequently, with inspection intervals of 3 to 6 years being common. This schedule means the inspection interval is the same order of magnitude as the failure interval. In addition, the offline tests are typically conducted at ambient temperatures, not at the operating temperature of the motor.

Protection with ground/phase fault relays is effective in shutting the machine down after a fault occurs, but does not give adequate advance warning of insulation degradation. In some instances the stator core can be damaged by an electrical fault in spite of the shutdown capabilities of protection relay systems. Core damage results in a much more expensive repair than a basic rewind, and in some cases the motor may have to be scrapped.

Partial discharge monitoring is the only currently available practical technology for online condition monitoring of stator insulation health. Feedback from our customers who have employed this technology for many years indicates that partial discharge data is difficult to interpret, and provides very little insight into, or advance warning of impending stator insulation faults.

Introducing a New Approach

Bently Nevada is introducing a new approach to online stator insulation condition monitoring. This approach is based on a new sensor developed in conjunction with GE’s Global Research Center scientists. It is a complete system consisting of new transducers, a new 3500 monitor card and the services required for installation and commissioning. While it is useful as a standalone monitor, even more value can be obtained when it is connected to GE’s System 1* asset management software.

System Description

As shown in Figure 2, the new stator insulation monitoring system includes the following components for each monitored motor:
- 3 each – High Sensitivity Current Transformers (HSCTs)
- 3 each – HSCT interface modules
- 2 each – Voltage dividers (for phase reference)
- 2 each – Voltage divider interface modules
- 1 to 3 each – temperature inputs (RTD’s or thermocouples)
- 1 each – BN 3500 Rack and HSCT monitor card

The HSCTs, voltage dividers and all interface modules are installed in or on the motor terminal box. Field wiring directs the signals to the 3500 monitor card.
FIGURE 2: Permanently-installed online motor stator insulation health monitor.

FIGURE 3: The HSCT is a special current transformer that is very sensitive to small values of differential current.

FIGURE 4: Equivalent circuit for stator winding insulation. C = capacitance, R = resistance, V = source voltage and I = source current.

FIGURE 5: Phase angle relationship between capacitive and resistive leakage current.

Dissipation factor = tan δ
= |Ic|/|Ir|
= (V/R)/(V/ωC)
= 1/ωRC

FIGURE 6: As the insulation system degrades, the change in capacitance and dissipation factor are indicated by the change in the phase angle between IC and IR. This example shows a case where capacitance remains unchanged, but aging increases the conduction through the insulation.

FIGURE 7: Example photo shows the inside of a 4160 V motor termination enclosure during testing of the new HSCT sensors. The large brown CTs are for normal differential protection. The HSCTs are the thinner aluminum-covered rings to the right of the protection CTs. To the right of the HSCTs are some test instrumentation CTs that were taking additional measurements as part of the test.
How does it work?

The HSCT (Figure 3) enables measurement of very low amplitude leakage current (which leaks through degraded winding insulation).

The HSCT interface module amplifies the low level signal, which is directed to the 3500 monitor card via field wiring. Voltage reference signals are similarly conditioned and directed to the 3500 monitor. Winding temperatures (from RTD’s or thermocouples) are the final inputs to the monitor card. The monitoring system conditions and processes these signals, providing access, trending and alarming for values of capacitive and resistive leakage currents, Capacitance and Dissipation Factor (C & DF).

The offline C & DF test is used by many of our customers as a part of their medium and high voltage motor preventive maintenance programs. Our new monitoring system brings the benefits of that assessment tool to the online condition monitoring world.

Figure 4 illustrates the basic relationship between capacitive and resistive components of the leakage current. In a new or rewound motor, the primary leakage path is capacitive, resulting in very low levels of resistive leakage current.

Figure 5 shows how the Dissipation Factor describes the phase angle of the current through the stator insulation. If the insulation were a perfect dielectric, its resistance would be infinite, the angle, \( \delta \), would be zero, and dissipation factor would also be zero.

Insulation systems degrade over time because of electrical, thermal and mechanical and environmental stresses. As the insulation system degrades, the resistive component increases, appearing as a larger dissipation factor, as shown in Figure 6. The leakage current measurement is temperature dependent, thus the need for the temperature inputs into the monitor.

Target Machines

Our initial solution offering targets 3-phase AC induction and synchronous motors in the 1,000 to 6,000 horsepower range, operating with supply voltage in the 2.3 kV to 5 kV range. The motor must be externally wye-connected (Figure 2). We must have access to both phase and neutral leads in the terminal box, as shown in Figure 7.

Value of this method

This new technology is the first commercially available online assessment of stator insulation system health on medium and high voltage motors via leakage current sensing. This means that you no longer have to shut your motor down for offline testing to determine if it is headed for trouble. The system allows you to realize the following advantages:

- Avoid unplanned outages
- Do more effective maintenance planning
- Avoid offline monitoring downtime and associated costs
- Detect many problems that are not detected by existing technologies
- Extend time between inspections
- Reduce the cost of repair versus a protection trip, by avoiding stator core damage

System Introduction

Our current development plan calls for availability in the third quarter of 2012. Please contact your local Bently Nevada sales engineer for more information. We’ll also be publishing more information on this technology in an upcoming issue of Orbit. Stay tuned for more information on motor condition monitoring!

References

1. GE Motors Pegasus MHV Medium Voltage AC Induction Motors brochure, GEA-12310C.

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