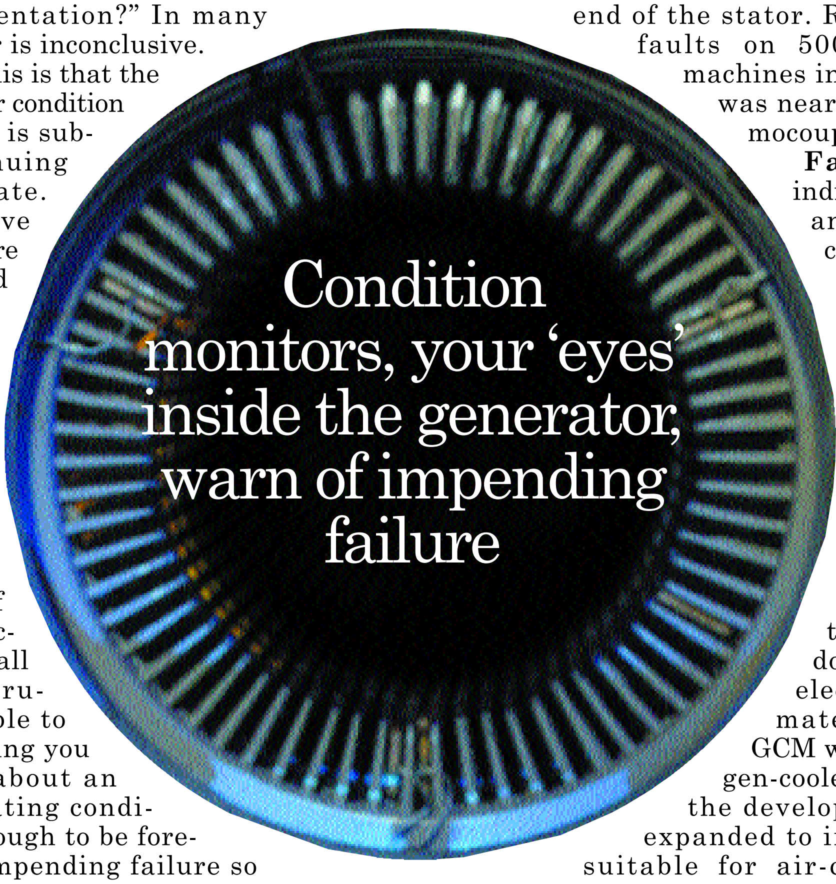
Condition monitors, your 'eyes' inside the generator, warn of impending failure



The failure of a powerplant generator is sure to raise the question, "Could this fault have been detected by installing additional instrumentation?" In many cases the answer is inconclusive. One reason for this is that the value of generator condition monitors (GCM) is subject to continuing industry debate. Though they have been used for more than 25 years and have prevented catastrophic failures, some plant managers question the ability of GCMs to provide reliable indication of generator overheating.

Is it a case of unrealistic expectations? Should all diagnostic instrumentation be able to tell you everything you want to know about an abnormal operating condition? Or is it enough to be forewarned about impending failure so that you can take corrective action? One would think that the latter is particularly important in today's competitive generation market where reliability and availability rule.

D J Wallis of the UK's Innogy Holdings plc, which owns and operates about 10,000 MW of generating capability in Great Britain, reported on more than two decades of laboratory and field experience with GCMs on both hydrogen- and air-cooled generators at the recent Steam Turbine/Generator Workshop. The meeting was conducted by the Electric Power Research Institute (Nashville, August 2003).

Development of the GCM was prompted by a rash of large-generator failures in the late 1960s and early to mid 1970s experienced by the Central Electricity Generating Board (Innogy's predecessor) and other utilities. When core faults began to occur regularly in 1969, according to Wallis, there were no methods by which they could be detected reliably until molten iron burned through the winding insulation and the stator ground-fault protection system kicked in. On some occasions, generators had to be tripped manually following internal explosions or other obvious signs of major failure.

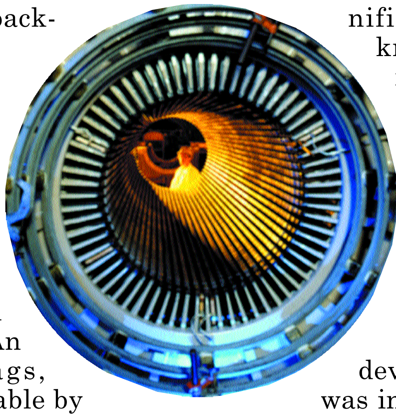
At the time, only the thermocouples installed in the core by the manufacturer could indicate overheating. But the number of thermocouples installed was limited by practical considerations, so that the region covered was a relatively small percentage of the whole core. Furthermore, the practice was to install thermocouples at only one end of the stator. Result: Of 11 core faults on 500- and 660-MW machines in the UK, only one was near enough to a thermocouple to be detected.

Failure analysis indicated the need for an instrument that could alarm on high temperatures in any part of the generator to warn of a developing fault and avoid catastrophic failure. One of the techniques investigated was the detection of particles produced by the thermal breakdown of overheated electrical insulating materials. The first GCM was for large hydrogen-cooled generators, but the development effort was expanded to include a monitor suitable for air-cooled machines because the higher power ratings of new units have pushed them closer to critical limits and increased the probability of overheating.

The GCM for hydrogen-cooled generators essentially works like a smoke detector with a special ion chamber for the specific application. One such monitor, manufactured by Environment One Corp, Niskayuna, NY, comprises an ion chamber mounted in a cabinet with an electrometer amplifier, output meter, and hydrogen flow controller. According to Environment One's Steve Kilmartin, a co-presenter at the EPRI symposium with Innogy's Wallis, the unit incorporates a filter that can be inserted in the hydrogen inlet by means of a solenoid valve. The filter removes any particulates to which the ion chamber is sensitive. Its use when ion-chamber output current falls would verify the presence of particles and permit their analysis to identify the source of the problem.

Environment One's GCM for air-cooled generators monitors multiple air sample lines using a Wilson cloud chamber as the particle detector. One sample line monitors ambient air, to serve as a reference, while one or more other lines monitor generator cooling air, which is then compared against the particle level of the reference.

Extensive laboratory and field tests confirm that when particles are present in the generator coolant, GCM output falls, also that the monitor is reliable. Because overheating may indicate a potentially dangerous operating condition, the slightest drop in the instrument's output current should get the attention of plant operators. However, powerplant experience suggests that no action be taken until GCM output falls below 50% of full scale and the alarm is verified through the system's electronics package.



Once an alarm is verified, immediate action is required to prevent further development of the fault. The current state of the technology does not allow operators to identify the exact location of the overheating, so corrective action should include all possibilities. An add-on technology, Gen-Tags, enhances information made available by the condition monitor, thereby increasing the chances of locating the hot spots. It relies on coded, encapsulated chemicals that are applied to critical areas of the generator. Some faults, particularly those affecting the stator core, can develop quickly and there may not be time to try operational corrections before it is necessary to trip the unit.

A significant reduction in load is the optimum corrective action for the majority of serious faults because it reduces stator current and, therefore, winding temperature. Reducing the core axial flux eliminates a cause of overheating in an area of the core most susceptible to failure. Rotor current and voltage also are reduced which should curtail overheating in this area.

If the GCM alarm persists after a load reduction, then operators must decrease load further. The time delay between successive load reductions depends on the recovery rate of the GCM once particulation ceases. One minute or so normally is sufficient time for the monitor to respond with an increase in output if load reduction has had the desired effect. The decision on whether to continue operation at reduced load should then be made on economic grounds. The unit must be tripped if the alarm still exists at no load.

Field experience. Several verified alarms have been reported by powerplants with operational GCMs. The term "operational" is significant because there is at least one known case where a severe core fault forced a generator out of service because the GCM was installed but never connected! Reports from other plants include these:

- Alarm associated with a major stator core fault essentially was ignored—specifically, no corrective action was taken—and damage resulted.
- GCM gave indication of a slowly developing overheating condition. Unit was inspected and personnel located a stator-winding Teflon hose that had become blocked causing overheating.
- Small changes in GCM readings were recorded over a period of about nine months and then the frequency, magnitude, and duration of the transients began to increase significantly. Partial unloading of the machine was necessary on several occasions before GCM output current recovered. Particle analysis revealed no organic materials that would indicate overheating of insulation or oil. Rather, the samples consisted of particles of zinc, copper, and low-alloy steel released by a high-temperature condition likely associated with internal hydrogen gas baffles or their location bolts and locking plates. Inspection revealed that the inner gas labyrinth seal at one end of the machine had become slack and dropped, allowing the brass blades of the seal to contact an attachment to the rotor endwinding retaining ring. Heat generated was sufficient to melt the brass blades of the seal.
- The onset of interturn rotor winding faults have been detected by GCMs at multiple plants. CCJ