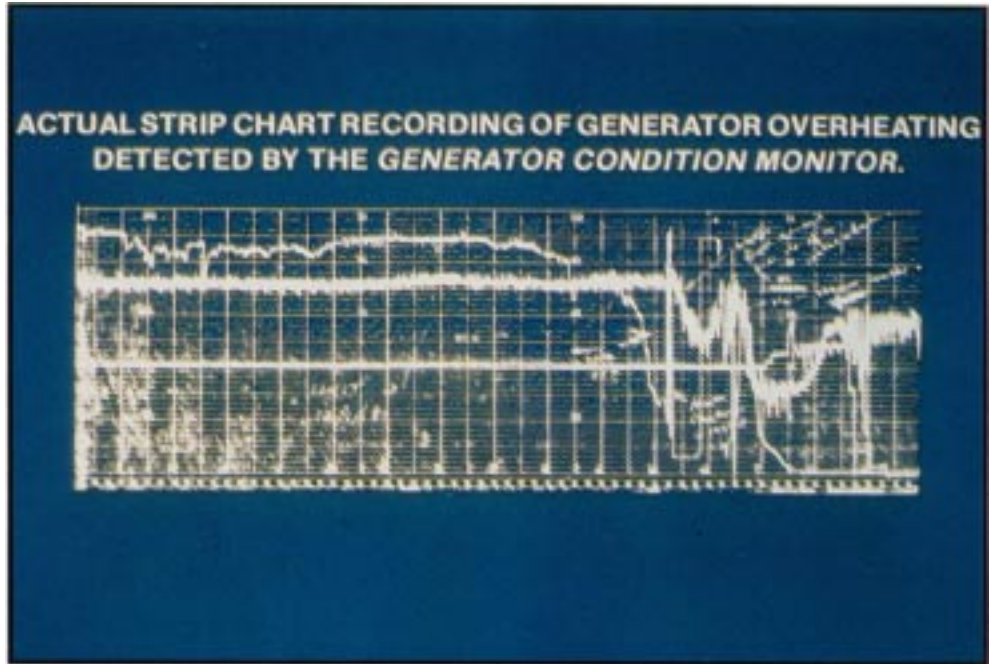


CONDITION MONITORING FOR TURBINE GENERATORS

Gas-cooled generators are among the most complex and expensive items of power station equipment. High voltages and potentially explosive hydrogen gas make early detection of generator hot spots imperative. George Vorsheim of Environment One Corporation reports on how a Generator Condition Monitor (GCM) can prevent a major catastrophe.



Actual strip chart recording of generator overheating detected by the Generator Condition Monitor (GCM or Core Monitor).

In Texas, broken conductor strands on the end of the stator winding could have caused massive failure of the generator, a problem which occurred on a sister unit the year before (750MW); in the UK, a stator cooling water blockage could have meant a complete rewind of a 500MW machine; and in Belgium, errant shipping baffles created overheating that could have led to major damage during generator commissioning (500MW). These power stations all had one thing in common, they were alerted of potential catastrophe by a Generator Condition Monitor (GCM).

Gas-cooled generators are among the most complex and expensive items of power station equipment. High voltages and potentially explosive hydrogen gas make early detection of generator hot spots imperative.

Corrective action prompted by early warning of generator overheating can mean the difference between a brief shut-down for minor repairs and a major overhaul involving weeks of costly downtime.

Life Extension

By 1999, the vast majority (80 per cent plus) of US fossil-fuel power stations will be over 20 years old, and more often than not over 30 years old. One strategy increasingly being recommended by both generator manufacturers and underwriters is predictive maintenance; the concept that monitors can determine when equipment requires repair.

Many utilities still rely on corrective and preventive maintenance. Corrective maintenance means fixing the failed parts after the breakdown, while preventive maintenance means inspecting and replacing parts on a regular schedule, sometimes sooner than needed. Scheduled outages for preventive maintenance help reduce risk, but many replacement intervals are not well known for old plants. In addition, preventive maintenance does not reveal when newly installed

equipment might fail prematurely.

With the major reduction in building new generating plants that has occurred over the past 15 years, an increasing amount of the world's electric power is becoming dependent upon aging generators. Downtime of a major unit can cost hundreds of thousands of dollars a day, making it critical for utilities to improve reliability and reduce such events.

The GCM is a sensitive real-time detector of submicrometer particles created by the incipient thermal decomposition of coatings and insulation. Also referred to as a 'core monitor', because it was originally designed to respond to core overheating caused by circulating currents between laminations, the monitor's applications have been extended to provide early warning of all forms of overheating sufficient to produce thermal degradation.

Particle detection is by means of an ion-

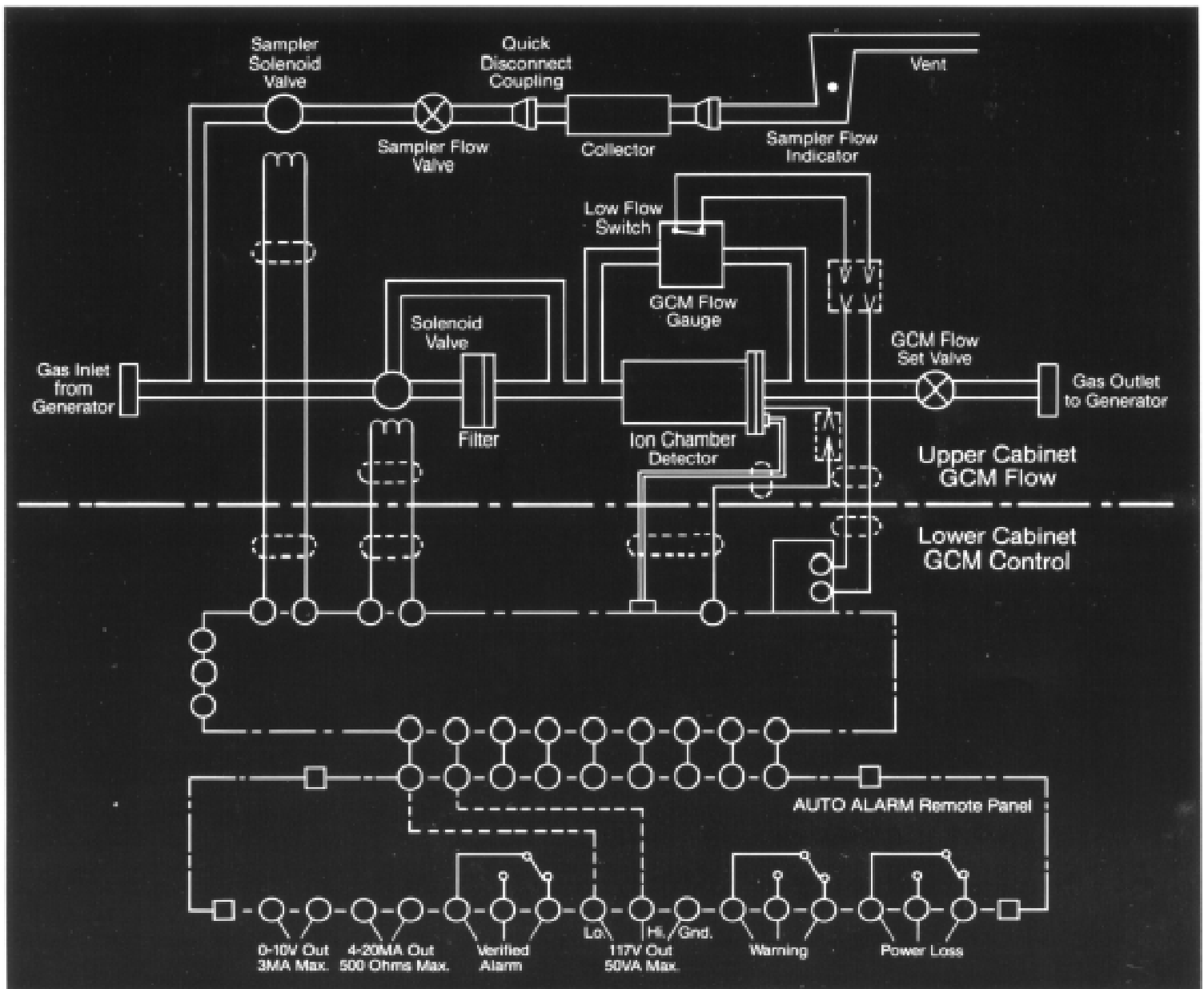


Figure 1. A GCM arrangement where a differential pressure gauge, which monitors the pressure drop across the ion chamber, is used to indicate flow.

ization chamber through which the hydrogen cooling gas is circulated by the pressures produced by the generator fan. The Ion Chamber Detector (ICD) consists of an ionizing section and an ion collecting chamber contained in a pressure housing. The gas first passes through the ionizing section which contains a low level alpha source (Thorium 232). The resulting ions then pass with the gas to the ion collecting chamber in which there is an electrode maintained at -10 volts. Because the ions are extremely small, they have a high ratio of charge to mass, giving them a high mobility when placed in an electric field. The -10V potential is sufficient to cause most of the ions to be attracted to a collecting electrode, where they produce the output current.

When particles are present in the gas, some of the ions will become attached to them. These particles, though invisible under a microscope, are many times larger than the ions. Therefore, the charge to mass ratio of the particle-ion combination is very much reduced (by a factor of approximately a thousand), and the mobility is very low. This means that only a very few are attracted to the collecting electrode, resulting in a reduced output.

The volume of the ionizing section of the ion chamber is made large enough to establish ion-particle equilibrium, which requires several seconds. Total source strength is less than 0.1 Microcurie, far less than is used in home smoke detectors.

A typical GCM is shown in Figure 1. In this

arrangement, a differential pressure gauge, which monitors the pressure drop across the ion chamber, is used to indicate flow.

Ion chamber output current is amplified by an electrometer developed for this application to withstand the environmental conditions likely to be encountered. The amplified current is displayed on a meter and/or recorder, and is also used to activate alarm contacts. The usual operating procedure is to adjust the flow to a given differential pressure indication, and then to adjust electrometer gain to produce an output of 80 per cent. The electronics will initiate the alarm verification sequence when ion chamber output drops below 50 per cent.

By comparing ion chamber output for filtered and unfiltered hydrogen, the system



GCM on-line.

diagnostics can determine whether an alarm is real or due to equipment malfunction.

Switching of the alarm contacts will also open the solenoid valve ahead of the collector for a pre-set time interval, allowing a fixed volume of gas to flow through the collector. The collector contains a filter to trap submicrometer particles. The collector can be removed and the trapped materials analyzed to determine their source.

Overheating

High concentrations of sub-micrometer particles (pyrolysis products) are produced whenever any material within the generator is heated sufficiently to produce thermal decomposition. These 'hot spots' can lead to catastrophic failure if not caught in time. When present in the hydrogen, these pyrolysis products are quickly detected by the GCM's highly sensitive ion chamber housed in the upper section of the cabinet. The GCM warns of impending failure much faster than temperature sensors such as RTDs or thermocouples.

Upon detection, an alarm verification sequence is initiated. If the alarm is confirmed, a verified alarm indication is given, alarm contacts are switched and a portion of the hydrogen flow is automatically passed through the sampling system where these particles are collected for laboratory analysis.

Confirmation of an alarm is made quickly by the automatic alarm verification circuit that

activates the solenoid valve in the filter/solenoid assembly. Normally bypassed, all the hydrogen that passes through the filter which removes the particles. If the alarm is valid and thermally produced particles are present, their removal in this manner will cause the ion chamber output current (amplified by the electrometer) to return to its normal level, confirming their presence and the existence of overheating.

Gen-Tags Locate Hotspots

The usefulness of the generator condition monitor has been enhanced by the development of sacrificial coatings (GEN-TAGS). These specially synthesized, chemically and thermally stable tagging compounds are incorporated in trace quantities in protective coatings applied to critical areas in the generator. These GEN-TAGS are designed to particulate at a lower temperature than the normal materials used in the generator and hence give an even earlier warning of overheating. The use of several different coatings, along with the ability to trap the particles in a collector (for analysis), can greatly aid in the location of the area being overheated.

Available in up to six different chemical signatures, GEN-TAGS early-warning hot-spot area distinction is now available for end windings, stator, rotor, bushings, and transformers.

The Benefits of Being Early

Generator condition monitoring benefits include:

- Maximized Generator Productivity - Enables maintenance professionals to look within the machine and improve its basic operation.
- Improved Maintenance Scheduling - Planned maintenance/repair is less expensive and more efficient than unplanned repair. To quantify the effect, 'repairs' should include the 'time to repair' as well as the 'waiting time' or the time lost between time of failure, reporting, personnel assignment, machine documentation and parts procurement, as well as the time to repair. Information generated through generator condition monitoring enables users to reduce unplanned maintenance by predicting a part's failure well in advance.
- Improved Repair Time - Pre-planned repair/maintenance is inherently faster and smoother than crisis fixing.
- Improved Uptime/Reduced Unplanned Outages - Condition monitoring provides information that implements scheduling maintenance/repair on a needs only basis.
- Increased Machine Life - A well-maintained generator lasts longer than a poorly maintained one. Condition monitoring provides a means to diagnose the cause of a deteriorating situation be it a mechanical failure in a rotor, retaining ring, fan, or bearing, or electrical failure from lack of adequate insulation protection, age, winding stress, surges, or short circuits.
- Improved Product Quality - Translates into reliability, availability and reduced cost to the customer.

Conclusion

In use since the early '70s, hundreds of GCMs have been installed at power stations throughout the world. Spectacular successes have been reported whereby major outages have been avoided by prompt operator action. The monitors are standard for many new generator installations, and are often supplemented by other diagnostic systems such as vibration detectors, and radio frequency monitors for arc detection.

Due to relative simplicity, absence of moving parts, and no critical adjustments, many GCM's have given continuous service for ten or more years with little or no maintenance. The GCM is just one of a host of monitors

POWER GENERATION

now available for today's power stations.

Various manufactures and research organizations (e.g. EPRI) are investigating expert computer systems to systematically aid plant personnel in the analysis of the data bombardment. In the meantime more and more plant operators are relying on the GCM for predictive information about a most critical part in the power station — the generator.

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GEN-TAGSTM

Detect and Locate generator hotspots



Having saved utilities millions of dollars by minimizing expensive repairs and costly downtime, Environment|One's Generator Condition Monitor (GCM) has an established reputation for providing early detection of overheating in electric power generators.

Now, GEN-TAGSTM, a new system of tagging compounds provides a positive means of identifying overheated areas in hydrogen-cooled generators. "Hotspots" release the chemically distinct GEN-TAG for collection by the GCM and easy laboratory identification.

GEN-TAGS' color coded, chemically and thermally stable compounds are applied to critical areas of the generator during normal maintenance outages.

GEN-TAGS are designed so that the physical and chemical properties of generator materials are not affected. Produced in encapsulated form, GEN-TAGS are thermally stable for the service life of the generator.

Now you can quickly locate costly "hotspots" before it's too late.

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