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DIAGNOSTIC AND MONITORING OF GENERATORS POWER PLANTS

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Described the construction and operation of electrical generators and the way they fail in service. The failure modes demonstrate how faults may be detected in their early stages by diagnostic and monitoring appropriate parameters. The main temperature, mechanical, electrical, chemical techniques and complex methods available for diagnostic and monitoring of electrical machines are shown. The future for diagnostic and monitoring of electrical machines will be heavily affected by multi-parameter diagnostic and monitoring and by the application of artificial intelligence. Considered how asset management could be applied to rotating electrical generators.

The book is intended for higher education students, post-graduate students, engineers and research workers of relevant specialties.

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ABSTRACT

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Generators convert mechanical to electrical energy and they achieve this by magnetically coupling electrical circuits across an air gap that permits rotational freedom from one of these circuits.

The economics of industry is changed, particularly as result of the privatization and deregulation of the energy industry in many countries, placing far greater emphasis on the importance of reliable operation of plant and machinery, throughout the whole life cycle, regardless of its first capital cost.

The electricity used so freely is generated in power plants by machines whose rating can exceed 1000 MW and which have evolved to a state of great sophistication. These power plants are supported by fossil fuel and nuclear energy industries that involve the transport of raw materials using pumps, compressors and conveyors in sophisticated engineering processes incorporating rotating electrical machines of powers ranging from 100 kW to 100 MW. These have been joined by a growing renewable energy industry using many of these and new techniques to extract energy from renewable sources often in combination with traditional sources.

Many sectors of industry, and particularly the electricity, water and gas utilities and the railways, have adopted maintenance planning based on replacement and overhaul at fixed time periods, so that outage work can be scheduled, and also diversions and loads can be planned. Such scheduling is usually planned on the basis of plant monitoring, which is typically done on a discontinuous basis. There are many estimates of the savings that accrue by adopting such an approach and an average reduction figure of 60 per cent of the total maintenance burden may be considered reasonable. It must be treated cautiously because such a maintenance policy makes heavy demands upon scarce, skilled manpower. Only 10 per cent of components replaced during fixed-interval maintenance outages actually need to be replaced at that time. The obvious implication is that 90 per cent of what is replaced need not be.

Electrical generators are of greatest importance where they are integrated into a large drive system. The great benefit of diagnostic and monitoring electrical generators is that by analyzing the machine it will be possible to detect deterioration both in the machine and the components attached to it. The modern electrical generators and the processes they operate in are growing in complexity, leads one to the conclusion that continuous diagnostic and monitoring of certain critical items of plant can lead to significant benefits. Electrical machines that have a high penalty in lost output costs need to be monitored continually. Large generators naturally fall into this category since lost output can exceed $600000 per day for a large machine in a high-efficiency power station.

Manufacturers are adding more functionality to new machines, while the utilities are more focused on aged, existing machines to extend their usable lifetime.

Electrical or mechanical failure modes are always preceded by deterioration of one of the mechanical, electrical, magnetic, insulation or cooling components of the machine. This is the case regardless of the type of electrical machine. If this deterioration takes a significant period of time and can be detected by measurement, then that root cause detection will be a means of diagnostic and monitoring the machine before a failure mode develops. The heart of diagnostic and monitoring is to derive methods to measure, as directly as possible, parameters that indicate root cause deterioration activity and provide sufficient warning of impending failure in order that the electrical machine may be taken off for repair or may be tripped before serious damage occurs.

Any fault involves a failure mechanism, progressing from the initial fault to the failure itself. The time taken for such a progression will vary, depending on a wide range of circumstances. What is important, however, is that all faults will have early indicators of their presence and it is here that diagnostic and monitoring must seek to look and act. Also, any fault is likely to have a number of possible causes and is likely to give rise to a number of early indications.

The duration of the failure sequence depends on the failure mode, the operating condition of the electrical machine and the ambient condition in which it is operating. If a failure sequence is very rapid; for example, a few seconds, then effective diagnostic and monitoring are impossible. This is the situation for most electrical failure modes, which actuate the electrical protection, where the period of action of the final failure mode may be only a few seconds or even only a few cycles of the mains. However, if the failure sequence is days, weeks or months, then diagnostic and monitoring has the potential to provide early warning of impending failure and the ability to continue operating the machine before failure and maintain it to avoid failure. Therefore diagnostic and monitoring must concentrate on those root causes and failure modes that exhibit a failure sequence of substantial duration and ability to detect its initiation and progress is crucial to successful diagnostic and monitoring.

The first objective of diagnostic and monitoring is to give early detection of a fault so that avoiding action can be taken, either by shutting the machine down before catastrophic failure occurs, or by taking preventative action that returns the plant to full operational functionality as soon as possible. Greater benefits could be achieved from diagnostic and monitoring if the information from monitoring is used to schedule maintenance, allowing planned shutdowns so that the life of plant, of which the electrical machine forms a part, can be extended. However, further benefits could be realized from diagnostic and monitoring if the total life-cycle costs of the electrical machine and the plant it serves could be reduced by its application. This in turn requires an estimate of the running costs of plant and forecasts of its variation throughout its life. In the light of this knowledge the plant or asset owner can operate, maintain, renew or dispose of that asset on the basis of the information made available through these processes. Therefore the diagnostic and monitoring techniques that are likely to have the most significance for the assessment of condition for the purposes of maintenance planning are techniques of global significance to the machine.

Diagnostic and monitoring has to establish a map between input signals and output indications of the machine condition. Classifying machine condition and determining the severity of faults from the input signals have never been easy tasks and they are affected by many factors. Therefore, experienced engineers still outperform most computerized diagnostic and monitoring systems. Experience and intelligence are extremely important in this interpretative stage when information from different sensors is sifted and condition precisely indicated by tracing the probabilities of different root causes.

One feature of diagnostic and monitoring is to detect impeding faults at an early stage, capturing weak signatures in measurements that are usually mixed with noise. Furthermore, some impeding faults may manifest themselves in non-electrical variables that are not normally used in control or protection. Before getting into the details of the instrumentation elements, we need to view a diagnostic and monitoring system from a higher level where the functionality of different parts of the system can be more clearly described. By doing this, it should be possible to identify the common elements of a diagnostic and monitoring scheme, irrespective of the system detail. In essence, an engineer examining occasional meter readings, with a view to producing an operational and maintenance strategy, is involved in a procedure that is analogous to a sophisticated diagnostic and monitoring system.

Although up-to date computer software packages are available for digital signal processing applications and can be used for diagnostic and monitoring of electrical machines, it is important to fully appreciate the characteristics of the different algorithms in order to avoid unreliable results being obtained, leading to misinterpretation of the power plant condition. Requirements of such algorithms and their limitations must be clearly understood.

It is likely that the most effective techniques will in future consider the failure modes and root causes of failure in machines and adopt artificial intelligence techniques relating various diagnostic and monitoring signals with one another in a multiparameter approach to give the earliest warning of deteriorating condition. The comprehensive analysis of signals must take account of the interrelationship between electrical and mechanical signals.

The costs of diagnostic and monitoring include the initial investigation, purchase, and installation charges, the staff training costs, and the costs associated with the data acquisition.

CONTENT

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