Application Note

An Aggressive Condition Monitoring Policy Gives Dungeness B Power Station the Competitive Edge — A COMPASS Case Story

Introduction

The newly privatised power industry in Britain presented special opportunities and challenges to Dungeness B nuclear power station. Since it is now necessary to be economically competitive with other power plants, stringent measures have to be taken to reduce Operation & Maintenance (O&M) costs and achieve higher performance while at the same time maintaining the high safety and reliability standards. Dungeness B met this challenge in part by adopting a new maintenance organisation and strategy. This included extending the existing performance monitoring systems to predictive maintenance monitoring capability, in which COMPASS™ and the Advisor™ Machine Diagnosis Software plays a key role.

Fig.1 Dungeness B Power Station in the foreground

Streamlining to make a profit

The 1200MW Dungeness B Nuclear Power Station was the first commercial version of Britain's Advanced Gas-cooled Reactor (AGR) series. These plants, much like the older, less efficient Magnox nuclear plants they were designed to replace, use CO_2 gas coolant and graphite moderators in the reactor.

The government-owned public utility, Central Electricity Generating Board (CEGB), was privatised in 1989 and was replaced by PowerGen and National Power for the conventional power plant industry, and Nuclear Electric for the nuclear power industry. Unlike the other generation companies, Nuclear Electric remained in the public sector, although it is also soon to be floated on the stock exchange at time of writing. This means that all power stations in the UK not only have to supply safe and reliable energy, but they are commercial competitors as well and need to be profitable if they are to attract future capital investment.

Dungeness B was already gearing up to be profitable and competitive in anticipation of a decision to privatise Nuclear Electric. Reducing O&M expenditure was one of the prime targets, so an effective Reliability Centred Maintenance (RCM) program was drawn up and is currently being implemented. As a result, maintenance costs are expected to be reduced by up to 30% over the next three years. Numerous improvements are being made to fulfil these goals, such as re-evaluating machine reliability standards and shifting from the older electrical and mechanical areas of responsibility to a systems maintenance approach for the turbines, pumps, etc. One of the main improvements, however, involved expanding the role condition monitoring played in the plant's maintenance strategy. This step was necessary if downtime were to be significantly minimised, machine availability and reliability improved, maintenance costs reduced and the plant's overall operating efficiency increased.

The Plant Monitoring Section took on this challenge. As part of the new maintenance strategy, it was decided to shift much of the routine monitoring system operation responsibility from the Plant Monitoring Section to the Production Department's 'front line' force – the operators. They have been taught a little monitoring theory as well as how to use the monitoring system. This added responsibility ensures that data acquisition and alarm handling is positioned where it is needed most – in the hands of those who are running the plant's machinery. Diagnosis and analysis of machine faults will still remain the primary responsibility of the Plant Monitoring Section, but even this

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activity will eventually be delegated out to systems engineers.

Cost-effective condition monitoring

Dungeness B has a total of 10 years monitoring experience with a variety of monitoring systems. One on-line performance monitoring system was installed several years ago to monitor pump efficiency, turbine heat-rate, etc., as well as overall vibration levels in the turbines, alternator and main feed pumps. Another system was dedicated to monitoring only the run-up and coast-down of the turbines and alternators for crack detection purposes. When the new maintenance strategy was implemented, it was determined that the existing on-line performance monitoring system, although very important for safety and performance considerations, could not meet the requirements for predictive maintenance to sufficiently minimise maintenance costs. Machine faults had to be detected as early and accurately as possible to enable proper maintenance planning ahead of time.

Although COMPASS is an integrated protective/predictive, on-line/off-line monitoring system, only the off-line version of COMPASS was selected. This provided the most cost effective way of adding a predictive monitoring capability. It has advanced fault detection features and the Type 2526 Data Collector is small and easy to use. Five Data Collectors were ordered for monitoring a total of 132 machines and 1200 measurement points at approximately one month intervals (see Fig. 2).

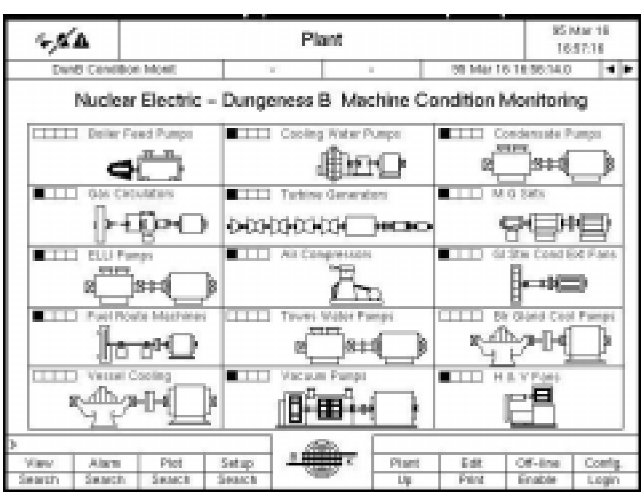

Fig. 2 COMPASS screen showing plant layout

A recent decision was also made to use the new automatic machine diagnosis software, Advisor, in order to help ease the task of looking after so many channels. It is intended to train the Systems Section to use Advisor to screen the detected faults that they feel they can handle from those that will require specialist decisions to be made. This division of labour gives the monitoring expert more time to concentrate on those more pressing problems, and allows the maintenance personnel to gradually acquire more experience in monitoring, as well as to gain more insight into fault analysis and the inner-workings of their machines (examples of some Advisor computer screens are shown in Fig. 3).

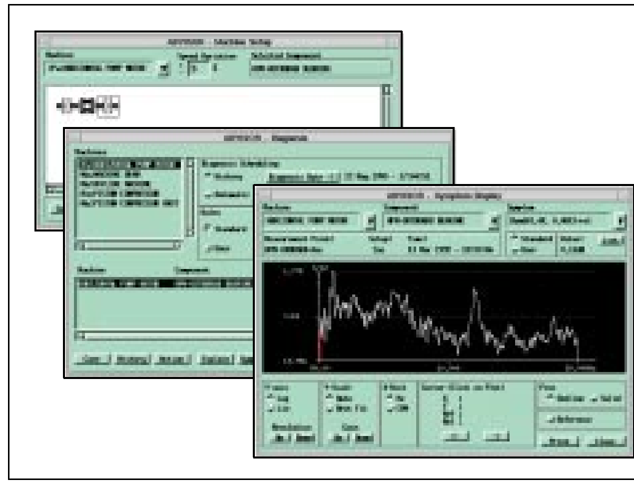

Fig. 3 User friendly screens are one of the factors that makes the machine diagnosis software user's job easier

Although many of the machines are monitored solely by COMPASS, an important role for COMPASS is monitoring those machines that are already monitored by the existing on-line performance systems, for the following reasons:

- **Fault finding** – Many kinds of faults cannot be detected early by the existing monitoring system because their energy level is so small (e.g. rolling-element bearing and gear problems) in relation to the overall vibration level. Moreover, the existing system has limited alarm annunciation capability. The Data Collector can automatically monitor just those specific bands of interest, so the slightest changes can be accurately and easily detected and used to trigger an alarm at various levels of severity.
- **Trending** – Although the existing monitoring system has its own database, its use is limited since it is based on overall vibration levels. COMPASS allows a wide variety of faults to be trended from an early stage of development.
- **Fault diagnosis** – It is very difficult to analyse the cause of a fault detected by an overall level type measurement used by the existing monitoring system. COMPASS (and Advisor) can be used to specifically monitor isolated harmonics, sidebands, toothmeshing frequencies, etc. for accurate identification of the fault.

Most machines in the station have stand-by units, and although important to generation, their failure will not cause unit shutdown – such as in the case of the cooling water pumps, condensate booster and condenser extraction pumps, vacuum pumps, vessel cooling pumps and the motor generator sets. Other machines monitored, such as heating and ventilation fans and air compressors, are considered secondary, meaning they would not cause a plant shutdown if they inadvertently fail. But big savings can still be made by monitoring these machines, as described in the section “Condition monitoring feasibility”.

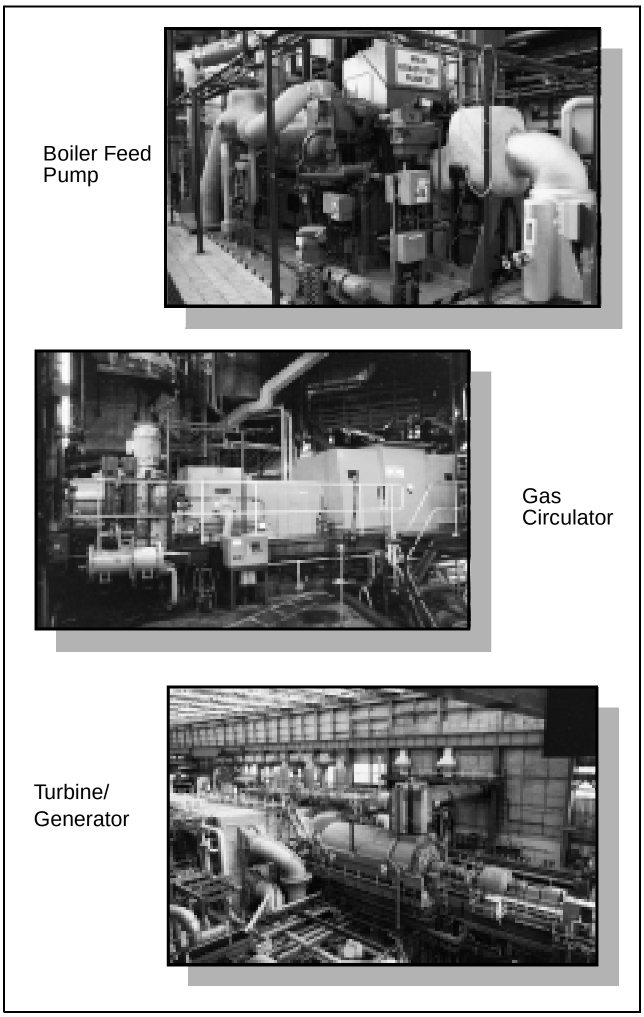

Fig. 4 Critical machines monitored

A number of critical machines, shown in Fig. 4, such as the turbines, boiler feed pumps, alternators and CO_2 gas circulators, have no stand-by unit. Here, the potential savings of avoiding a catastrophic failure are quite high, as briefly summarized in Table 1. Needless to say, when monitoring these kinds of machines, the monitoring system and technique used have to be carefully selected in order to avoid undetected faults and false alarms, because these can also lead to a loss of generation.

Machine	Fault that could lead to failure if undetected	Cost of repair (US$) ①	Downtime for repair (days) ②
Alternator	Shaft crack	3.4 million	42
Gas Circulator Motor	Bearing, shaft problem	0.5 million	14
[illegible] Circ. Pum[illegible]	Impelle[illegible]	[illegible]	20
Feed pump, turbine or gas circulator	False alarm ③	—	1 – 2

① 1994 prices
② To calculate the total cost of plant downtime, multiply the number of days downtime for repairing a particular failure by US$430000
③ Even a false alarm generated by an improperly selected or set up monitoring system can be expensive!

Table 1 Sample listing showing the cost of failure and false alarms for some critical machines

Actual performance of the monitoring system

Table 2 lists only some of the actual faults detected by COMPASS over a one year period. Notice that three of the faults detected were on critical machines.

The total maintenance savings for the early detection of these faults is not given here, but the next section gives a glimpse into some of the economic benefits.

Machine	Fault Detected
IFD Cell Fan	Cracked seal/thermal misalignment
Alternator 1	Possible thermal bend in rotor due to asymmetric cooling
Fuelling machine Gas Circulator	Loose bearing on shaft
Gas Circulator 2	Gearbox problem
Gland Steam Condenser Extraction Fan	Coupling misalignment
Main Cooling Water Pump 4	Gearbox problem
Main Cooling Water pump 1	Flow instability
Motor Generator Set	Coupling problem
Motor Generator Set	Coupling bolts sheared
Inst. Air Compressor 2	Rotor bar problem
Motor Generator Set	Loose bearing in housing

Table 2 Faults detected by COMPASS at Dungeness B Power Station over a two year period

Condition monitoring feasibility

Motor generator sets provide 110 and 415V guaranteed power supplies at Dungeness B and operate continuously from float-charged batteries. In the event of loss of grid supplies, the motor generator sets will continue to operate from the batteries (i.e. no break in supply) for a minimum of 30 minutes, by which time the diesel generators will have become available.

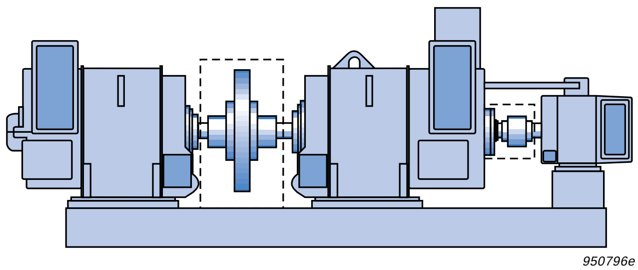

Fig. 5 A typical motor generating set

In the past, the bearings were replaced every two years during overhaul, but now the life of the bearings has been greatly extended. Of course, other types of faults have been detected on these sets that represent hypothetical savings, such as loose holding-down bolts, coupling problems and misalignment, but for simplicity, these are not included in the summary of savings in Table 3. The table only gives the savings involving replacing the bearings. Although modest, this application alone actually allowed COMPASS to pay for itself in the first year!

	Time-Based Maintenance①		**Condition-Based Maintenance②**			
	Bearing Costs (US$)③	**Install. Labour (hours)**	**Bearing Costs (US$)③**	**Labour (hours)**		
				Install.	**Monit-oring④**	**Total**
1 set/2 yrs	805	312	81	42	3	45
All 24 sets/2 yrs	19320	7488	1940	1008	72	1080
Total Savings⑤	US$83509/2 years (86% annual savings) or **US$41755 per year**					

① Before condition monitoring there was a full overhaul every two years
② This includes a minor overhaul every two years
③ 1994 prices and assuming US$1.72 to one pound sterling exchange rate
④ There are 144 channels that are routinely monitored off-line once a month
⑤ Assuming US$10.32/hour wage at 1994 prices

Table 3 Condition monitoring of motor generating sets at Dungeness B Power Station

Conclusion

Dungeness B operates with the other power generators in the competitive, privatised electricity industry. The implementation of new maintenance strategies will assist Dungeness B to make substantial contributions to Nuclear Electric's overall profitability over the next few years.

COMPASS and Advisor have demonstrated high performance capability. Moreover, the system paid for itself within the first year just with the savings made in replacement bearings and installation time for 24 motor generator sets alone. In addition to this, 11 significant faults were detected on these plus the other 108 machines, as shown in Table 2. This results in considerable costs savings due to maintenance that had been properly planned ahead of time.

When plans get under way for extending the off-line predictive monitoring capability to an integrated on-line system, COMPASS will obviously be a prime contender!

For further information regarding this application, contact Michael Hastings, Brüel&Kjær Denmark, or your local Brüel&Kjær representative

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