6Σ+

RCM2

£6 Million for ScottishPower

by David Campbell & Derek Hastings

ScottishPower, an international energy company serving gas and electricity customers in the United Kingdom and United States, is known for its aggressive application of business improvement tools to enhance efficiency, reliability, profitability and customer satisfaction. This innovative approach was recently applied to the management of its power generation assets. The result is a ground-breaking blend of two respected business improvement strategies: Six Sigma and Reliability Centered Maintenance (RCM2) producing a cost savings of £6 Million ($11.3 Million).

Six Sigma Stalled Without Valid Data

Six Sigma is a rigorous methodology that uses statistical analysis to measure and improve manufacturing and service-related processes through five procedural steps: define, measure, analyze, improve, and control (DMAIC). The objective is to increase profitability by improving performance and reducing variability.

Since 2001, ScottishPower has successfully implemented Six Sigma to its Energy Retail business by drawing data from an environment of frequently reoccurring transactions, allowing statistical analysis, and the delivery of a textbook DMAIC process.

However, the same could not be said for ScottishPower's asset-intensive Energy Wholesale business where assets do not fail often enough to produce data which is statistically significant. At the heart of the Energy Wholesale business is 6,400 MW of complex generation assets ranging from state of the art combined cycle gas turbines to seventy-year-old hydro schemes, advanced control software and brand new wind farms as well as thirty five year old coal fired power stations. In this environment, it was possible to "Define" the business problem and validate the business opportunity, but without the appropriate statistical data, there seemed to be little opportunity to get to the six sigma "Control" phase within a time scale acceptable to the business.

"It was a good news/bad news situation," said Paul Parry, Business Transformation Manager, with the Energy Wholesale Business Improvement Team. "If our generating facilities had been experiencing failures at the statistically relevant rate, we'd have been out of business. Yet, at the same time, without the appropriate asset performance data we couldn't use Six Sigma to measure analyze and improve. Rather than give up on Six Sigma we had to reconsider what Six Sigma meant to us."

RCM2 and Six Sigma Combine to Drive Improvements in an Asset-Intensive Environment

This resulted in an approach which is now an established mantra within Energy Wholesale:

Start with Define
End with Control
Use the right analysis tool

The right analysis tool in this case is RCM2, an established process used to determine what needs to be done to keep physical assets, systems and processes continuously doing what the business wants them to do. RCM2 looks at safety, environment, output, throughput, speed, range, and carrying capacity. By gathering detailed system information, it identifies the ways in which a system can fail to meet business goals and pinpoints the events which are reasonably likely to cause the failure. Finally, RCM2 identifies appropriate actions to manage each failure mode in terms of both its technical and business consequences of failure.

Based on prior experience, the Business Improvement team was convinced that RCM2 could produce the robust analysis required to complete the DMAIC cycle. In collaboration with Hugh Colman of Aladon, the originators of RCM2, the Six Sigma process was successfully redefined. Using this new approach the required asset information could be gathered from, and validated by, the supervisors, operators and maintenance professionals - even when there was no formal historical data available. This proved to be a significant departure from traditional Six Sigma thinking.

RCM2 and Six Sigma's strengths compliment each other very well but it must be noted that they also share many common values. Both methodologies focus on defining business goals up front and both use cross-functional review groups of users and maintainers to supply performance information and apply the process. The resulting approach provides an effective solution to an asset-intensive environment.

Applying the RCM2/Six Sigma Solution

A pilot project was conducted on the oil burners at one of ScottishPower's coal fired power stations, Cockenzie, located near Edinburgh. The required information was gathered from a cross section of station operators, maintainers and engineers. This process that required only four three-hour sessions, which was significantly less time than any previous 'Analyze' phase. From this work the group was able to develop an asset management program focused on improved availability and reliability. The pilot project lasted three months and delivered significant financial benefits.

Bolstered by this success, the new approach was applied across a range of generation assets including:

- Hagshaw Hill wind farm
- Ash Disposal Facilities at Cockenzie Power Station
- Refurbished Generation Machines at Cruachan Pumped Storage Scheme

What is Six Sigma? And how does it apply to reliability?

By Ricky Smith, CMRP

Six Sigma is a methodology to manage process variations that cause defects and to systematically work towards managing variation in order to eliminate those defects. Defects are defined as unacceptable deviation from the mean or target. In asset reliability these defects are known as equipment failures. The objective of Six Sigma is to deliver high performance, reliability, and value to the end customer.

The process was pioneered by Bill Smith and Dr. Mikel Harry of Motorola in 1986 and was originally defined as a metric for measuring defects and improving quality, and a methodology to reduce defect levels below 3.4 Defects Per (one) Million Opportunities (DPMO), or put another way, a methodology of controlling a process to the point of ± six sigma (standard deviations) from a centerline. Six Sigma has now grown beyond defect control in all segments of total business world to include asset reliability.

The Six Sigma methodology uses many tools which may be applied to asset reliability in its toolbox. A few of these tools include, Lean, Visual Factory, Statistical Analysis and the DMAIC Process (define, measure, analyze, improve, and control). The value of Six Sigma is to provide not only a process to reduce defects, and reduce cost, but to increase shareholder value both tactically and strategically.

The objective of Six Sigma is to provide performance breakthrough. In most attempts to improve reliability, a company will implement a strategy which minimizes risk and thus minimizes the outcome. Using the Six Sigma methodology performance breakthrough is the objective and, when applied in an asset reliability initiative, it minimizes risk while maximizing the outcome which results in "optimal reliability at optimal cost".

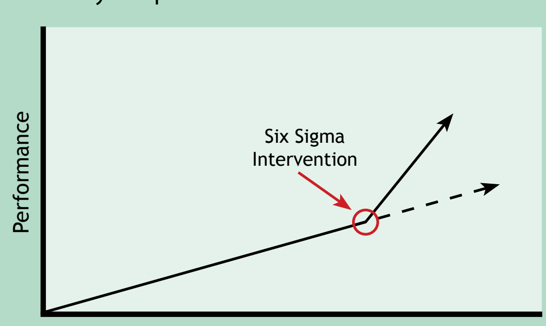

Fig. 1 - Longannet Power Station - One of the largest coal-fired power stations in Europe. It has four 600 megawatt (MW) units.

A Practical Application of RCM2/Six Sigma Combined

Primary Air Fans at Longannet Power Station

Longannet Power Station is one of Europe's largest coal fired stations. The loss of a primary air (PA) fan represents a 300 MW loss or 12.5 % of the station's total output. In the UK's deregulated electricity market a loss of this magnitude is extremely significant and costly. A Six Sigma/RCM2 analysis was performed on the PA fan system to define a proactive maintenance program and optimize the performance of this critical asset. The steps included:

Define

The 'Define' phase focuses on validating the problem, nominating a project leader, defining the project scope and assembling the Six Sigma/RCM2 review team. The research demonstrated clearly that the PA fan issue was a real problem and not simply someone's "pet project".

Measure

Historically the plant did not measure and track individual asset reliability, which is an essential success metric of any asset performance improvement program. During the "Measure" phase of the project, availability was selected (downtime in relation to generated output) as a representative measure of reliability. This was a departure from the traditional, because at the start of the project, in 2004, the importance of reliability and availability was not obvious to all involved. Yet, its importance became evident once station availability was defined in financial terms. For example, a reduction in availability from 99.8% in February 2003 to 98.11% in March 2004 represents a loss of revenue of £1M.

With the importance of availability now clearly understood, research established that PA fan availability had deteriorated over time, dropping from 99.91% in January 2000 to 94.66% in April 2005. This reduction in reliability, and its potential impact on business results, justified further work to establish a resolution to PA fan failures. Availability was established as an ideal measure of project success.

A key element of the 'Measure' step is a clear definition of what is to be measured (current and achievable states) as well as its boundaries. RCM2 provided the ideal tool to achieve this: the operating context. The operating context includes a basic history of the plant, the historical, current and projected operating profiles of the station as well as a detailed description of the equipment or system to be analyzed.

In addition, during the 'Measure' phase online condition monitoring data was reviewed to define and quantify the improvement opportunity. As seen in Figure 2, the PA fan's bearing gradually deteriorated over a 9 to 10 month period and eventually failed in April 2004. When the bearing reached this point it was too late to avoid incurring downtime costs.

Figure 3 demonstrates the benefits achievable using the P-F interval as described by RCM2. Had Potential failure (P) and Failed state (F) been properly defined, vibration analysis data would have been used to confirm that the PA fan bearing was failing prior to a scheduled outage and corrective action would have been undertaken during the Fall

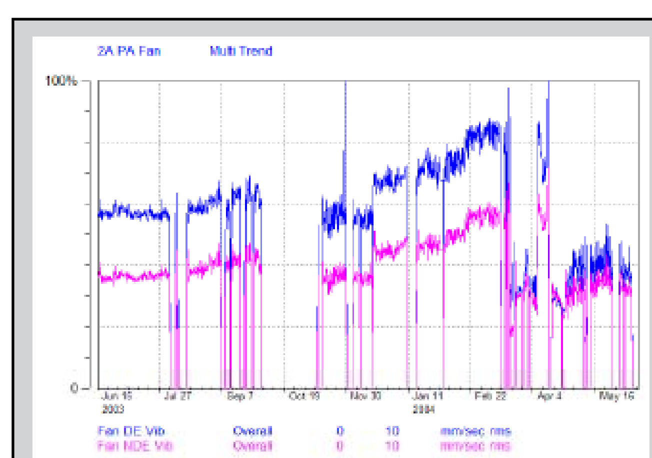

Figure 2 - Vibration amplitude plot for PA fan 2A

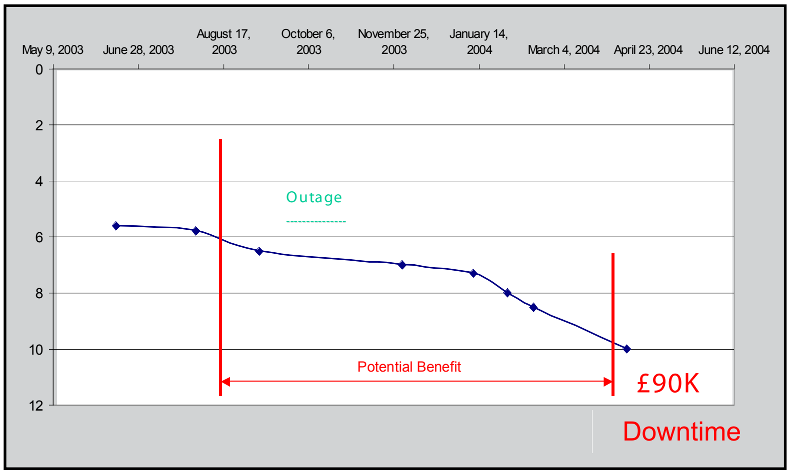

Figure 3 - P-F Vibration View of the Primary Air Fan

scheduled outage of 2003. This would have eliminated the resulting unplanned outage and saved the organization £90,000 in lost revenue.

Analyze

During the 'Analyze' phase, the information gathering phase of RCM2 is executed and Functions, Functional Failures, Failure Modes and Failure Effects are identified. At this stage, it is critical that those involved understand the RCM2 process as RCM2 relies on knowledge and experience rather than statistical data as with the DMAIC process. The review team in question had over 100 man-years of experience with these PA fans.

Improve

During the "Improve" phase of the DMAIC cycle, solutions are identified to eliminate the root causes of failures. The project team used the RCM2 decision diagram to develop sustainable solutions aimed at preventing failures which could have a significant business impact, be it safety, environmental, operational or non operational.

In total 50 maintenance recommendations were identified. They encompass: procedures, investigations, modifications, specifications, actions, routine tasks and training. The recommendations were reviewed by the project team as well as maintenance and operations staff to ensure the proper level of scrutiny and secure buy-in from those who will implement and use the program. The recommendations were then consolidated into a report for senior management approval.

Control

Senior management approved the final project report and the recommendations were implemented using strong change management techniques from the Six-Sigma tool kit. Asset performance improvements were sustained by applying the rigor of the Six Sigma "Control" phase. The ongoing tracking of PA fan availability ensures performance remains at a level acceptable to the business.

Results: The New Maintenance Strategy

The Six Sigma/RCM2 analysis conducted on the primary air fans resulted in a new proactive maintenance program that defines the right maintenance work at the right time. An example of this new program is the PA fan bearing recommendations:

Recommendation #1: Vibration and temperature monitoring of PA fan bearings.

In developing vibration and temperature indicators for the bearings, severity levels were defined such that an impending bearing failure provides early warning sufficient to allow for a planned and scheduled intervention. This predictive approach has proven very effective in preventing an unscheduled outage and is well received by the station staff.

The recommendation included an increase in internal vibration monitoring capabilities and the associated training program. Today, sev-

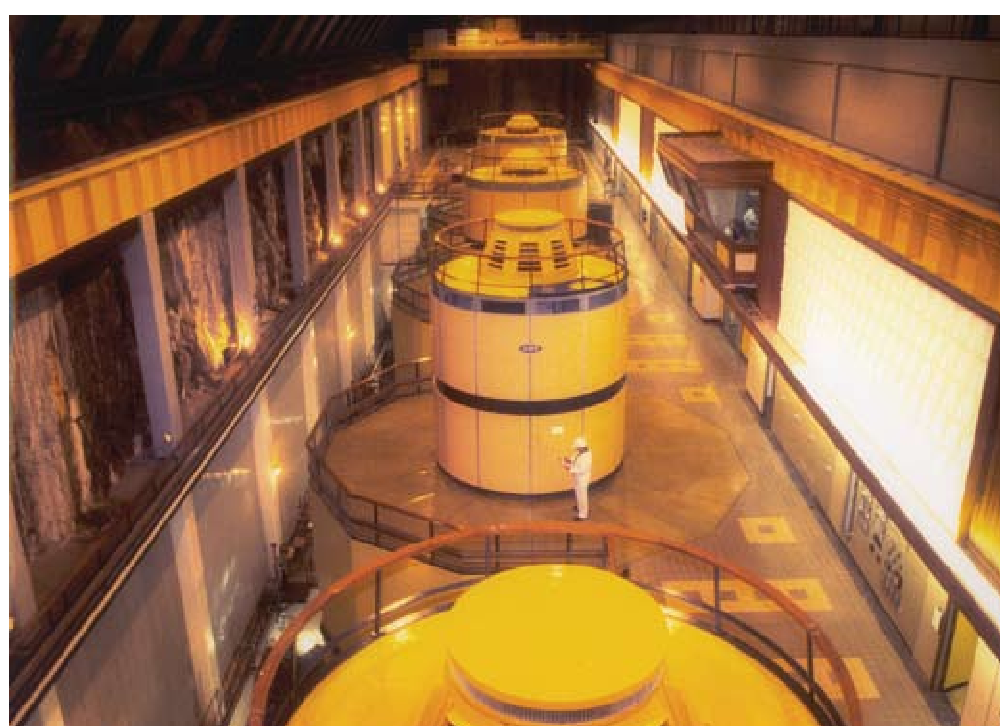

Figure 4 - Turbine Hall at Cruachan Power Station, a 440MW reversible pumped-storage Power Station.

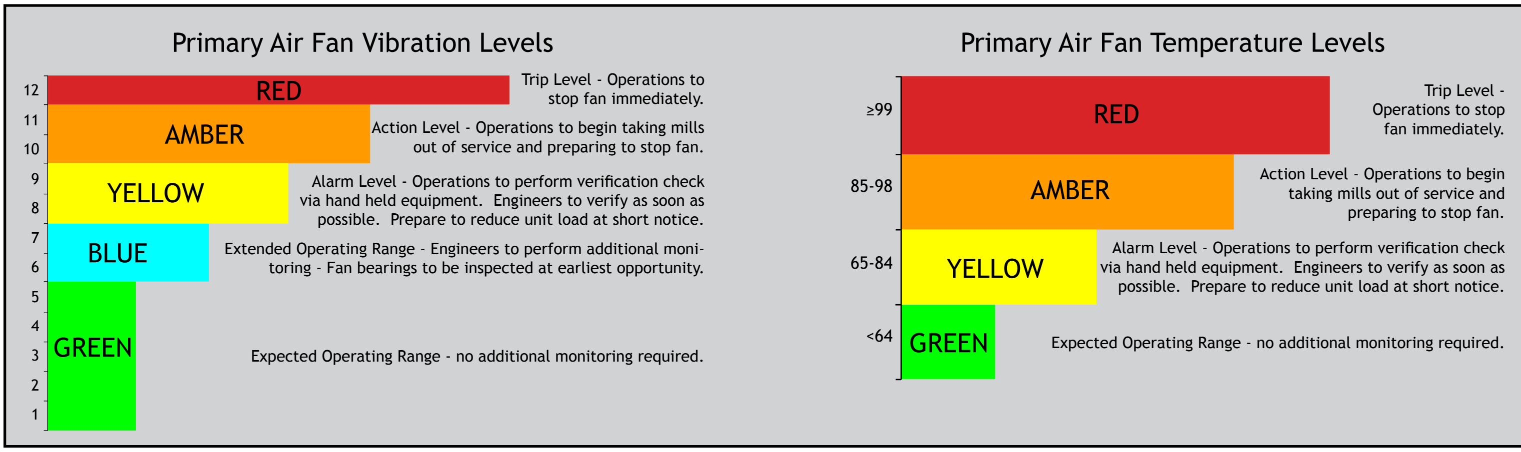

Figure 5 - Primary Air Fan Vibration and Temperature Limits

eral employees are conducting vibration and temperature monitoring activities every day.

The charts in Figure 5 illustrate the new, more graphical approach that has been adopted as well as the severity levels and actions to be taken. The computerized control desks have had their software updated to reflect these new levels and now the operators, maintenance and engineering staff all work to the one set of values. This approach offers a common basis for decisions.

Recommendation #2: Develop an alignment procedure for the PA fans that lists target alignment values. Final alignment values provided by 3rd party staff are to be witnessed by Engineering/Maintenance.

Recommendation #3: Specify bearing grease type and quantity.

Recommendation #4: Ensure that suitable spares and grease are available.

Recommendation #5: Replace the PA fan bearing sets every 4 to 5 years.

Given the increasing pressures to control costs and reduce budgets, power stations no longer have the same number of staff at their disposal that they once had. As a result, outsourcing is common as well as assigning maintenance work to an internal team who are not normally responsible for this work. In both instances, there are 'work control' implications, e.g. record keeping, ensuring that the correct instructions are given and ensuring that up to date information is available.

The PA fan bearing recommendations outlined above clarify the work that is required to ensure the bearing operates at optimal performance. All of the recommendations resulting from the bearing analysis are captured in ScottishPower's Computerized Maintenance Management System, ensuring that these critical tasks are not overlooked.

The Six Sigma/RCM2 PA fan analysis set the benchmark for fan reliability at Longannet. ScottishPower Engineers are starting to use this approach across the organization for both old and new installations.

Implementing and Sustaining an RCM2/ Six Sigma Initiative

ScottishPower understands that sustainable improvements are key to its long-term corporate wide strategy. To sustain improvements resulting from the Six Sigma/RCM2 initiative, considerable effort must be applied when embedding the change. This is where the Business Transformation team relies on the rigor of the Six Sigma methodology, specifically the 'Improve' and 'Control' phases of the DMAIC model. Through vigorous project tracking and monitoring of "critical to quality" (CTQ) metrics agreed upon by the project sponsors and key process owners, the business aims to make permanent improvements within its asset base.

To validate the improvement effort and prove a return on investment, the Business Transformation team employs the services of a qualified management accountant. "It's important that our improvement projects are treated with the same rigor as any other company investment," explains Paul Parry. "The financial benefits from our Six Sigma projects are published in the company results and undergo independent verification."

Benefits To-Date from the RCM2/Six Sigma Initiative

Considerable business benefits have been derived from the improvement initiative. Highlights include:

- The financial return from the initiative has grown from £150k in its first year to over £6m cumulative benefits in its third year.
- Numerous soft benefits including signifcant safety and environmental improvements.
- Recommendations free up manpower resource to attend to other critical activities.
- Knowledge sharing has been a significant feature of this deployment; at least once in every project someone has said, "I never knew that."
- Staff members enjoy Six Sigma and RCM2 and feel engaged with the change. They like the inclusiveness of the process as well as being part of the solution.

Solution Greater Than the Sum of Its Parts

Six Sigma and RCM2 work well together in an asset-intensive environment as they are meticulous processes created to develop solutions that specifically meet established business goals. Both also focus on identifying and correcting the root cause of obstacles and highlighting concrete, achievable solutions.

ScottishPower continues to reap the financial, safety and environmental benefits of its new business improvement practices and has successfully completed over a dozen Six Sigma/RCM2 implementations. There are ten more currently in progress. The program is targeted to deliver in excess of £10 Million ($18.8 Million) by the end of FY 06/07.

David Campbell is a Charted Mechanical Engineer, having graduated in 1986 with an Honours Degree in Mechanical Engineering, achieving an MBA in 2005. Various maintenance and operations posts followed at hydro, pumped storage and thermal power stations with ScottishPower. David moved into the Business Improvement Team in 2003 and is now a Six Sigma Master Black Belt and RCM2 Practitioner.

Derek Hastings is a Chartered Mechanical Engineer. He joined ScottishPower in 2004 as a Six Sigma Black Belt and RCM2 Facilitator and is currently one of the senior engineers at Longannet Power Station. Previous to this Derek has worked in various engineering and project roles within underground railway systems, hydro power station refurbishment and engineering and pump design.

Figure 6 - Hagshaw Hill Windfarm, part of ScottishPower's expanding portfolio of windfarms.