Experience from the use of SIEMENS Diagnostic and Monitoring Systems

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INTRODUCTION

At Siemens Power Generation (PG) Industrial Applications we have been performing remote data collection since 1993 when we first connected a modem to the Rustronic MkII Turbine Control System. The MkII data collection utility was very simple. It comprised around 50 of the most important variables, with readings taken every 10 minutes. Data was stored for a maximum of 7 days. When a shutdown occurred, a faster log was taken; this contained 30 seconds of data at 1 second resolution for the same set of variables; up to 10 shutdown logs could be stored. Remote assistance was not possible, so the benefits we were able to offer the customer were minimal.

With the introduction of a Human-Machine Interface, (HMI) replacing the simple VDU (Visual Display Unit) that had initially accompanied the Rustronic MkII Control Turbine System, the possibilities for enhancing the data collection and remote assistance changed dramatically. Data logging was now done through the HMI, which meant that data could be logged as fast as it was being transmitted up the serial data link (typically at the rate of 1 second); long-term data storage was restricted only by the size of the hard disk. Furthermore, two-way data transfer and remote assistance were possible, immediately offering the customer additional benefits. In 1996 the first HMI's were despatched from Lincoln with a third-party remote control package installed.

Since the introduction of remote monitoring, Siemens PG have recovered, stored and analysed several million hours of site operating data. This represents valuable information that we are now feeding back into the Company to help us improve the products and services we offer to our customers.

As the Original Equipment Manufacturer (OEM), Siemens PG are in a prominent position to be able to use their intimate knowledge of the products, coupled with their expectations of the products, to be able to determine quickly what is at issue when there is an incident. Using the historic data, and the ability to provide remote assistance, Siemens PG can advise customers on the best course of action to take in order to alleviate, or reduce, unnecessary downtime.
ARCHITECTURE

The remote monitoring and diagnostic system employed within PG has been developed to target multiple audiences and consists of a diagnostic application, hosted from within Siemens but which is available to all, including customers, and the option of either a complex or simple on-site application, subject to the customer's requirements.

The Complex On-Site Application:

This application is delivered to those customers who require a product that can assist them in optimising the running of their plant, or those who wish to perform some local analysis of the performance of their equipment. This application performs real-time condition monitoring, and consists of a database for long-term data storage, and a number of analysis tools. Remote assistance and automated data collection is possible if the customer provides a telephone line. Alternatively, data can be returned on CD periodically for analysis and evaluation in Siemens.

The Simple On-Site Application:

This application consists of a very simple data logging tool that can record and store data for one month, and a third-party remote control package. It is integrated as standard in a number of our products and helps us to provide enhanced aftermarket services. Remote assistance and automated data collection is possible if the customer provides a telephone line. Alternatively, data can be returned on CD or by e-mail periodically. This system performs no on-site analysis.

Diagnostic Application:

The diagnostic application consists of a large relational database for storing the data that has been returned from site. A number of automated agents supplement the database. These perform mundane tasks, such as contacting site and retrieving/processing data through to more complicated tasks such as the evaluation of key indicators and forward trend prediction. Any
results generated by these agents are also stored in the database; thus allowing a richer and complete picture of the situation to be established.

The following diagram illustrates the architecture of the complex and simple systems and their interaction with the diagnostic system.
BUSINESS INTEGRATION

One of the hardest steps to take for any condition monitoring / diagnostic system is its integration into the business it is there to serve. It is important to engage not only technical experts but also the broader business community by providing straightforward access to relevant information rather than raw data and by drawing the attention of experts to where it is needed.

The approach we have taken within Siemens PG has been to use the experience of our engineers and translate this into a number of automated agents that can then process the raw data. The best test for these agents is to prove that they can replicate an engineer's diagnosis. Therefore we have taken real diagnosed problems, where we have recovered sufficient data, and tested the agents against them. When the agents have proven themselves satisfactorily we have deployed the agent on the fleet.

With any utility, where it is important to provide users with reliable and accurate information as early as possible, there is always a trade-off to be made between how soon the advice is given, and how confident we are that the utility is making the correct diagnosis. Giving advice too early, when it is based on too little data or has too wide a margin of error, runs the risk of generating primarily false alarms. Alternately, being too slow to reach a diagnosis means that there is no time to act in order to help the customer. In both scenarios the utility will fail to be accepted by the business as it is not providing any useful information.

The examples included demonstrate how manual experience has been turned into:

i) a forward predictive trender,

ii) a method for determining the root cause of a flow switch failure,

and how these have been used to assist customers reduce unnecessary downtime.
Experience Leading to the Introduction of a Predictive Trender Agent

In late June 2004 one of our SGT-400 units (formally known as Cyclone) developed a vibration problem following a routine shutdown. After a few days of running with increasing vibration levels the unit was automatically shut down by the control system. At this time we had not thoroughly implemented our predictive trender agent, and this proved to be a very useful test in order to validate the work we had been doing.

Diagram 2 is a plot of the inlet bearing vibration levels between the 16th June and the 1st July. As can be seen, the vibration levels were reasonably normal until sometime on the 23rd when there was a sudden upturn. Following the shutdown and a restart on the 26th, the vibration levels increased to almost twice their previous normal levels.

Diagram 3 shows the results from the predictive trender agent. The three dark blue lines represent upper 95% prediction, best linear fit and lower 95% prediction. As can clearly be seen, the trender has correctly determined an upward trend and has reported that a shutdown could be expected anytime in the next 4 days.
Implementation of the Predictive Trender

To alleviate the risk of generating primarily false alarms, we met with a select sub-set of users and determined what rules we should put in place to govern when alarms would be raised. With these in place the utility was implemented for a two week trial period. During this trial the utility was only permitted to send alarms to that sub-set of users. After this trial period the rules were examined and tightened or relaxed accordingly. The process of putting the utility on trial, and then revising the rules was repeated until we were satisfied that the alarms being raised were genuine.

Use of the Predictive Trender in Reducing Customer Downtime

This example uses data from an SGT-200 (formally known as Tornado) gas turbine from September 2004. There had been some concern with the levels of vibration on the inlet-bearing module. The levels remained higher than usual during the following two months of operation.
(diagram 4) and the customer had experienced 4 running trips caused by high vibration (diagram 5).

Following a shutdown on 10th November 2004, a jump in vibration level was detected immediately after a restart. The predictive trender application also picked up the high vibration level and determined that these would breach the shutdown levels within the prescribed 14-day period if current trends were maintained.

Diagram 6 illustrates the predictive trender output as generated on 17 November, and diagram 7 represents the output 24 hours later. Vibration levels had started to level off but were still close to the shutdown level, and obviously higher than was deemed good for the turbine.
At this point the predictive trend was still generating alarms, although the estimate of when a shutdown would most likely occur had moved out by about 11 hours.
The alarms that had been generated by the diagnostic system were automatically relayed into the SAP business system in the form of notifications requesting that the Technical Support Help Desk investigate the problem. In addition, an e-mail was sent to the Customer Support Manager advising them of the issue. Between them they interrogated the diagnostic system and reached the decision that an engineer should be sent to site on 20th November to investigate further.

**Site Visit - 20th November**

During this site visit, it was determined that the worst vibration levels were reported during reduced load operation; full load operation resulted in only a steady (and almost imperceptible) increase. However, due to the customer’s operational requirements, further investigation was impossible at this time, and a second visit was scheduled for 30th November.

**Site Visit - 30th November**

The second visit included a vibration survey; the outcome of which resulted in the vibration trip and alarm levels being temporarily raised to prevent unnecessary trips. This allowed the customer to continue operation to a routine service on 13th December whilst the remote monitoring system continually updated us on the condition.

**Service - 13th December**

During the service, the inlet bearing was examined and a decision was taken to replace it as it was found that there was some wear on the reverse side of the journal pads.

**Post-Service**

Since the service (and the shutdown period over Christmas and New Year) the vibration on the inlet bearing has been of an acceptable level, as shown in diagram 8.
Experience leading to a method for determining the root cause of a flow switch failure

The second example shows how 6-sigma projects within the business can be helped by the provision of reliable and useable site data, which in turn assists in the development of applications to bring about the improvements the 6-sigma project was aiming for.

A powerful use of the data collected from a large fleet of equipment is to use it to learn how the product performs over the long term and the problems faced by users. Siemens PG has a policy of continuous product improvement and has a number of projects that use 6-sigma improvement techniques which draw on the database of fleet experience to identify and implement product improvements.

The information in the central database allows each type of event to be analysed across the fleet of equipment to identify areas of common occurrence. Groups of experts are then tasked with reviewing key events and determining the root cause. This is assisted by the type of information available from the system; which includes both data and alarms/events.

In this example, a running trip (shutdown) caused by a ventilation flow switch on the turbine enclosure was identified as a candidate for analysis.

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In many applications, the gas turbine is located within an acoustic enclosure as shown in diagram 9. Air is drawn through the enclosure, both for cooling and for removal of flammable gas under fault conditions. A flow switch is used to detect the operation of the system.

If, whilst the turbine is in operation, the flow switch indicates insufficient air flow, then a trip is generated and reported by the control system. In practice, a ‘flow switch trip’ can actually be caused by one of a number of different causes, including:

- failure of the A.C. supply to the fan motor,
- an operator opening the enclosure door (without following the correct procedure),
- a fault in the flow switch.

Using data mined from the system, the experts were able to identify the root cause of each event, and also to develop rules which encapsulated the decision process used. For instance, the differential pressure across the inlet filter of the turbine enclosure shows a different characteristic.
as the fan ‘runs down’ as opposed to when the door is opened. This characteristic gives clues as to the event which took place.

![Diagram 10 - Inlet Pressure Differential Characteristics](image)

In a similar way, the pressures in the Lubricating Oil system are influenced by whether the A.C. powered lubricating oil pump is running (implying the presence of an A.C. power supply).

Similarly, there are alarm messages recorded by the control system which are indicative of certain operational activities taking place. For instance, if the operator intended to enter the turbine enclosure then the fire detection / discharge system must be set to a special mode.

By cross checking this information with other tell-tale events reported in the alarms and event history, the experts were able to build a richer picture of the circumstances surrounding a trip. This work has led to improvements being identified in the systems and operational processes, but has also resulted in extension of the automated monitoring system. As with the earlier example,
it was possible to take the rules generated by the experts and build these into automated analysis within the remote monitoring system.

**Use of the Flow Trip Agent in Reducing Customer Downtime**

The resulting automated agent recognises each trip of this type on any engine in the fleet and applies the rules elicited from the experts. By doing so, it generates textual comments which describe the root causes of the event. These comments are then inserted into the database for future reference.

In practice, the agent is able to automatically recognise and provide useful commentary on 80% of the events of this type compared to a team of experts spending 30 minutes analysing the same event. Equally importantly, in tests this agent has not misdiagnosed a cause.

The agent performs its analysis each time new data arrives from an installation, so by the time any user looks at the data, the richer explanation of the root cause has already been created.

From what we have learnt we are able to target those customers whose operators are not following the defined procedure and highlight the problem. Where the problem is caused by power failure or flow switch fault, the experience we are gaining through this agent is allowing us to provide better feedback to the design departments, which will result in a better designed product, offering future customers the benefits of these improvements.
INTERFACING WITH THE CUSTOMER

Having taken something from the customer, it is nice to be able to give them something in exchange. The diagnostic element of our remote monitoring system has been developed with customers in mind, and they have access to all information through the web portal. In addition, operational reports are generated by the diagnostic system and are available either on-line or via e-mail.

Web Portal

Through the web portal, the customer has full access to the raw data that we have recovered from their equipment, as well as the results of the analysis that has been performed. The web portal provides a number of pages that offer different views of the information; each being tailored to a specific set of requirements. The following contains a summary of the most useful pages:

Equipment Summary

The equipment summary page provides a brief operational history of the selected item of equipment. The information presented to the user consists of key indicator graphs (e.g., shaft speeds, power output) and annunciated messages over predefined periods (i.e., daily, weekly or monthly). This page is useful for users wishing to get a general overview of the operation of their items of equipment.

Key Performance Indicators

This page provides an overview, over a user-selectable time period, of the key performance indicators of reliability, availability, fired hours (gas, liquid), scheduled and unscheduled maintenance downtime, and start reliability for the user’s selected fleet of equipment.
Message Summary

The message summary page is a pareto ranking of messages for the selected equipment over a user-selectable time period. Messages are grouped by type, and can be ordered by count or downtime. In this way, common problems across a fleet can be seen and plans put in place to address the issues.

Operational Summary

The operational summary is a top level overview of the key events that have occurred on the selected fleet over any user-defined time period. It is aimed at site managers who need a quick overview of how their installation is operating, without the need to plough their way through streams of irrelevant messages.

Diagram 11 - Operational Summary

Other Pages

Amongst the other pages available to the user are ones allowing them to:

- plot graphs of any available tags over any available time period,
- view messages,
- query messages,
- view the output from the predictive trender,
- view reports,
- view tasks.
**Periodic Reports**

For those customers with long-term service agreements (LTSA) Siemens PG produces reports periodically (normally once per month). These reports contain summarised information for the selected equipment over the period in question. Reports are available within the diagnostic system as a group of HTML pages, and the customer can view them through the web portal. Alternatively the report can be e-mailed to the customer as a PDF document.

A typical monthly report would consist of the following sections:

- A top-level summary containing automatically generated commentary, supplemented by comments from either the support engineers and/or the customer support manager. The automated commentary would report on the salient facts, such as how many hours the equipment had been operated, how many starts it underwent and how good (or otherwise) the data recovery was.

- Operational overview detailing when the equipment ran, a breakdown of the key operations (e.g., start, stop, fuel changeover), and a breakdown of any starts and trips that occurred during the period of the report.

- Pages are also provided for each sub-system (e.g., core engine, fuel system, driven unit) that give an overview of alarms that have been associated with the relevant system, together with charts of the most significant tags.

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SUMMARY

It is frequently quoted that a company's most valuable resource is its staff. This is quite probably true, as the experience and know-how of a company is still all too often stored in the heads of its personnel. By being able to extract the know-how from those personnel, and couple it with real site experience, it is possible to generate utilities that can only result in one thing - a better level of service for our customers.

This paper provides two examples where we have extracted knowledge from our engineers, applied it to real-life situations and generated applications that are now benefiting others.

By continuing to work closely with our engineers, and to provide them with a wealth of data, we will be able to develop additional applications that will in turn provide customers with levels of service beyond their expectations.