Continuous Process Quality Monitoring and Early Detection of Faults by means of Key Performance Indicators

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KEYWORDS

Process Quality Monitoring, statistical methods, statistical process quality control, fault detection

ABSTRACT

Power plants and their components are subject to continuous changes in their operational behaviors. These changes regularly lead to undetected deteriorations of the degree of efficiency of the plant or to seemingly sudden failures of components with economic consequences. In order to avoid such additional costs, the use of statistical methods lends itself to obtain reliable evidence of imminent failures as early as possible through the continuous evaluation of existing performance values.

1.0 BOUNDARY CONDITIONS OF POWER PLANT OPERATION

In an economically difficult environment, it is necessary for the power industry to continuously optimize the entire value chain in the power plant. A comprehensive approach to this task has to account for a range of topics as diverse as improving the degree of efficiency, decreasing the maintenance costs, and efficiently deploying the available human resources in equal measure.

1.1 IMPROVING THE DEGREE OF EFFICIENCY

A prerequisite for improving the degree of efficiency is to promptly know the current heat consumption of the power plant unit and to assess the sources of possible losses quantitatively. On the basis of such an analysis, deviations from a reference mode of operation are detected in a timely manner and suitable measures are evaluated regarding their economic efficiency. In daily business, however, the implementation of such an analysis using only the operational data provided in the DCS is complicated by the vast amount of data in the DCS. Without the support of suitable IT systems, it is not continuously possible to deduce the essential characteristics for the process and the main components out of typically 5,000 measured values in the DCS displayed across perhaps 100 views. Only by means of an automated data analysis (fig. 1) can the data flood be condensed into information about the condition of the process and the plant, and the power plant staff be supported in performing their tasks.

1.2 REDUCING THE MAINTENANCE COSTS

Maintenance is another effective lever to optimize the value chain. However, an optimization at that point has to factor in the attainable plant availability and the costs of unplanned shutdowns. Thus an intelligent combination of reactive, preventive, and state-oriented maintenance in order to minimize the life cycle costs will become an increasingly important task in the time to come. At the same time, the relevance of state-oriented maintenance will rise in the future. This requires that changes in the condition of a component are detected early on and reliably. Then a quantitative analysis of the trends is the basis for choosing the appropriate action and determining the cost-optimal point in time for its implementation. This task, too, cannot be fulfilled on a continuous basis in day-to-day operations without the support of suitable IT tools. Without such IT tools, not all main components can be evaluated promptly and based only on the data flood of the DCS; even more so, as with increasingly varying load demands, the change of an individual measured value does not necessarily indicate changes in the plant condition. It can also result from differing operating conditions. So mostly, the actual state of the component can only be deduced from the interaction of various measured values.

1.3 UTILIZING RESOURCES EFFICIENTLY

To some extent, staff members experienced over many years have developed a “procedural feeling” for such complex coherences. Based on their jobs, they know which combinations of measured values are normal and which ones are exceptional. However, these skills are not equally distributed across all shifts. Also, in times of demographic change and at the same time scarce human resources, there is the risk that when such high performing staff members leave the company, the valuable know-how gets lost and can only be rebuilt in the medium term. Here, too, the knowledge from experience can be quantified through the use of IT tools for data analysis. Thus the “Best Practice” becomes secured in an IT system independently of individual experience and can then be developed further in a continuous improvement process not just site-specifically, but company-wide.

Irrespectively whether the necessity for optimizing the value chain in the power plant is regarded from the point of view of improving the efficiency, of state-oriented maintenance, or of the efficient deployment of human resources: In any case, the use of IT systems for continuous data analysis is indispensable for condensing information out of the variety of data. On the basis of this information, a more efficient work is possible.

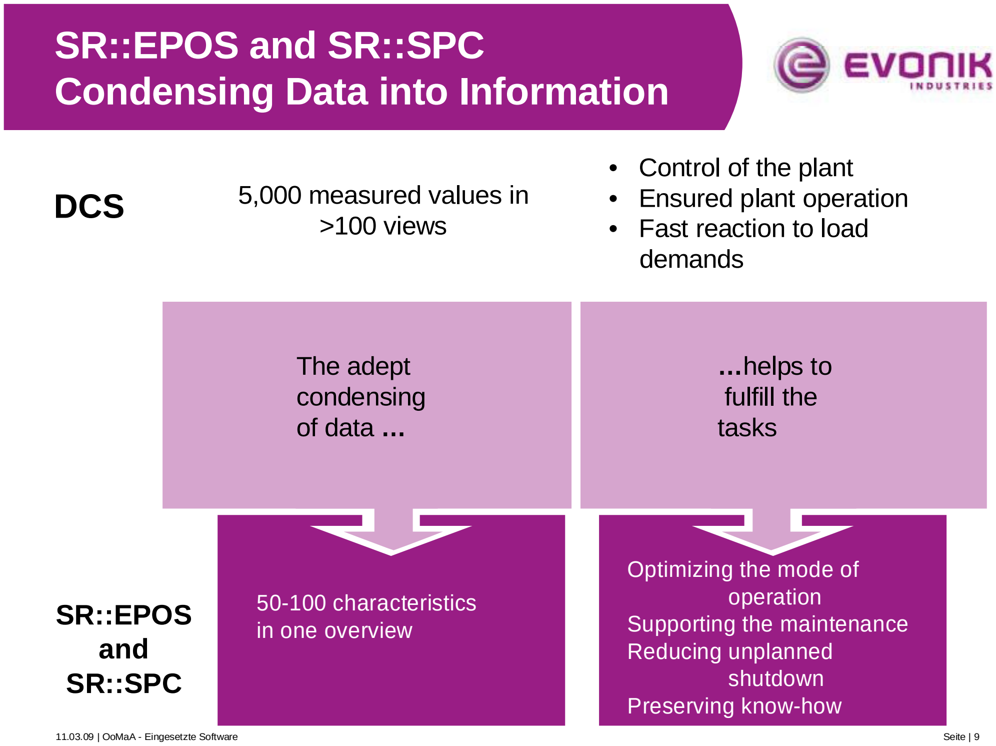

Fig. 1 Data are condensed into information by means of expert analysis

2 METHODS OF DATA ANALYSIS FOR PROCESS QUALITY MONITORING AND EARLY DETECTION OF DAMAGES

The analysis of the requirements for optimizing the value chain shows that the data analysis of in-service measurements has to cover various ranges of tasks. On the one hand, the point is to determine the current status of the process or the main components. To do so, key performance indicators (KPIs) have to be defined that only depend on the status but not on the current operating conditions and ambient conditions.

A particularly prominent example for this is the condenser pressure. This important measurand is not directly suitable as a characteristic for the status of the condenser, because it is raised not only by fouling and ingress of air, but also e.g. by the cooling water temperature, load, and, if applicable, a district heat extraction (fig. 2a). So assessing the status of the condenser is not readily possible from the current value of the condenser pressure alone but only in comparison with an operation-related reference value. This reference value must not be a constant but has to depend on the said influencing variables. It has to represent the condenser pressure that would have to be expected under the current conditions of load, district heat, and cooling water as well as “good” status of the condenser. Then the discrepancy between the current value and the reference value depending on the mode of operation is the measure for the status of the component and can be used as KPI. A similar situation exists for nearly all key quantities of power plant operation, from the power consumption of a fan via vibrations up to the net heat rate.

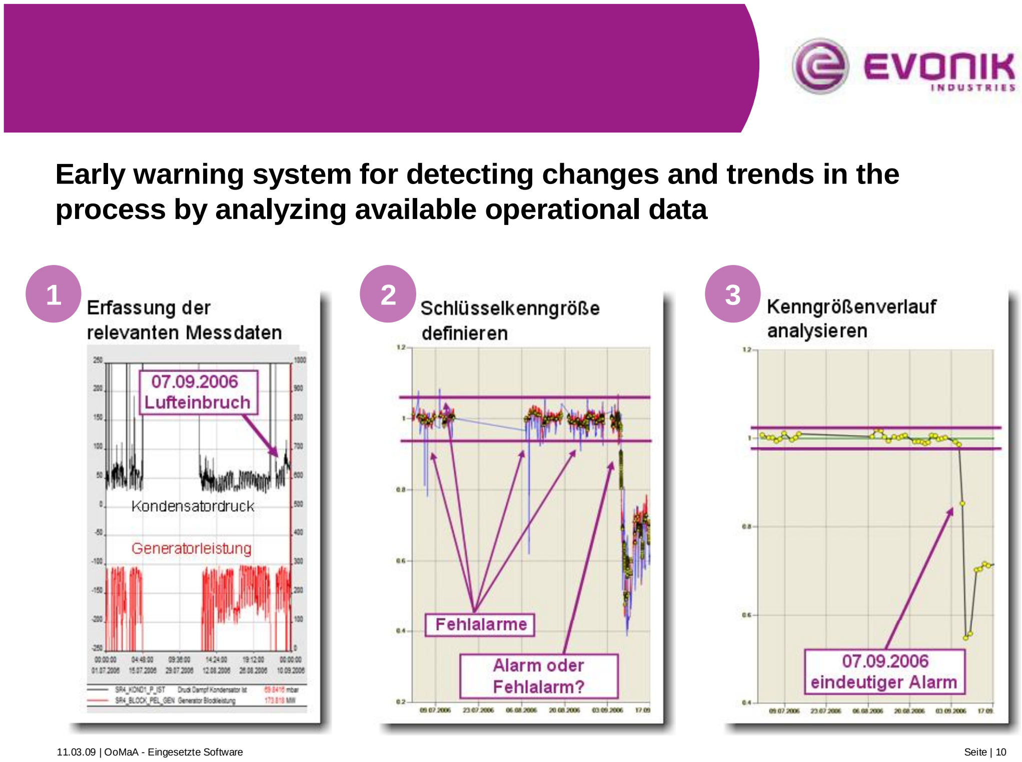

Fig. 2: Detecting critical changes in the process by evaluating available performance data

2.1 DETERMINING THE REFERENCE VALUE

Hence an IT system for the continuous analysis of operational data has to contain a tool for the balancing and simulation of the process by means of which the reference value for important process variables can be established depending on the mode of operation. Here the first choice for those variables accessible for thermodynamic description is a *modeling on the basis of physical base equations*. Such models “know” the physics of the plant, so they can be adjusted to the condition of the plant with a comparatively limited data pool. This way, they are able to extrapolate with a good degree of accuracy and thus will also yield reliable results if rare or “new” operating conditions arise.

However, numerous measurands defy the modeling with physical base equations. Typical examples are the classical indicators for the status of large equipment units like vibrations or bearing temperatures. Therefore a system for quality monitoring in the power plant would not be complete if it didn’t offer the possibility to determine reference values for those in-service measurements, too. Here, *data-based models* based on e.g. neural networks or similar techniques can be applied. These methods allow to reconstruct (“to learn”) the reference value from historical data (from spaces of time when the component to be monitored was in a good condition) depending on the mode of operation, the load, the ambient conditions etc. The procedure has long been tried and tested but will only yield reliable results as long as no operating conditions arise that did not occur during the learning phase.

2.2. “KEY PERFORMANCE“ INDICATORS

For the quality monitoring in power plants, physical models or (if not feasible in any other way) data-based models on the basis of neural networks provide the reference values of key quantities that can be compared to the current value. As KPI, the deviation is then suitable for evaluating the process or a component. Because the KPIs have to be deduced from operational data in a continuous (online) monitoring of the power plant, they are subject to a certain degree of fluctuation due to measurement inaccuracy (fig. 2b). Nevertheless it is essential to automatedly detect significant changes in the condition as early as possible in order to relieve the power plant staff from the regular manual analysis of the KPIs. On the other hand, the acceptance of the system will be seriously affected if changes are signaled due to such fluctuations while no actual cause can be detected in the component or in the process.

2.3 STATISTICAL DATA ANALYSIS

Thus the third component of an advanced system for continuous process quality monitoring and early detection of damages from in-service measurements are *statistical methods* that analyze the chronological events of the condition online in an automated way. This tool imitates the engineer’s work of analyzing time series and – just like the experienced engineer who looks at a recording strip or history of measured values, but automatically – detects significant trends and patterns or sudden leaps in the monitored characteristic (fig. 2c). By applying various procedures and suitable rules for evaluating the results, the reliability of the statements can be further enhanced.

The “IT toolkit” for process quality monitoring is perfected by modules for deducing optimization suggestions. This module is able to deduce indications for an optimized mode of operation of the plant on the basis of simulation in the context of thermodynamic modeling or also by means of heuristic approaches like fuzzy logic. Prominent examples of such applications are the optimization of the cold end of a power plant regarding the amount of cooling water / the mode of operation of the cooling tower or intelligent sootblowing.

3.0 THE BENEFIT OF DATA ANALYSIS IN THE POWER PLANT

The operational benefit of such systems is manifold:

Data from the DCS are condensed online into uniform characteristics. The mode of operation and the condition of components are assessed quantitatively and objectively. This leads to a gain in transparency that facilitates a continuous improvement process and allows to learn from the best within an organization.

Reliable anticipation data for maintenance are provided and thus a cost- and availability-oriented maintenance strategy is supported. In addition, experiences of the shift personnel are sampled and mapped when implementing the systems. This way, valuable know-how is saved and the mode of operation of the plant becomes independent of the individual experience of the shifts in times of demographic change.

With the SR::EPOS / SR::SPC System of Evonik Energy Services, Evonik STEAG has introduced such a system for continuous process quality monitoring and early detection of damages from in-service measurements comprehensively. Three examples shall illustrate the benefit.

The figures for the three following examples of application are designed identically. To begin with, in each case a characteristic measurand (dark purple) of the examined component that directly correlates with process quality or the condition of the component is shown top left. Additionally, in this illustration a constant threshold value (yellow green) is entered to make it clear that a direct monitoring of the measured value is unrewarding due to the superimposed influences. The figure also contains information about the depicted measurand and the monitoring period. To the right, the normed and averaged characteristic of the measurand, the so-called KPI, is shown. If the value of the KPI is within the limits (light purple) and does not show any statistically significant distribution patterns, it is shown in purple, otherwise in red. The two bottom illustrations show the results of other statistical evaluations. Also for these evaluations applies: if the value of the analysis is between the two shown threshold values, the process or the component is normal; if it is outside, this will be rated as a significant change. Usually, online systems will only trigger an action if one or more analyses show abnormalities. In the examples of application, this point in time is always marked by a yellow green arrow in the first picture – false alarms during the online monitoring did not occur in any of the examples.

3.1 PROCESS QUALITY MONITORING – EXAMPLE: CONDENSER

Figure 3 shows the successful application of SR::EPOS and SR::SPC using the example of a condenser. Here, ingresses of air and thus declines of quality had occurred over a longer period of time due to smaller leakages and a fault of the vacuum system. These ingresses/declines cannot be detected in the measured data concerning condenser pressure (fig. 3, top left), because they occurred only in longer off-design operation and, in addition, were superimposed by other influences like e.g. cooling water temperature and district heat extraction. They become visible only by conversion of the measurand into a KPI (fig. 3, top right), which took place by means of SR::EPOS based on a physical model. The SR::SPC online monitoring downstream detected and signaled the ingresses/declines without major delay directly at the beginning of the increased off-design phases with a high degree of district heat extraction (see arrow).

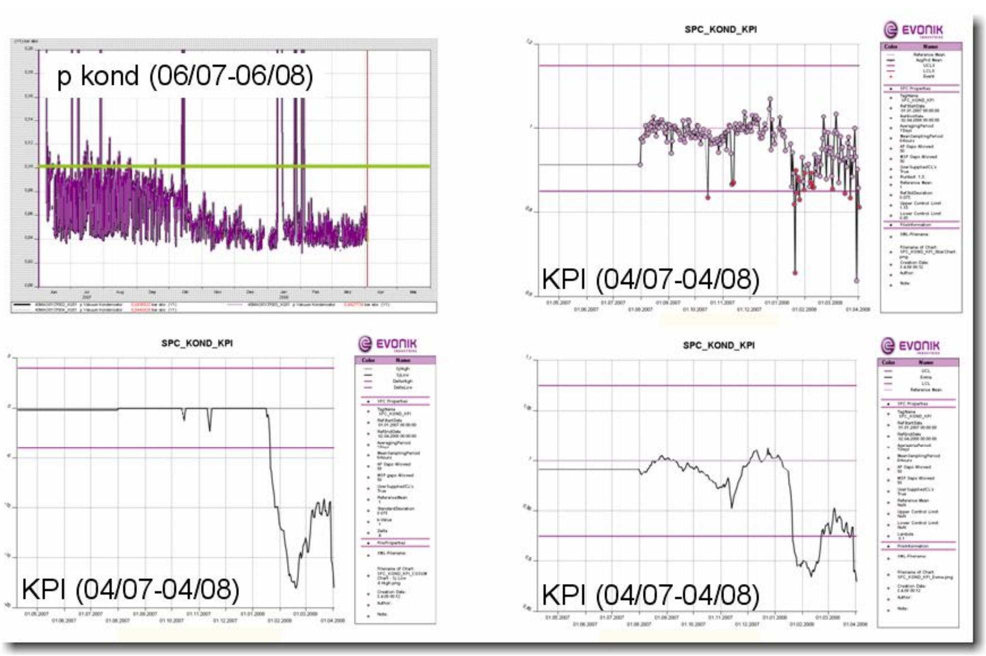

Fig. 3: Decline of process quality: condenser in off-design operation

3.2 CONDITION MONITORING – EXAMPLE: BOILER FEED PUMP AND ID FAN

The two following examples (fig. 4 and 5) show the application of data-based models – neural networks were utilized here for KPI determination – that are used for assessing the condition of a boiler feed pump and an ID fan. In both of the illustrated cases, already the changes in the raw measured value are quite significant. Nevertheless, in both cases a fictive threshold value (yellow green) would have been transgressed several times for no reason before the occurrence of a fault. In the case of the ID fan, it would also have been undercut several times after the fault occurred. In both cases, even with an optimal definition of threshold values no reliable notification could have been effected semi-automatedly, or several false alarms would have been generated – a monitoring system with such a rate of false alarms would not have been accepted by the operating crew for understandable reasons. By combining the KPI determination and the statistical analysis of the KPI behavior, however, it was possible to achieve an unambiguous analysis result and the operator could be informed about the changes online and thus in a timely manner in both cases. In the case of the boiler feed pump, the cause of the changes in the vibrational characteristic was an incipient crack of the shaft, and in the case of the ID fan probably fouling on the blade.

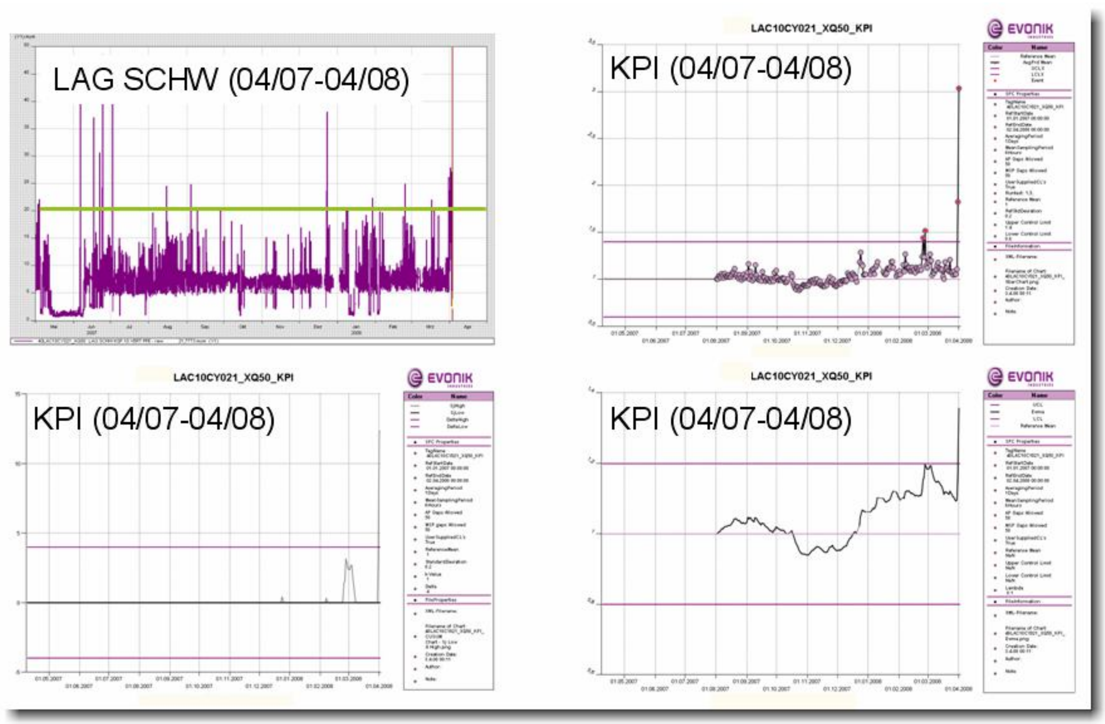

Fig. 4: Incipient crack of the shaft of a boiler feed pump → increased bearing vibrations

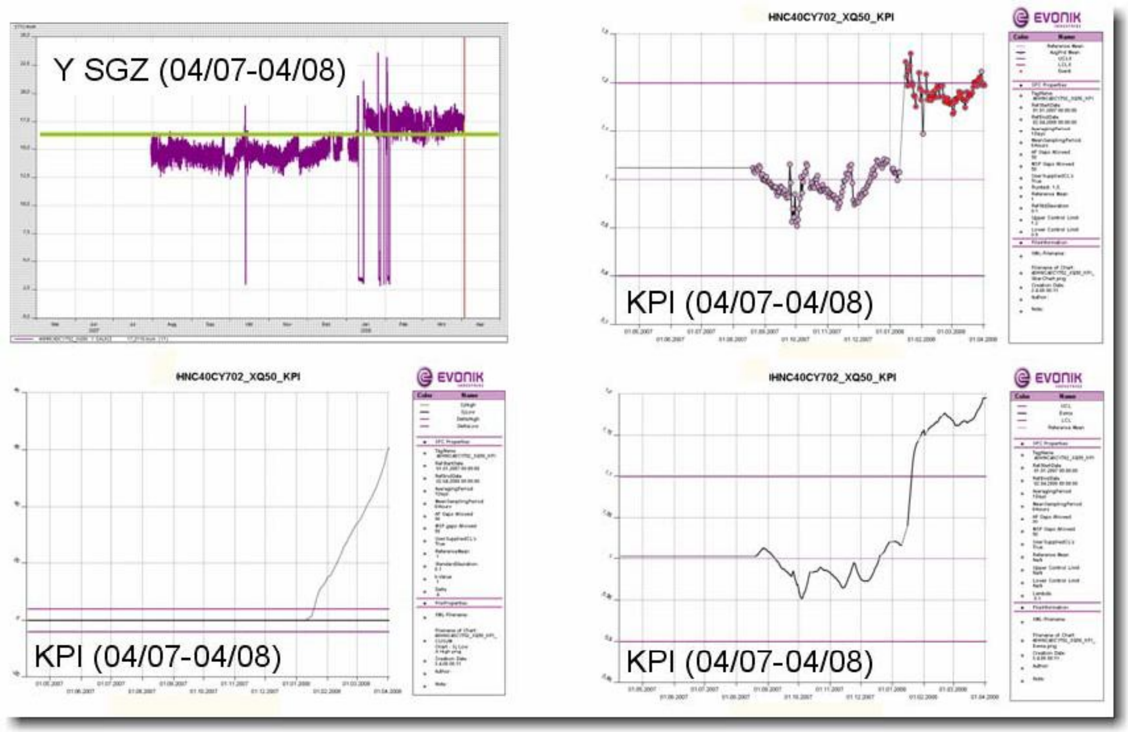

Fig. 5: Fouling on the blade of an ID fan → increased vibrations

4.0 STATUS AND DEVELOPMENT POTENTIALS OF DATA ANALYSIS

Advanced systems for continuous process quality monitoring and early detection of faults from in-service measurements calculate key performance indicators for the condition of the process or individual components from the comparison of in-service measurements with reference values for the "good" plant condition that result from a thermodynamic or also from a data-based modeling. The complementary application of statistical procedures allows to evaluate the time series of the KPIs automatedly and to detect changes early on and reliably. In doing so, the flood of data from modern DCS systems is condensed into information without burdening the power plant staff with extensive evaluations. The examples have shown that hereby, operational benefit is generated out of an increased transparency of the power plant operation, the support of state-oriented maintenance, and the safeguarding of know-how in times of demographic change.

Early on, reliably and in a partly automated way, the systems available today provide indications that significant changes in the condition of a plant or process have taken place. When such a change has been detected, mostly a first causal research can take place by means of a detailed analysis of the characteristics. In many cases, it will furthermore be requisite that the final analysis of the cause be carried out by an experienced person in charge, if necessary on site. In the medium term, however, additional tools e.g. on the basis of statistical procedures for correlation analysis or of known methods for fault tree description will be integrated, which further facilitate it for the person in charge to conduct this analysis.

Beyond these applications, data analysis in the power plant offers potential for further developments. The described methods and systems are flexible and allow power plant-specific application. E.g. the monitoring of actuating variables and controlled process variables (in addition to the procedural measurands) can provide information about components not collected so far. This way, wear and tear of actuating components, drift in position transmitters or similar events can be detected early on.

It also suggests itself to further examine the potential for early warning in the case of pipe leakages in the steam generator. So far, such damages to the boiler have mostly become obvious only by noise development or a significant increase in the make-up water consumption. Here the application of statistical procedures for analyzing the mass balance in the power plant would be able to indicate such events early on and trigger well-directed inspections. Thereby, the response time before a possibly required shutdown of the unit would be raised and the danger of an extension of the damage would be reduced. First studies and prototypical implementations have already yielded promising results.

MANAGING INFORMATION EXPLOSION WITH KNOWLEDGE AUTOMATION

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KEYWORDS

Knowledge Automation, Operations Asset Management, Knowledge Management, Information Overload

ABSTRACT

The amount of data and information we receive on a daily basis is increasing. There are declining numbers of people with the skill to analyze this wealth of information. Those people who have the skills, no longer have the time. These factors combine to mean that the treasure trove of information we could be using proactively, is only being used reactively. Instead of using this rich source of information to exploit efficiency improvements and avoid future failures, we only have the time and skills to use it to determine the cause of a problem that has already arisen. What if there was a way to use this abundance of information more effectively?

This paper examines the use of modeling, intelligent and self learning systems as tools to extract increased value from this store of information.

We are starting to see organization using these tools combined with real-time information and fundamental or experiential knowledge to allow for optimization, intelligent alarming, early warning and root cause analysis. This paper summarizes the techniques, the benefits and the challenges associated with these first steps towards knowledge automation. On the journey, we will also glimpse into the future to where we see value being created from information assets in a way that doesn't result in just more information overload.

We see that:

- Yesterday was all about gathering information;
- Today it is all about ease of access to information and extracting value from the information assets; and
- Tomorrow it will be all about extracting maximum value from information assets.

1.0 INTRODUCTION

We are living in the information age with large amounts of information easily accessible electronically. For power plants and other large operations, this information comes from both internal and external sources.

The main internal sources of data are:

- Electronic data from plant control systems such as integrated control management systems, supervisory control and data acquisition systems (SCADA) and plant historians; and
- Electronic data from business control systems such as enterprise resource management (ERM) and computerized maintenance management systems (CMM).

The main external sources of electronic data are:

- Internet with Wiki, blogs, tools etc; and
- Reference materials including books, papers etc.

These easily accessible data and information sources help complex operations. They are not, however, being fully utilized and in some cases can introduce new problems to the organization. It seems that a fresh look at how value can be extracted from these valuable data and information assets is required.

2.0 THE CHALLENGE

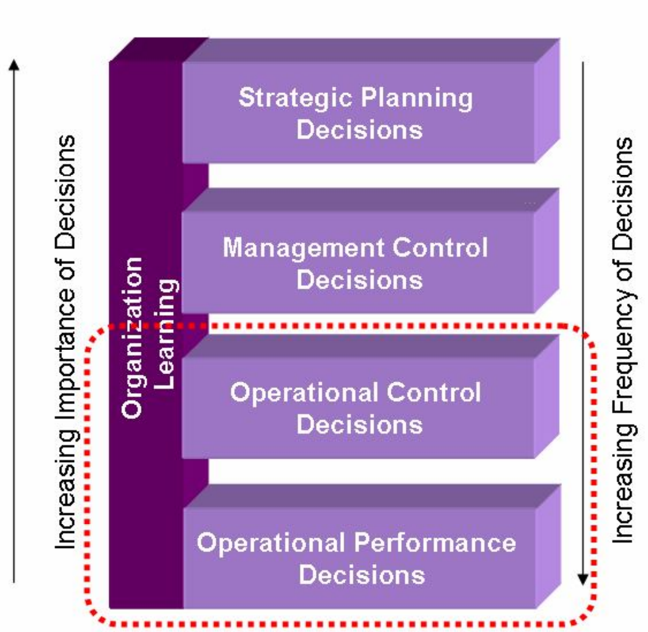
The challenges arising from the massive amounts of data that is readily available to organizations include:

- How to make collaboration between geographically separated personnel more effective.
- How to resolve conflicts in the data available.
- How to standardize operations given the multiple ways that data can now be analyzed.
- The increased knowledge required to understand the multiple data analysis methods that are available.
- Reducing numbers and the increased mobility of employees at power plants to conduct data analysis.

New techniques have been developed to overcome some of these challenges. These techniques endeavor to automate some of the activities traditionally performed by knowledge workers.

3.0 CURRENT MANGEMENT PRACTICES

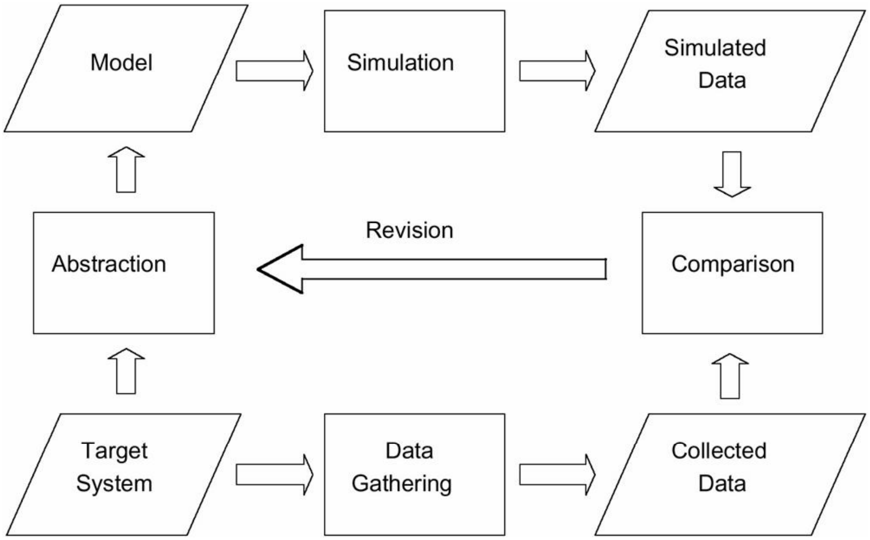
Some organizations use techniques to improve the efficiency of their operation and reduce the amount of information directly interacted with. In essence they are using tools to assist in making the higher frequency and lower importance decisions as shown in the figure blow. This automation of the decision making process provides consistency of operation and removes the effort required for data analysis.



Real-time information is being better used through real-time analysis to assist in real-time decision support. There is, however, a significant effort required to automate the decision making process in the form of configuration and maintenance. Some of the earlier techniques for automated decision support are described below.

Modeling

A general format to modeling a target system is provided below. In this format, a model is created based on the target system through a layer of abstraction. The model can be used to simulate the target system behavior. The results from the target system and the simulation of the target system are compared. By determining the differences between the target system and the simulation of the target system, the abstraction between the target system and the model can be adjusted to improve the accuracy of the model and the simulation. This is known as model validation.



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There are two main ways of abstracting between the target system and the model:

- a fundamental abstraction; and
- an empirical abstraction.

Self Learning Modeling

Self learning modeling has been around in the empirical form for some years. In its si self learning empirical model could be a curve fit to some historical data, and then usi of the curve to predict an output, given an input. The next level of complexity for self empirical models is the multi dimensional linear and non-linear modeling techniques s least squares and neural networks. These essentially are multi dimensional curve fittin given some historical data in the form of inputs and outputs to "train" the empirical mo generate an input/output model that represents the historical data. Inputs can be adjus outputs predicted.

All of these empirical models are basically looking for relationships between data and what is or is not possible from a physical perspective. The result is that a large amoun required to "train" the model as all possibilities are required to be experienced. If the d empirical model will just learn the relations to the wrong data.

A new form of self learning model has evolved to overcome the problems associated w models. These are hybrid models combining both empirical and fundamental modelin provide a self learning capability while still using the fundamental aspects of the proce the data. The hybrid model also requires less training. Hybrid models also allow for extrapolation with little danger into areas where the model has no experience.

Optimization

Once a model of the system is developed and the simulation of the plant through the model is possible, the model can be used to optimize the operation. Optimization is basically adjusting the controllable inputs to achieve an improvement in the predicted outputs. The closer a model is to the target system the closer the target system optimum will be to the optimized model optimum. Self learning models improve the precision of the model reflecting the actual target system and can improve the optimization of the target system in its current condition.

Empirical self learning models, however, have to experience a large range of operations before they can build a model of the complete operation and lose precision when discrete events occur. Self learning hybrid models can still provide the benefits of learning target system actual conditions and can do it with very little data. This is because all that happens is that the plane the plant is operating in changes, rather than the process relationships. The system only needs to learn the new plant characteristics rather than the entire relationship of the data.

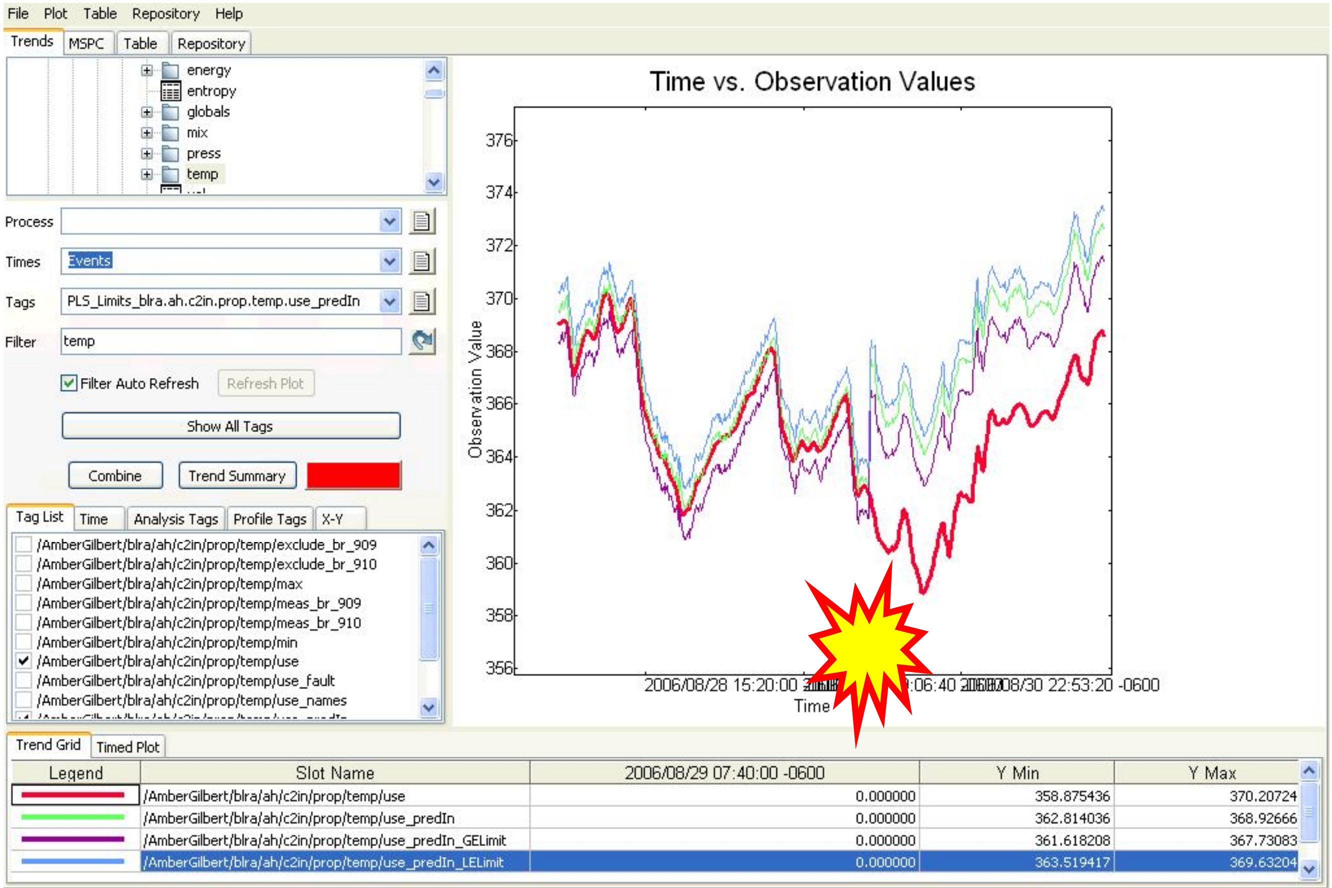
Intelligent Alarming

Intelligent alarming provides a basis for reducing the number of alarms that an operator has to deal with. It does this by providing a relationship between alarm states and a hierarchy of alarms. This means that if a high level alarm is activated (for example a boiler trip) then the lower levels alarms that the system knows will be as a result of the boiler trip will be suppressed. This allows a smaller number of alarms to be actioned by the operator. Basically the system predicts which alarms will be activated as a result of the high level alarm. This process is very effective at preventing alarm overload.

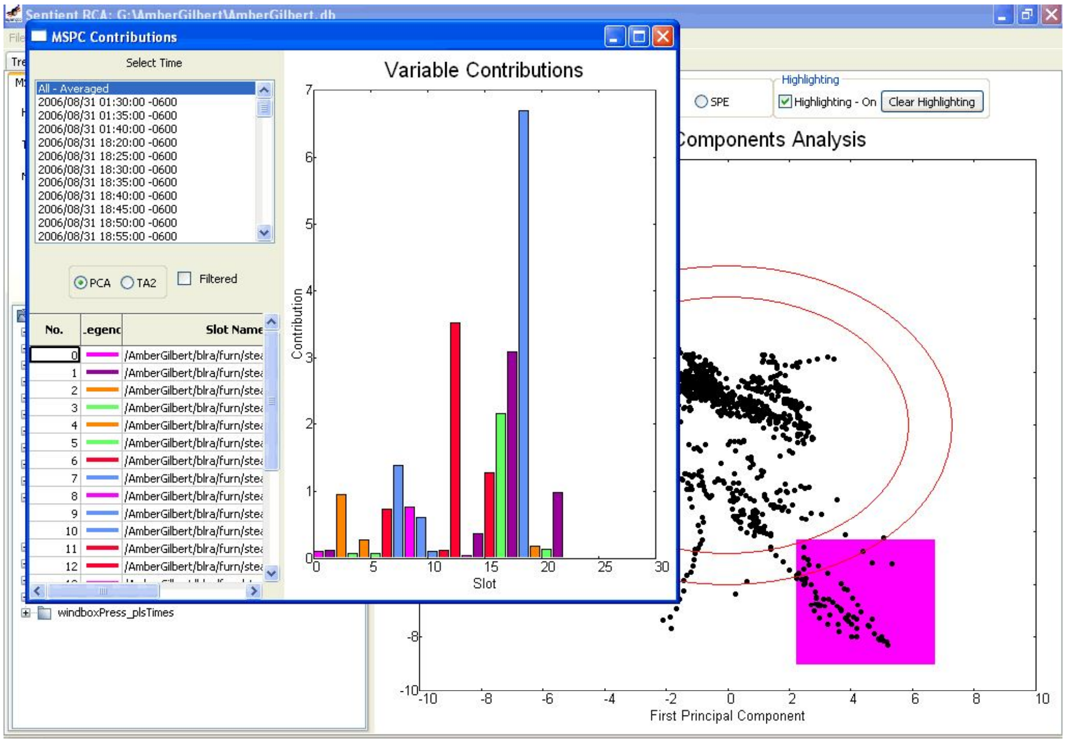
Alarm management also deals with using alarm information and the sequence of alarms to determine the high level root cause of a problem. For example, a mill may start to have alarms such as low outlet temperatures and high mill amps. This provides a root cause alarm of high moisture coal.

Early Warning System

Early warning systems take an alarm system to a new level by providing dynamic limits to alarms. The dynamic limits are established by predicting the process and then establishing limits around the predictions. Again the precision of the prediction and the ability to accommodate discrete activities provides additional value to the early warning system. By providing dynamic alarm limits, the limits can be much closer and related to the current plant operation. A subtle change in the process may not be enough to trigger fixed alarm limits but will be enough to exceed the dynamic limits and hence provide early warning. The technique can also reduce the number of false positives as the dynamic limits also means that when the plant is being operated outside the normal operation, then the early warning limits will be adjusted to reflect the extreme operation.



Another methodology is the use of a multi dimensional statistical approach where multiple parameters are monitored for statistical variations. One of the more common techniques is principle component analysis. In principle component analysis the parameters are transformed to a different plane. The first principle component explains the major variance in all the data. The second principle component explains the next significant variance and so on. Each principle component is orthogonal. To visualize the first two principle components, imagine an ellipse with the major axis as the first principle component and the minor axis as the second principle component. Two principle components is generally enough to detect a significant change in the data relationships. A 99% confidence limit can be used to bound the baseline data so that if new data fall outside the limits for a defined number of samples, an early warning of a changes is possible.

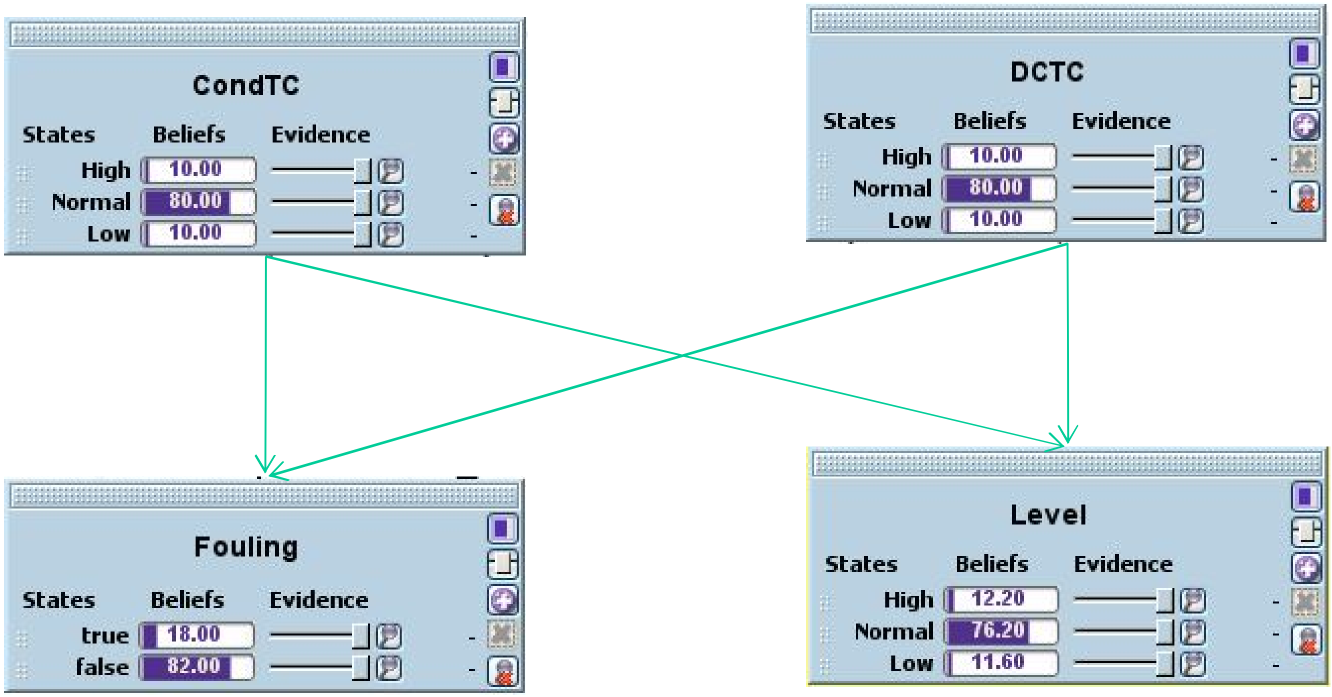


Root Cause Analysis

Root cause analysis can be driven off many aspects of an operation. It basically relates to establishing a signature of a root cause and then detecting the signature pattern in a repeatable manner.

A number of statistical methodologies are used to look for statistically relevant pattern changes. These changes can provide an indication of a change as previously discussed in the principle component analysis. The way the signature patterns deviate (i.e. the direction the samples go outside the 99% limits) in the case of a principle component analysis above, can be used as a signature for a particular root cause. This can be automated by setting up cases for different failure modes so that when a change is detected it can be compared to different cases.

Another common method to provide automated root cause analysis is to use Bayesian networks with evidence provide by deviations in predicted behavior or statistical variation is the data. An example of a prediction deviation is provided below.



4.0 NEW NEEDS

As decision support systems within a learning organization become more common place and complex, the next challenge becomes how these systems can be developed, maintained and coordinated in a cost effective manner to:

- reflect changes to the operation;
- new information becoming available; and
- new knowledge of the plant's behavior being experienced.

All this needs to be done without becoming just another source of information / maintenance requirements and contributing to information overload. It will be exceedingly difficult to maintain decision support system in a consistent manner within the learning organization if a there is no systematic method to develop and maintain it. The systematic methods need to be robust and cost effective. It is this need that has provided the starting point for the journey to knowledge automation.

With the massive amount of data, analysis and decision support tools now available we need to have a robust framework to allow:

- the data to be received, analyzed and compared to what we expect; and
- transform the information and analysis into action as an output.

In this way, getting to the action point is the important outcome from the previous steps and a method of overcoming the information overload. If the process can be automated, the large amount of data and information can be used without the physical amount of data and analysis causing problems such as information overload. The framework needs to be such that, regardless of the individual's own personal model of the operation, a common corporate model of the operation is provided as a basis for all individual interaction and machine based interaction. If this framework could become ubiquitous to the operation it forms the basis for all understanding of the operation, analysis on the operation and decisions made on the operation.

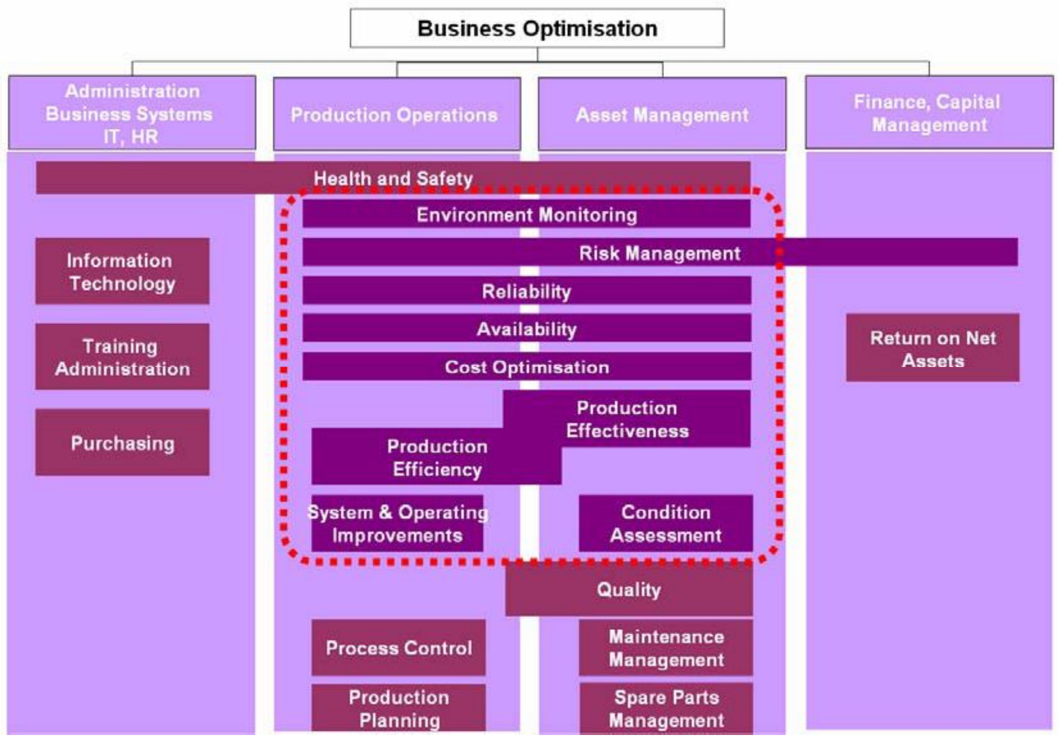
The framework proposed is a framework for knowledge automation. A framework that:

- takes information and data from internal and external resources;
- takes global and local knowledge from knowledge workers; and
- automates the knowledge to allow consistent outcomes for higher frequency decisions within an operation.

As systems become more sophisticated, they will provide support for higher level decisions within an operation.

5.0 THE FUTURE?

If we look at overall business optimization in the figure below, there are several areas that a great deal of effort has been put in to optimize that part of the operation (purchasing, health and safety etc) and there is limited opportunity for further cost effective improvement in isolation. We do, however, see opportunities for improvement in the area bounded by the red dotted line. This is the area of significant current activity.



So where in the future do we see business optimization going?

We see the future as being able to optimize the integration between the various aspects of an operation such as people, process and assets to form what we have termed an "Operations Asset Management System". Instead of silo solutions, this type of system looks to get leverage from the interaction of the various aspect of an operation and drive to a common operational outcome.

When looking at the operational outcome, there are opportunities to reduce cost in the overall operation. For example, in the maintenance field where instead of maintaining an asset to a specific level, the level may change as a result of the operational impact that asset has on the operation. The asset may need to be at a high level of efficiency at one point of the operation and a high level of reliability at another point of the operation. The impact of the operation itself may have as much or more impact on the asset characteristic for efficiency and reliability as the maintenance activities on the asset. By integrating both the operation and the asset management, cost optimization has more controls to drive to a lower overall cost.

The next big gain in business optimization is to optimize the interaction between the various aspects of an operation. This means looking at ways that not only the physical assets are made to "sweat" but also how the intellectual assets (knowledge workers, data and information) can be used to improve the operational outcomes for a business.

The process, key to the operation, also provides a useful framework to provide the interaction between intellectual assets and physical assets.

This next wave of business optimization will introduce an increased level of data, information and knowledge which is already approaching levels causing information overload within some operations. So how do we create "Operations Asset Management Systems" that will require increased data, information and knowledge without becoming overloaded.

The key is knowledge automation

Systems like the brain only different

The knowledge automation process needs to reflect how our brains do it.

The brain receives a massive amount of data every second from our sensors (eyes, hearing etc). It also recalls massive amounts of historical data to remember and recognize. How does it handle the large amounts of information without becoming overloaded? Recent research has shown that the brain handles this sheer quantity of information in specific ways to manage the information streams. With the increasing processing power available in computing and advances in technology there are some significant common areas where systems could manage the increased amount of data available in the same way that the brain does.

We see that the future for managing large complex operations with increasing amounts of data is "knowledge automation" systems utilizing the same techniques that the brain does to handle the sheer quantity of data and the complexities within processing the data. Some of the parallels between the brain and knowledge automation methodologies are described below.

Maps

When the brain receives new data it likes to piece the new information to an existing internal map by seeing where the connections between this new data and the information stored within internal maps are. The map allows the brain to simplify the processing required on the new information by associating it with an existing map. If the new information aligns with the internal map then there is very little processing required as the processing has already been done for the internal map. If the new data conflicts with internal maps then more processing is required to try and understand the conflict and perhaps create a new internal map.

Within the knowledge automation system, the maps are replaced by models of a process. Process is the core to any operation with physical plant processes and business processes forming the majority of the process within any operation. The process is a useful map for new information to be associated with. The process is something that can be established as a common model for many different personnel within an organization. If a process is fully defined, then an organization can learn the process characteristic. Once the process characteristics are learned, it provides a map of how the process is expected to behave in the future. New information received can be quickly evaluated against the expected behavior. If the behavior is as expected, than limited analysis is required. If the process deviates from the expected behaviors than further analysis is required either to detect a problem or to better learn the characteristics of the process.

Conscious to Subconscious

The Brain is constantly trying to automate processes, thereby dispelling them from consciousness; in this way, its work will be completed faster, more effectively and at a lower metabolic level. Consciousness, on the other hand, is slow, subject to error and "expensive". Gerhard Roth (2004)

The brain has a way of reducing its processing requirements by delegating the routine items that it processes from the conscious to the subconscious. We can see this in the development of a baby's movement. Initially the baby has to process in the conscious mind the movement of limbs and coordinating all the muscle movements with the feedback from senses. Over time, the coordination becomes "hardwired" and there is very little conscious activity required for the movement of limbs. The same process occurs when learning to walk, riding a bike, or playing cricket. The same process is also used by elite athletes. The repetitive nature of activities means a lot of the coordination becomes hard wired and delegated from the conscious to the subconscious and so improves the efficiency and effectiveness, reduces errors and removes processing requirements from the conscious part of the brain.

Within the knowledge automation system, the conscious is the human knowledge worker with the subconscious being the knowledge automation. The same parallel between efficiencies and error free operation that apply to the subconscious also apply to the knowledge automation system. By providing a system to automate knowledge you have the basis for a learning organization. To this extent there needs to be an efficient mechanism to pass from the human knowledge worker to the knowledge automation system and back in the same way there is an efficient mechanism to transfer from the conscious to the subconscious and back again. Basically the process needs to establish a map/model that both the knowledge worker and the knowledge automation system interact with. This provides the mechanism to transfer knowledge and analysis. Once a common map is established then the knowledge transfer can take the form of empirical and explicit knowledge and/or global and local knowledge.

Predictions

Prediction is not just one of the things your brain does. It is the primary function of the neocortex, and the foundation of intelligence. Jeff Hawkins (2004)

By comparing the new data with the internal map, a lot of approximations are possible and the processing even further simplified. Basically the brain is using internals models to predict what is expected. If new information matches the predicted behavior then the amount of processing required is vastly reduced. We see examples of this all the time when we are driving on roads. If the other cars are doing what we predict, then we take very little notice of them. If they deviate from what we predict, then we take increased notice. The key here, however, is that the predictions need to be able to adjusted to accommodate changes that have been observed through feedback. When we drive in a new country, we need to adjust our predictions based on what we observe. It does not mean we have to discard all the knowledge we have built up driving a car in our home country, we just have to "adjust" the map to accommodate the observed changes.

Within the knowledge automation system predictions could come from traditional model based predictions using fundamental and empirical models however these techniques do not have the same ability to "adjust" based on feedback. The fundamental models need extensive recalibration to "adjust" to a new operation and in the case of plant degrading over time would require extensive maintenance to provide flexible and accurate predictions. The empirical models can "adjust" to new information however they basically lose all the previous knowledge built up. It would be like having to learn the entire driving process because you now are in a country that drives on the opposite side of the road.

Knowledge automation system predictions need to be able "adjust" easily while still using core knowledge built up over time. A hybrid model that utilizes fundamental and empirical modeling techniques gets closer to how the brain works by being able to retain fundamental knowledge but "adjust" to the current conditions. This type of modeling will be the key to knowledge automation systems.

6.0 CONCLUSION

Learning organizations need to take control of the decision process and the supporting data, information and knowledge that is used to support the decision process. For high frequency decisions, the decisions need to be automated, removing the need to human analysis with human intervention only required if the systems do not respond in the expected manner. The human interaction needs to be by exception to reduce the amount of information the human is being expected to process. To improve the effectiveness and efficiency of the learning organization, a general philosophy of learn once, apply forever needs to be embraced, with the flexibility to adapt the application of the learning as more information becomes available or the operation materially changes. Knowledge automation is the process proposed to allow the knowledge to be transferred between knowledge workers and automation systems.   It is predicted that the transfer between knowledge workers and knowledge automation will be very similar to the conscious and subconscious in the brain: – Learn in the conscious and then push down to the subconscious so that the response is automated. This will overcome the information overload problem and free up the knowledge worker to focus on issues that required conscious thinking. Once the conscious thinking is completed, it can become subconscious through knowledge automation.

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N. Reference N

GLOSSARY OF TERMS:-

ICMS – Integrated Control Management System
SCADA – Supervisory Control and Data Acquisition System
ERM – Enterprise Resources Management System
CMM – Computerized Maintenance Management System

Wireless as Emerging Technology – Reliable & Secure

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KEYWORDS

Wireless, WiHART, WirelessHART, Automation, Self-Organizing Mesh network, TSMP, SmartWireless, Reliability, Simplicity, Security, Frequency Hopping, Encryption, Authentication, Verification, Predictive Diagnostics

ABSTRACT

The world is going wireless! Wireless is a common topic for anyone involved in the design, operation, maintenance, or upgrading of industrial plants and mills because it offers to lower construction costs while greatly expanding the ability of personnel to monitor and communicate with equipment in remote or hard-to-reach areas. The first wireless industrial networks are already in operation in process industries including power plants.

The single most important factor in adopting any new technology is reliability. We will talk about how the reliability is taken care of in wireless networks used in process industries including power plants

A very real issue with all wireless transmissions is that some outsider might be interested in intercepting or altering the data. Security is taken very seriously by IT experts, who have identified five keys to wireless transmission security. The paper will discuss the ways in which this is achieved

Wireless field instruments produce an array of device diagnostics that offer operational and financial benefits to end users

Finally, so where does wireless fit in today's world of fieldbusses & digital communications. Possible applications in Power plants are discussed. A case study is discussed before conclusion.

1.0INTRODUCTION

The world is going wireless! The evidence is everywhere -- in-house communicators, cell phones, wi-fi computers. Now, industrial applications have caught the imagination of process control designers and automation engineers who envision vast wireless networks eventually replacing costly, bulky wired systems.

Wireless is a common topic for anyone involved in the design, operation, maintenance, or upgrading of industrial plants and mills because it offers to lower construction costs while greatly expanding the ability of personnel to monitor and communicate with equipment in remote or hard-to-reach areas.

The first wireless industrial networks are already in operation – including iron and steel mills. Almost all are comprised of wireless field devices monitoring processes where wired devices are impractical or impossible; monitoring equipment in hard-to-reach places; monitoring a remote part of a mill; or even off-site where installing cable would be very expensive. These devices have no control functionality at this time, so two-way communications are generally not provided.

After successful application in Europe and North America, Smart Wireless technology was launched in the Asia-Pacific region in June 2007.

According to Peter Zornio, chief strategic officer for Emerson Process Management, "The new wireless infrastructure will allow installation of sensors virtually throughout a plant on a broad range of field devices. Many assets that previously weren't touched by a data-retrieval network, including critical rotating equipment, can now be tapped for data. A user can start with a vibration transmitter, add a few pressure transmitters, then add temperature transmitters, and continue to grow the network as new sensor types become available."

"Because installed costs of measurement points are as much as 90 percent less with wireless," Zornio says, "plant assets that were once prohibitively costly to monitor can now be outfitted to return real-time data, helping managers improve reliability driven maintenance, production processes, and overall asset management. "

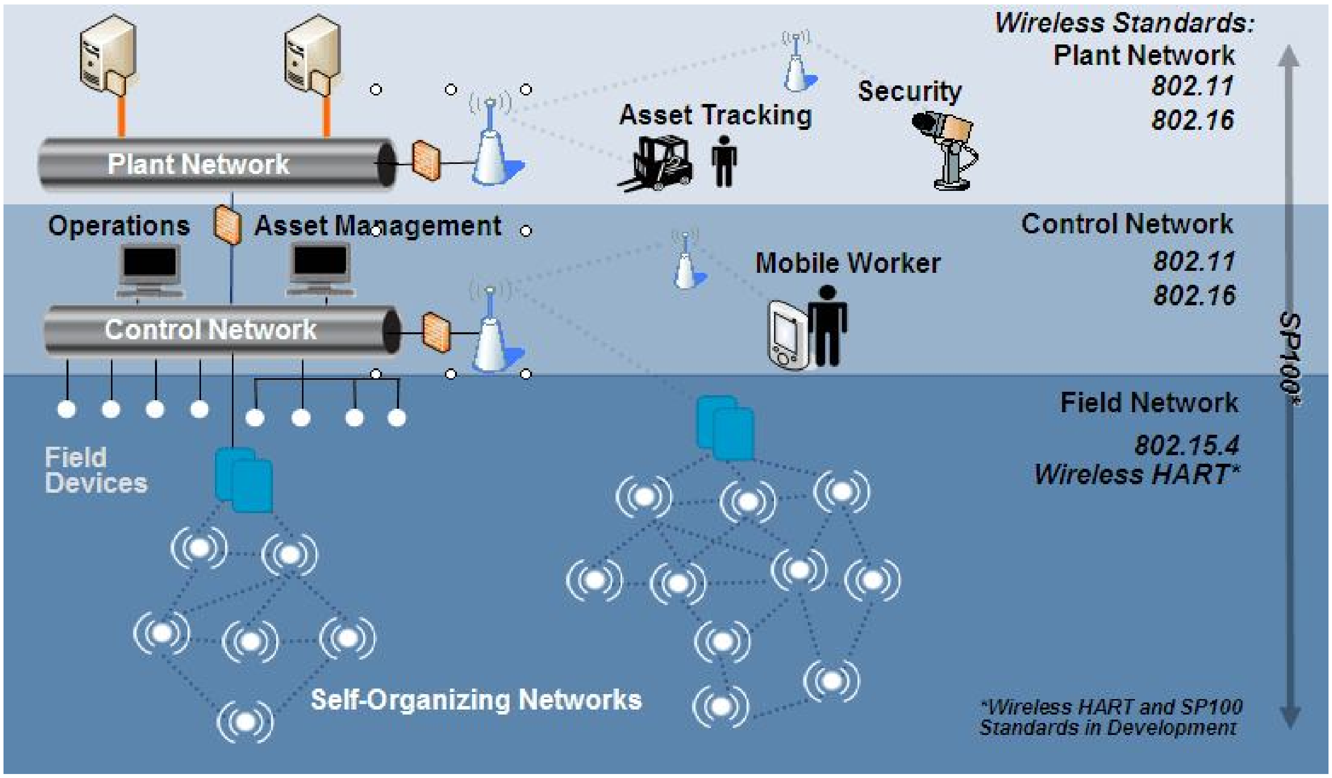
The single most important factor in adopting any new technology is reliability, and wireless is no different. Security is equally critical, so the best wireless applications will be subjected to the same scrutiny as information technology (IT) systems with respect to their security. For a wireless network to succeed, it must provide reliability and security as good as or better than existing wired systems.

2.0 RELIABILITY

The reliability of wireless systems depends on having multiple paths of communication so that if one device fails or is blocked, another path can automatically be taken. This is solved through the use of a "self-organizing mesh network" that offers different paths for transmissions to follow in order to reach the gateway (or receiver), which directs the communication to a control system or other appropriate location in the plant. This self-organizing network provides redundancy that yields a high level of communication reliability no matter what permanent or temporary obstacles may exist between the transmitting device and the gateway. This is *not true* of all wireless systems.

Another assurance of reliability is an electronic technique called "frequency hopping". If one of the assigned frequencies is jammed or compromised by noise or other interference, the wireless transmitter senses the problem and automatically uses another channel.

With multiple paths between devices and many frequencies available, the reliability of these wireless networks is at least equal to wired systems, and they are not subject to power outages or inadvertent damage to cables. The mesh network concept and frequency hopping techniques are characteristic of the already-approved WirelessHART® standard to which leading Smart Wireless technology globally are designed.



Currently, equipments available are Smart Wireless pressure and temperature transmitters, digital valve controllers, and vibration monitors along with a Smart Wireless Gateway to receive the transmissions and funnel the data to a control platform. Networks using self-organizing technology are scaleable from 5 to 100,000 devices. Devices based on this technology have been proven in use to demonstrate greater than 99 percent data transfer reliability.

Where the wireless transmitters rely on battery power, battery life typically runs between 5 and 10 years, depending on how fast a given device updates. This is a distinguishing characteristic between wired and battery-powered devices. Wired instruments send information almost constantly, whereas wireless devices may operate on a one-minute schedule, remaining at rest most of the time and coming to life just long enough to transmit an update. This can be done more frequently if necessary, but with a corresponding reduction of battery life. In addition, these devices provide an estimate of remaining power life that enables scheduled maintenance.

3.0 SECURITY

A very real issue with all wireless transmissions is that some outsider might be interested in intercepting or altering the data. Security is taken very seriously by IT experts, who have identified five keys to wireless transmission security.

The first of these is encryption, which is a string of seemingly random symbols that surround each transmission. Even if the message is intercepted, it would take too long to decode to be of use. Encryption keys are changed frequently so that anyone trying to read intercepted messages by comparing them will not be able to break the code before it is changed.

In addition, each transmission must be authenticated, meaning that the sending and receiving devices must recognize each other, or the transmission will be ignored. A third step is data verification by the receiving device. The authentication and verification rules are built into the devices, so no foreign device will be able to intercept a transmission or send bogus information to the receiving station.

The channel hopping feature discussed earlier is a protection against jamming of channels by either intentional or non-intentional sources, which is the fifth key to secure wireless transmissions.

Again, all of the required security features are built into the Smart Wireless system.

4.0 CAPTURING DIAGNOSTICS

Wireless field instruments produce an array of *device diagnostics* that offer operational and financial benefits to end users, but they need a way to manage the intelligence these devices generate about their own health and that of the equipment they are monitoring. An Asset Management System software like Emerson's AMS® Suite: accomplishes this feat via connection to a Smart Wireless gateway.

Field device transmissions received by the gateway are passed on to the Asset Management System, generally via an Ethernet connection. For example, alerts transmitted by wireless field devices make the operators aware of a potentially unsafe situation and enable them to take action to avoid an unscheduled shut-down.

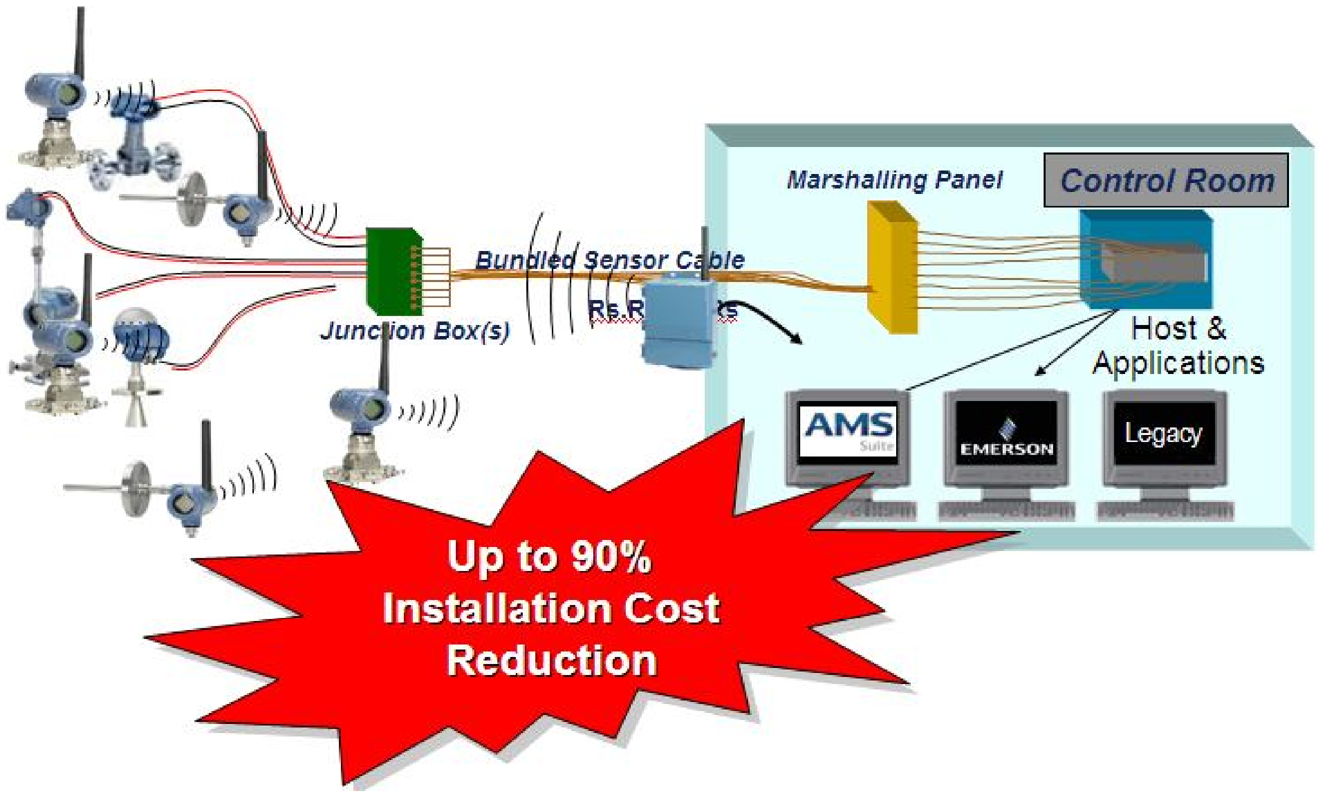
The Asset Management System can be used in conjunction with both wired and wireless devices regardless of the system employed for process control. In fact, it is capable of communicating with a wide range of smart field instruments, including HART® and FOUNDATION™ fieldbus devices, to gather information giving plant personnel an otherwise unattainable view of real-time conditions throughout a plant or mill. It is fully compatible with the *Wireless*HART standard.

It's no longer necessary to waste the valuable diagnostics generated by Smart Wireless devices. That information can be captured and used to improve efficiency, reduce maintenance costs, and generally make life easier for maintenance personnel.

4.0 WHERE WIRELESS FITS

Wireless offers many benefits over wired applications in the right circumstances, but wireless should not be viewed as a direct replacement for wired instrumentation. Wireless devices are typically slower but can be installed in a matter of minutes, and they can be repositioned just as easily. They can often be installed where wired devices cannot -- in hard-to-reach locations, in areas hazardous to mill personnel, where power doesn't exist, and where running wires is not allowed or would be prohibitively expensive, such as a remote wastewater treatment facility.

Applications of the wireless technology are growing daily, fired by the imaginations of innovators who see this as a means of adding to operators' awareness of their surroundings for the improvement of whole processes.



5.0 APPLICATIONS IN POWER INDUSTRY

- Sea or River Water Intake Facility
- pH Control in Raw Water Treatment
- Monitoring of Injection Water Pumps
- Coal Stack Pile Monitoring
- Monitoring of Coal Pulverizers
- Thermal Cycle Loss Monitoring

- Heat Load Estimation on Lube Oil Coolers
- Monitoring of Auxiliary Power Transformers
- Monitoring of Balance of Plant Equipment
- Heavy Fuel Oil Heat Exchanger Steam Flow Control Valve
- Flue Gas Bypass Damper Position
- Monitoring of Effluent Outfall Quality

Sea or River Water Intake Facility

Objective:

- Remote monitoring of intake/discharge water parameters
- Comply with strict cooling water discharge temperature norms

Present Approach/Challenge:

- Local gauges and thermometers
- Conventional wired approach is not economical

Wireless solution:

Wireless transmitters for following services:

- Raw water inlet and discharge temperature
- Differential pressure across strainer and screens
- Pump discharge and suction pressure

Benefits:

- Increased plant availability through continuous supply of cooling water
- Compliance with local environmental regulations

pH Control in Raw Water Treatment

Objective:

- Control of pH in raw water
- Ensure optimal pH value for flocculation and coagulation

Present Approach/Challenge:

- Lime is generally dosed at an excess
- Large fluctuations in pH due to changes in raw water quality

Wireless solution:

- Wireless transmitters for pH in flocculation tank

Benefits:

- Allows for accurate pH control in the flocculation tank

- pH value can be incorporated in feed-forward control to reduce lime usage.

Monitoring of Injection Water Pumps

Objective:

- Prevent unexpected failure of Injection Water Pumps
- Injection Water Pumps supply cooling water to Boiler Feed Pump bearings

Present Approach/Challenge:

- Often multiple pumps are run simultaneously to ensure one is running already

Wireless solution:

- Wireless transmitters for Vibration monitoring of pump bearings

Benefits:

- Single pump can be run normally, leading to better pump performance
- Back-up pump can be turned on only when needed.

Coal Stack Pile Monitoring

Objective:

- Monitoring of coal pile temperature in open coal stack yards

Present Approach/Challenge:

- Infrared cameras are used to detect stack yard fires
- Moving coal feedstock does not allow any permanent wired installations

Wireless Solution:

- Portable temperature sensors with head mounted Wireless transmitters
- Discharge water pressure on quench jets

Benefits:

- Easy re-positioning of sensors on coal stack piles
- Avoid coal fires by detection of rise in coal temperatures
- Implement early warning system and remote indication

Monitoring of Coal Pulverizers

Objective:

- Prevent unexpected failure of motor, fan, and coal pulverizer thrust bearings

Present Approach/Challenge:

- Bearing failure can develop unexpectedly over period of months
- If periodic measurement is missed, developing problem could be missed

Wireless solution:

- Wireless transmitters for vibration monitoring of bearings, particularly the pulv bearing with PeakVue® can give more frequent updates to plant personnel

Benefits:

- Advanced warning of bearing failure can be identified
- Large, expensive replacement parts can be ordered as needed rather than stored

Monitoring of Auxiliary Power Transformers

Objective:

- Remote real time monitoring of auxiliary transformers

Present Approach/Challenge:

- Insufficient measurements on transformer oil and winding temperatures
- No measurement on oil tank level and transformer pressure
- Wired solutions near transformers have very high electro-magnetic interference

Wireless solution:

- Wireless transmitter to monitor transformer oil/winding temperature, tank level and gas pressure

Benefits:

- Increased plant availability due to reduced transformer failures
- Reduced manual inspection routines

Monitoring of Balance of Plant Equipment

Objective:

- Prevent unexpected failure of "Balance of Plant " Motors, Pumps, Fans, Compressors, etc.
- Balance of Plant machines typically monitored only with portable technology

Present Approach/Challenge:

- Measurement can get skipped when human resource arrives to collect data if machine is not running
- Permanent installed vibration monitoring not seen as cost effective for "balance of plant" machinery due to installation expense

Wireless solution:

- Wireless transmitters for vibration monitoring of rotating machine bearings, can be performed with very low installed cost

Benefits:

- Changes in machine vibration can be viewed by operators and stored in plant data historian
- Repair activity can be scheduled based on machine condition.

5.0 CASE STUDY

CHALLENGE

A Power generation company with a 500 MW gas-fired turbine facility in Milford, Connecticut, USA utilizes two gas-fired turbines to produce electricity for the grid. The site includes eleven remote buildings that house water pumping and circulation equipment serving a variety of needs of the power generation infrastructure. Since winter brings freezing conditions, small heaters are located in each remote building to ensure the pumps operate properly. Freeze damage of a pump system would cost Rs 5 to 10 lacs to repair or replace and take that pump out of commission for up to three days. They wanted to find a technology to bring temperature measurement into the control room as part of an early warning system. Wiring of these points was not feasible, since running trays over the roads or conduit under existing structures was cost prohibitive.

SOLUTION

The Power Company installed Rosemount Wireless Temperature Transmitters in all eleven remote buildings around the plant. The devices then communicated through a Smart Wireless Gateway back to the control room.

RESULTS

Damage to the water pumping and circulation equipment was prevented by monitoring the temperature with Smart Wireless solutions from Emerson. An early warning detection system for rapid temperature change was achieved, at a fraction of the cost of a wired solution.

ACKNOWLEDGEMENTS

Emerson Process Management Asia Pacific Singapore

TURBINE TRIP CASE STUDY AND THE LEARNING THEREOF

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KEYWORDS

Triple Module Redundancy(TMR), KN Series Turbine, Procontrol P13/42, EHTC, turbine Protection, Root Cause Analysis (RCA), Why-Why Analysis, 2/3 Logic, Permissive, 24 V DC, OEM, etc.

ABSTRACT

The subject ' Turbine Trip Case' study talks about the corrective action taken, at Tata Power Jamshedpur Division, to minimize the tripping of Unit 2 and 3, 120 MW Units, because of card fault in the procontrol based system. Unit 2 and 3 were installed in the year 2000 and 2001 respectively. The 120 MW Turbine, at Jojobera, is double cylinder type KN series Turbine. These Turbines have only electronic governor and do not have any hydraulic governor. The Governing Control of Turbine and its protection are implemented in TMR (Triple Module Redundancy) configuration in Procontrol P13-42 system. TMR works on '2 out of 3' logic wherein at least two TMRs have to vote tripping signals to trip the machine. In case, for some reason, one TMR goes in fault status the Turbine Control shifts to second TMR and protection logic changes to ' 1 out of 2'. Unit 2 and 3 have tripped 11 times in last 3 years because of procontrol card fault problems. From 19/11/2008 to 28/11/2008 Unit 2 tripped 4 times. During the fourth tripping, an indepth Root Cause Analysis was done. The findings suggested that some of the I/O cards were simulating fault in one of the TMR panels and the alarms were not coming because they were also configured as per ' 2 out of 3' logic. Since the card design is proprietary to the OEM the root cause of the faults in card could not be established. Therefore team made some modifications in the Turbine Trip circuit to ensure that spurious trips because of card failure in any of the TMR panels is stopped. Since November'08 the machine has not tripped till date, though similar fault signals have come 3-4 times. Some modifications were also done in the alarm circuit so that even if any 1 out of 3 signal goes high the alarm is generated.

To carry out the Root cause analysis (RCA), the team used "Why – Why Analysis Tool". The RCA revealed that I/O cards supplied by the DCS manufacturer had signal simulation tendency. The findings of the analysis needed an immediate corrective action. As a result of RCA, modification in the existing turbine trip logic was carried out in consent with the DCS manufacturer. The modified logics were then subjected to on–site testing. On successful completion of the testing, the logics were incorporated in turbine protection circuit and since then, no unwanted outage of unit has occurred due to I/O card faults.

1.0 INTRODUCTION

Tata Power, the pioneer in power generation in India is the largest private power utility in the country. The Jamshedpur division of Tata Power started its operation in 1997 when it acquired a 67.5 MW CPP from Tata Steel. Keeping in view of the industrial development of Jharkhand & modernization / expansion program in Tata Steel, Tata Power set up 2 more units of 120 MW each which started their commercial generation in February 2001 and February 2002 respectively. These 2 units constitute first ever IPPs in the state of Jharkhand. To keep pace with the growing in demand of Tata Steel and other major industries in Jamshedpur, the division commissioned another 120 MW unit in September 2005. Today, Tata Power, Jamshedpur is one of the most efficient & reliable power generating utilities and flagship of its progenitor in the eastern region of India.

In line with the Mission of the company of 'being a partner of choice and exceeding stakeholders' expectation', any unwanted tripping of machine is a big concern for the team. Repeated trippings because of card fault one such concern. While the Division was always in touch with the OEM to resolve this issue, Tata Power decided to take some proactive measures to stop the tripping of units because of card faults. Some of the measures taken are as follows:

Critical cards of EHTC and protection panels were changed with new cards.

Grounding system of the control panels were reviewed and found OK. The earth pit resistance was 0.2 ohm.

As the Heat dissipation in control system cubicles was high, the temperature of the control room was maintained at 21-23 deg and the same was also put in the DCS history to monitor it continuously.

But above actions did not stop/ reduce tripping of units because of card failures. As the card details were proprietary to the supplier, the biggest challenge for the team at Jojobera was to stop this menace in spite of the intermittent false simulation by cards.

1.0 KN SERIES TURBINE

Turbine Type : K30 – 16 + N30 – 2 * 3.2

K30 – 16 : Combined High Pressure & Intermediate Pressure Module designed for 160 MW

N30 – 2*3.2 : Double Flow low pressure module

The given KN Series turbine has a High Pressure Turbine Governing System. It works on Electro-hydraulic Turbine Control System (EHTC) alone to convert mechanical energy into electrical energy. It has the following advantages:

Excellent steady state and transient response

Accurate positioning of control valves by using high performance servo valves

Rapid closing of stop and control valves (<150 ms)

Compact hydraulic actuator

Standard components and minimum spares + Advantages of electronic system.

Since the given Kn Series Turbine does not have any hydraulic back-up control, Electro-hydraulic Turbine Control plays the major role. Any failure in EHTC shall trip the machine.

2.0 THE CONCEPT OF DISTRIBUTED CONTROL SYSTEM

A complex process like steam generation and utilization of the same in a turbine-generator for electromechanical energy conversion, is divided into sub-processes for purposes of working out a control strategy. This process is called partitioning and is documented in the so-called Partitioning Diagram. Each partition is assigned to a suit of panels or single panels depending on the functionality grouped together. This is the process of distribution of controls. The distribution could just be functional alone, in that the panels are all placed in one Central Equipment Room or it could functional and geographical in that the panel allocation is further portioned into Inputs and Outputs brought together and placed in the outfield closer to the point of acquisition of the set of logically connected Inputs and Outputs.

The partitioning process creates a hierarchy for the controls called the Drive Control Level where the logics for a specific Drive say the FD Fan Motor are allocated to and controlled by a Drive Control Module. This could be a software module as is current these days or a hardware module. The next higher level in the hierarchy is the Functional Group Control Level, where all the analog and binary control loops for a particular section of process like say the Electro-Hydraulic Turbine Control (EHTC) or the Turbine Protection (TP) Control is allocated to a controller. The next level is the Unit Level Controls where all the controls for the major components like Boiler, Turbine or Generator are placed together. The hierarchical levels built into the control strategy implementation afford Operator intervention at various convenient levels for saving the plant in times of emergency.

3.0 PROCONTROL P 13/42 BASED CONTROL SYSTEM

A well-designed 50 module hardware library forms the platform of Procontrol P 13/42 control system on which the plant inputs and outputs are obtained by the control system. This is a bus-based system where a Local Bus[LB-P13] is considered as a unit where a section of the plant's control partitioned into logical control groups brings in up to 100 I/Os in hard connections from the field. The control strategy resides in the Programmable Controller. The program in the controller is written in a control language called P10 which forms the Application Software. This Application Software is supported by a compact 40- instruction, basic set and about 100 -150 standard process control specific subroutines called the Multifunction Library. The Application Software and the Multifunction Library are resident in EEPROMS.

These Local Buses are in turn connected together by a coaxial cable based Intra-Plant Bus [IPB-P42], over which control signal interactions between Local Buses take place. The two buses are linked by hardware modules called Bus Couplers and other support electronics. The actual signal interchange is programmed-in into EPROMs placed in the Bus Couplers. These constitute the marshalling programs.

4.0 BASIC CONCEPT OF TRIPPLE MODULE REDUNDANCY

In general, it can be denoted as NMR where N is always an odd number. For example TMR, 5MR, etc. Triple Module Redundancy triplicates the hardware / software and performs a majority vote to determine the output of the system. If one of the modules becomes faulty, the two remaining fault free modules mask the result of the faulty module when the majority vote is performed.

Module 1, Module 2 and Module 3 shown below are the input modules in which the hardware signal is taken and the output is sent to the voter. Since the number of inputs is always an odd number, there is bound to be an unambiguous majority opinion. The voter accepts the inputs from the three sources and delivers the majority opinion as an output (Ref. Fig: 4.1)

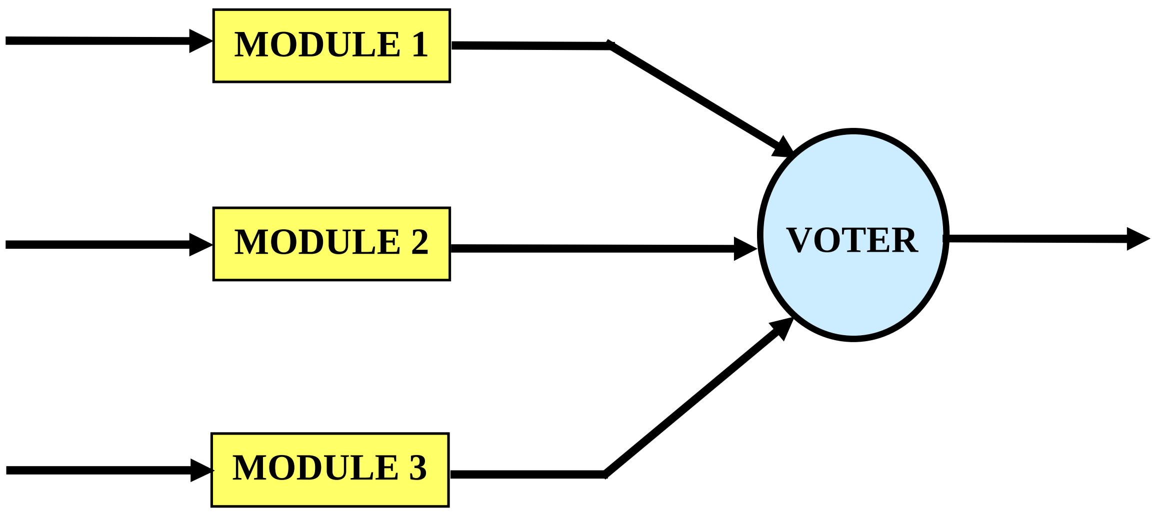
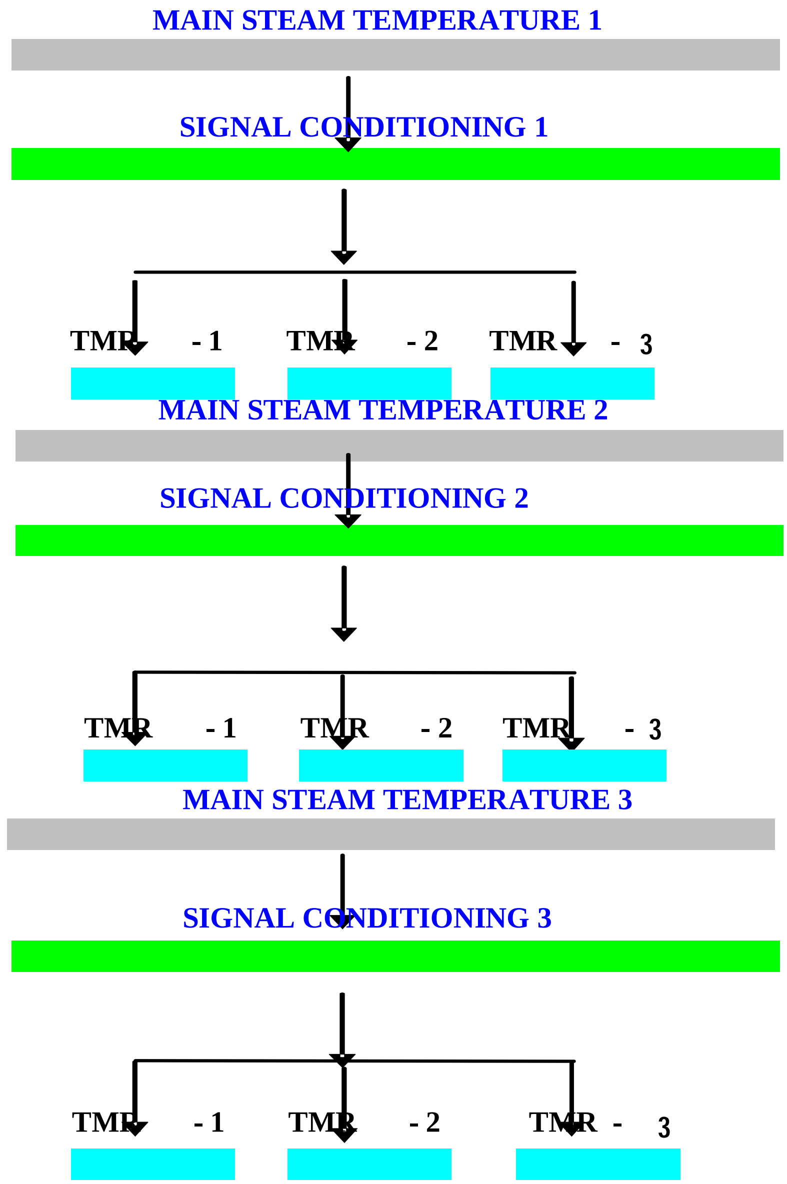


Fig. : 4.1

5.0 TMR IMPLEMENTATION IN EHTC & TP CONTROL

Signal from field is acquired first in signal distribution / conditioning panel, from where these signals are distributed to independent TMR panels. (Ref. Fig: 5.1). The controllers in the TMR panels accept these signals as an input, execute the programs as per the process control strategy written in the controller and performs the majority vote. The majority voted outputs from all the three controllers are then sent to the EHTC & TP panels, where once again the voting takes place in hardware controller (Ref. Fig: 5.2). The output of this controller is passed on to the final elements in the field. The elements of the turbine trip circuit in the field are normally energized with 24 V DC. When a trip signal occurs, these elements are de-energized to trip the turbine. Refer the figure given below. (Ref. Fig: 5.3)

Fig.: 5.1


MAIN STEAM TEMPERATURE 1
SIGNAL CONDITIONING 1
TMR - 1
TMR - 2
TMR - 3
MAIN STEAM TEMPERATURE 2
SIGNAL CONDITIONING 2
TMR - 1
TMR - 2
TMR - 3
MAIN STEAM TEMPERATURE 3
SIGNAL CONDITIONING 3
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TMR - 2
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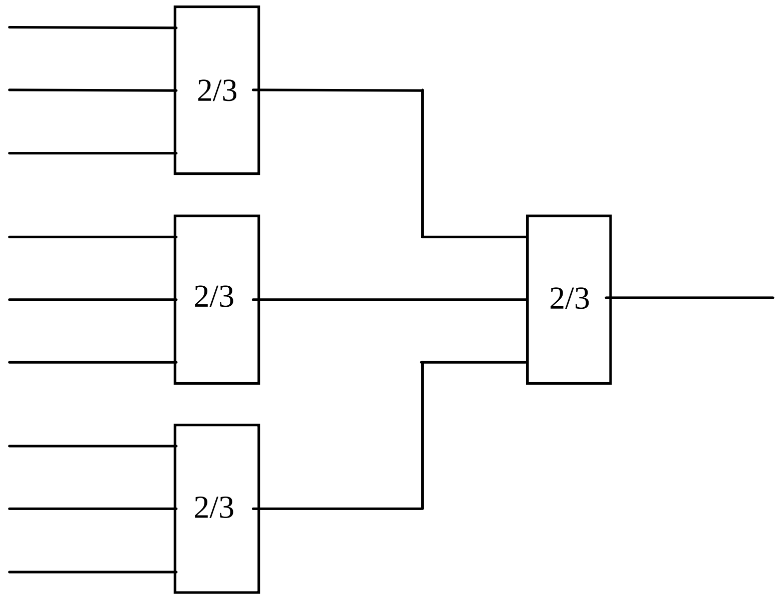

2/3
2/3
2/3
2/3

Fig.: 5.2

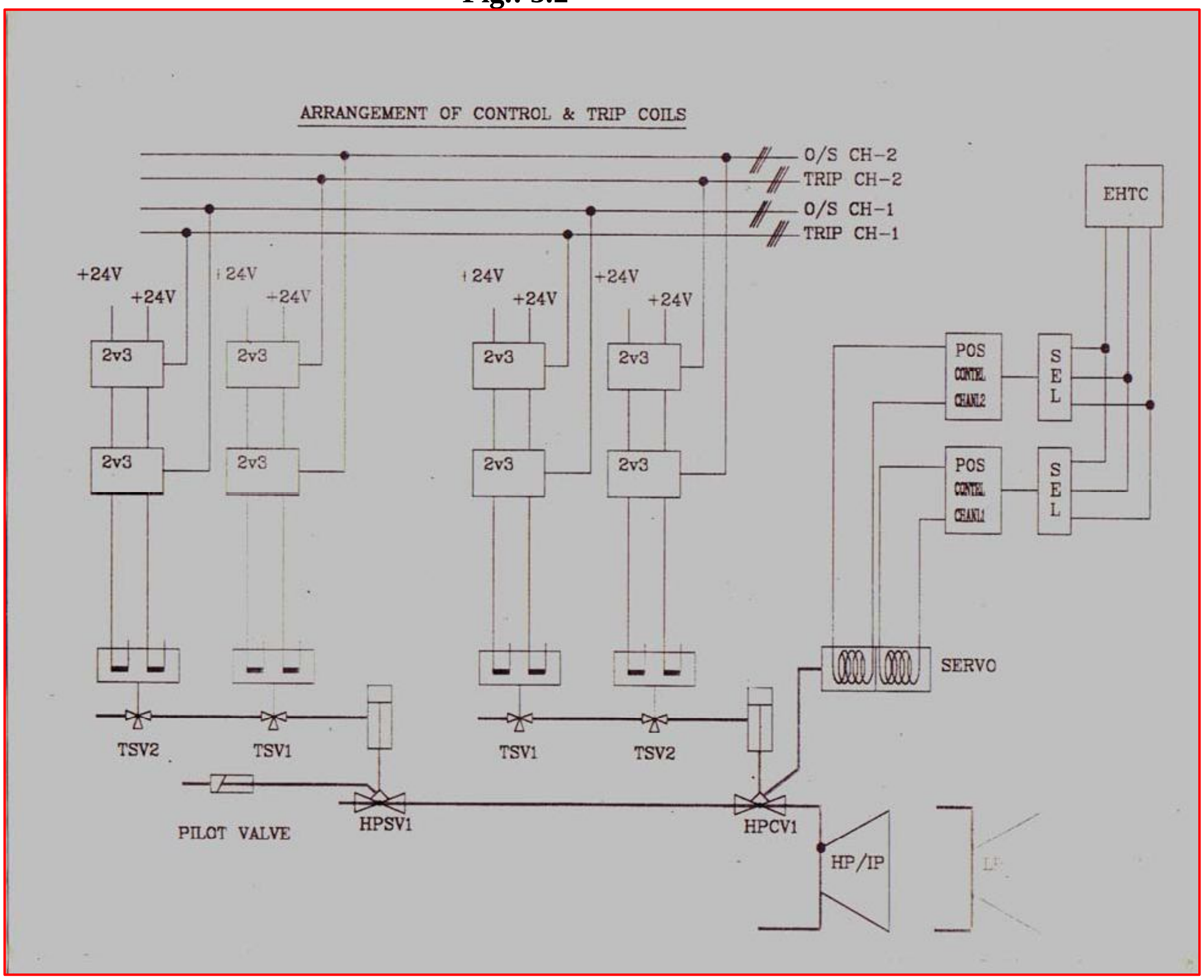

ARRANGEMENT OF CONTROL & TRIP COILS
O/S CH-2
TRIP CH-2
O/S CH-1
TRIP CH-1
EHTC
+24V
2v3
POS CONTRL CHANL2
POS CONTRL CHANL1
SEL
SERVO
TSV2
TSV1
PILOT VALVE
HPSV1
HPCV1
HP/IP

Fig. : 5.3

6.0 TURBINR TRIP CASE STUDY

1) **Date:** 19th November 2008 **Time:** 16:30 Hrs.

First tripping took place on 19.11.2008 at 16:30 hrs when the machine was running at full load. As a general practice, the alarms that were generated during the trip were investigated. However, the only alarms that Sequence Event Recorder recorded were

Turbine Trip 1

Turbine Trip 2

Turbine Trip 3

Since there was no alarm preceding Turbine trip there was no clue available as what had made the turbine to trip, a thorough physical investigation was carried both in the field as well as in the system side. After confirming that nothing was wrong, the unit was resynchronized at around 19:20 hrs.

2) **Date**: 24th November 2008 **Time**: 05:30 Hrs.

The second turbine trip took place on 24th November 2008 at around 05:30 hrs. When the alarms were investigated, it was again found that no alarms had been generated. In the process, it was suspected that there were automatic turbine shutdown signals coming from ATRS panels which if get simulated may lower down the Load and the Speed set points of the turbine.

One of the trends (Fig.: 6.1) supported this finding which indicated that there was the sudden lowering of load set point, speed set point followed by the turbine trip. As per the trend, there should have been some load throw off in the electrical system which could have led to sudden lowering of the load set point. But, Load Dispatch Centre confirmed that there was no such load throw off in the electrical system during this occurrence. Therefore, it was more or less concluded that the ATRS panel had simulated the signal based on which turbine had tripped on full load throw off.

As a result of this finding, it was decided to bypass the signals coming from ATRS panel to EHTC common station. This was done to ensure that no further signal simulation in ATRS panel shall affect the turbine control.

After carrying out the necessary logic modification in the EHTC controller so as to bypass the load and the speed set point lowering signals from ATRS, the unit was resynchronized at 19:20 hrs.

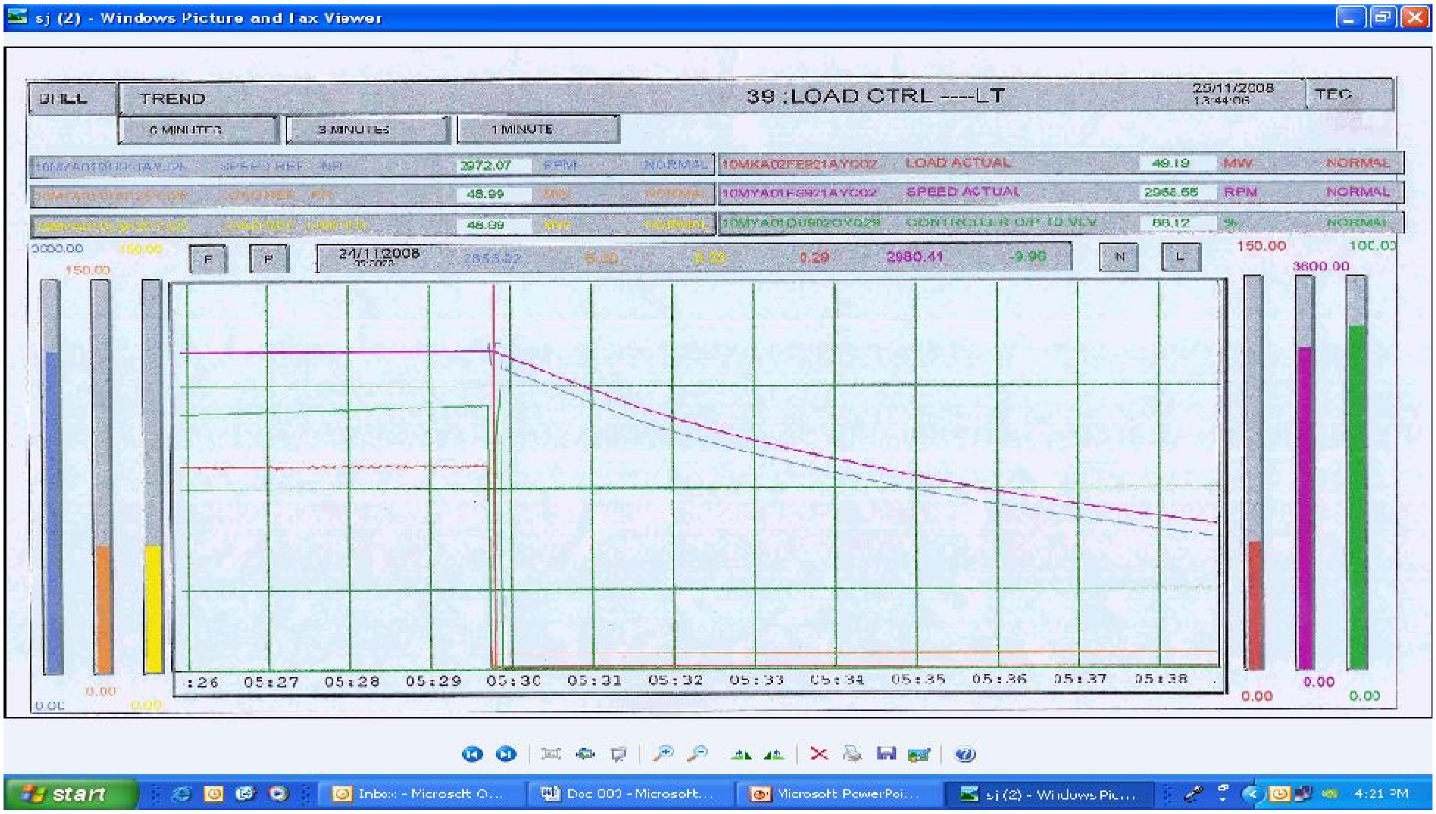


Fig. : 6.1

3) **Date**: 25th November 2008 **Time**: 03:45 Hrs.

The unit generated load for around next 24 hrs without any problem. However, at 03:45 hrs on 25th November, unit 2 tripped again without generating any alarms. This time, it was proposed to extend this outage till the fault was found. But, due to customer's full load requirement it was not permitted and a limited time was given to restore the machine. Therefore, in order to eliminate some of the probable causes of the tripping, it was decided to change some of the cards which were common to turbine control. In this regards, bus traffic director (FV01) module and the bus-coupler (BK02) modules of CCA02 and CCA05 (ATRS panels – since these were in alarm condition) were changed.

4) **Date:** 29th November 2008 **Time**: 05:45 hrs

The fourth tripping took place on 29th November at 05:45 hrs in the similar fashion. An extended outage of 8 hours was given to carry out the root cause analysis of the occurrences. "Why-Why Analysis" tool was used to reach to the bottom of the tripping occurrences. Some of the major findings of the analysis tool are listed down for the reference of fault finding:

a) Why did the unit trip?

Ans: Because turbine trip command was issued from TMR panels.

b) Why did TMR controller issue trip commands?

Ans: i) Because of change in process parameters
ii) Because of field element mal-operation.
iii) Because of signal simulation by I/O cards in TMR panels.

Note: Since there was no change in the process parameters, point no. (i) Was disqualif

c) Why did the alarm not appear if the field element had mal-operated?

Ans: The alarm is configured based on the majority voting philosophy, i.e, "2 out o
Therefore, the alarm shall not come if only one element mal-operates in the fie

d) Why the alarm is not configured for single element mal-operation?

Ans: OEM design gap.

e) Why would the card simulate fault signals?

Ans: Inherent problem of the I/O cards. These cards simulate the fault signals on its
causing a trip signal to initiate in a TMR controller.

f) Why would the unit trip on single TMR controller trip signal?

Ans: The unit shall not trip on single TMR trip signal. But, as stated earlier, if one o
out of three elements gets faulty, the protection logic changes from 2/3 to ½ logic in th
controller (As stated in para 4.0). Now, if any of the cards simulate a false signal, it sh
signal in that particular TMR controller (Ref.: Fig. 6.2)

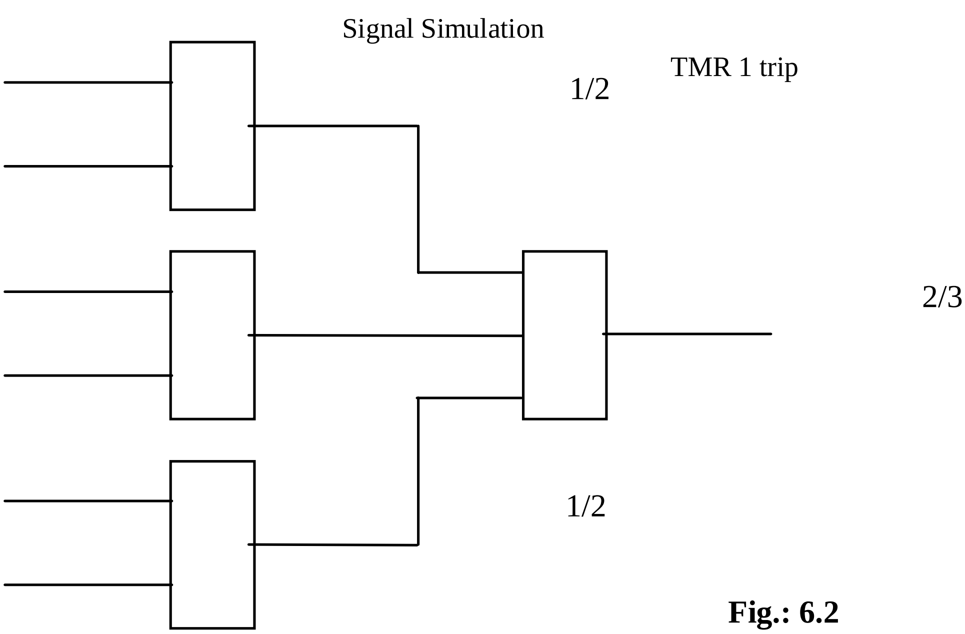


Fig.: 6.2

Since TMR 1 is in trip condition, now if one card simulates in the TMR 2 panel, the turbine shall trip based on majority voting of the final controller. (Ref.: Fig. 6.3)

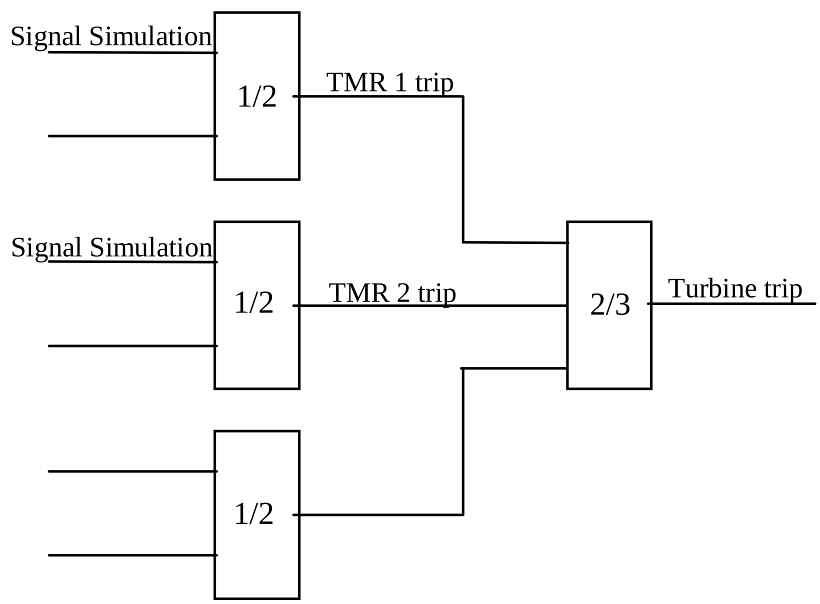


Fig.: 6.2

7.0 CORRECTIVE ACTION

Based on the RCA findings, it was decided to modify the alarm and trip logics of the individual TMR controller for which OEM also gave their consent.

In the original trip circuit, an additional logic is added which checks the status of other TMR signals. Here, if the signal simulation fault causes tripping of one TMR panel it immediately checks for the status of other two TMR panels. If the other two TMR panels do not trip for next 20s then a 3s pulse is generated as input to RS flip flop to reset the single TMR trip. Under normal circumstances, in case of a genuine trip signal conditions, all three TMR trip voting signals are generated within 1-2 second.

TRIP LOGIC MODIFICATION (Ref Fig.: 7.1):

The fig. 7.1 shows that a turbine trip signal is issued from the controller when an actual trip is initiated based on actual process parameter trip from Turbine or Boiler or Generator side. However, this circuit did not take care of false signal simulation.

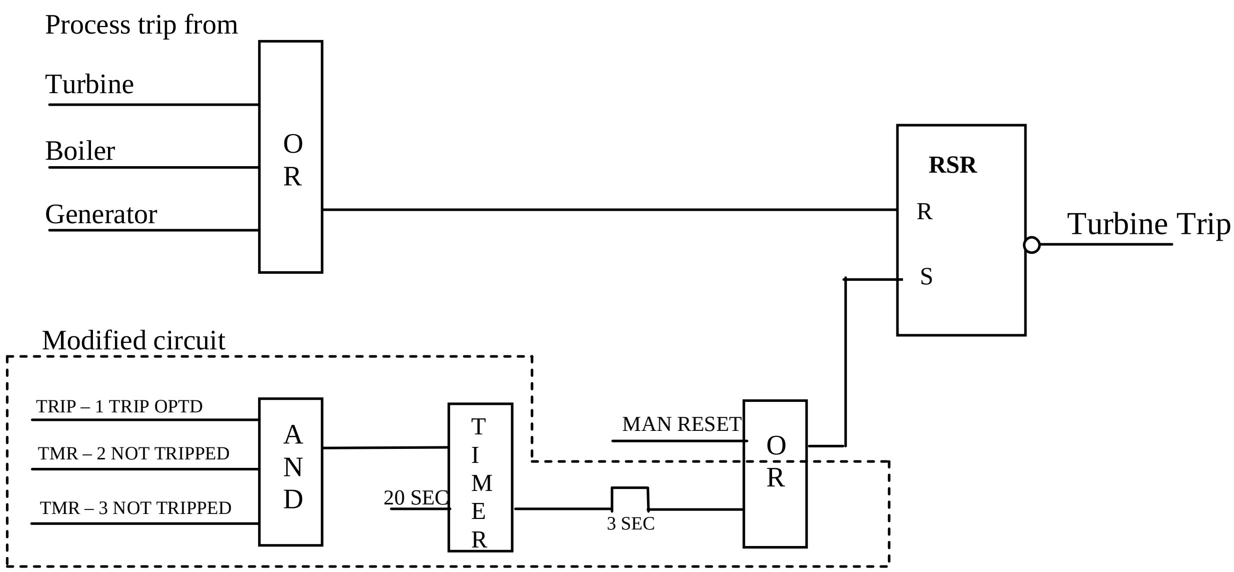
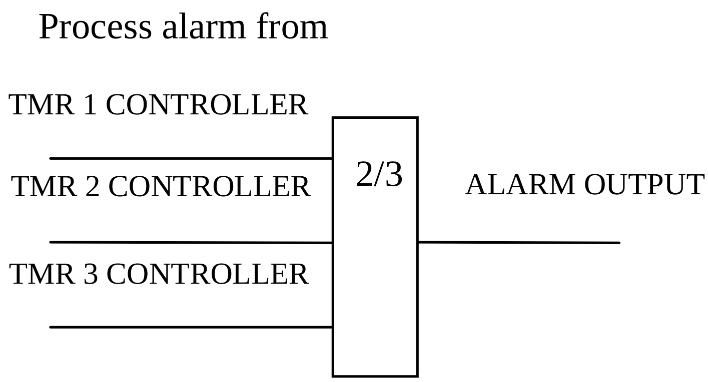


Fig.: 7.1

NOTE: Same logic modification has been carried out in TMR 2 and TMR 3 controllers.

The fig. 7.1 shows that a turbine trip signal is issued from the controller when an actual trip is initiated based on actual process parameter trip from Turbine or Boiler or Generator side. However, this circuit did not take care of false signal simulation.

ALARM LOGIC MODIFICATION (Ref Fig.: 7.2):



Modified circuit

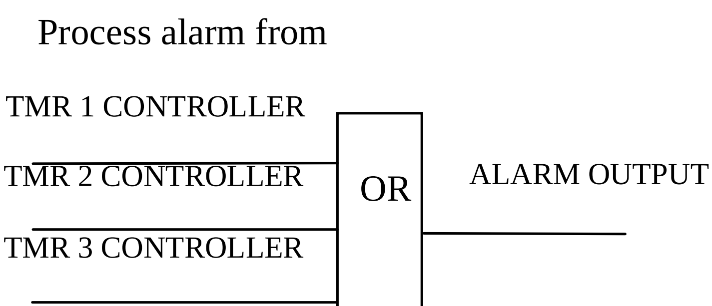


Fig. : 7.2

The RCA findings had revealed that the alarm was configured on majority voting philosophy of the TMR concept. But, due to its short-coming of not generating alarm in case of false signal simulation, or in case of single field element mal-operation it was decided to change the 2/3 logic into an OR GATE logic. This modification also had an additional benefit of taking a proactive action of replacing the faulty field element before the trip occurs.

7.0 CONCLUSION

After the analysis, the root cause of the problem was identified as spurious fault simulation by I/O cards.It was later confirmed by the OEM that this was an inherent problem of their I/O cards and therefore cannot be eliminated at site. Also, these cards are not intelligent enough for self diagnosis. However, to improve the reliability of the units, the corrective actions were taken at logic level to eliminate the tripping because of false simulation of cards. The same modifications shall be carried out as and when opportunity comes.

As a result of the above shown modifications, the unwanted unit outages were immediately stopped. Since then no such occurrences has taken place (Ref. Fig.: 7.1)

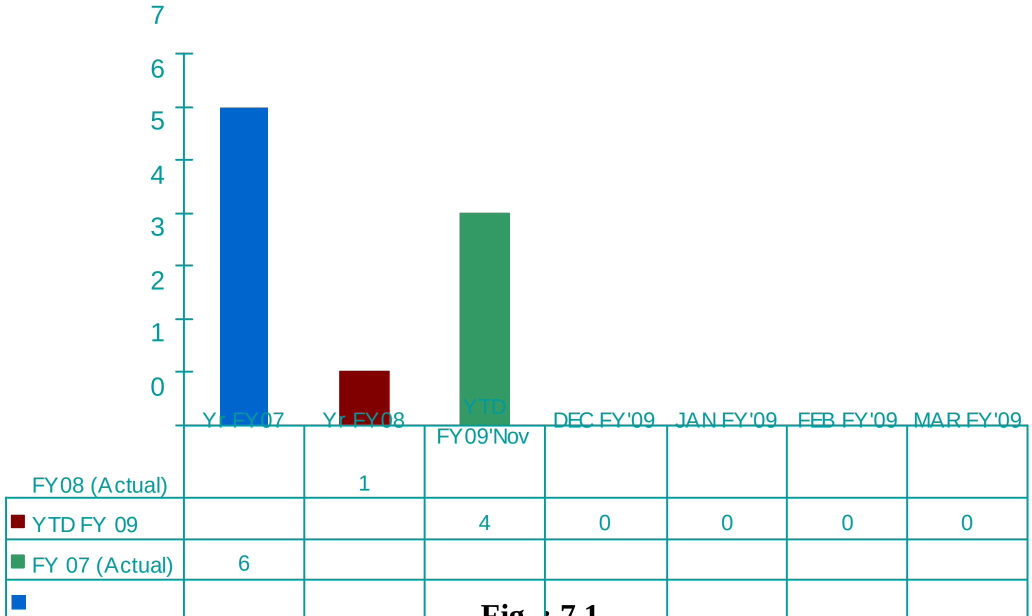


Fig. : 7.1

8.0 SOME MORE EXAMPLES OF PROCONTROL CARD FAILURES

LOSS OF 24 V DC (Ref. Fig.: 8.1)

A block diagram given below shows that if two signal of "Loss of 24 V DC" appears, boiler trip of that particular panel shall also appear. And if this happens in two boiler panels, the boiler shall trip. During one of the instances, it was found that 2 signals of Loss of 24 V DC was flickering (digital card output) in Boiler # 1 panel. When these two signals flickered simultaneously (once in hundred times), Boiler Trip # 1 signal also appeared. Due to this, purge complete signal was disappearing which is required for boiler light up. Now, if Boiler Trip # 2 signal appears, the boiler shall trip. (However, this has not yet occurred)

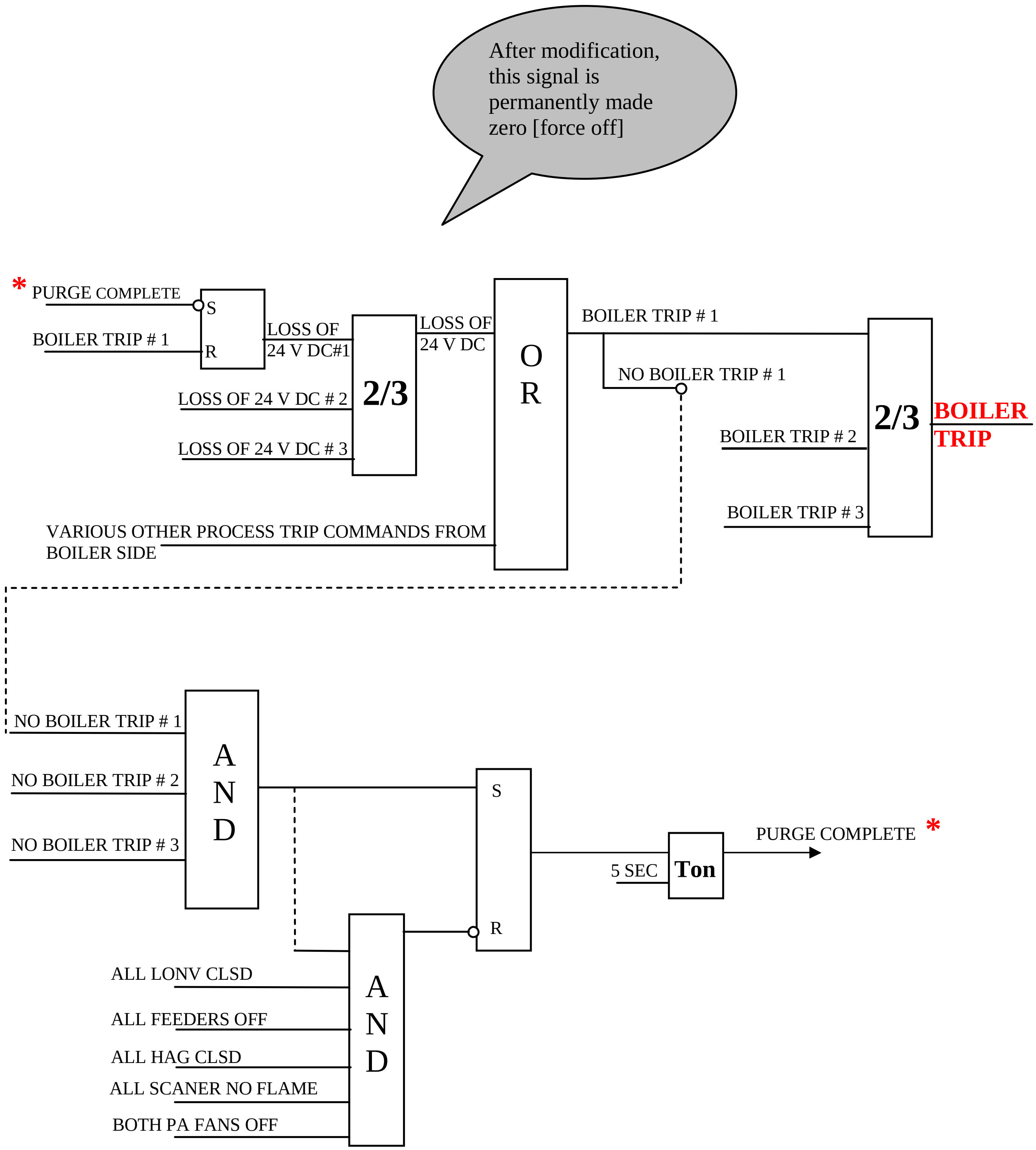

After modification, this signal is permanently made zero [force off]
* PURGE COMPLETE
S
BOILER TRIP # 1
R
LOSS OF 24 V DC#1
LOSS OF 24 V DC # 2
LOSS OF 24 V DC # 3
2/3
LOSS OF 24 V DC
OR
VARIOUS OTHER PROCESS TRIP COMMANDS FROM BOILER SIDE
BOILER TRIP # 1
NO BOILER TRIP # 1
BOILER TRIP # 2
BOILER TRIP # 3
2/3
BOILER TRIP
NO BOILER TRIP # 1
NO BOILER TRIP # 2
NO BOILER TRIP # 3
AND
S
R
5 SEC
Ton
PURGE COMPLETE *
ALL LONV CLSD
ALL FEEDERS OFF
ALL HAG CLSD
ALL SCANER NO FLAME
BOTH PA FANS OFF
AND

Fig. : 8.1

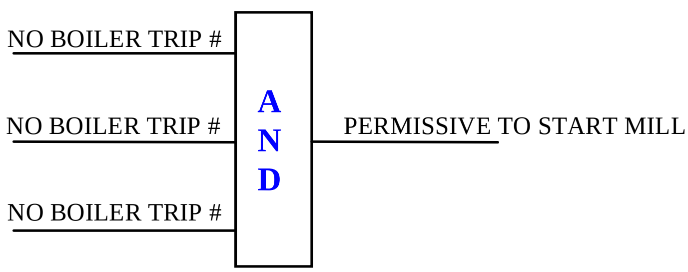
MILL PERMISSIVE (Ref.: Fig. 8.2)

Three inputs of No MFT signal is required from three MFT panels in each mill panel to get the release for starting any mill. These signals are sourced into the mill panel from MFT through bus – coupler module BK02 placed in mill panels. In one of the mill's panel (Mill Elevation E) it was found that NO MFT # 2 is low, though the same signal was found to be high in other mill panels. This was a case of missing address in the local bus. Due to this, we were not able to start the mill from DCS. Even after we had changed BK02 module with a new one, the case was not solved.

After a detailed study, it was then proposed to change the AND GATE in the logic into two out of three (2/3) logic to get the permissive for starting MILL E.

NOTE: If the actual process trip of the Boiler appears, minimum two Boiler Trip signals shall get high and the boiler shall trip.

BEFORE MODIFICATION



AFTER MODIFICATION

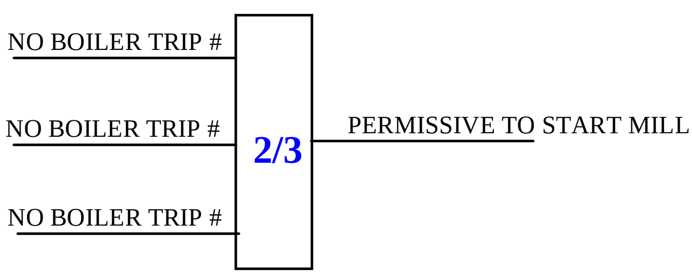


Fig.: 8.2

ACKNOWLEDGEMENTS

We thank the whole team of Tata Power, Jojobera Division who helped us in solving the above stated problem. We do acknowledge the continuous suggestions and participation of Mr. Surodh Dey and Mr. Phanindra, in particular, from the Instrumentation Maintenance Department. Last but not the least, the station head of Jamshedpur Division, Mr. P L Manjrekar who had full confidence on us and who was always with us during the odd times to boost our morale.

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CONDITION MONITORING, BASICS AND A CASE STUDY

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KEYWORDS

Vibration monitoring , Predictive Maintenance, Machine Down Time, Condition Monitoring, Vibration analysis, Monitoring strategies, Off Line Monitoring, On Line Monitoring, Data Acquisition, Condition monitoring Economics, Features of Monitoring system, Application and uses if various monitoring strategies.

ABSTRACT

This lecture introduces the predictive maintenance concept of Condition Monitoring for industrial rotating machines. This makes it easier to understand how important the need for Condition Monitoring is, and describes the fundamentals upon which the Condition Monitoring systems are designed and built. What features should one look for when deciding to install a condition monitoring system in the Process/ Utility Industry. To drive the point home a case study is discussed which defines how condition monitoring has been successfully used to prevent catastrophic failure of the vertical pumps, which had been frequent in past, before monitoring system was installed.

1.0INTRODUCTION

The author is in the field of Vibration monitoring and diagnostic technologies for past 16 years, and has vast experience in providing vibration monitoring solutions for industrial rotating machines, and TG sets. The details below provide a brief insight into the strategies that define the use of condition monitoring systems and what makes vibration monitoring so special over other parameters monitoring system. Though multiple techniques are available in the market for condition monitoring why vibration monitoring is specifically used by most condition monitoring engineers.

Maintenance Strategies and their Development over time :-

Condition Monitoring is a broad concept that involves many disciplines. We will look at a few of the important concepts surrounding Condition Monitoring. Firstly, we will briefly look at maintenance strategies and its development over time, of which Condition Monitoring is an integral part. Then we will look at some specific aspects of Condition Monitoring such as the principle, Condition Monitoring strategies, Condition Monitoring types, Condition Monitoring system fundamentals, and finally some Condition Monitoring economics.

Although maintenance has always been considered important, it was not always considered a main-stream function. In the past, it has often been regarded as a non-value adding division of the company, as a sub-system of production, or worse as an unplanned overhead. Now, maintenance is no longer an overhead, but a primary requirement to avoid unplanned expenses! Maintenance combines management, financial and engineering skills to achieve optimal *economic advantage in the life cycle* of the plant. Modern maintenance strategies no longer focus on maintaining machine parts - they focus on "maintaining" the entire production capacity.

The purpose of maintenance is to preserve machinery in a condition in which it can operate in a safe economical way. The major areas of concern which are addressed by maintenance are *loss of machine operating time and efficiency,* where the effective cost of any repair has to be less than the economic loss arising from the reduced efficiency and *loss of function*, where the maintenance costs are not only for the parts to repair the machine (plus any consequential damage), but also the downtime and lost production incurred while machine is being repaired. Maintenance has evolved from run-to-breakdown methods, to time-based methods to modern predictive maintenance practices. This has resulted in less spares and manpower to maintain machines, and higher machine availability.

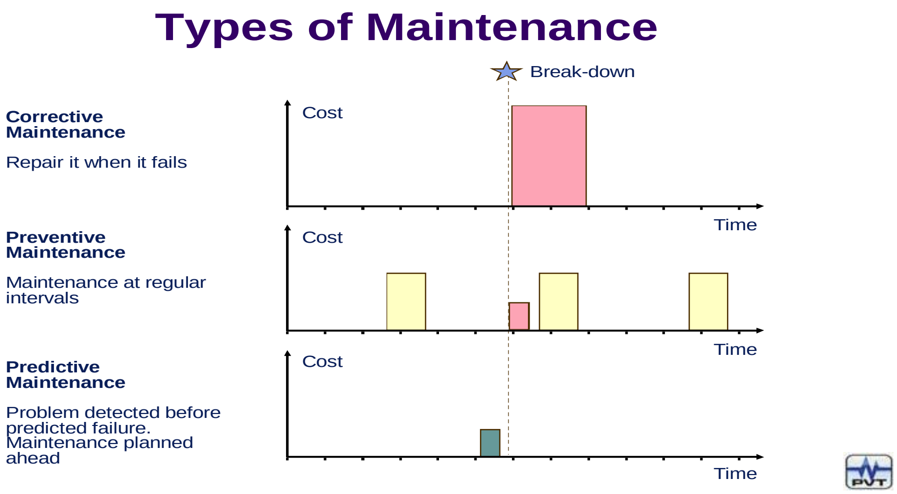
Breakdown maintenance, carried out after a failure has occurred, was the only maintenance program used till 70s. Most critical machines cannot be cost-effectively maintained this way for one of the following reasons:

- A catastrophic failure could adversely affect other components of the machine.
- It's not unusual for machines to fail at the most inconvenient times- during high load/high production times (Murphy's law still is applicable)
- Failure at odd hours, on a weekend or during a holiday can be longer and dearer.
- Certain processes cannot be interrupted. The product may get spoilt while a critical machine is stopped in process industry (eg. Rubber or glass industry).
- Since you never know when the machine will break down, you have to stock spares for longer periods of time, which is not viable today.

Preventive maintenance, i.e. time-based / calendar based maintenance, was conceived as a result of demanding maintenance requirements not met by time based maintenance. It involves doing statistical failure analysis to predict when a component will fail, and plan maintenance before actual failure occurs i.e preventing catastrophic failures. Today, just like breakdown maintenance, time based maintenance is still cost-effectively used but in limited situations. There are many cases, especially for critical machines, where this technique is difficult to justify because:

- Machines have to be stopped often for inspection - extra downtime
- Difficult to estimate overhaul intervals - premature failures are a risk

- Incorrect reassembly of an otherwise well operating machine
- Complete overhauls replace many working components, not just defective parts
- Experienced personnel required to check if parts can still be used

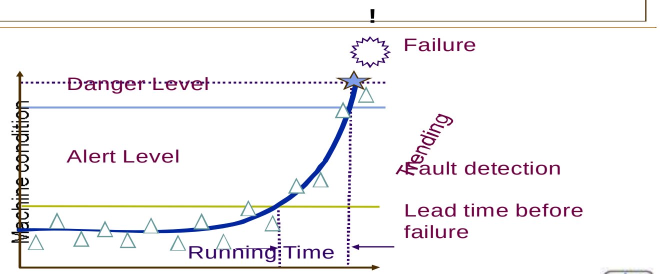


<u>Condition Based / Predictive Maintenance</u>: - *Reliability*, *availability* and *maintainability* became more important as production became more automated and computerized, plants become larger and aging machines were pushed to their limits of performance and beyond. More and more failures affect the ability to sustain *quality standards* and have
serious consequences on *safety* and the *environment*. As a result of all this, predictive maintenance was developed, which strives for machinery to be operated and monitored up to a predicted failure condition. This includes also analyzing machine failure modes and their effects and adopting Condition Monitoring strategies.

<u>Condition Monitoring</u>. Condition Monitoring is a part of a predictive or condition-based maintenance strategy which measurements are used to characterize the state of components in a system. The basic principle of Condition Monitoring is to select a physical measurement which indicates that deterioration is occurring, and then take measurements at regular intervals. Any upward (or downward) trend that is detected could indicate that a problem is developing, but operation is still possible provided the measurement "do-not-exceed" a limit. In Condition Monitoring there are 2 interesting events to be detected as early as possible; initiation of a *potential failure* (alert), and the maximum allowable level before a *functional failure* (danger).

Principles of Condition Monitoring

- Detection of a developing fault
- Trending of the fault
- Operate the machine up to but before failure



When an alert alarm occurs, there is lead time where the machine can still be operated with little or no performance degradation, and the development of the failure, its cause are determined and maintenance is planned ahead. Condition Monitoring permits monitoring of progressive failure modes in measurable terms, such as:

- Progressive changes in the dynamic forces of moving components
- Progressive changes in wear
- Progressive changes in performance

There are many kinds of Condition Monitoring methods and techniques for rotating machinery. Some are only for fault detection while others are for diagnosis. It is necessary to know which part is failing and to define the expected lifetime of the part in question so it is easier to decide whether the manufacturing process should be stopped for maintenance or whether it could be possible to continue until a more suitable moment for shutdown.

Advantages of Condition monitoring :-

Since overhauls are done according to the condition of the machine,

- The number of overhauls is minimized, without compromising on the plant or personnel safety.
- The lesser number of times a machine is opened, the lower is the risk of incorrect reassembly.
- Overhaul maintenance focuses only on those parts which are in need of service.
- Manpower and Spares needed to carry out an overhaul are automatically reduced.
- Most importantly, catastrophic failure that would be unseen in a run to breakdown/ time-based maintenance program is virtually eliminated.

Condition Monitoring Strategies :-

There are two primary CM Strategies to monitor the plant:

- *Protective Monitoring* : Monitor only for dangerous fault conditions so a machine can be shut down to avoid a catastrophic failure
- *Predictive Monitoring* : Monitor slight changes in the machine condition so maintenance can be cost-effectively planned ahead of time by identifying the fault.

Protective monitoring is intended to prevent dangerous situations occurring for machine, man and environment. This requires continuous automatic monitoring with a trip relay Functional faults are detected, almost just before breakdown. Here there is little or no co-ordination with production since trip relays are often used to shut down the machine before breakdown. It is used for problems such as axial shaft position, axial shaft rubs, high temperature, high pressure, high vibration, etc.

Predictive monitoring recognizes potential failures with enough lead time such that there is enough time to diagnose the fault and plan maintenance ahead of time. Predictive monitoring can be used for a number of faults such as unbalance, rotor stability, misalignment, blade contamination, blade wear, gear wear, local tooth defects, bearing wear, coupling lock up, looseness, crack formation, seal leaks, etc.

Traditionally, independent systems were used based on the organizations condition monitoring strategy because the monitoring and system requirements for each were

different. But in applications where both strategies are used, it makes more sense to use integrated systems that are being introduced that can perform all the functions. And for plants where there already exists one strategy the ideal solution is to select a system that can interface with the existing one & provide both strategies in an integrated system.

Most Informative Condition Monitoring strategy :-

There are actually many techniques for monitoring the condition of machines these can range in sophistication from a simple pot hole for viewing in a boiler to a sophisticated computer based system that monitors the condition and performance of all the machines in a large plant. Many other techniques are normally dedicated to specific machines for very limited fault detection, however **VIBRATION ANALYSIS** plays the most important role for machine Condition Monitoring for the rotating machinery. *No other system can compete for detecting such a large number of potential failure modes at such an early stage of development for such a wide range of machines.*

It has been reported that in over 90% of all rotating machinery failures there is a change in the vibration behavior of the machine. Vibration is a by-product of the transmission of cyclic forces in a machine, where most of the components vibrate to some degree during normal operation. Each component has its own characteristic vibration pattern. As the machine wears, foundations settle, and parts deform, subtle changes in the dynamic properties of the machine begin to occur. By detecting these minute vibration pattern changes, early warning of incipient faults is possible since most machine faults develop slowly and progressively.

Benefits of Condition Monitoring

- Reduces frequency and time of overhauls
- Improves maintenance efficiency — early planning, less manpower, less spares, fewer chances of incorrect reassembly
- Improves machine availability
- Minimizes the chance of catastrophic failures

Most developing faults manifest themselves as increasing vibration levels since the forces that underlie these vibrations are increasing, such as misalignment, unbalance, greater clearances, pitted or worn sliding surfaces, etc. The increasing vibrations can be destructive in nature, since they can put increased dynamic load, hence increased fatigue and wear on the bearings, seals, couplings, blades/impellers and gears. The vibrations can also excite the resonances of other components, thus compounding the problem even further. In practice, it is not difficult to detect subtle vibrations since they transmit well through the machine. Moreover, vibration analysis can be used to identify specific vibration frequencies that correspond to certain machine elements and faults.

No other form of Condition Monitoring gives such a complete health description for such a wide range of machines than vibration monitoring.

Choosing a Condition Monitoring system is also an important part of a condition-based monitoring strategy. Condition Monitoring systems range from hand-held instruments to fully automatic, computerized systems that are permanently installed. System features and functions will be the subject of other lectures, but some of the important system considerations when selecting a system are listed below:

- Data reduction
- Ability to work, exchange data with other systems
- Condition Monitoring system reliability and security
- Fault detection capability
- Fault diagnosis
- Alarm handling
- **Ease of use, training required, manpower required**
- Installation requirements

The first step and the most important one is to evaluate your maintenance and Condition Monitoring needs and work out a Condition Monitoring strategy. For vibration monitoring, the following techniques are used:

Permanently installed (on-line) system: This is the most expensive type of Condition Monitoring strategy and accordingly offers the most precise machine condition information. Unmanned installations, remote sites or dangerous areas are best monitored with this type of system. This is also the only solution for protective monitoring and automatic relay and machine trip applications.

Portable data collection system (off-line): This is often the most cost-effective method for plants using only predictive type maintenance. There is actually very little difference between on-line and off-line system technical capability for predictive monitoring. The off-line system though is much more labor intensive. Off-line systems are also the entry level system for many Condition Monitoring system users, especially if the measurement databases can be shared between the two systems.

Permanently installed (on-line) system with Diagnostic capabilities : Modern monitoring systems with latest microprocessor based technologies can process an enormous amount of data within no time, so a means is needed to ensure only significant data is used and stored.
There are several means for reducing data:

- Event-based data acquisition (Dynamic and Transient data)
- Time Based data acquisition on-line-permanent system, portable data collector)
- Database compression
- Expert system

Overall measurements are primarily used for protective monitoring systems, but still can be used for certain predictive monitoring applications. Spectrum and other measurements, however, are ideal for predictive monitoring systems because of the wealth of diagnostic information that they contain.

The measurement data gathered by a Condition Monitoring system is primarily used for detecting potential failures modes, i.e. the symptoms of a functional failure. Diagnosis is the process of arriving at an explanation of a symptom so that repair can be made. It takes a fault indication and transforms it into informative data. This often supports a maintenance person in taking crucial statistical decisions. Diagnosis isolates the real cause of a fault rather than just the symptom. A diagnostic system with a historical database can be used for studying the pattern of failures, i.e. by *trending*. What can now be done if the services of an expert are desperately needed only a few times a year? *Tele-monitoring* is the solution, which is a consultant service that has a computer connected to a client's monitoring system over a modem. When the client detects a fault that he himself cannot diagnose, He asks the tele-monitoring firm (Many times the supplier of the monitoring and diagnostic system) to analyze it for him. Manufacturers of monitoring system are known to make special arrangements with selected customers to remotely monitor their machines. This gives more realistic information than what can be obtained from laboratory testing. These Condition Monitoring services are a result of remote monitoring capability of modern monitoring systems.

Economics of Condition Monitoring System :-
The "initial" price of a Condition Monitoring system is not the same as the "total" price.
For many of us, when we think of the cheapest system, we think only of the purchase cost of the system, i.e. cost of the hardware and software sitting inside the cabinet on the shop floor. In practice, however, there are actually several factors other than purchase price that determine how cheap the

system actually is. The operating cost of the system over a period of years has a much more significant affect on how cheap the system is than the actual cost for purchasing the system or starting it up. The largest contributor to this cost, aside from the costs associated with the reliability of the system, is the manpower needed to run the system with ease and efficiency, which greatly varies from system to system.

The simpler to operate the system is, the less operator time is needed. A portable off-line system uses much more manpower than a permanent on-line system. Many routine tasks, if simplified enough by the system, can be done by technicians rather than by the experts such as system setup, alarm handling, simple diagnoses, etc. There are also cost considerations for the maintenance of the system itself. A system that performs self-tests and has extensive error message facilities can significantly reduce the time to keep the system running. The price for service should also be considered.

The performance reliability of a Condition Monitoring system determine how effective the system is in reducing maintenance and downtime costs desired by the customer. Much like the operating costs mentioned earlier, there is a great diversity of performance in Condition Monitoring systems.

When a Condition Monitoring system says there is a machine problem when there actually isn't one, this could result in expensive maintenance and downtime. Obviously if the false alarm was caused directly by a Condition Monitoring system malfunction, all these costs could be considered as part of the system's operating costs.

The same can be said for a missed alarm, i.e. not detecting a fault, or a missed data in data acquisition system when there is need for data acquisition. These can even be more critical than a false alarm if it results in a catastrophic failure. But more often than not, it is not a question of *not* detecting the fault, but how *early* the fault can be detected. The earlier the fault is detected, the more time there is to plan maintenance cost-effectively ahead of time.

Conclusion: - Various Condition Monitoring techniques and equipments are available in the market today, some are redundant others are complimentary to each other. Deciding on the Condition monitoring strategy for your plant you must select the right kind of Condition monitoring equipments which are easy to operate, maintain, and cost effective in long run. Critical machines must have a Preventive and Predictive Condition based maintenance strategy in place for advance intimation on possible faults and protection against fast developing problems, leading to catastrophic failures.

A Case Study:

VIBRATION MONITORING ON A LOW SPEED VERTICAL HOT WATER PUMP

Pump Application *: The pump is a critical machine for Power plant operation in a Geothermal plant, and its breakdown directly impacts the power generation. The pump function is to utilize the thermal energy trapped underground, for power generation. The pump sucks the water from ground level and pushes it down the earth; the heated water is discharged at the outlet of the pump, and used for steam generation.*

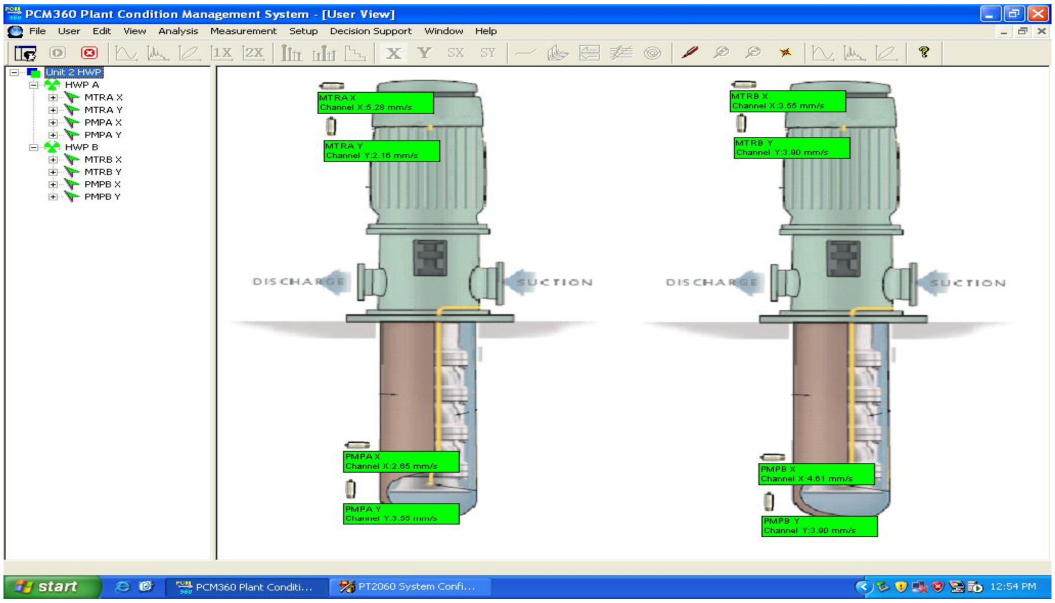
Instrument used for Vibration Monitoring:

ProvibTech USA Make multi channel on line Vibration monitoring system Model PT 2060, with CONDITION MONITORING and diagnostic software PCM 360.

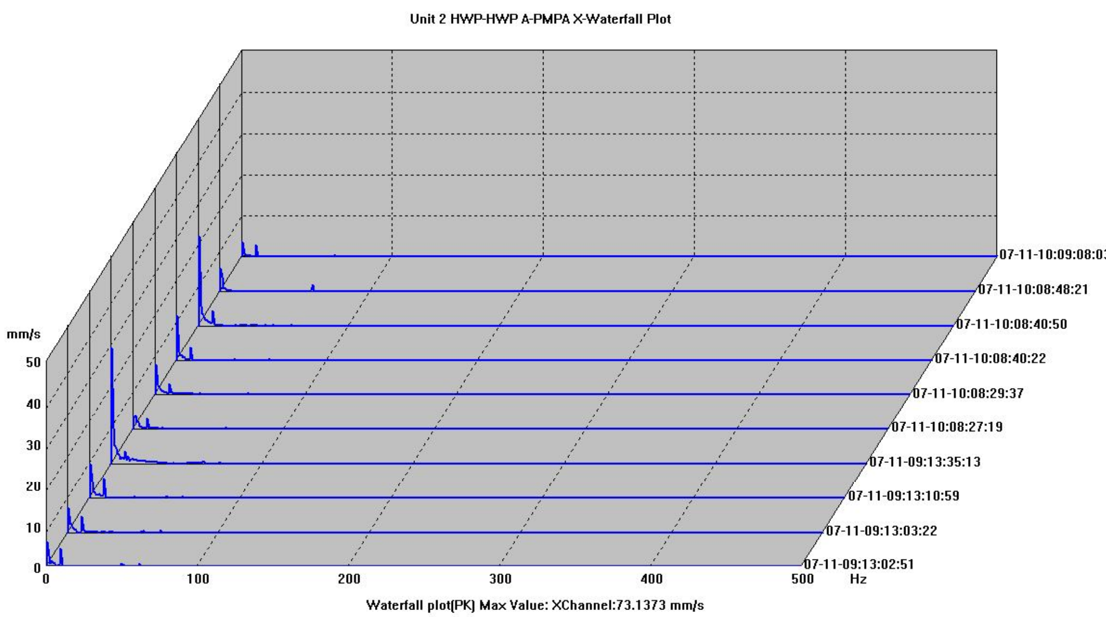
A **Geo-Thermal** power plant in south Asia region at Philippines has vertical hot water pumps installed and were operating without any monitoring system installed on them. In the past, pump failure have not proven to be enough incentive for operators to install a monitoring system. Failures of submerged vertical pumps often occurred without warning as no warning system i.e sensors and monitors were installed. Further the off line measurements of the motor done in the past had proved futile as it provided no information of what is going on in the hole below where the pump is installed

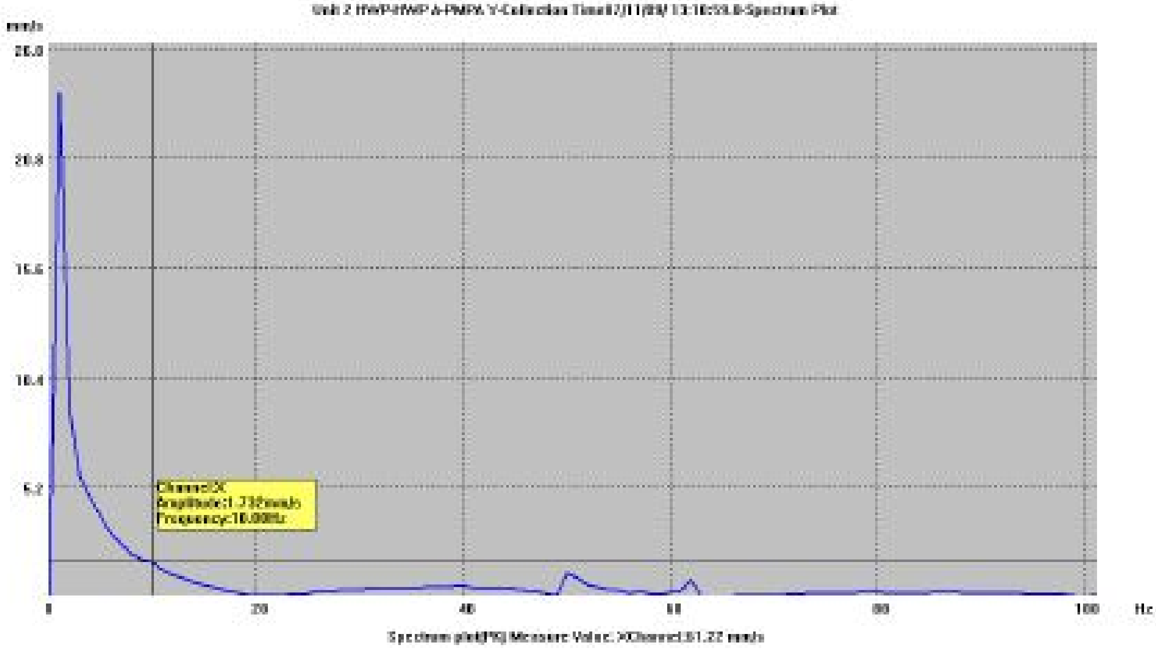
However with continuous pressure for regular power supply, from the Government and right solution suggested by the ProvibTech application engineers, proper instrumentation and condition monitoring system was planned to be installed.   Installations of two accelerometers at the bottom bearing of the Pump which itself remain submerged in water with special mounting arrangements and two accelerometer sensors at the bearings at the motor, with an on line vibration monitoring system was suggested. The condition monitoring system from **ProvibTech** was installed with diagnostic software capabilities.

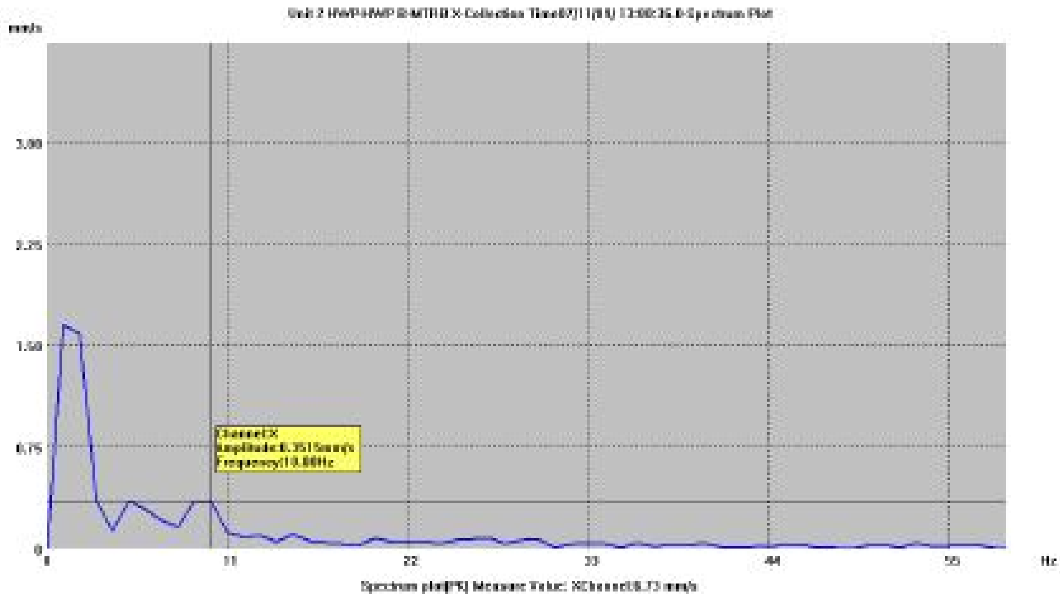
The sensors installed at the bearings of the pump were submerged in water and hence subjected to turbulent water force, hence special precaution was taken to fix the sensor specially designed for such applications and the cable from the transducer secured to the surrounding wall. The monitoring of the pumps was started in late 2007, and the vibration on the pumps at the bearings submerged showed higher and unstable vibrations as compared to the vibration readings on the motor. This was in line with the off line measurements carried out on the motor and indicated lo vibration levels and hence gave no indication of the activity at the pump end.



The decision to install the sensors at pump proved useful, and with the help of the diagnostic system installed the vibration spectrum plots indicated a 1 Hz component being the major source of vibration in the pumps, and further analysis was carried out

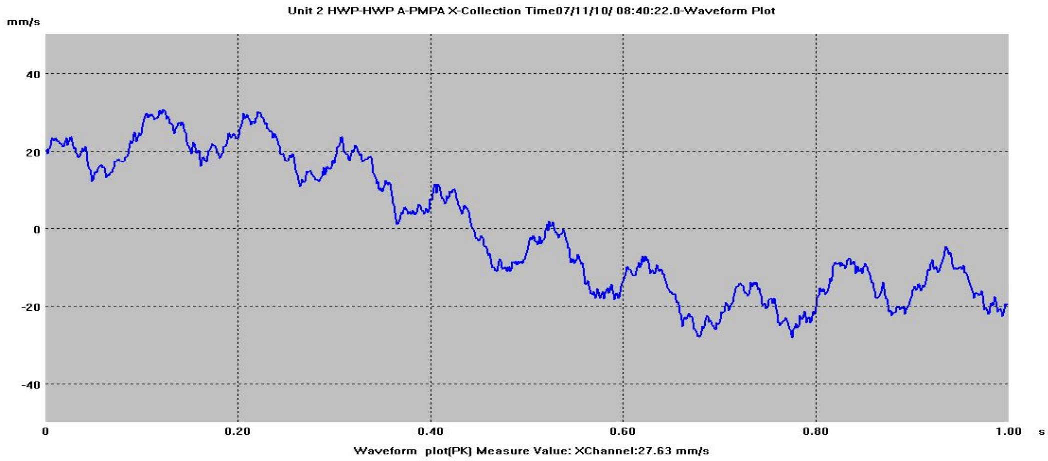






To analyse the root cause of the vibration caused at frequencies which correspond to the 1 Hz. Harmonics of the rotating frequency were observed and as is clearly visible, these frequency components are found to be well within the vibration limits of the pump, specified by the manufacturer of the pump.

Time plots indicate that the rotation speed components in the plots are stable and very low in amplitude, where as the 1 Hz freq observed in the spectrum is causing the plot amplitude to vary, the vibration levels from the pump are clearly superimposed on the 1Hz component. This caused the overall values of vibration to indicate the high level of vibration, giving alarm indications and causing concern to the safe operation of the machinery.



Since the rotating frequency and its harmonic components were not the source of vibration, the other possible causes like, turbulence, foundation and mounting arrangement for the pump and the sensor were analyzed. On close observation it became evident that the mounting bolts holding the pump are getting loose because of rusting and causing increase in the vibration levels. The Condition monitoring system helped the customer analyze the vibration source. Before installation of the monitoring system, customer was practicing time based maintenance and used to take a shut down every 3 months, to avoid pump failure and the maintenance of the pump was carried out lasting 2-3 days. Now with installation of Vibration Monitoring system and diagnostic software customer is able to operate the pumps till vibration values are in acceptable limits, and shut down is taken before vibration values exceed the safe limit. The pumps are in continuous operation and customer is now able to operate the pumps for as long as a year without any shut down. Further even the shut down time is reduced to 4-6 hrs as problem creeping in the machine is detected by the rising trends of vibration, and analysis pin points the problem in the pump. The shut down duration being reduced from 2-3 days to few hours due to **installation of CMS has resulted for the customer in a saving of Php 25,000,000 (US$ 500,000) per shut down** only in terms of generation cost. Besides reduction in maintenance cost, Labour cost, part replacements of pumps is not taken into account.

Conclusion: - The installation of condition monitoring system has proved itself in many process related and utility industries. In every successful case where the condition monitoring system has helped detect a failure in advance, it has helped recover the cost of the system many a times over. Through the use of Condition monitoring software the machines can not only be protected from catastrophic failures but these software also help to define the maintenance strategy of the plants, and help reduce the plant downtime, reduce inventory, increase availability of plant machinery, and helps in operation of machines/ components to their maximum available life cycle.
Condition monitoring system does not cost you it pays you.

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UNIFORM HMI: A DISTANT DREAM OR A NEAR POSSIBILITY

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KEYWORDS

Uniform HMI, Distributed Control System (DCS), Programmable Logic Controller (PLC), OPC Guarantee, Response Time, Native HMI, Security, interoperability

ABSTRACT

Packaging concept in power plant execution has many advantages; the first & foremost being that of cost. But needless to say, one of the de-merits is the plethora of control system (DCS & PLC) & consequently the variety in HMI. Uniformity of the front end to the process being controlled has always been the wish list of the end user i.e. the operator, being oblivious to the underlying dynamics of the platform. One of the traditional & very obvious approaches of achieving this is to deviate from the multi-packaging concept, and go for a total turnkey package. But this is nothing different from running away from the problem.

This paper presents some of the technology solutions, known to the authors, which can be deployed to achieve uniform HMI without compromising the packaging concept. But easier said than done, these solutions have many intricacies, mostly non-technical, which are also deliberated in the paper. Finally, the paper includes some solutions & underlines the expectations from the DCS & PLC vendors for achieving the above goal.

1.0 INTRODUCTION:

Ever since the introduction of Distributed Control Systems (DCS), the operator interface to the process has undergone a sea change. Fast navigation, trends, Large Video screen based annunciation provide the operator all tools for effective operation. The advent of (Distributed control systems (DCS) and Programmable Logic Control (PLC) based systems with more processing capabilities further boosted the appetite for the real time process data. The DCS/PLC based systems of early 90's eras were based on proprietary operating systems, both for the control system as well as for Human Machine Interface (HMI) .The communication network between the control system and HMI was also proprietary, requiring system specific interfacing hardware and software. Now with systems based on open architecture & commercial off the shelf (COTS) hardware, the capabilities of the DCS have increased many fold; so are the demands from these systems. Availability of process data from open architecture systems & the portability of the same to third party software through communication interfaces have become very common & the slogan “Field to Boardroom” has become the buzzword today.

2.0 A TYPICAL DCS/PLC NETWORK IN A POWER PLANT:

A typical large size power plant of 1000-4000 MW capacity in India generally comprises of several independent generating units. Each of these generating units has one or more DCS based systems controlling Steam generators, Turbine generators and balance of plants. There are also various auxiliary plants common to all these generating units which are some times PLC based or DCS based depending on the complexity, geographical location and operating hours of these plants. Various plant operation and maintenance personnel utilize the real time process data of these unit(s).This necessitates a station wide Local Area Network (LAN) connecting various DCS and PLC’s of the plant. There are various customized applications which run on the client PC’s. Further process data is also required to be delivered to companies head office, through company’s private network for further analysis and monitoring of the geographically distributed power plants.

3.0 NEED FOR UNIFORM HMI:-

At present, the packaging philosophy envisages SG package, TG package & Station C&I package. Each DCS supplied under these packages can be different, with a different operator interface for each of these sub-systems. This leads to a situation where the operator from the unit control desk has to operate the unit (main plant) with a different HMI for different areas; a different set of faceplates, different lookout of graphics, etc. Above all, this situation does not aid true inter-operability. i.e. operation of any area of the main plant cannot be done from any TFT or LVS. (Inter-operability though is possible within each of the above HMIs). This eventually leads to increase in number of screens & also to a certain extent number of operators.

Sometimes, even if the boiler controls, turbine controls & the balance of plant & auxiliaries controls are in the same package, the DCS supplied may not be same, due to different specifications for boiler controls & turbine controls from the balance of plant controls. No matter whatever the compulsions, (packaging philosophy, different specification requirements or work distribution), operating of drives of the feed water cycle of the power plant from different HMIs is not the solution, plant operating staff are looking for and C&I personnel are not at ease answering the question “ Why not a uniform HMI” across the plant.

This philosophy of uniform HMI is not only felt in the main plant controls; but also in offsite areas. Since the offsite systems are also tendered as separate packages, the HMI of these systems are also different leading to again non-uniform HMI. As a result, HMI also will be a contributing factor for the difficulty faced in operating an offsite plant by an operator operating the main plant& vice versa.

4.0 STRATEGIES FOR HMI UNIFICATION:

This subject, being always on the mind of the power plant engineering personnel, has got the attention & immediate action, wherever the situation demanded. One strategy is to tender all the main plant equipments under a single package, i.e. main plant turnkey package. In such a case, it had been possible to get same DCS for all the controls of the main plant, resulting in uniform HMI.

Another case is the case of coincidence where the boiler & turbine supplier turns out to the same, in which case it is possible to have uniform HMI for at least boiler & turbine; albeit with some contractual adjustments, for reduction in equipment common to both the HMIs. Another case of lucky coincidence is BOP C&I vendor also turning to be same as the boiler & turbine supplier; in which case also uniform HMI has been attempted & engineered.

Another strategy employed by utilities for offsite controls integration with main plant controls is a unique one, which does not disturb the offsite packaging concept. This is to separate out the controls part from offsite packages & include in the main plant BOP C&I package. This essentially results in the same DCS for main plant BOP as well as the off sites & consequently same HMI across the plant except the boiler & turbine controls. In this case, engineering efforts in the offsite controls passes on to the Owner’s engineering personnel or the consultant. It definitely involves a good deal of coordination between the DCS vendor & the main equipment OEMs.

5.0 SEPARATION OF HMI FROM CONTROL SYSTEM:

All the above strategies are based on some kind of precursor; either it is same vendor by coincidence or compromise of the packaging concept or offloading of the engineering by main equipment OEMs to Owner’s engineers or consultant. This is due to the fact that the above strategies are based on a premise that if we unify DCS, HMI uniformity is guaranteed. The underlying concept is the strong coupling of DCS control system with the DCS HMI.

While the above is true for power plants & DCS in general, it is not the case with small control systems & PLC. There are many HMI software s which are decoupled from the control system hardware & as such work with any control system.

This leads to a paradigm shift in the very concept of power plant HMI. No matter whatever the packaging concept; how diverse the control systems; if the HMI is separated out & made to work with any control system, uniformity is ensured. This calls for massive standardization of communication interfaces & also HMI core functionality.

6.0 OPC AS ENABLER FOR UNIFORM HMI:

Talking of standardization in communication interfaces, we enter the OPC arena. The origin of OPC can be traced to Microsoft‘s DDE & later OLE. Intended for communication between software components, this became the base for what we call today “OPC”. The OPC foundation was founded as an independent non-profit organization with the aim of developing & supporting the OPC standards. These are freely accessible technical specifications that define sets of standard interfaces for different fields of application in automation technology. These interfaces allow a highly efficient data exchange between software components of different manufacturers & provide interoperability between these products. Use of OPC technology makes the most diverse OPC components of different manufacturers to work together.

Various specifications exist for different applications. OPC DA is the flagship standard & is the most prevalent. One of its main use is for real time exchange of data between two systems. It is based on server client architecture. An OPC DA client polls or subscribes to data from an OPC DA server. DA client consumes data & DA server produces data. DA server implements the process data as groups & items. Item is an individual process point. Group is a collection of items with common properties like update rate, % dead band for subscription.

OPC Alarms & Events specification defines an interface between client & server programs for structuring, monitoring, transmitting & acknowledging events & alarms. While DA servers make available continuous flow of data through adaptation of dead band, Alarms & Events server sends events based on binary status change, analog limit value exceeded, operator actions.

OPC DA only communicates ‘on the fly’ values from its Server to client. If history/trend is needed, OPC HDA specifications come into play. Two types of data are used, one raw data & another, processed data. Accordingly, two types of server implementations exist; one simple trend data servers & other complex data compression & analysis servers.

The OPC UA specification, released recently, encompasses all the DA, A&E & HAD into one & supports redundancy & web enabling besides many other advantages.

As already brought out above, interoperability & concurrent working of OPC products are only guaranteed when the products are developed complying to OPC standards. As such, compliance certification is important. For this, OPC foundation offers a self certification test that is run by server manufacturers. These tests are designed to verify whether a server is compliant with the various specifications that comprise the standard. For client vendors, the OPC foundation conducts interoperability workshops three times a year, where client vendor gets an opportunity to test their OPC client implementation against standard OPC server vendors. The results are published on OPC foundation’s website. Recently, third party labs, accredited by OPC foundation, are also known to provide certification. “OPC Certified” can only be displayed on the product when the product passes the test.

OPC is presently used in the power industry at large, for communication of DCS with a third party system such as PLC /PADO or between DCS of SG-TG package & DCS of Station C&I package. However, OPC also has been used for direct communications with the PLC or DCS, thereby substituting the HMI server of the DCS/PLC. Thus, OPC as a true DCS/PLC API has more potential than only for data exchange, which can be achieved by other protocols like MODBUS.

Exploring the full use of the OPC standard can result in one single HMI acting as OPC client interfacing to multiple OPC servers of different DCS of multiple packages.

7.0 CONFIGURATION SCENARIOS OF UNIFORM HMI WITH OPC:

The above concept as basis of achieving uniform HMI gives rise to various configuration scenarios as described below;

a) BOP C&I HMI connected to HMI of boiler/turbine through OPC link & acting as unified HMI for whole of main plant. The operation of the unified HMI will be through the native HMI of the boiler/turbine for boiler/turbine controls. Native HMI operation acts as a backup to unified HMI & is intended to be located room adjacent to control room, (typically programmer’s room) just like backup push buttons kept adjacent to control room.

b) HMI of boiler/turbine connecting to HMI of BOP C&I through OPC ink & acting as unified HMI for whole of main plant. Here, the operation of the unified HMI will be through the native HMI of BOP C&I system for BOP C&I drives. Similarly, here also, native HMI acts as backup.

c) HMI of boiler/turbine control system getting replaced by an OPC server of that control system and the HMI of BOP C&I acting as an OPC client.

d) HMI of BOP C&I getting replaced by an OPC server of that control system and the HMI of boiler/turbine controls acting as an OPC client.

e) HMI of all the systems getting replaced by OPC servers of their respective control system & a different HMI acting as OPC client for unification of HMI. Typically, this will be included in a separate HMI package.

Each of the above scenarios depend on the capabilities & readiness of the OPC servers of the DCS of the above systems. For example, recently there was news about a generic OPC server establishing connectivity to a turbine control system making possible operation of turbine controls without going through the native HMI of the turbine control system.

Operating through a native HMI of other control system is expected to be slow when compared to operating directly from an OPC server, because of the two step communication. But this has the obvious advantage of not disturbing the existing HMI setup as the OPC HMI client is one level above the system bus of the native DCS. Further, commissioning can be done through the native HMI, thereby reducing risk of any teething problems in OPC connectivity hampering the commissioning activities.

On the other hand, if a direct OPC server interfacing with a control system, is developed & is proven through testing & established working, nothing can be a better alternative. Integration of PLC & DCS through a unified HMI has been attempted successfully using this concept & as such scenarios at c, d, & e should be attempted as the end target. Scenario a) & b) can be the intermediate stages of the uniform HMI path.

8.0 OTHER TECHNOLOGY OPTIONS

Other options for enabling interconnectivity between systems with the aim of unified HMI is Modbus. The TCP variant is very popular; but Modbus is basically a communication protocol among industrial devices whereas OPC is an API with standardized interfaces. One more option available with all DCS vendors is the proprietary gateway to third party systems, mostly PLCs. However, connectivity established with other systems varies from DCS to DCS & is never complete. Nevertheless, this option can be employed when the systems to be interfaced are known to have connectivity.

9.0 ISSUES IN ADOPTION:

One of the foremost issues confronting the implementation of this concept is the lack of incentive for the tremendous development efforts required on the part of the DCS vendor in developing interfaces which enable operation from another HMI. Suppliers of standalone HMI packages & also suppliers of OPC servers do find lot of opportunities in this kind of concept. Just like a loop tuning software sells on the number of controller makes & models the software is able to interface, generic OPC servers also thrive to connect as many DCS/PLC/Microcontrollers as possible for their success. However, the same very spirit is not reciprocated by DCS vendors due to fear of "losing out" to a third party HMI. Moreover, this segment is not the core expertise area of DCS vendors & hence hampers progress in this direction.

Another important criterion which becomes important for the adoption of this concept is guarantee from the DCS vendor. In case of an independent HMI, there is a chance of responsibility getting diluted & the issue of guarantees, which will include response times & command update time, needs to be addressed.

The need for factory testing cannot be undermined for the validation of the connectivity & functionality decided at design stage. But this needs to be carried out at an early stage of the contract as the success or failure of the configuration scenarios may decide the final BOM. This can at best be an experiment to which the concerned parties jointly agree, & cannot be a contractual requirement. For the later case, certification similar to OPC certification facilitated through interoperability workshops will be required and such certification will require a broader framework than a end user organization level.

At the end, a SWOT analysis of OPC as an enabler for uniform HMI is presented below:

STRENGTHS	WEAKNESSES
• Benefit of standardized interfaces • Designed for communication between software products from different manufacturers; as such best suited to the mission	• Current specs based on DCOM which is known to eat away bandwidth
OPPORTUNITIES	**THREATS**
• OPC UA standard is not based on DCOM & has redundancy included in specifications • OPC UA encompasses DA & A&E in one standard. As such, suited to the application which is a combination of analog & binary transfer	• Guarantees from DCS/Main plant OEMS • Drive on the part of DCS vendors

Table 1: SWOT analysis of OPC solution to Unified HMI

10.0 CONCLUSION:

Given today's technological options available, it is possible to realize the dream of unified HMI for a power plant comprising of multiple DCS platforms, off shooting from the packaging philosophy, without changing the latter. What is needed is support from the DCS vendors, especially the control system suppliers of power plant equipment OEMs, to rise to the occasion & chart a road map for achieving this goal, common to all end users. Some of the DCS vendors have already gone ahead in this direction & there are many instances of operation from a third party HMI.

Independent organizations like the OPC foundation will have to play a big role in this endeavor. Eg, Facilitating interoperability workshops, is considered very important & is a key enabler for the validation of the uniform HMI functionalities in various scenarios & checking the parametric requirements of the interfaces developed.

Finally, more assertive participation from the end users are required in demanding such solutions from the DCS vendors. Knowledge is the key to such solutions, which all end users must realize & informing the basis of such requirements along with the approximate framework helps. The above framework can transform the concept of uniform HMI into a near possibility.

11.0 ACKNOWLEDGEMENTS:

The authors are grateful to Mrs. Arundhati Bhattacharya, AGM & HOD (PE-C&I) NTPC Ltd. for reviewing this paper and providing constant encouragement on the study of this subject. Special thanks are also due to Mr. R.Sarangapani, Chief Design Engineer, NTPC for technical support and valuable inputs for the preparation of this paper. The authors also express their gratitude to ISA, Delhi section for providing an opportunity to express issues of concern from the end user perspective in the POWID INDIA conference.

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Electrostatic Discharge on a Large Steam Turbine Generator

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Mark Snyder | Bently Nevada Sales Engineer | GE Energy

Electrical or mechanical characteristics can induce an electrical potential (voltage) on the rotors of some rotating machines. If this voltage is not managed, or if the voltage mitigation system (often a shaft-grounding brush) fails to operate properly through lack of maintenance, the voltage seeks an alternate path to ground. That path will be the metal component—typically a bearing or seal—closest to the shaft. The electric arcing to that component as this voltage is discharged is termed electrostatic discharge. Arcing erodes metal surfaces and opens the tight clearances that these components depend upon for proper operation. If undetected, electrostatic discharge will gradually destroy the bearing or seal, change the rotor dynamics of the machine, and may ultimately result in damage to the shaft that requires expensive rework.

Properly maintaining and inspecting the voltage mitigation system and monitoring the rotor dynamics of the machine with a highly sophisticated machinery condition monitoring system can help avoid this problem.

Fluid-Film Bearing Machines

In an operating steam turbine generator (STG), there are at least three possible sources of voltage between the shaft and ground:

1. Electromagnetic loop voltage due to asymmetries in the generator magnetic paths may create an electric potential between opposite ends of the generator shaft.
2. Static charges may build up from droplets of water being thrown off blades in wet stages of the turbine.
3. A capacitive voltage due to a ripple on the DC field voltage may result in a voltage from shaft to ground.

Manufacturers take these voltages into account when they design their machines. The bearing at one end of a generator is normally insulated to create an open circuit and prevent electromagnetic loop voltage (this is why special care must be taken to ensure the insulating properties are maintained whenever instrumentation is installed in insulated bearings). Voltages between the shaft and ground, due to a static charge or DC voltage ripple, can be mitigated by the installation of grounding brushes that ride on the shaft near the un-insulated generator bearing. The brushes keep the shaft-to ground voltage at a safe level by bleeding off current and causing the weak source voltage to decay.

Rolling-Element Bearing Machines

Industry observers suspect that similar mechanisms are behind a rise in rolling-element bearing failures in motors controlled by adjustable-speed drives [1]. These drives simulate three-phase power by creating a series of voltage pulses that only approximate the smooth sinusoidal waveform of each phase. Since the roughness of the "pulse width modulated" waveform prevents them from adding vectorially to zero at every given instant, a "common mode voltage" relative to ground is created. This common mode voltage can generate bearing currents in at least three possible ways:

1. The air gap between rotor and stator acts like a capacitor that periodically discharges when bearing components contact. This is believed to be the major cause of bearing damage.
2. Another phenomenon causes current to flow when the effective bearing impedance is very low, and the bearings become the path to ground for parasitic winding capacitances.
3. An inductive effect causes a current to circulate through the bearings, shaft, and stator enclosure when the impedance of this circuit is low. Mitigation techniques for these situations

either block bearing currents or provide a low-impedance path to ground. These techniques include shaft-grounding brushes, bearing insulation, ceramic rolling elements or conductive grease, a Faraday shield, and dual-bridge inverters that balance the excitation of the motor.

Failure Mechanisms

Occasionally, insulation or grounding brushes wear out or become ineffective, resulting in a large current flow through the bearings. In fluid-film bearings, this can lead to electrostatic discharge through the oil film, resulting in the melting of a tiny area of the Babbitt metal. Continued discharges over a period of time can lead to pitting erosion, visible as a frosted appearance of the bearing surface, and ultimately a wiped bearing. If the problem goes undetected long enough, the shaft surface at the bearing may become pitted to the extent that surface repair is required. This results in a significant machine outage to remove and repair the shaft. In some cases, the shaft also requires degaussing to remove a high level of residual magnetism.

A similar pitting occurs in rolling element bearings. In the early stages, the bearing race exhibits a satiny finish that is evenly distributed. In advanced stages, evenly spaced deep flutings appear on the outer bearing race. The fluting is especially distinct when the motor runs at a constant speed.

Detection

In fluid-film bearings, electrostatic discharge results in erosion of the bearing and is observable by changes in the bearing clearance. For machines instrumented with proximity probes, this can be monitored via the probe gap voltages; as the bearing clearance opens, gap voltage will change. Therefore, the following are recommended practices for monitoring:

- Enable gap alarming on machinery monitoring system. This is typically available on numerous monitoring modules of a sophisticated machinery monitoring system available in the industry today.
- Regularly review shaft centerline plots and gap voltage trends using advanced diagnostic and trending tools.

A June 1995 ORBIT article [2] provides additional information about trending gap voltage and using average shaft centerline plots.

Some machines have voltage and current measuring instrumentation in the grounding brush circuits that will alarm on a high level of either parameter, and this instrumentation is typically provided by the Original Equipment Manufacturer (OEM) with the machine’s control system. Both the voltage mitigation system and its associated instrumentation should be checked regularly.

For rolling element bearings, seismic transducers can be used to trend bearing vibration levels. In the advanced stages of pitting on the outer race, higher vibration levels can be detected. However, electrostatic discharge can be difficult to differentiate from other rolling element bearing problems based solely on examination of the vibration signals. Typically, visual inspection of the bearing is required after failure to positively confirm the root cause.

Historical Perspectives

One of the earliest complete references to this specific malfunction was an ASME paper [3] by two General Electric engineers: J.M. Gruber, and E.F. Hansen. Gruber and Hansen dealt primarily with large turbine generator sets, and they addressed the destructive effects of shaft voltages upon bearings. Categorically, they identified five distinct types of shaft voltages:

1. The electromagnetic or 60-cycle ac voltage.

2. The ground detector 120-cycle ac voltage.
3. The ignitron excitation voltage.
4. The high-frequency exciter ripple voltage.
5. The electrostatic dc voltage.

In their review of these categories they went into considerable detail on electrostatic voltage where they stated:

The electrostatic shaft voltage has been found to have several reasonably well-pronounced characteristics as follows:

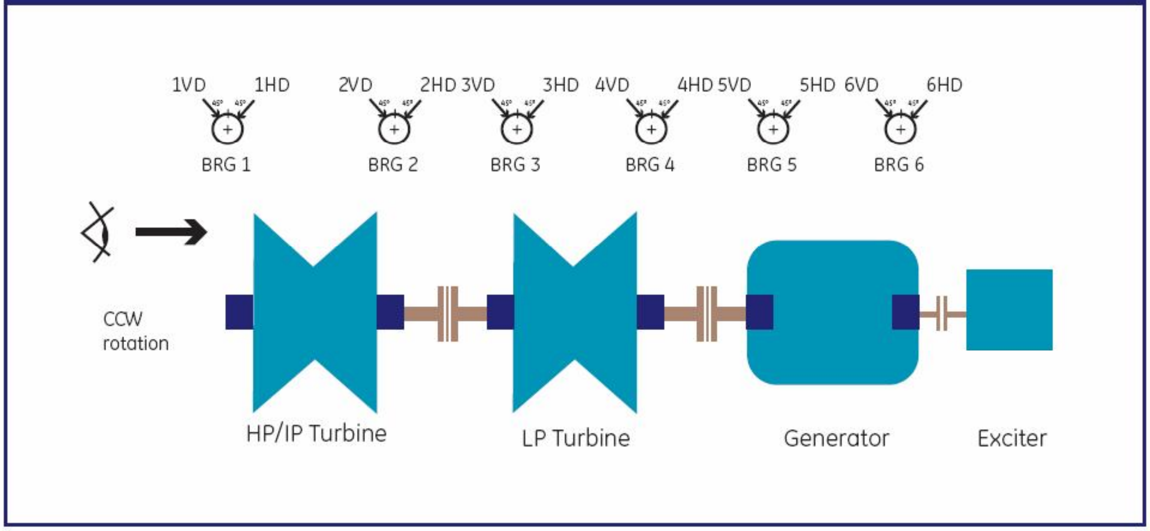
- *The voltage between shaft and bedplate is direct current. This means that the polarity does not reverse periodically.*
- *The magnitude is not usually constant and in some cases falls repeatedly to low values after which it climbs back up to higher values. This means that the voltage contains both a-c and d-c components even though the polarity does not reverse.*
- *The maximum magnitude observed by oscilloscope was about 250 volts peak.*
- *The rate of rise of shaft voltage was often in the range of 200 volts per 1/60 sec. or 12,000 volts per second.*
- *The voltage decay when falling to zero is less than 0.1 millisecond*
- *The minimum magnitude observed was a few tenths of a volt.*
- *Typical magnitudes were between 30 and 100 volts peak value.*
- *The shaft polarity was positive on many turbines and negative on fewer turbines.*
- *The potential at any instant is essentially the same anywhere along the turbine or generator shaft. The shaft voltage appears between shaft and bedplate, which is grounded.*
- *The maximum current observed in a resistance circuit connected between shaft and ground, regardless of how small the magnitude of resistance, was approximately 1 milliamp.*

Sound engineering conclusions are timeless. This technical summary by Gruber and Hansen is as applicable now as it was in 1959. Certainly this list could be modified to reflect some different measurements, or different machines, but the fundamental concepts, descriptions, and characterizations of the phenomena are still the same. It is comforting to note that physical principles remain constant, and that our understanding of many of these physical principles has a tendency to grow with improved technology, measurements, and communication.

Case History

A 340 MW Steam Turbine Generator (Figure 1) tripped twice within two weeks due to intermittent high vibration on the generator outboard bearing (bearing 6). Unfortunately, there was no online vibration monitoring system to provide data that would have enabled straightforward diagnosis and identification of root cause. As such, investigation done by mechanical and instrument teams after the trips did not yield any evidence of a problem, and the machine was restarted with the caveat from plant management that vibration data be obtained to further investigate the problem. The plant enlisted the services of one of GE’s Bently Nevada machinery diagnostic engineers to collect and interpret this data using a suitable data collection and analysis system.

Figure 1 - Machine train diagram.



The data collected on the machine train bearings at steady-state conditions revealed erratic and high overall vibration amplitudes on bearing 6; however, the filtered 1X vibration amplitude was fairly low and steady. Figure 2 shows the direct and filtered 1X vibration trends on bearing 6. Vibration trends recorded on all other bearings of the machine train showed some spiking (Figure 3), but to a lesser extent than on bearing 6. The spectrum waterfall plot on bearing 6 was also examined and found to be clear of any significant harmonic or sub-harmonic components other than a small amount of 2X (100 Hz) vibration as shown in Figure 4.

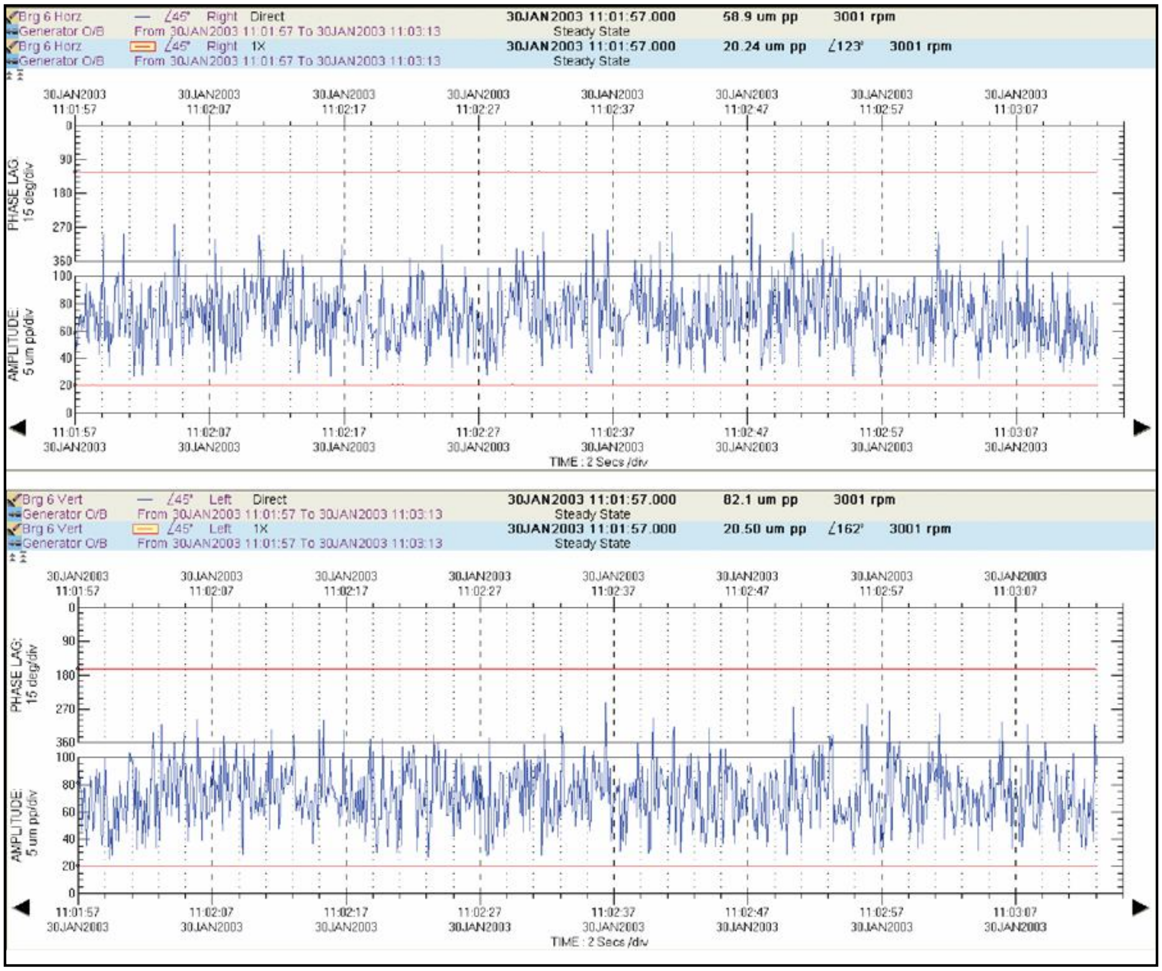


Figure 2 – Direct and 1X vibration trends on bearing 6 showing erratic behavior (top plot shows X probe, bottom plot shows Y probe).

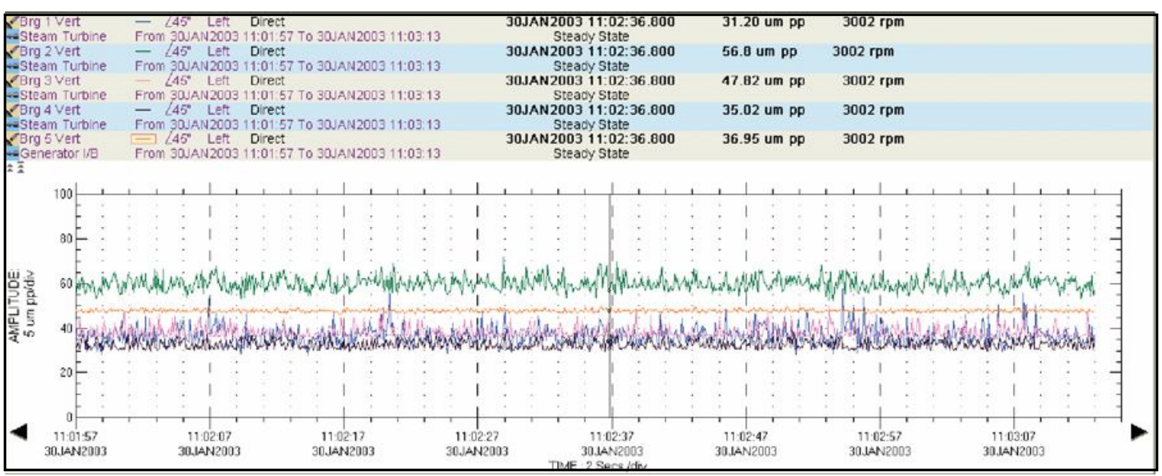


Figure 3 – Trend of overall vibration levels from Y probes on bearings 1-5 showing stable behavior.

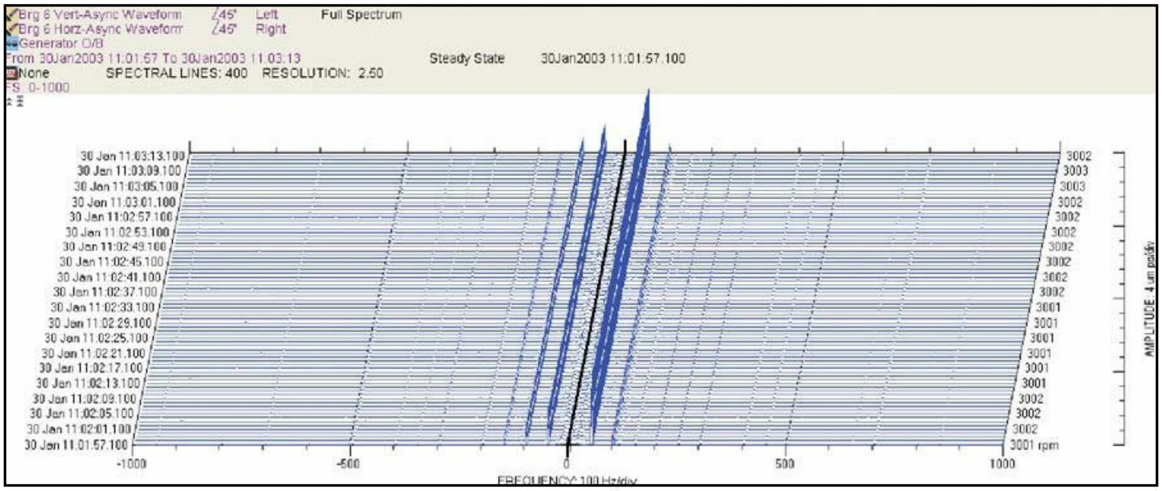


Figure 4 – Full-spectrum waterfall plot from bearing 6 showing predominantly 1X (50 Hz) vibration and small amount of 2X vibration (100 Hz), free from other harmonics or sub-harmonics.

None of these plots explained the presence of the erratic signals on bearing 6. However, the orbit/timebase plots shown in Figure 5 exhibited numerous spikes superimposed on the vibration signal. The spikes were non-repeatable and were randomly distributed in both positive and negative directions. They were also absent or considerably attenuated on some of the other probes along the machine. And, they were present on both X and Y probes at the particular bearing. This is a classical signature of electrostatic discharge induced in rotating machinery for the following reasons:

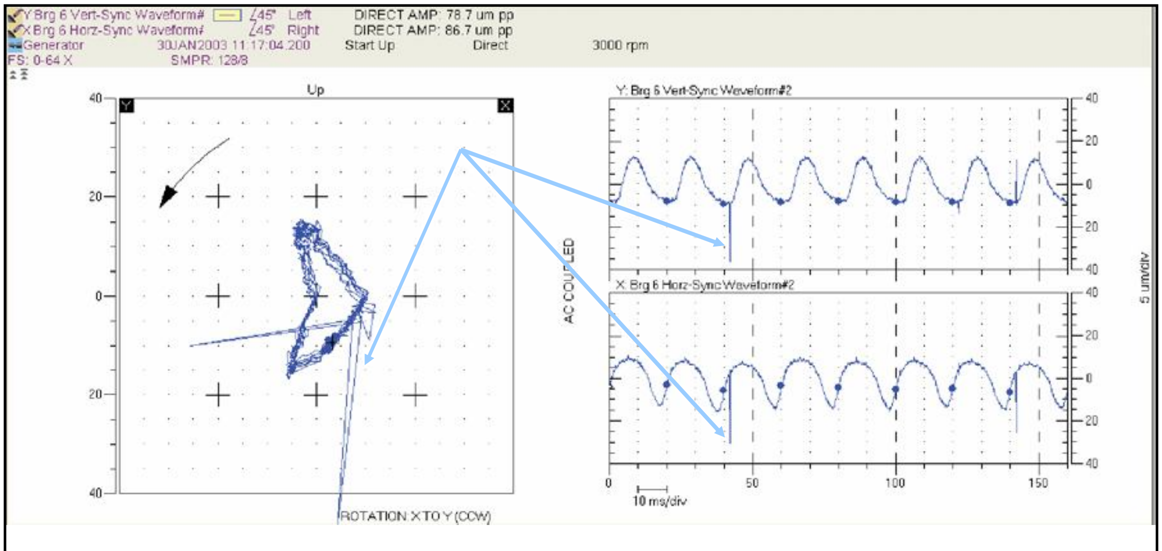
1. It is clearly impossible for the shaft to physically move that quickly and to such an extent as shown by the spikes, and then immediately resume its "normal" orbital path inside the bearing clearance.

2. The spiking is non-repeatable. If the spike were the result of a scratch on the shaft, it would be repeatable from one rotation to the next. It would also yield distinct spectral components since it is periodic in nature.

3. The spiking has both positive and negative excursions, again ruling out a scratch on the shaft (a scratch always results in an instantaneous increase in gap between the probe tip and shaft surface).

4. The electrostatic discharge will typically be on the order of several thousand volts when it arcs and is modeled by a mathematical impulse function. This function generates a broadband frequency spectrum, typically known as "white noise," some of which can be picked up by the coil in a proximity probe. The closer the probe is to the arcing, the more pronounced the observed spiking. As one would expect, the spiking is considerably more pronounced at the probes closest to the discharge location—in this case, bearing 6. It was also observed on both X and Y probes for bearing 6. If the spiking were due to a loose or intermittent wiring connection, it would only be observable on the affected probe (not both X and Y probes), and nowhere else along the machine train.

" CONFIDENT THAT ELECTROSTATIC DISCHARGE WAS THE CULPRIT, THE ROTOR GROUND SYSTEM WAS INSPECTED, INCLUDING A SPRING-LOADED GROUNDING BRUSH WIRED TO THE PLANT GROUND. TESTS SHOWED THAT ADDITIONAL SPRING FORCE WAS REQUIRED ON THE BRUSH TO MAINTAIN A PROPER GROUND."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X Brg 6 Horz-Sync Waveform# ∠45° Right
Generator 30JAN2003 11:17:04.200
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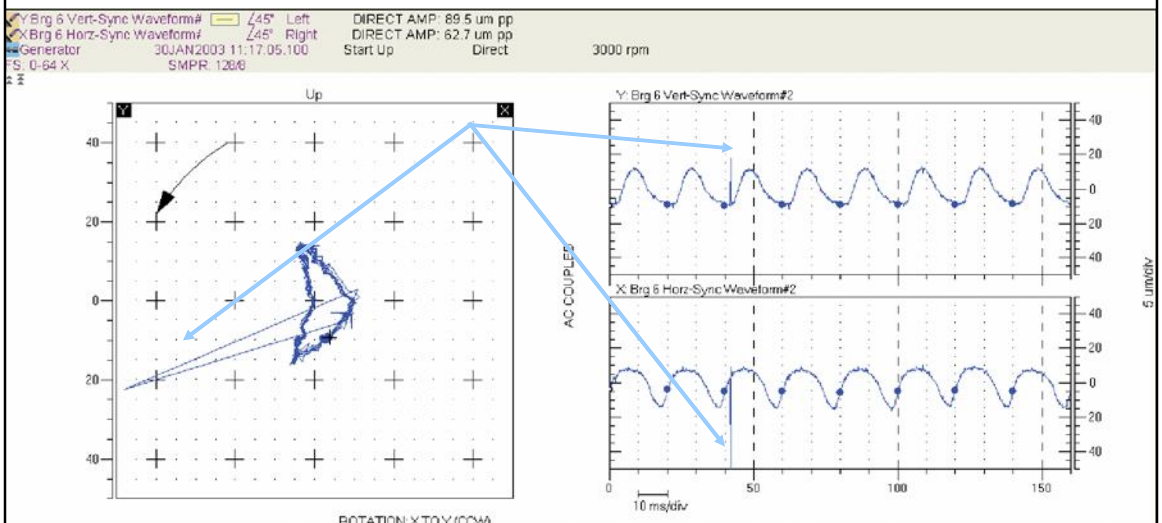
DIRECT AMP: 78.7 um pp
DIRECT AMP: 86.7 um pp
Start Up Direct
3000 rpm
Up
ROTATION: X TO Y (CCW)
Y: Brg 6 Vert-Sync Waveform#2
X: Brg 6 Horz-Sync Waveform#2
AC COUPLED
5 um/div
10 ms/div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DIRECT AMP: 89.5 um pp
DIRECT AMP: 62.7 um pp
Start Up Direct
3000 rpm
Up
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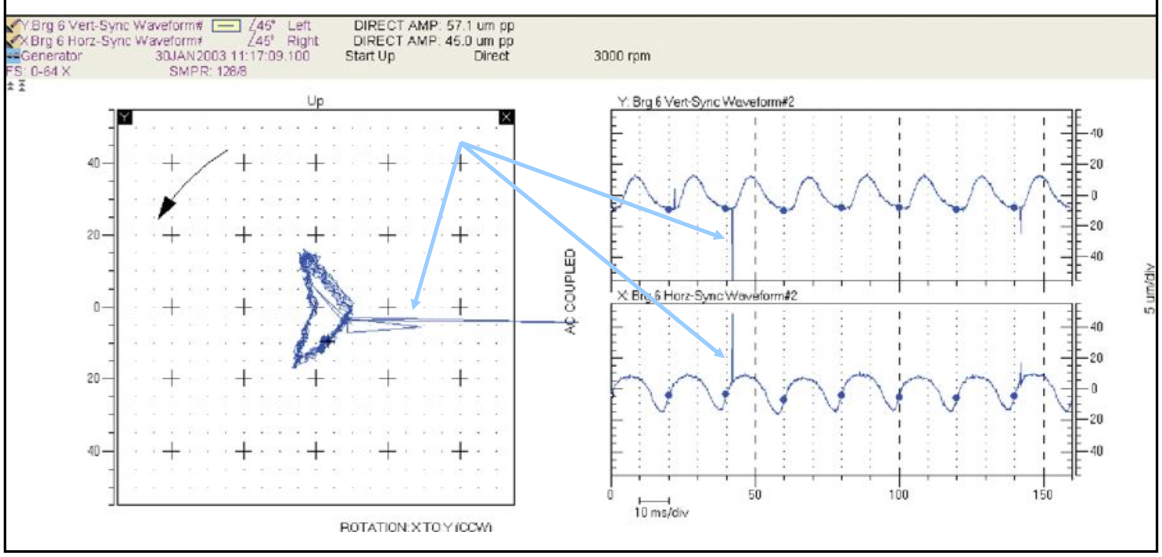
X: Brg 6 Horz-Sync Waveform#2
AC COUPLED
5 um/div
10 ms/div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DIRECT AMP: 45.0 um pp
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10 ms/div

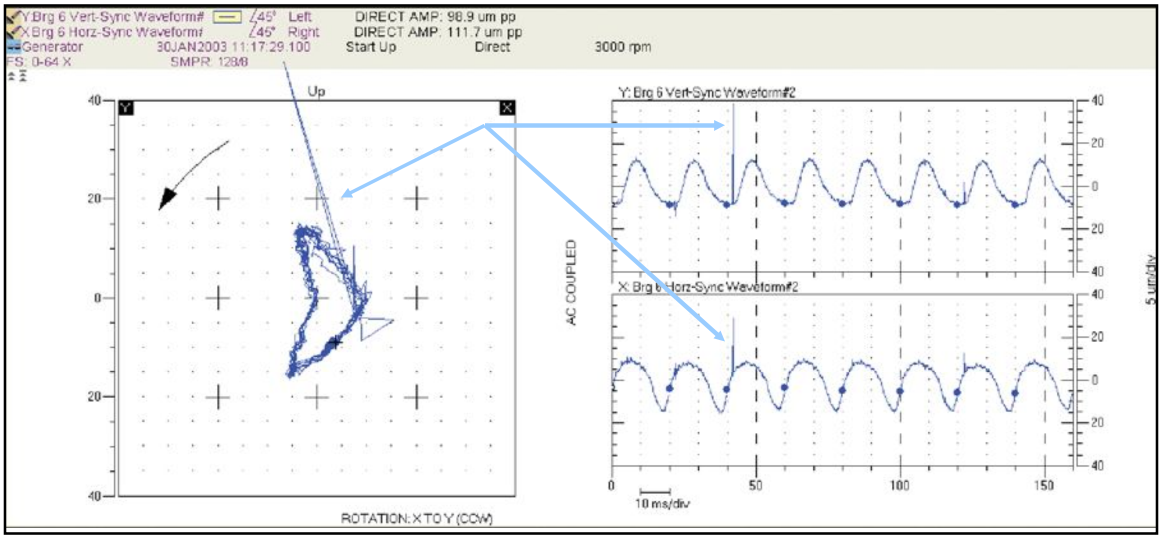

Figure 5 – Series of unfiltered orbit/timebase plots from bearing 6 showing random positive- and negative-going spikes due to electrostatic discharge.

Confident that electrostatic discharge was the culprit, the rotor ground system was inspected, including a spring-loaded grounding brush wired to the plant ground. Several tests were conducted while the machine was running, one of which included adding additional spring force to the grounding brushes and trending the vibration with and without this additional spring force present. Figure 6 shows the result, clearly indicating that additional spring force on the brushes provided the necessary path to ground to mitigate the electrostatic discharge problems.

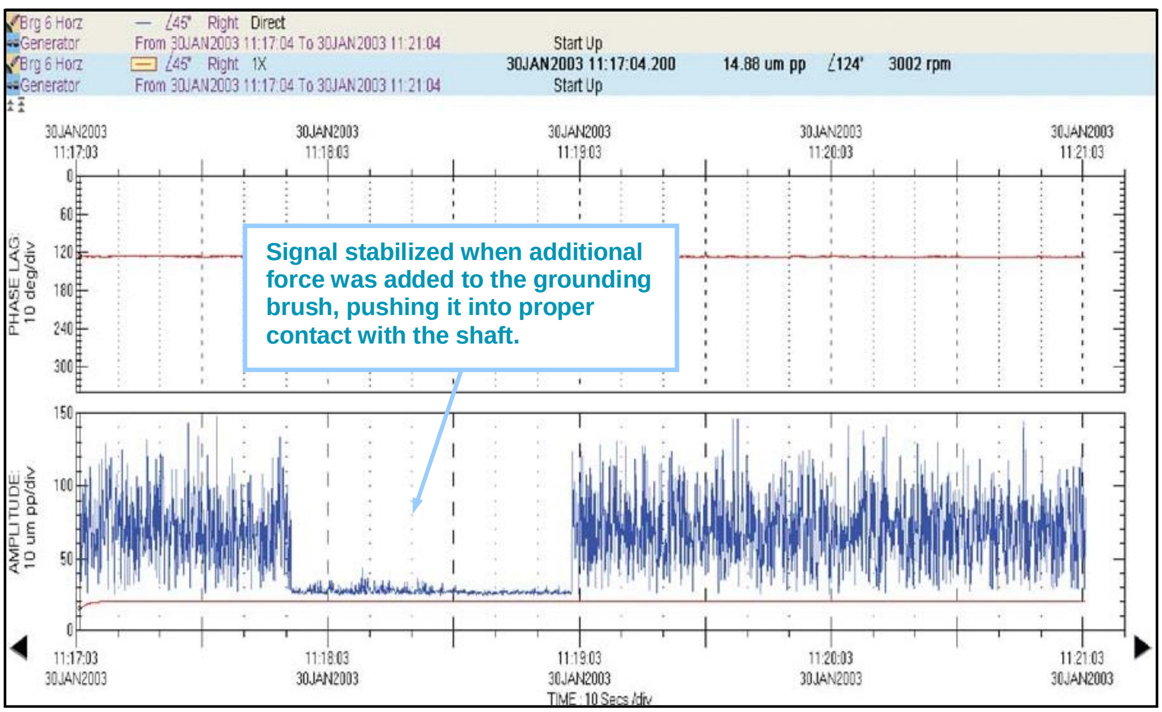

Figure 6 – Vibration trend showing effect of spring force on grounding brush.

Summary

Electrostatic discharge causes bearing and machine damage when electrical currents pass through bearing areas on their way from shaft to ground, or as they circulate through rotating and stationary components. This malfunction often goes undiagnosed because of its subtle symptoms and gradual effects, and because it is an electrical phenomenon that manifests itself as mechanical damage. Even non-electrical machines, such as turbines and gearboxes, are susceptible because rotating motion can induce voltage on the shaft without the presence of a generator. Although proper maintenance of brushes and insulators is the first line of defense, failures can occur between maintenance intervals and inspections. Ideally, instrumentation that directly measures voltage and current in the voltage mitigation system will be available. However, when it is not, a properly configured vibration monitoring system can also detect electrostatic discharge and allow timely intervention before bearing, shaft, or seal damage occurs.

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POWER PLANT AUTOMATION PROJECT MANAGEMENT - CHALLENGES & OPPORTUNITIES

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KEYWORDS

Automation Package, Standardization, Knowledge Capture, Project Management

ABSTRACT

The experienced Indian Utilities see significant value in procurement of Automation Systems directly from the Automation Vendors. What started as a classical Control Panel and associated Field Measurement Package has, over the time, grown in scope to include a wide assortment of systems and devices for measurement, monitoring, control, display, surveillance, communication, power conditioning, integration, calibration and accessories thereof to create a distinctive integrated solution.

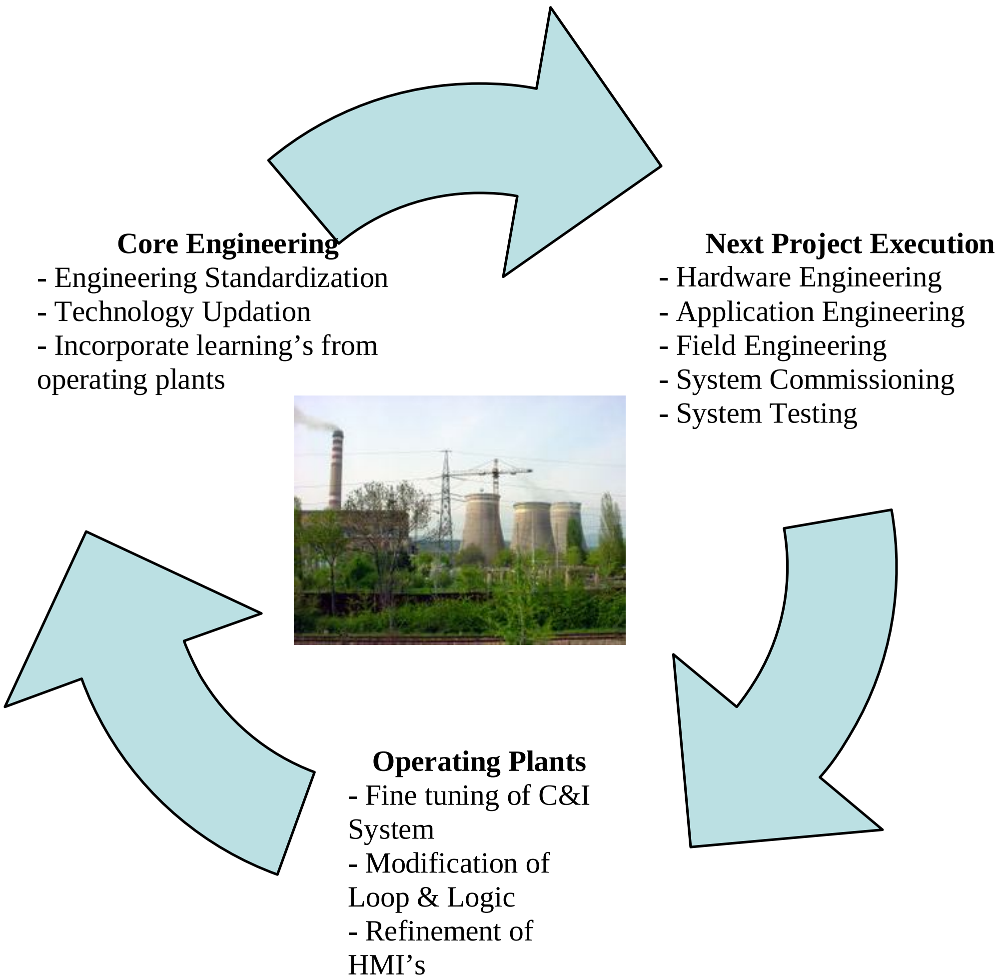
While the foot print of automation in power plants is getting broader, the Third Party procurement component is growing steadily for the Automation Vendor. The project timelines are shrinking rapidly. As a consequence, the performance bar is getting raised continuously for the Automation Vendors.

This paper examines the unique characteristics of a modern day Automation Project in the context of changing Power Plant market in India. The salient practices of Project Management disciple that make a significant impact on the project outcome, by addressing the challenges and leveraging the opportunities, are highlighted.

1.0 WHY SEPARATE AUTOMATION PACKAGE?

Many Indian Utilities – both in public and private sector, who have long been in the power generation business, see significant value in procurement of Automation Systems directly from the Automation Vendors for their green field projects. For power plants and other large operations, more than ever before it, has become imperative to standardize their operation and maintenance practices across the fleet in order to meet global performance benchmarks. One of the key facilitators of this standardization is Control and Automation.

The diagram below depicts key activities in different spheres of the organization for continuous improvement of performance of the plant automation systems.



The central key to continuous learning is capture of knowledge and deep insight in to loop and logic required for safe, uninterrupted and efficient performance of the plant on sustained basis both at system and equipment levels.

A separate automation package facilitates continuous improvement of performance of the plant automation system in the following ways:

- Elimination of “black boxes” for control from plant OEM’s
- Greater understanding of “loop and logic” requirements during project execution
- Freedom of choice – automation technology and measuring devices
- Consistent engineering and documentation
- Better documentation of “loop and logic”

2.0 DEMANDING SCOPE OF WORK

The automation package, which started as a classical combination of Control Panel and associated Field Measurement has, over the time, grown in scope to include a wide assortment of systems and devices for measurement, monitoring, control, display, surveillance, communication, power conditioning, integration, calibration and accessories thereof to create a distinctive integrated solution.

The table below is indicative of typical scope of work in contemporary automation package.

S. No.	Item	Remark
1	Distributed Control System for Power Islands	Typically BOP
2	Burner Management System	Exceptionally
3	Turbine control	Rarely
4	Automation of Offsite & Utilities	Exceptionally
5	Field transmitters & sensors	
6	Analyzers – steam/ water/ flue gas	
7	Vibration Monitoring System	Outside Purchase
8	CCTV system	Outside Purchase
9	Power conditioning system – UPS/ DC supplies & batteries	Outside Purchase
10	Trunk Cables	Exceptionally
11	Instrument erection hardware	Outside Purchase
12	Video walls	Outside Purchase
13	Control desk, control panels and control room furniture	Outside Purchase
14	Control valves, actuators and flow elements	Rarely
15	Intra plant communication system	Exceptionally
16	Test & Calibration equipment	Outside Purchase
17	Plant Information System	Exceptionally
18	Plant Optimization System	Rarely
19	Operator Training Simulator	Rarely
20	Master clock system	Outside Purchase

The Indian utility industry has shown a pronounced tendency to include in the automation package any new electronic and/ or microprocessor based systems required for a project, especially where such systems are to be integrated with and/ or connected to the automation system. Thus, the package content grows in to an assortment of dis-similar control, measurement and mechanical/ electrical/ electronic devices and systems

3.0 SHRINKING TIMELINES

Large utility projects have always been capital intensive and with long gestation periods. Until late 1980's, overall project schedules were as long as (60) months. Since the 90's, the overall schedules started shrinking, and today Project Developers want to fast-track their projects at all times.

As a result, present-day overall project schedule are no longer than (36) months, typically. Shorter time periods are not unheard of. Equipment delivery has become decisive in vendor selection, and fast-tracking strategies are central to the long range planning of major utilities that are in capacity addition mode in a big way. Strategic alliances with major plant OEM's and key technology suppliers is not an uncommon practice embraced by some of such utilities both in Government and Private sector.

The direct implications of the foregoing for the Automation Vendor are:

- Shortened duration for Front End Engineering and Design (FEED) for the responsible agency
- Reduced period for Design and Basic Engineering for Automation Vendor
- Shorter delivery of equipment
- Fast tracking of Outside Purchase items

4.0 UNIQUE CHARACTER

The automation project as described above becomes unique on several counts. The salient, unique characters of a modern-day automation project are:

- High level of customization
- Integrated solution
- Engineering intensive
- OEM and Customer data driven engineering
- Multi-disciplinary engineering
- High Outside Purchase content
- Large field engineering content
- Construction phase highly inter-dependant on Others

As a result, management of automation project (separate automation package) throws up unique challenges and issues for the key stake holders in the overall project.

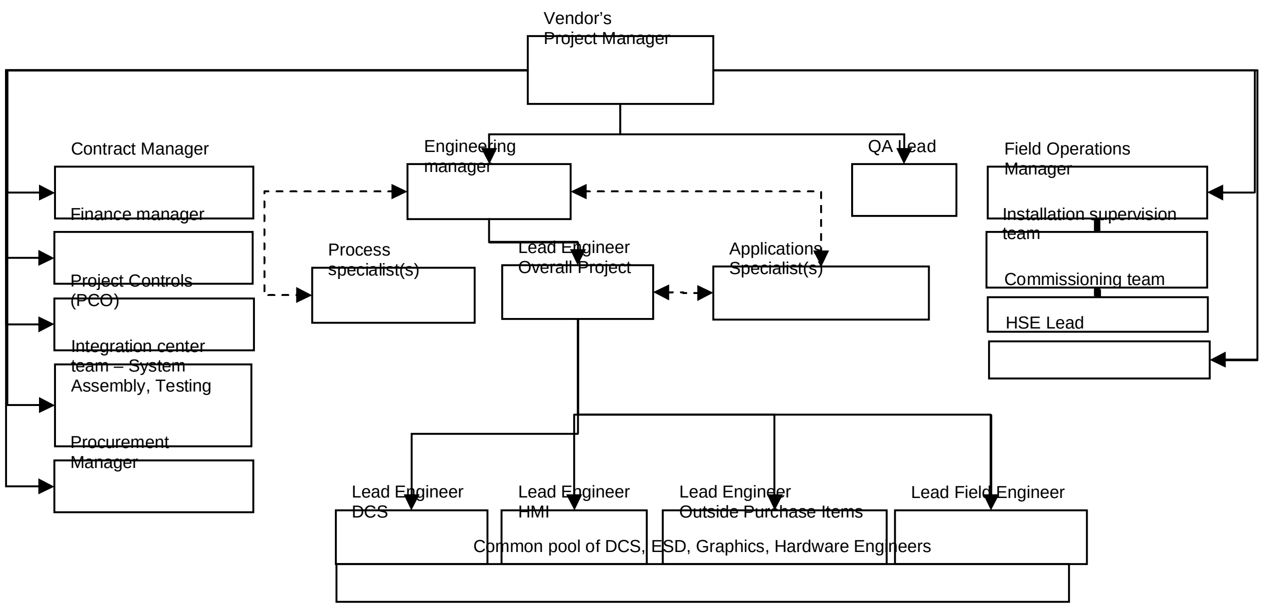
5.0 PROJECT MANAGEMENT PROCESSES

Management of Automation Projects in the context of Indian Utility industry as articulated earlier in this paper require adoption of some of the unique Project Management practices. The following paragraphs describe some of the key elements of Management of Automation Project.

Project Organization:

To deal with the complexities of a modern-day automation package, a multi-disciplinary project team is required. The team is lead by a set of dedicated resources for project management and engineering. The key tasks performed by the team are:

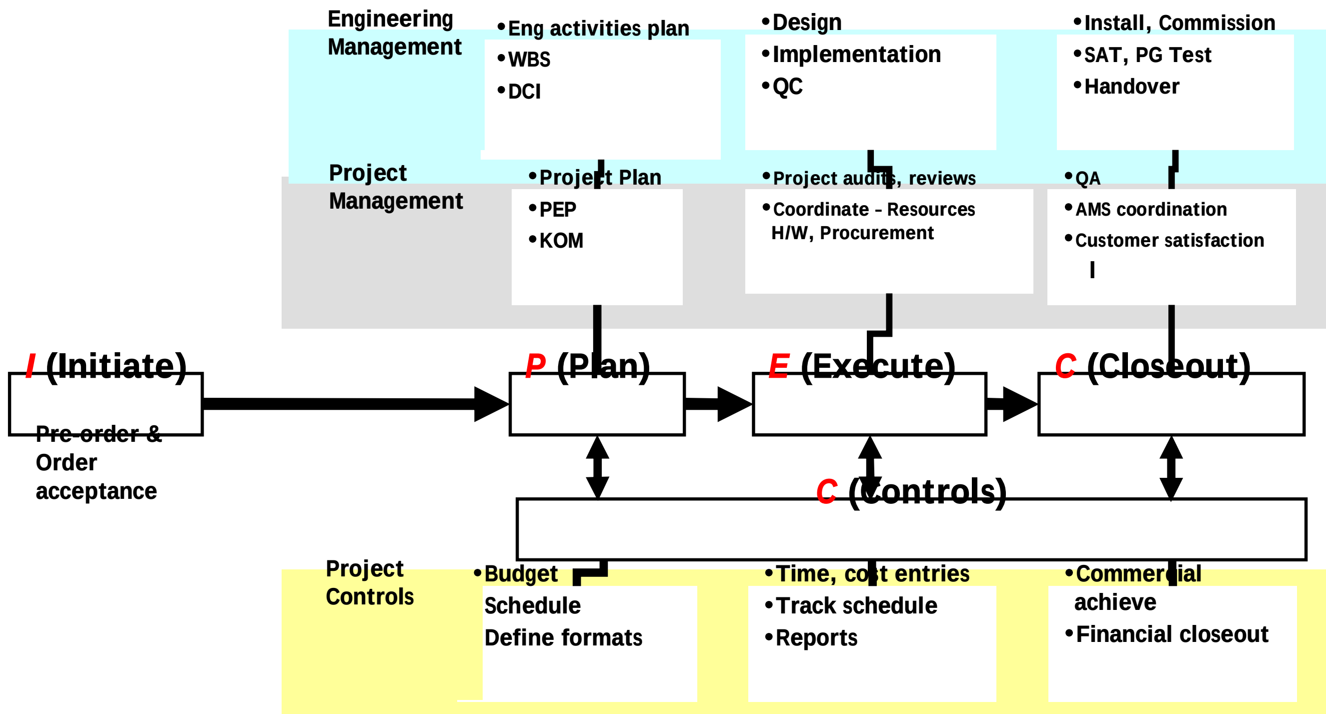
- Analysis of Customer Requirements
- Aligning organizations standard operations processes and systems for project delivery as per the contract
- Project communication – External and Internal
- Coordination with internal service/ function groups – factory/ procurement/ finance
- Management of Customer Inputs
- Facilitate Customer Review and Approval of the Project Deliverables



The general methodology of Project Management for the automation project is depicted in the figure below. Some of the key areas of project management requiring special attention are:

- Project scope management
- Project communication management
- Project procurement management
- Project risk management
- Project human resource management
- Project integration management

IPECC concept: I(Initiate) P(Plan) E(Execute) C(Control)



The constant focus of project management has to be custom elements of the integrated solution and alignment with Customer processes and systems.

6.0 THE FUTURE?

As new power generation capacity addition gathers pace in India, the direct engagement of Automation Vendors by Utilities will evolve further to meet with the emerging challenges of the fast growing generation industry. The future scenario may include the following:

- On technological side, unified automation architecture covering the entire power islands and common plants
- Alliances with automation technology solution providers
- Early selection of automation vendor
- Structured and systematic engagement of automation vendor in FEED phase of the project
- Risk sharing between Utility and automation partner

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GLOSSARY OF TERMS:-

PM – Project Management
FEED - Front End Engineering and Design

CONTINUOUS TOTAL MERCURY EMISSION MONITORING SYSTEMS

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KEYWORDS

CEMS, CMM, Total Mercury (HgT), Clean Air Mercury Rule (CAMR), Coal, Fossil Fuel Emissions

ABSTRACT

Launched in 2005, the Thermo Scientific Mercury Freedom™ System was designed to meet the strict guidelines of the Clean Air Mercury Rule (CAMR). This legislation, passed in 2005, required most US coal fired power generation plants to continuously monitor their Total Mercury (HgT) gaseous emissions. The rule also stipulated that the monitoring systems must be in place by January 1, 2009.

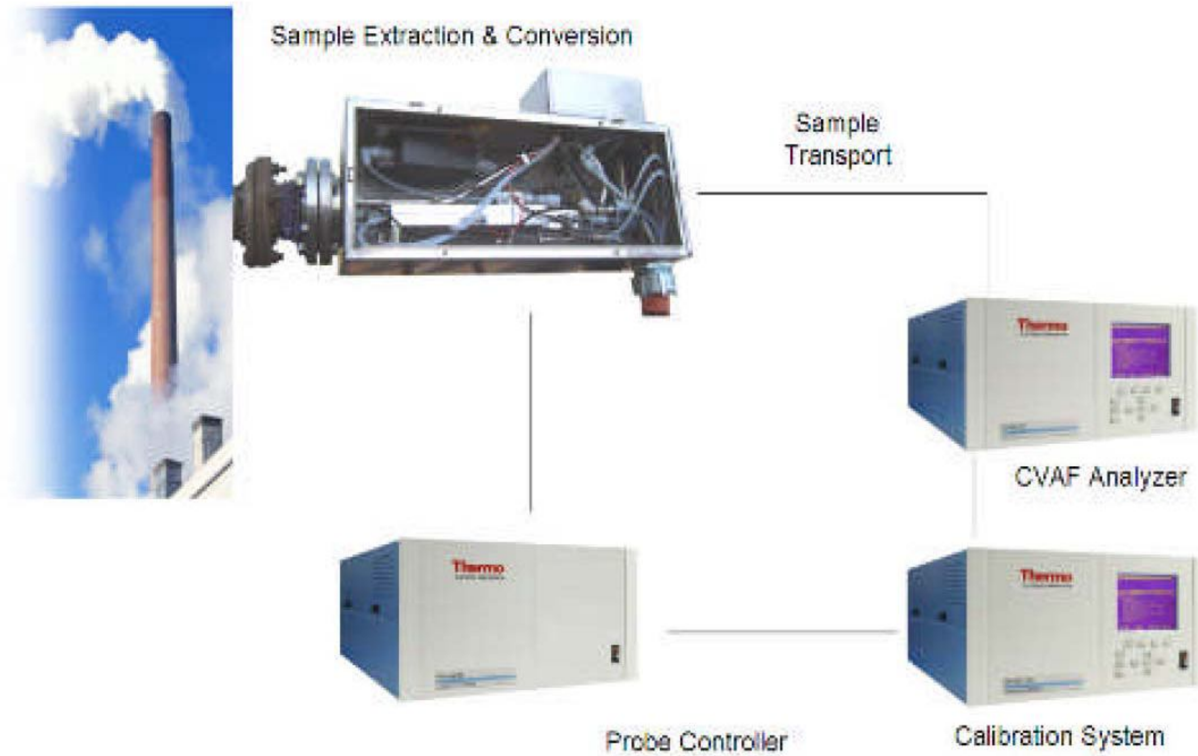
In order to allow end users to achieve compliance easily, a key feature incorporated in the CMM system design was simplicity. This required integrating a complex technology into a package that was easy to operate and in a layout that was consistent with existing continuous emissions monitoring systems (CEMS). The result was the Mercury Freedom System, the only commercial real-time mercury fluorescence CEMS.

The recent directive by the Ministry of Mining in India to greatly enhance the mining of coal to support the use of coal for power generation through the use of various technologies may make it necessary to monitor this hazard to the environment in India as well. This paper presents a simple break-down of available technology and systems to allow the monitoring of hazardous Mercury levels in the environment.

1.0 INTRODUCTION

Thermo Fisher Scientific is the market leader in CMM systems sold, with more than 450 systems shipped (Corvese, 2009). Figure 1 shows how the CMM is configured. The key components are the Sample Extraction & Conversion system with the Probe Controller, the Analyzer, and the Calibrator.

Figure 1 ThermoFisher Instruments Mercury Freedom System (Corvese, 2009)



2.0 Sample Extraction and Converter

Flue gas is sampled from the stack by the probe and is typically diluted at a 40:1 ratio with air. Within the probe is a converter that converts oxidized mercury, which is mostly in the form of $HgCl2$, to elemental mercury. Therefore, all of the mercury sent into the lines to the analyzer is in the form of elemental mercury. This makes the sample somewhat easier to transport and also puts the mercury in a form that the analyzer is capable of measuring, as the analyzer only measures elemental mercury. The sample line must be heated to 120^{o}C (248^{o}F) in order to ensure that sample integrity is preserved. The probe also provides the means to convert elemental Hg gas from the calibrator to oxidized mercury for the purpose of system integrity checks.

3.0 Probe Controller

The Probe Controller sends signals to the probe that control the oxidized Hg to elemental Hg converter and the elemental Hg to oxidized Hg converter, nitrogen supply and other functions performed within the probe. It also controls probe and sample line temperature.

4.0 CVAF Analyzer

Within the analyzer the sample is continuously measured using Cold Vapor Atomic Fluorescence (CVAF). In CVAF, free mercury atoms (elemental mercury) in a carrier gas are excited by an ultraviolet light source. The excited mercury atoms re-radiate their absorbed energy (fluoresce). The fluorescence intensity is related to the amount of mercury present. The technique is sensitive, selective, and linear over a wide range of concentrations; however, molecular gases (such as oxygen) present in the carrier gas can quench the fluorescence signal, which reduces instrument sensitivity.

The analyzer provides a measure of total mercury and cannot speciate mercury on its own. In order to measure mercury speciation, it is necessary to take two measurements – one with the converter in the probe operating (for total mercury) and another with the converter bypassed and with $HgCl_2$ removed from the gas (to arrive at elemental Hg). The difference between the amount of total mercury and the amount of elemental mercury results in the amount of oxidized mercury.

The gas in the analyzer is maintained at a vacuum to suppress quenching and improve sensitivity. Sensitivity of the analyzer's CVAF measurement can be improved roughly five-fold by using nitrogen as the dilution gas in the probe rather than air because oxygen has a greater tendency to quench the atomic fluorescence than nitrogen. Therefore, for low concentration measurements, nitrogen dilution gas is recommended.

The analyzer has digital outputs for various data protocols. The advantage of digital output is that, with the high degree of linearity of the CVAF analysis method combined with digital output which covers a broad dynamic range, only one span measurement is needed.

5.0 Calibrator

Manufactured calibration gases are not available for mercury that meet the National Institute for Standards and Testing (NIST) requirements. To address the need for calibration gases without the availability of manufactured calibration gases, the instrument produces its own calibration gases. By carefully controlling a sample of Hg and gas to specific temperatures and pressures, it is possible to generate a gas stream with a mercury vapor pressure that is related to the temperature and pressure that the gas is being controlled to. In this manner it is possible to generate mercury calibration gas on site using the calibrator. During a calibration check, gas from the calibrator is sent through a tube up to the probe where it is sampled and then transported to the analyzer for analysis.

For system integrity checks it is necessary to also measure oxidized mercury to ensure that the oxidized to elemental converter in the probe is operating properly. Therefore it is necessary at the probe to oxidize the calibration gas to oxidized mercury and then send it to the probe tip where it is drawn through the probe and through the converter and to the analyzer. It is necessary to have a bottle of chlorine gas at the probe for this system integrity check because the chlorine is necessary to convert the elemental mercury vapor produced by the calibrator to oxidized mercury. The probe, of course, converts the oxidized mercury back to elemental mercury, which is then transported to the analyzer for measurement.

6.0 Features of the CMM system design

The Thermo Scientific Mercury Freedom CEM System uses cold vapor atomic fluorescence, and offers many similarities to existing NOx and SO2 CEMS.

Some of the more important features of the Mercury Freedom System include:

* Inertial Filter Sample Conditioning
* Dilution based measurement
* Conversion of oxidized mercury into elemental mercury at the Stack
* Direct Measurement via Cold Vapor Atomic Fluorescence
* High sensitivity
* True Real-time monitoring
* i-Series platform
* Measures either HgT or Hg0
* Analyzer Detection Limit: ~1 ng/m3 (~0.1 ppt)
* No cross interference with SO2
* No Wet chemistry methods are required

It has Patents Pending on:

* Combining aspects of NO chemiluminescence and SO2 fluorescence technologies
* Vacuum operation to achieve required detection limits
* High temperature total Hg converter which ‘cracks’ Hg+2 into Hg0
* Vacuum operation to reduce recombination reactions
* HgCl2 Generator, Integrated into probe assembly for ‘in-situ’ generation
* Using dry Hg and Cl2 to avoid transport issues

Issues and challenges in Renovation and Modernizations (R&M) of control and Instrumentation Systems

By N. K Srivastava AGM (R&M) / ENGG.

Introduction

Maximization of power generation at the least cost from the existing power generation station is the need of the hour. This requires the optimization of the O&M processes which will try to match the lower production cost of the giant units coming in India. The power engineers have to work hard and take measures against any deviation in this regard. Therefore, the Renovation and modernization of the plants are the ultimate solution for the above challenge.

R&M Strategies

The main issue of the running system is how to define the active life of the equipment or system. Till date the practice is to take the original equipment manufacturer's view. The R&M of Thermal power plants are allowed to be carried out after 25 years of start of operation as per the current CERC norms effective from 1st April 2009.
There are no first hand guidelines for C&I systems of active life. The original equipment manufacturers normally agree to supply the spare parts for 10 years.
Therefore, this is an issue to have a global uniform norm.
The major issues which necessitates the change of existing version to a newer version are as follows

- Ensuring a very high Plant Availability
- Improvement in plant efficiency
- Improved environment friendliness
- Improvement in Management Information System (MIS)
- Advantage of leveraging the new technologies
- Fast changing electronic technologies

In addition, we have to maintain the basic issues like Ensuring safety for Plant & Personnel and Convenience in Operation & maintenance.
Thus, prima-facie it was very difficult that C&I equipment can be maintained without renovation for 25 years.

R&M activities and future R&M projects in NTPC

Renovation and Modernization of the following C&I projects are being undertaken under NTPC own program or GOI Accelerated Power Development Reform Program. (APDRP)

Under Implementation

- 2X110 MW Talcher TPS
- 2X210 MW Badarpur Thermal Power Station.
- 2X110 MW Muzzafarpur TPS/ KBUNL
- 2X110 MW Barauni TPS /BSEB
- 2X500 MW Singrauli STPS
- 2X500 MW Korba STPS
- 663.6MW Auraiya GBCPP
- 656.26 MW Kawas GBCPP
- 2x110 MW Talcher FSSS pkg.
- Kawas Training Simulator Gas Turbines
- 6X210MW Remote Oil Firing for Vindhyachal STPS
- 2x500MW FSSS package for Rihand

Under Approval

- 5x200MW Singrauli STPS
- 3X200 MW Korba
- 3X200MW +3X 500MW Ramagundam STPS
- 4X210 MW NCTPP-Dadri TPS
- 4X210MW Kahalgaon STPS
- 200/500MW Training Simulator at Korba
- 840MW Dadri GBCPP
- 630MW Gandhar GBCPP

Obsolescence

The obsolescence of electronics is much less compared to a time span of 25 years the owner of the utility has to develop strategies to take care of the obsolesce for ensuring availability of the Power plant. Further with advanced technologies with smart and more accurate field instrumentations from the manufacturers, statutory requirements mainly from environmental norms also necessitates adoption of better and advances Control and Instrumentation systems

The guiding criteria for deciding obsolescence may be as follows.

-System is no longer commercially feasible to maintain.

Difficulty in maintaining the system due to reduced or non-availability of spares. Many a times the spare parts are not available from OEM and other manufacturers due to stoppage of production of the equipment. It has been observed that even if the spares are available they are repaired/serviced components. These spares are usually at a very high cost.

-Supplier is no longer capable of supporting the product technically
(Earlier systems were relay or solid state based)

Frequent failure/break down of the equipment or system of the equipment in due course of time takes place due to aging. Due to frequent failure of the component/equipment the whole system gets affected leading to non-availability of the system.

-Successor system is with more functions, better performance

-Lower maintenance cost (e. g less type of modules)

Need for upgrading an existing system, which may be performing in a satisfactory manner, may arise due to the fact that a decision has been taken to upgrade the associated systems. Because of Associated system being upgraded, it may become difficult to leave out a part of the system remain without being upgraded.
The C&I system in a power plant has many components and sub systems. To analyze the need of determining the obsolescence in C&I system each component / sub system/ system has to be identified separately and examined.

Implementation and packaging concepts of R&M package

The whole process of selection of systems and instrumentation to be taken up for R&M, selection of a R&M vendor , Packaging of R&M jobs, duration of plant shutdown required, execution philosophy Site activities and finally the tie up for annual maintenance contract are extremely crucial for satisfactory completion of the job with in the stipulated time. Packaging concept for R&M of C&I should take in to consideration the availability of system in the market

As all the investment requires techno-economic viability at first place, the system and instrumentation selected for R&M should result in minimum escalation in terms of tariff. Also there should be a reasonable pay back period for such investment say about 5 to 7 years. Further the selected systems after R&M should give a trouble free operation for a minimum period of about 10 years.

Typically packaging for C&I for thermal power plant cover following.

Thermal (Coal fired)
-SG C&I
-TG C&I
-Station C&I
-BOP C&I
Thermal (Gas based)
-GT C&I
-ST & WHRB C&I
-BOP C&I

The consideration of procuring a common platform for all the plant wide system is in the interest of power plant owner.

However, the reasons like availability of expertise in the market; proper competition to get cheaper spares etc largely governs the actual packaging. For example in a combined cycle Gas Power Plant the C&I vendor may not have experience in both GT and ST control systems.

The Packaging to ensure a large participation of vendors in the bidding process as well as taking appropriate care for interfacing with proprietary systems like Governing systems is to be balanced. Further the manufacturer/ bidders having following features needs to be encouraged.

-Use of Open systems to minimize proprietary hardware / software.

-Customer support policy and future road map regarding supply of spares, up gradation, software support, migration to latest platform, upward compatibility of hardware/software.

As the availability of Power plant of immense commercial sense in today's context the time period for implementation i.e. completion of site activities is critical. Typically a Plant shutdown time of about 30 days for completion of the job is adequate provided the planning of pre- shutdown activities availability of material and preparedness for contingencies are available.

Reduction of Inventories

The concept of procuring a common platform for all the subsystems of the main plant reduces the varieties of inventories and in turn reduces the cost. The controls of Off-sites plants such DM plants, Ash handling plants, Coal handling plants, CW system plants etc. are required to hooked to the main plant DDC controls so as to reduce the inventories.
Similarly, there shall be less numbers of software. Effectively, because of unification of software, the software inventory will be less. With less number of experts, the system can be maintained. Thus, the reduction in manpower can be achieved.

Reorientation of control room components

The recent changes in control philosophy necessitate the re-orientation of control rooms. The conventional man machine has been replaced by large video screen (LVS) and corresponding operator works station (OWS) based man machine interface (MMI). Thus the control desks and control panels are replaced. Therefore, undertaking of Civil works like CR/CER modification; electrical contract like mounting of interface relays in the existing switchgear to synchronizing with R&M schedule has got utmost importance. The above concepts will reduce the **number of existing control rooms.** Thus the additional space generated can be used suitably for the future application or the control space required for installation of new equipments for environmental purpose. Such large scale renovation / investment should ultimately lead to reduction in the operating staff so as to justify the techno economic viability.

Replacements of field devices/ field panels

Replacement of local instrument enclosure /local instrument rack (LIE/LIR), other local panels, Fixing of cable trays, Cabling etc are of immense importance are to be completed during pre shutdown period.

These require proper planning at the start of R&M job. The following activities are to be planned during planning stage in collaboration with site personnel.
-Philosophy for laying of cable trays some times in congested existing cable galleries.
-Routing for new cables to keep cable quantity to minimum.
-Reuse of dismantled cables.
These are the major challenges in implementation of the R& M of C&I system.

Replacement of field devices.

The issues of replacement of existing field Instrumentation with the latest one (Individual Instruments) should be based on purely techno economic considerations.

As specific recommendations the following should be adopted as far as possible:-

(a) When needed to change switch devices, attempts should be made to use transmitters with limit value checking done in DDCMIS (where available), keeping adequate redundancy as per application.

(b) Bearing & winding temperatures elements gradually may be changed to Thermocouples from RTDs due to latter's failure rate.

(c) Attempt should be made to club all such requirements to be taken at one go to ensure uniformity and having less inventory.

(d) Procurement of these items should be clubbed with the R&M of DAS and DDCMIS, in case they are likely to be executed within 6 months of each other. Else these shall be procured with independent limited tender.

For the items like SWAS, UPS, DC power supply, vibration etc it is found that the failure rate/obsolescence of these systems is not a major problem. Generally only some parts of the system may face some specific problem, and partial replacement can be done.
Total replacement need not be done before 10 years.
Partial replacement may be done through OEM on a single party basis. Also partial up gradation of the system could also be considered from OEM on single party basis.

In case of total replacement, the latest state of art of technology should while renovating these devices.

Annual maintenance contracts.

Lastly system being procured under R&M is also going to be obsolete. However to protect the owners interest in the O&M phase one of the areas to be commercially tied up with suitable guarantees is annual maintenance contract(AMC).
AMC primarily of two types
Comprehensive AMC

Though this is more expensive as the service as well as replacement of spare parts is to be carried out by the vendor free of cost it gives the owner a peace of mind from the hassles of maintaining a spare at the plant level. The spares can be at the central warehouse of the vendor.
Non-comprehensive AMC

Routine servicing is carried out by the vendor in this option but replacement of spare parts is to be maintained and arranged by the owner.
Depending on the Failure pattern, declared MTBF figures, criticality of the system, in built redundancies these AMC modules may be finalized with the main vendor. Further, it may be necessary to tie up with the OEM to ensure that the services from OEMs are available where the items are bought out in nature for the main C&I vendor. This could be used as one of the tools to insulate the owner against obsolescence, but there are issues relating to Long term servicing Contract which need s to be worked out suitably to have a win -win situation.

Conclusion

Thus, it may be seen that it is important to work out the R&M policy in respect of obsolescence of C&I equipment and the advantage of leveraging the new technologies. However, the challenge is there to implement the R&M program in short shut down. But with the latest technology and optimized inventory it should result for better process control there by trying to achieve better efficiency.

Issues and challenges in Renovation and Modernizations (R&M) of Control and Instrumentation Systems

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PRESENTATION OUT LINE

- Policy framework for R&M
- R&M Strategies
- Packaging of R&M jobs
- Selection of R&M vendor
- Execution issues like Cabling, Civil works
- Issues regarding replacement of existing Instrumentation with the latest one
- Requirement of AMC of C&I systems

Policy Framework for R&M

- Present policy for Renovation & Modernization (R&M) in NTPC is a generalized one for nearly all equipment depending on the running hours, except in few cases where the R&M is allowed due to prevailing condition of the equipment severely affects generation/availability

Policy Framework- Issues

- Formulation of guidelines for C&I renovation.
- Regulatory Issues.
- Techno- economic viability.
- Extent of Modernisation.
- Disposal of old system.
- Risk perception.

R&M Strategies

The major issues which necessitates R&M of C&I system:

- Ensuring a very high Plant Availability
- Improvement in plant efficiency
- Improved environment friendliness
- Improvement in Management Information System (MIS)
- Advantage of leveraging the new technologies
- Fast changing electronic technologies

Current R&M projects in NTPC

Under various stages of Implementation

- 2X110 MW Talcher TPS
- 2X110 MW Muzzafarpur TPS/ KBUNL
- 2X110 MW Barauni TPS /BSEB
- 2X500 MW Singrauli STPS
- 2X500 MW Korba STPS
- 663.6MW Auraiya GBCPP
- 656.26 MW Kawas GBCPP
- 2x110 MW Talcher FSSS pkg.
- Kawas Training Simulator Gas Turbines
- 6X210MW Remote Oil Firing for Vindhyachal STPS
- 2x500MW FSSS package for Rihand

Future R&M projects in NTPC

Under Approval

- 5x200MW Singrauli STPS
- 3X200 MW Korba
- 3X200MW +3X 500MW Ramagundam STPS
- 4X210 MW NCTPP-Dadri TPS
- 4X210MW Kahalgaon STPS
- 200/500MW Training Simulator at Korba
- 840MW Dadri GBCPP
- 630MW Gandhar GBCPP

Obsolescence

- The guiding criteria for deciding obsolescence may be as follows
- -System is no longer commercially feasible to maintain.
- -Supplier is no longer capable of supporting the product technically
- -Successor system is with more functions, better performance
- -Lower maintenance cost (e. g less type of modules)

Packaging of R&M jobs
(To replace following existing systems)

1. Replacement of existing ACS .
2. SG C&I (FSSS, SADC, Soot blower controls etc.)
3. and TG C&I (Turbine protection, EHTC, ATRS, ATT etc.)
4. Power Supply systems, SWAS, Vibration monitoring etc.
5. Selection of MMI system

Packaging of R&M jobs

- Packaging concept for R&M of C&I (separate vendors /systems or a common platform)
  - » **Thermal**
  - » -SG C&I
  - » -TG C&I
  - » -Station C&I
  - » -BOP C&I

  - » **Gas Project**
  - » -GT C&I
  - » -ST & WHRB C&I
  - » -BOP C&I
- What should be qualifying requirements for vendors in particular for Gov. system of GT & ST

Selection of R&M vendor

- Selection of OPEN SYSTEM to minimize proprietary hardware / software used.
- Customer support policy and future Road Map regarding supply of spares, up gradation, software support, migration to latest platform, upward compatibility of software.
- Practice of other users in a) Indian Utilities / other industries b) Utilities abroad / other industries

Duration of Plant shutdown

- Plant shutdown time for R&M job is about 30 days
- The planning for pre shutdown activities are to be done meticulously.
- Placement of LIE/LIR, Panels, Cabling etc can be completed during pre shutdown period.

Execution issues like Cabling, Civil works

- Congestion in existing cable galleries.
- Fixing new cable trays ,routing for new cables.
- Reuse of dismantled cables.
- Modification work required for CR/CER
- Interfacing with Electrical equipment
- Upgradation of Generator panels and other control panels

Issues regarding replacement of existing Instrumentation with the latest one (Individual Instruments)

- Based on the feedbacks received from various stations, it is seen that obsolescence rates of these items are pretty low. As such, one to one replacements with newer instruments are quite feasible in these categories. However doing such replacements, latest specifications being followed for new projects should be used.
- Attempt shall be made to club all such requirements to be taken at one go to ensure uniformly and having less inventory

Issues regarding replacement of existing Instrumentation with the latest one Small systems/ sub system
(SWAS, UPS, DC power supply,Upgradation of various aux systems i.e. PLC based)

- Partial replacement may be done through OEM.
- Issue regarding upgrading and merging offsite control with main controls

AMC

- **AMCs - comprehensive and non-comprehensive**
- **Comprehensive AMCs - more expensive**

  (service as well as replacement of spare parts is carried out free of cost)

- **Non-comprehensive AMCs –**

  (routine servicing is carried out, but replacement of spare parts is chargeable)

Conclusion

- **Reduction of Inventories**
- **Unified system**
- **Reduction in control room/ control hardware and software**
- **Reduction in manpower**

Thank you

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