Minutes of Meeting

VGB-Technical Committee: **Generation and Technology**

VGB-Working Panel: **PGMON**

Power Generation Maintenance Optimisation Network

28th Meeting on April 22nd, 23rd 2004 in Lisboa

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TOP 1 Implementation of a Maximo maintenance management system in Powergen
Rachel Pisani, Powergen

A common asset management system Maximo has been installed across the Powergen Generation portfolio to converge all asset management information systems into one common system and one standard. The asset management system Maximo consists of a number of modules, which include assets (equipment), work, inventory, purchasing and contracts.

The benefits of a common system were presented and include:

- Reduced support costs
- Defect tracking and trends across a wider population for feedback into maintenance planning
- Internal maintenance cost tracking
- Transparency of costs
- Monitoring of multi-site contracts
- Replicable, i. e. easy extension to add new sites

The implementation process was described, utilising a standard Maximo solution with minimised customisation and development of a common design and business process, followed by system testing, implementation and data validation. The difficulties in implementing a common system were also discussed, including data quality, system confidence and individual customisation.

The system continues to be developed via user group meetings and working groups, and include expansion for new generation sites, IT improvements, document linking and future integration of other systems.

TOP 2 Organisation of Central Maintenance System
Santos Silva, EDP

The Maintenance Organisation and Management will be accompanied the changing in the European Electric Power Generation Sector.

In order to fighting against Costs Reduction, loose the Critical Know – How, and Downsizing, the EDP Produção was created a Centralized Maintenance Unit, for Thermal and Hydro Power Plants.

The reasons for the new structure of EDP Produção Maintenance was to:
Enforce a decentralized organisation
Efficiently use human and material resources
Create clear customer relations
Use of internal synergies
Maintain internal know-how
Improve Reliability, Competitiveness, Profitability, Quality, and Maintenance Costs

At this moment, in EDP Produção, the Centralized Maintenance Unit, it seems to be the best option, and answer for all those questions.

The Centralized Maintenance Unit function can be regarded as a business unit with targets and costs or as a function offering services to the rest of the organisation (i.e. the other functions in the enterprise). This indicates a customer - supplier relationship that leads to the customers making certain demands from the supplier, which again must be reflected in an external objective. The maintenance function will typically be a supplier to the production function but it can also be regarded as a contributor to safety, quality etc.

The presentation prepared for meeting, show the actual Maintenance Organisation and Strutucture at EDP Produção, key competences, main clients and main services.

TOP 3 Simulation of maintenance strategies using Petri net
Antoine Despujols, EDF

Maintenance people have generally choices to make between various alternatives when they work out the preventive maintenance programs. On critical systems EDF applies a Reliability Centred Maintenance method, taking into account the possible consequences of failures and the collected experience feedback. However the maintenance program is based in a qualitative way on experts opinion. Until now, RCM method does not make it possible to estimate, nor to compare quantitatively various alternatives.
The objective of this work is to model and to simulate the maintenance programs in order to provide quantitative results which could support choices between different maintenance tasks and frequencies. Associated with Monte Carlo simulation, Stochastic Petri nets offer an efficient solution to this kind of problem.
The first stage of this work consisted in establishing a generic model of equipment which represents the operational states (operation, shutdown, standby, disable state), the physical states (up state, obvious fault, hidden fault, degraded state...), and the various maintenance tasks carried out (external inspection, internal inspection, scheduled replacement, test, repair...).
On the basis of this generic model, the second stage consists in representing a system of several equipment and simulating its behaviour when a given maintenance strategy is applied, so as to estimate the maintenance costs and the resulting system unavailability. The proposed method is structured and modular. It makes it possible to build simple models which can be validated independently, and then associated in order to simulate complete systems.
Based on encouraging results, this work is going to be continued and enlarged in order to be applied to practical cases.

TOP 4 Application on Risk Information Method for optimising maintenance
Claude Degrave, EDF

For several years, Regulators and Utilities are developing new approaches for optimizing NPP Operation & Maintenance using risk insights. These approaches, the so-called Risk-Informed

Methodologies, aim to adapt operators' effort on the most critical Systems, Structure and Components regarding their contribution to the overall risk. These approaches make
intensive use of Probabilistic Risk Assessment tools together with deterministic considerations. Many topics are covered by these applications, such as Maintenance optimisation, Technical Specifications definition, In Service Inspection and Testing optimisation. The US are leader in this field and many utilities have got substantial benefits from implementing such methodologies. Other countries, particularly in Europe, try to promote Risk-Informed approaches, but this represents a cultural change both for Nuclear Safety Authorities and for Operators and
the spreading of these new concepts is dissimilar among the "Nuclear Countries". However, competitiveness of nuclear energy partly depends on the success of such initiatives.

TOP 5. Condition Oriented Ageing and Plant life Monitoring System, COMSY
Helmut Nopper, Framatome

Abstract
For the optimization of inspection effort, Framatome ANP GmbH has developed the software tool COMSY, which is designed to support an efficient plant life management strategy for piping and vessels. The tool provides the capability to establish a program guided technical documentation of the plant by utilizing a virtual plant data model. Integrated analytical functions serve to identify an existing degradation potential on a plant-wide basis for degradation mechanisms typically experienced in thermal power plants. The integrated risk-informed assessment tool provides the option to optimize the inspection activities in respect to degradation potential and the associated damage consequence.

Introduction
The COMSY software has been developed to provide a software tool for ageing and plant life management and ISI optimization. It is designed to support a plant-wide strategy providing lifetime assessment for piping and vessels in respect to degradation mechanisms typically experienced. The lifetime assessment process requires detailed information on design and operating conditions as well as the components' as-is state. This information is kept in a user-friendly database application, which is continuously updated via the integrated inspection management functionality. Hence, the software tool servers to address the following PLIM related topics:

- Prevention of failures by identifying degradation sensitive systems and components
- Streamlining of inspections by focusing inspections activities on priority locations utilizing a combination of condition oriented and risk-informed methods
- Know-how conservation by providing compiled documentation on individual systems and component level.

The purpose of a systematic ageing and plant life management program is to allow the lifetime of plant components to be planned, and to indicate when a component has reached the end of its effective lifetime before it fails. Another important function of such a strategy is to increase the availability of power plants and to enable implementation of a targeted maintenance strategy in terms of its economic and technical effect.

The COMSY Concept

The COMSY software system acquires, manages and evaluates component and operating parameters relevant to service life. The program performs a condition-oriented lifetime analysis for various degradation mechanisms which are commonly experienced in power plants. Those are e.g.

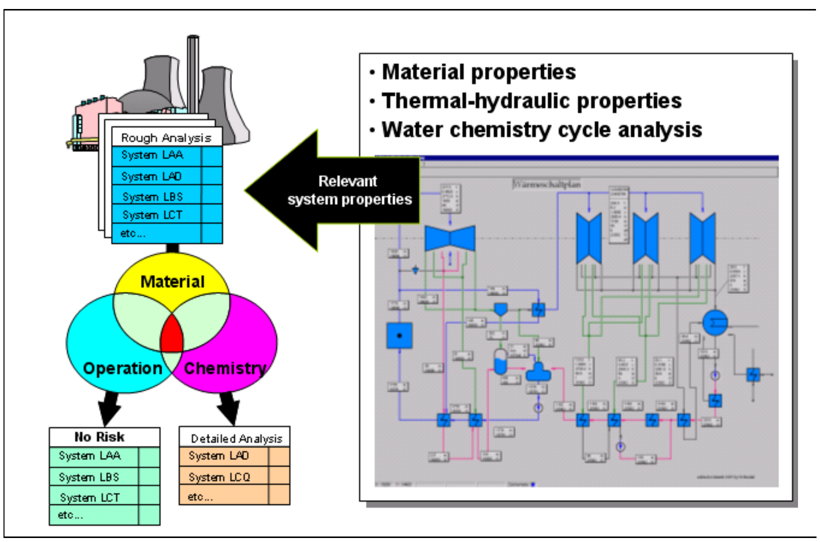
material fatigue (transient, stratification and cycling), strain-induced cracking, erosion corrosion, cavitation erosion, droplet impingement erosion, stress induced corrosion cracking (IGSCC, TGSCC, PWSCC), pitting, crevice corrosion and MIC. A model for high temperature corrosion and the creep behaviour of structures is currently under development.

The degradation analysis process is supported via

- an intelligent user interface,
- by effective analysis functions (stress analysis, thermal-hydraulic and flow analysis functions, water chemistry cycle analysis),
- by a comprehensive material libraries (e.g. material data catalog),
- by a module for management and evaluation of examination results.

A risk-informed function serves to prioritize and to optimize the inspection schedule based on risk and cost criteria.

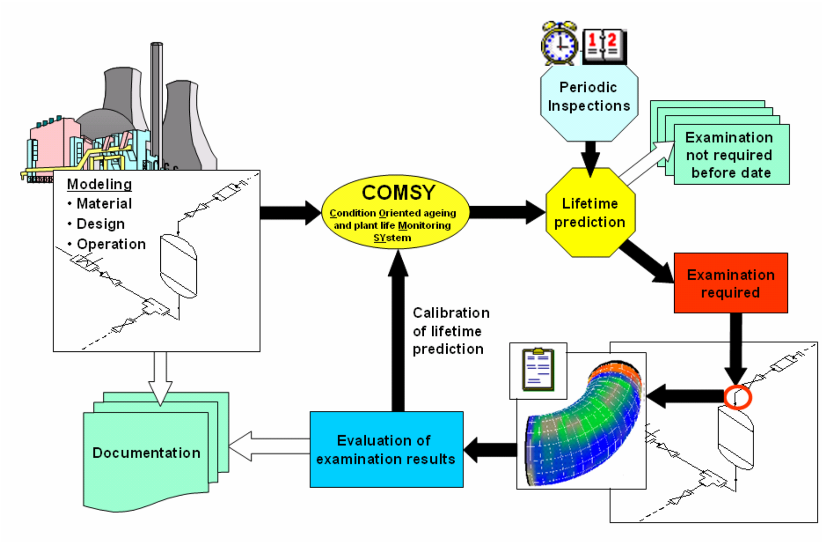
In order to efficiently screen a plant unit for systems potentially affected by specific degradation mechanisms, the heat balance diagram of the water/steam cycle in the power plant is modelled using graphical tools. In a second step the system parameters (pressure, temperature, mass flow and enthalpy) are specified for each system area. The resulting model establishes the basic data structure of the virtual power plant, and allows for an analysis of the water chemistry cycle to be conducted. The water chemistry cycle calculation subsequently provides the distribution of local water chemical conditions for each system and sub-system of the BOP. In the next step representative materials brands are specified for each system area. As the sensitivity in respect to degradation mechanisms is primarily controlled by the combination of operating parameters, chemical conditions and materials applied, the system areas can now be evaluated by the program to determine the local degradation potential. The resulting table indicates which degradation mechanism may be relevant for the individual system or sub-system. It also indicates, which degradation type can be disregarded due to the systems design and operating parameters. Based on the priorities determined, the program provides the option to analyze selected systems areas in detail, in order to further localize and quantify an existing degradation potential.



Plant-wide screening using COMSY

Closed Loop Process

Service life assessment is the key function of a software system for ageing and plant life management. On this basis inspection management and plant availability can be optimized and the service life of components can be extended. The ‘closed loop’-methodology applied builds on these degradation predictions, which are validated and calibrated by existing examination results.

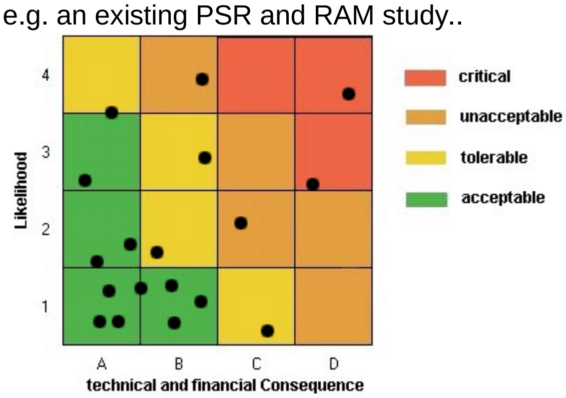


The closed loop process for PLIM

By establishing a closed loop process, the program is capable to adapt a condition-oriented approach on a step-by-step basis. This makes lifetime predict-ions more and more accurate with every year or program application. Based on the predicted service life, components can then be prioritized for examination programs. The results of component examinations are fed back into the program system, and are used for further optimization of service life predictions over the life cycle of the component. Overall, this systematic, closed-loop process enables up-to-date inspection strategies, utilizing quantifiable data characterizing the technical as-is status of the plant.

Risk-informed assessment

The risk-informed assessment tool provides the option to utilize existing data from detailed analysis and previous inspection results to evaluate the damage probability within a given time period. The damage probability is associated with the expected damage consequence which is obtained from e.g. an existing PSR and RAM study..



Risk matrix

The availability criteria is associated by means of an availability relevance factor or a given availability category. Finally, the inspection priority for each inspection item is determined by consideration of the expected damage probability and the damage consequence. This indicator allows for optimizing inspection activities using a risk-informed approach.

Conclusions

For many utilities a systematic and efficient ageing and plant life management system is becoming more and more important to ensure an economical power plant operation in spite of continuous facility ageing.

In this regard the COMSY software system makes a knowledge-based program system available which integrates advanced analysis tools, comprehensive material libraries with a inspection management and technological documentation system. It provides the option to perform a plant-wide screening for identifying degradation sensitive system areas.

A detailed analysis function enables the condition-oriented service life evaluation of vessels and piping systems in order to localize and quantify the effect of degradation. The resulting condition-oriented knowledge provides the basis for a continuous optimization of inspection efforts. The implementation of COMSY in various nuclear power plants has confirmed that systematic plant life management makes good economic sense, as cost reductions can be achieved while increasing the plants availability. The implementation of high temperature degradation mechanisms will make COMSY fully applicable also for fossil fired plants.

TOP 6 Ageing and life extension
Henk Wels, NRG

Based on work carried out in the Netherlands, NRG-KEMA has developed a systematic approach to modelling the forced unavailability of ageing power plants that are candidates for life extension. A reliability block diagram model, that has been validated taking into account plant specific data as well generic data, serves as a reference model. Based on data, trends in failure frequencies as well as in repair times (for instance waiting on spares), an extrapolation is made for the plant components if no life extension is carried out. Next, activities on components are defined, that should be based on discussions with plant personnel & maintenance records as well as probabilistic calculations (for instance failure probability as a function of time for steam headers etc.). In order to model the effectiveness of these activities, the ratio of low failure rates compared to average failure rates in NRG databases was used. For some plant components, “ageing” was found in the pattern that however turned out to be related to minimal maintenance in combination with cycling of the plant.

The analysis can be extended to assess the cost-benefit ratio of life extension activities on certain components for optimization purposes. It is envisaged to carry out a benchmark on life extension costs. Typically, life extension costs are in the range of 50-150 EUR/kWh for 10-15 years of life extension depending on the plant, its past operating and its design.

TOP 7 Latent faults due to maintenance
Henk Wels, NRG

Latent faults go unnoticed and may especially be important when a plant has redundant systems. Latent faults may have as a result that the redundancy is thought to be present, but is not when it is needed most. NRG experience with latent faults has been acquired when carrying out detailed reliability analysis of some flood barriers in the Netherlands as well as during the reliability analysis of a power plant producing steam for chemical industries. Similar to safety culture at nuclear power plants, at a number of projects NRG found that RAM = Reliability Availability Maintenance culture is important. The presence of RAM culture can be measured by asking specific questions and numerical scoring. Full outsourcing of maintenance without adequate checks, no risk analysis and no configuration control was encountered versus use of contractors wisely decided upon, dedicated checks and keeping good relationships. RAM culture of an organization may change preceding privatization. According to NRG, in order to score better on

RAM than one's competitors, it pays to intimately knowing component technical life, risk and maintenance efficiency as a function of business factors.

TOP 8 An Assurance Assessment carried out in relation to a major Unit Refurbishment
Richard Sheehan, ESB

This presentation discussed the steps taken in defining a workscope for a major unit refurbishment and the challenge process which followed to identify any significant deficiencies within the workscope.

A major refurbishment overhaul was recently implemented on a 250MW oil-fired generating unit. A scheduled refurbishment of the unit was brought forward as a result of an electrical incident on the plant. Due to commercial and technical pressures, the overhaul was scheduled to take place with relatively little lead-in time; thus it was necessary for the Station to develop the workscope without the normal degree of resources for preparation. A project team was set up to critically examine the workscope and to account for any identified deficiencies.

A methodology was established to allow the workscope to be challenged and to highlight any deficiencies. A number of criteria were established against which the workscope was examined such as

- Assessment of Current Plant Condition
  - Had the station carried out a comprehensive assessment of current plant condition?
- Performance Targets and Running regime
  - Had the Station taken due cognisance of the performance targets expected of the unit and the likely future running mode?
- Internal and External technical reviews
  - Had the workscope included the various technical recommendations arising from a number of recent technical reviews such as HILPS, Insurance recommendations etc
- Technical Integrity Self-Audit
  - Had the Workscope included recommendations arising from the internal integrity auditing process?
- Assessment of historical Forced Outages
  - Had the workscope accounted for historic 'repeat offenders' which gave rise to forced outage events?
- Comparison with Workscope and findings on Overhaul of sister unit
  - Had the workscope integrated the work items identified on the workscope implemented during the refurbishment of a sister unit, and had the findings during that overhaul been integrated into the current workscope?
- Technical Standards and Guidelines
  - Did the workscope include the technical requirements of internal technical policy documents in order to ensure full compliance?
- Cycling Study
  - ESB recently participated in a R&D study in relation to cycling effects on conventional thermal plant. Had the workscope included the recommendations set out in the final report, to ensure that the unit would be capable of running in a cyclic mode of operation?

- Critical Plant Inventory
  - Had the Station derived its workscope with reference to a plant inventory to ensure that no critical plant items were over-looked?
- Statutory Inspections
  - Did the workscope allow for forthcoming statutory inspections?
- Benchmarking Study
  - Did the workscope include recommendations derived from a recent benchmarking study based on visits to other European utilities?

The Study concluded that the original workscope had included ~90% of the required action items to ensure the unit would be able to achieve its proposed performance targets. The remaining 10% included overlooked plant items in addition to specific action items which could now be added to the workscope. Having addressed these deficiencies, the study allowed a high degree of assurance to be reported to the senior management team that the workscope was sufficiently comprehensive to return the unit to service with high commercial availability. The study undertaken also allowed a template to be developed for use in assessing the workscopes of future major overhauls.

TOP 9 Model to determine optimum spend pattern on maintenance

Alan Joslin, Innogy

Introduction

This project, which was started in 2003, utilises three of the tools developed by and used by RWE Innogy as part of its business planning and asset optimisation process brought together into a single model. The model seeks to optimise gross profit from a power plant over the remaining lifetime of the plant. Gross profit excludes fixed costs such as salaries, insurance, connection charge, rates etc. Gross profit is taken to be the tolling income based on full availability outside planned outage periods, less the commercial cost of unplanned plant outages and load restrictions, less the cost of maintenance, less costs of plant refurbishment. Within the model, each of these is determined on a year by year basis, and is aggregated to the end of the assets life applying appropriate discount factors.

Model Elements

The three tools that support the model all operate at high level, and are as follows:

PLUS (Plant Life Usage System)
PLUS is concerned with the condition of the plant currently, and how the condition of the plant in the future will be influenced by operating regime, spend on maintenance, and refurbishment spend. Condition is expressed using a scale of 0(inoperable) – 10 (as new) assessed at sub-system level across the station (examples of sub-systems are Unit 1 LP turbines, Boiler 3 draught plant, station cooling water systems). It is then aggregated across each unit and across the whole station.

RCover
Lost opportunity cost model using operating regime, market prices, and availability factors to forecast the cost of lost opportunities due to forced outages. RCover was originally

developed as an internal insurance process, so that the expected commercial losses due to breakdown could be determined.

Availability model
A model that forecasts availability factors that can be applied in RCover, based on plant condition, determined by PLUS, and operating regime. The relationships between condition, operating regime, and availability losses are based on historic data extending over more than 10 years.

Process
The model determines tolling income (before plant breakdown) simply by aggregating the product of spark spread (£/MWh) and capacity (MW) for all periods where market prices and plant costs show that it would be profitable to run the unit. Start-up costs are taken into account.

Lost income (lost opportunity costs) are a function of availability losses (determined taking the expected operating regime and plant condition into account), market prices (for power and fuel) and the type of loss. Type of loss is important to take into account. Short unplanned breakdowns cost significantly more in terms of lost opportunity than, for example, high impact low probability events where the notice to failure for most of the outage is lengthy.

The modelling for the Optimum Maintenance Spend Project operates in annual increments. For each year, the condition at year-end is determined based on variable inputs of maintenance spend, refurbishment spend, and operating regime.

The PLUS system determines how change in condition is influenced by each of these variables. Generic relationships, based on benchmark PLUS data across a number of stations, are used in a number of areas. These include the variation of availability losses with plant condition, and how the required refurbishment spend for incremental condition improvements.

Experience to date within RWEnpower
The model is used within RWEnpower in a number of ways. For a given operating regime covering the expected residual life of the station, the model can find the optimum maintenance spend and investment strategy. Alternative strategies can be examined, and their influence on the NPV of the plant established. Business plans can be sense checked, and sensitivities to changes in the assumptions considered.

Overview and conclusions
The models that make up the Optimum Maintenance Spend Project are integral parts of RWEnpower's business planning process. Some shortcomings are recognised in the integration process. The overall model has so far only been used for coal-fired plant. This is because the experience database is limited, although growing, but more data is available for coal-fired stations. However, as strategies for coal plant are more uncertain, there is more value is being able to use the modelling for such plant.

The model has proved particularly valuable when examining the impact of changes in strategy, but it is recognised that results are less certain in the determination of absolute optimum spend. The results inevitably provide only a gross position, as fixed costs are outside the scope of the process. Variation of spends over the medium term with the overhaul programme are averaged across the years, so the output can be seen only as a high-level view. Nor does the process seek to identify where best to invest in refurbishment. Nevertheless, the output of the Project is seen a valuable tool to support, and in some cases challenge, the strategies being developed by power station and asset managers.

TOP 10 Vibration Monitoring system of wind turbines
Anders Rasmussen, Elsam Engineering

Elsam Engineering has delivered complete project design work for the Horns Rev offshore wind farm off the west coast of Denmark.

The project includes 80 2 MW turbines.

The access for maintenance is difficult and expensive on an offshore wind farm.

Therefore, a monitoring system was needed to acquire knowledge of the machinery's condition in order to minimize the number of maintenance visits.

The most important requirements for the monitoring system:
- Completely embedded solution
- Self-learning system
- The turbines must function autonomous
- Transmission of time series of data through the turbine communication system to onshore computers
- Simple interface to PC-tools on shore
- No Microsoft
- Main focus on analysis of rolling element bearings

Embedded solution
The monitoring system is fully integrated in the wind turbine control system and thereby it has all the measurements, which goes into the controller.

Self-learning system
The self-learning system is built on statistics.

When the turbines are new, the monitoring system is started in learning mode.

The learning process is separated into 18 power levels from 200 KW to 2 MW, because the vibration level depends on the power level.

The mean value and the standard deviation are recorded as learned values after a number of running hours on each level.

These values are then used in the statistical calculation of alerts and alarms.

Every time the measured value exceeds the learned mean value with a certain amount, one place in the circular buffer is set to fault.

When for example 40% of the buffer is fault, the system will give a warning and when for example 80% are fault, it will give an alarm and stop the turbine.