STEPPING UP CONDITION-ORIENTED MAINTENANCE OF TECHNICAL SYSTEMS IN UNDERGROUND GAS STORAGE FACILITIES OPERATED BY VNG - VERBUNDNETZ GAS AG – USING THE ZEDAS® ASSET MANAGEMENT SYSTEM

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ABSTRACT

For some time now, VNG has undertaken extensive studies of its technical systems in the course of optimizing general procedures required for operational and maintenance reasons. Apart from saving resources and minimizing costs, the company also needs to meet a set of important initial conditions. These include conformance to gas industry standards, upholding high safety levels, and ensuring a continuation of operating authority.

Following intensive preparation and a successful pilot test, VNG opted for ZEDAS, an asset management system available from PC-soft GmbH of Senftenberg / Germany. In the course of system analysis, the program filters out technical readings which need to be maintained, and it also diagnoses errors, analyzes causes and then shows results clearly arranged for evaluation.
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1 BACKGROUND

For some time now, VNG has undertaken extensive studies of its technical systems in the course of optimizing maintenance operations. Apart from pursuing major goals, i.e. resource saving and cost minimization, the company has also had to meet a number of important initial conditions such as conformance to (obligatory) supply standards, upholding high safety levels and ensuring overall operational control.

VNG is a gas importer headquartered in eastern Germany where it operates a grid of high-pressure pipelines with a length of approx. 7,300 km and 6 underground gas storage facilities. The latter compensate for seasonal variations in consumption and help to optimize purchasing.

At the end of 2005, the storage facilities had a working gas capacity of $2.2 \times 10^9$ m³. This will grow to $2.5 \times 10^9$ m³ when expansion of the UGS Bernburg caverns is completed in 2010. VNG will then be able to widen its business and meet the supply and other requirements nowadays made on gas utilities.

EU provisions (Directive 2003 / 55 EG) and national laws for unbundling transmission and distribution grids and related equipment, i.e. separating them from other elements in the value chains of utilities, may in future shift responsibility for equipment, operational management and maintenance to different structures. This will create new conditions for maintaining the efficiency of management and maintenance when it comes to grids and underground storage systems.

2 BETWEEN TWO EXTREMES

Various maintenance procedures may be used for the efficient upkeep of equipment, and the point in time chosen for maintenance depends on the specific method selected. These methods may be roughly classified as follows:

- I. Failure-based maintenance
  (Whenever a failure / damage occurs)
- II. Planned preventive maintenance
  (Predetermined / periodical / preventive maintenance at constant intervals to suit specific criteria)
- III. Condition-based maintenance
  (Periodical determination of wear, maintenance at a time which suits production planning)

These methods have different effects on ensuring equipment availability, and on direct and indirect costs. Direct costs result from personnel and material expenses, and from the frequency of maintenance. Indirect costs result from follow-up expenses and losses caused by equipment downtime.

Maintenance normally accounts for over 50 % of the operating costs of an underground storage, which gives operators with the right concepts for upkeep tremendous leverage. In the present climate of competition, continuous preventive maintenance as practiced over many years has been abandoned as too expensive. On the other hand, too much neglect will increase the threat of system failure which may cause even greater costs.

A middle course between these two expensive extremes can be steered with the help of condition-based maintenance which aims to keep maintenance costs low while ensuring maximum availability and operational reliability.
In the last few decades, ways of assessing the technical condition of equipment have been developed using a variety of new sensors and advanced solutions for data processing and the presentation of results. However, all of these methods apply only to specific pieces of equipment, and their advantages and drawbacks for maintenance as a value-creating operation should be optimized in their entirety from the angle of business management.

3 ASSET MANAGEMENT

Asset Management as defined in a recommendation (NAMUR NE91) means activities and steps designed to maintain or enhance the value of a plant or facility. It includes operations management, process optimization, as well as value-maintaining and, where possible, value-increasing maintenance. This calls for an optimal balance between upkeep and upgrading costs on the one hand, and plant availability for production on the other.

Asset management is the job of those who bear responsibility for an operation as a whole (Source: NAMUR recommendation NE91 „Requirements made on systems for plant-related asset management“, first edition Nov. 1, 2001, p. 4) (Figure 1).

![Asset Management Diagram](image)

Figure 1: Fields of asset management

For a comprehensive look at its underground storage facilities, VNG relies not only on the definition given in NAMUR recommendation NE91 but also on the classification of plant management shown in Figure 2.

In the 1990s, the company introduced IPS, a maintenance planning system software with a clearly commercial orientation. After gaining practical experience, IPS users wanted to include more online data from process control systems into condition monitoring.

To translate this strategy, a system was needed that would give ideal support to IPS. The one chosen by VNG was ZEDAS made by PC-soft, a software house from Senftenberg in the eastern part of Germany.
Studies undertaken by VNG have shown that a mix of condition-based, planned preventive and failure-based maintenance is best to meet the above requirements, with cost-intensive planned preventive maintenance restricted to safety-relevant components. The basis for such a combination is a technical compromise between two cost extremes – plant damage and rigid preventive maintenance. The aim then is to ensure a maximum of operation safety and plant availability while at the same time meeting cost cutting requirements. In practice, this means to:
- Detect defects early before a system has suffered major damage,
- Practice condition-based planning for inspection, upkeep and repair;
- Optimize operations through direct rating factor / efficiency / energy consumption and
- Statistically follow up on events / damage to individual plant components (units, apparatus, instruments, equipment etc.) and analyze failure frequency.

When introducing ZEDAS for underground storage facilities, the focus was on load / condition-based maintenance for plant components:
- Compressors,
- Gas drying / gas purification systems,
- Pressure reduction systems and
- Gas storage caverns / wells.

For the UGS Bernburg caverns, these quantities for data tracks per technical unit have been established (Table 1):

<table>
<thead>
<tr>
<th>Technical unit</th>
<th>Compressor</th>
<th>Gas drying system</th>
<th>Pressure reduction system</th>
<th>Caverns</th>
</tr>
</thead>
<tbody>
<tr>
<td>total</td>
<td>143</td>
<td>33</td>
<td>160</td>
<td>133</td>
</tr>
</tbody>
</table>

Table 1: Data tracks per technical unit of UGS Bernburg caverns
The following was agreed for retention times and scanning intervals (Table 2):

<table>
<thead>
<tr>
<th>Process factor</th>
<th>Retention time, days</th>
<th>Scanning intervals, seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>analogue data: temperature</td>
<td>93</td>
<td>600 (10 minutes)</td>
</tr>
<tr>
<td>analogue data: pressure etc.</td>
<td>93 (10 minutes)</td>
<td></td>
</tr>
<tr>
<td>binary data</td>
<td>732</td>
<td>2,400 (40 minutes)</td>
</tr>
<tr>
<td>cavern data</td>
<td>732</td>
<td>7,200 (120 minutes = 2 hours)</td>
</tr>
</tbody>
</table>

Table 2: Data tracks of process factors of UGS Bernburg caverns

4 METHODS

Key standards against which maintenance operations are measured include system reliability and process availability. A wealth of process information and/or process-relevant data therefore had to be collected, processed and made available for maintenance monitoring.

After a successful pilot test to verify maintenance applications of the ZEDAS plant management system marketed by PC-soft at the Bernburg underground gas storage facility, VNG obtained this software for practical use. This has given the company an IT tool for condition recording, diagnosis and the archiving of technical data. The system will be used in future to further optimize the planning and performance of condition-based maintenance in particular.

As a result of plant analysis, ZEDAS provides readings for systems that are eligible for maintenance from existing process control facilities. It also diagnoses errors, analyzes causes and then summarizes results in a clearly arranged presentation. Specific questions such as
- "Why did an error occur? ",
- "How can failures be detected early and breakdowns prevented?“ or
- "Where are the defects that cause failures?“ are answered.

Plant condition can be verified with ZEDAS while a system is in operation. Necessary maintenance work is optimized for a condition / load-based mode of operation. Through an integrated view and monitoring of systems, component defects can be detected, analyzed and eliminated.

Readings are linked in the form of alarm rules ("If - Then") so that plant damage is detected early, preventive action can be taken and downtime is avoided. In modifying the contents of the warning system, a wealth of experience gathered by maintenance personnel can be used, particularly as regards the assessment of critical loading times and the remaining useful life of plants.

In addition, loads, the consumption of energy and auxiliary materials, and the operational performance of equipment are statistically evaluated. Depending on the mounting position, differences between expected and actual operational performance are registered.

As part of an integrated approach to machinery and equipment, specific assessment tables are drawn up for classifying individual systems with regard to lengthening their maintenance intervals based on existing quantities and long-term statistical records of events and equipment conditions.
5 RESULTS

Due to varying local conditions, types of equipment etc., each maintenance operation needs to be considered separately, which means that site-specific system introduction is rather working and time intensive.

The ZEDAS IT system gives effective support here on a uniform surface and optimizes handling. Advantages of ZEDAS include:
- Better operating safety / plant reliability,
- Lower maintenance costs (efficient working),
- Better fail safety of technical systems (minimal downtime / preventive diagnosis / more effective troubleshooting),
- Better transparency at all stages of a system's useful life (longer service life of technical equipment),
- Optimization of cost-benefit ratios for monitoring / diagnosing systems and
- Support to prove conformance to safety rules.

The following approach is recommended:

<table>
<thead>
<tr>
<th>General operating experience</th>
<th>Specific operating experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Generic database</td>
<td>- Component / system failure</td>
</tr>
<tr>
<td>- Plant-specific data</td>
<td></td>
</tr>
</tbody>
</table>

Data collection using data tracks from process management system / maintenance contractors' experience

Preparation by classification, evaluation and determination of MTBF, MTBR, MTTR, RPN, LCC, etc. and by process data value processing for selected areas

Risk analysis and plant / process optimization

Figure 3: General procedure for determining optimal operating condition

Other important project steps include:
- Developing and implementing a data flow / security concept for coupling commercial and production networks,
- Selecting data tracks for units, drawing up maintenance plans, setting intervals and
- Analyzing load-descriptive parameters with a first definition of links and message / alarm values (rules).

First results have shown that such a thorough study of maintenance operations can give saving potential between 5 and 30%, depending on the type of equipment / system.
Allowance should be made for these aspects:

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Probable effect (%)</th>
<th>Effect experienced by VNG (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs</td>
<td>2</td>
<td>2 to 5</td>
<td>Statistical records for current expenditure give rather reliable results. Possible damage and its causes is partly known, related expense can be estimated.</td>
</tr>
<tr>
<td>Personnel requirements</td>
<td>0.5</td>
<td>0.5 to 2</td>
<td>Condition-based maintenance calls for skilled, experienced, motivated staff.</td>
</tr>
<tr>
<td>Availability</td>
<td>1</td>
<td>0.5 to 4</td>
<td>Requirements affected by current supply/demand.</td>
</tr>
<tr>
<td>Risk</td>
<td>0.5</td>
<td>0.5 to 2</td>
<td>Stricter safety requirements call for repressurizing / precaution management.</td>
</tr>
<tr>
<td>Standards set by legislation</td>
<td>1</td>
<td>0.5 to 2</td>
<td>Standards set on a large scale by laws, directives, guidelines and recommendations call for accurate observation of time limits and for work instructions, the provision of documentary proof, and statement of reasons for exceptional regulations.</td>
</tr>
<tr>
<td>Awareness of condition</td>
<td>5</td>
<td>1 to 15</td>
<td>Knowledge of condition (rate of wear) and specific damage enables better planning/preparation of maintenance / investment projects.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10</strong></td>
<td><strong>5 to 30</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Expected saving potential in maintenance operation by using ZEDAS

6 SUMMARY

The ZEDAS asset management system makes it possible to monitor the condition of equipment online, enables automatic fault diagnoses and reduces the risk of drifting to damage-based maintenance. However, it gives meaningful information only if it has recourse to empirical and comparative values. This is why reference statements for different operating modes should be entered into the system, which will be collected and stored automatically. Not until links are established with the plant-specific knowledge of cavern operators will related reference values and remedies be selected. Operators will thus be forced to continuously interact with ZEDAS and watch out for the condition of storages.

The following approach to projects is recommended:

- 1) Develop / implement a concept for organization, data flow and data security, particularly when coupling commercial and process control networks.
- 2) Select process information to be imported online (data tracks from PLS / SPS) for units chosen in keeping with risk assessment – includes drawing up maintenance schedules and observing time limits.
- 3) Analyze load-descriptive parameters, give a first definition of links and of message / alarm values (alarm rules).
- 4) Gradually optimize maintenance / inspection intervals making allowance for (failure) frequency and damage classes (see also VGB leaflet M 130 and DVGW worksheets G 495 and W 400/3).