Condition based risk management of power system asset

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Abstract: Due to liberalisation of the energy market the operating cost of power generation and transmission became a strategic key factor for decision makers. In order to reduce the cost of operation by acceptable risk exposure of power system components, the forced outage hazard should be quantified and kept within controllable limits. To meet the mentioned needs an Asset Management System (AMS) is required integrating online condition monitoring, financial policies, operational and corporate strategies.
This paper provides a systematic approach for handling of conflicting business objectives as cost and risk. The presented approach is aiming at the hierarchical, systematic evaluation of the system function breakdown risk and at taking decisions based on online information about the current plant condition.
The authors deal with the following questions: How to form a single indicator, which gives a reliable estimation and good visualisation of changing risk? How to derive quality information can be used for optimisation of various cross functional business processes as budgeting, procurement, risk and quality management. The paper shows also a conceptual architecture of the proposed AMS integrating standalone online monitoring units of primary electrical equipment's and a central diagnostic unit.

1. Introduction

In line with the ongoing liberalisation of the energy market many power generation and distribution companies have been undergoing business process reengineering (BPR) programmes in the last few years. Despite the large expenditure on BRP and the established modern process-based organisation [1], the cost of operation can't be reduced satisfactorily.

The reason of the discrepancy pointed out above lies in the insufficient information management between core business processes (production, sales, maintenance, procurement etc.) having direct impact on each other and on the main financial performance indicators.

In order to overcome the mentioned trouble, the integration of various kind of data of many sources into system and the automated online conversion of those to appropriate, comprehensible information are essential. An AMS is needed, which is able to acquire the asset relevant data (condition, historical etc.), to convert them into demand-oriented information and to direct this to the appropriate process owner(s) [2].

The paper is structured as follows: the main components of the assets having significant effect on the profitability of utilities and a short overview of requirements for an AMS will be given in section 2. In section 3 the "bridge" function of AMS between functional units of different nature (technical, financial etc.) will be explained and the developed model visualised. Section 4-5 outlines the proposed AMS. The quantifying of the state-of-system indicators will be described in section 6. Finally, section 7 concludes with some summaries.

2. Assets in power industry

The assets that the organisation invests mainly consists of physical, financial and human asset. The management of those should involve their entire lifecycle in order to make sure the maximal return on investment.

The basic questions, an AMS should be able to answer persistently, are the followings:

1. what does the organisation own
2. where are the assets located
3. who is responsible for them
4. what processes and activities are related to each unit of the assets
5. how much are they costing
6. what components of the assets are monitored
7. what are the relevant condition measurement data
8. how big is the degree of system function fulfilment at the moment
9. how big is the contribution of an asset unit to the system risk increment due to its current condition
10. how far does any expected change on the assets effect the planed financial performance indicators (ROA, ROI etc.)

According to the requirements 9-10 above the AMS takes an enterprise out of a reactive position and puts them into proactive stance by providing current and expected information to make solid decisions.

3. The "bridge" function of an AMS

In order to make well-informed decisions on future operation of physical assets and on capital investment in general, an equipment-oriented online analysis of cost development (ex-ante, ex-post) is of crucial importance. Asset managers would like to know where money is best spent to achieve the highest return on investment (ROI).

There appears to be a large information gap between actual condition development of the physical assets and the budgeting procedure identifying the annual budget for assets maintenance. The mentioned deficiency results in significant inaccuracy with regard to the actual amount of maintenance expenses, which leads to remarkable loss on ROI due to non-optimal capital allocation.

The prerequisite of closing the "gap" is the implementation of comprehensive real-time diagnostic tool for asset condition assessment and for the online calculation of expected repair cost by means of condition related measurement data delivered by the respective monitoring units. The figure 1 elucidates the critical interface in information management to be bridged through the proposed AMS. In fact, the model represents an online performance measurement tool.

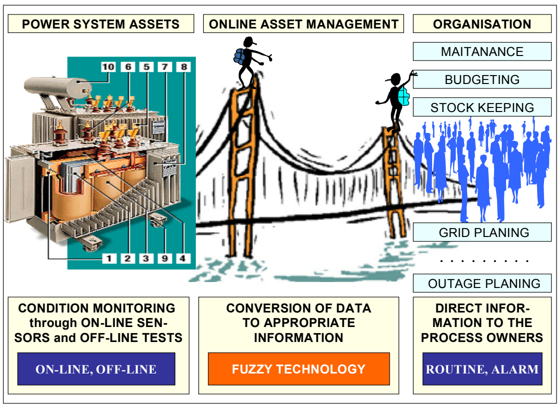


Figure 1: Visualization of the online condition performance measurement model

4. The complex asset management system

With increasing energy throughput and economic pressure to save on maintenance costs, electricity network failure has a high chance of being catastrophic.

Power generators, power transmission and distributors can only meet the new market requirements, when they have a complex AMS providing a high transparency on the current assets condition and computing the key indicators of relevant business process continually.

The task to be solved has a very high complexity characterised by a big number of users and by varying requirements on the manifestation of the information about the assets (*i.e. content and form*).

In order to be able to sink the process cost and to keep the power supply reliability high, process cycle time, actual stocking options, repair cost, remaining life time of system components, the system risk in dependence of different maintenance scenarios etc. should be calculated in proactive manner with acceptable accuracy.

The key indicators of assets

The basic indicators characterising the state of the power system and underlying the computation of control and performance indexes are the condition, the risk contribution of asset units and the risk of breakdown.

According to the comprehensive, hierarchic approach presented in [3], the equipment condition can be calculated trough the aggregation of function contribution (FC) of components supporting its function fulfilment. The risk exposure of the overall system function due to the condition deterioration of the respective equipment can be assessed using the risk diagram shown in Fig. 2. The linear combination of current equipment's condition and the importance assigned to this unit gives the length of the risk vector. The diagram shows the mentioned vector, which facilitate the system risk assessment [4] and its visualisation in the selected asset portfolio. For more details on calculation of importance index refer to [3].

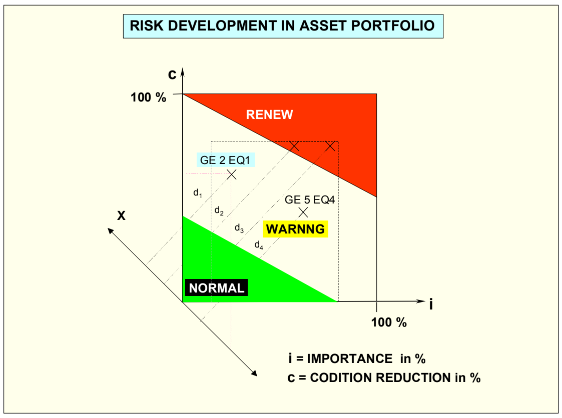


Figure 2: Assessment of system breakdown risk development in terms of equipment condition and its importance in system

5. Hierarchy of condition evaluation

According to substation's hierarchy pointed out in Figure 3, the asset is decomposed and classified on 5 levels as follows: substation (ST), group of equipment (GE), equipment (EQ), parts of equipment (PE) and elements of part (EP). The interconnection between them has been described in matrix form, which indicates the aggregation's network of function's contributions in the chosen asset hierarchy:

$$ST = [GE_1, GE_2, \dots, GE_g, \dots, GE_k] \quad (1)$$

$$GE_g = [EQ_{g1}, EQ_{g2}, \dots, EQ_{gh}, \dots, EQ_{gl}] \quad (2)$$

$$EQ_{gh} = [PE_{gh1}, PE_{gh2}, \dots, PE_{ghi}, \dots, PE_{ghm}] \quad (3)$$

$$PE_{ghi} = [EP_{ghi1}, EP_{ghi2}, \dots, EP_{ghij}, \dots, EP_{ghmn}] \quad (4)$$

where: k, l, m and n are the maximum number of system components belonging to one node of higher hierarchic level in the tree structure (see in Fig. 3).

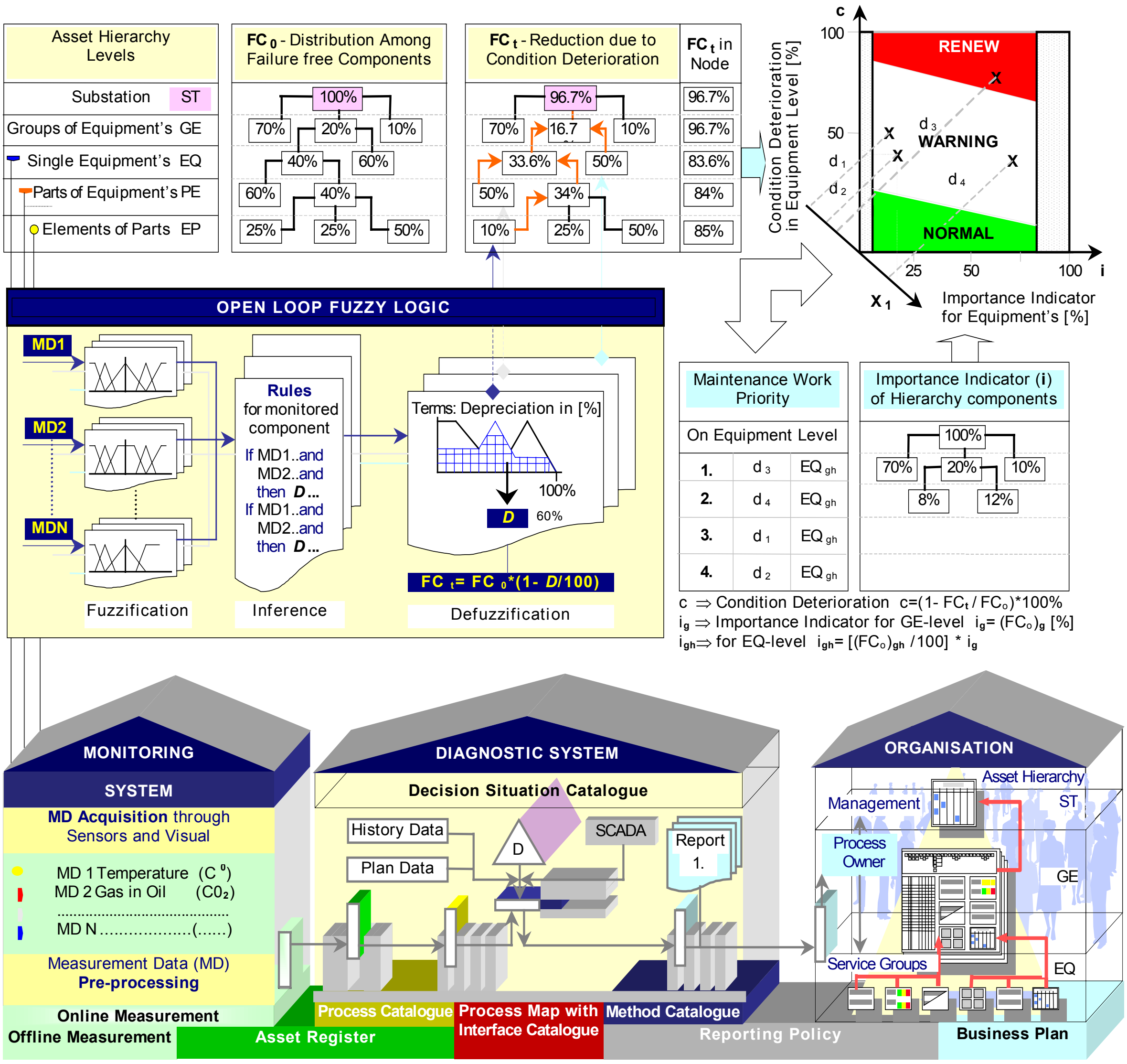


Figure 3. Comprehensive Asset Management Model in process-oriented business environment supported by multilevel diagnostic system and one of its application for online equipment's condition and system risk assessment

6. Quantifying state-of-system indicators using monitoring data

Electrical failure, which are a major cause of forced outages is recognised as being particularly difficult to predict with acceptable accuracy. Because the probability of failure calculated statistically is not reliable enough for expected repair costs computation, more precise methods are needed for its estimation.

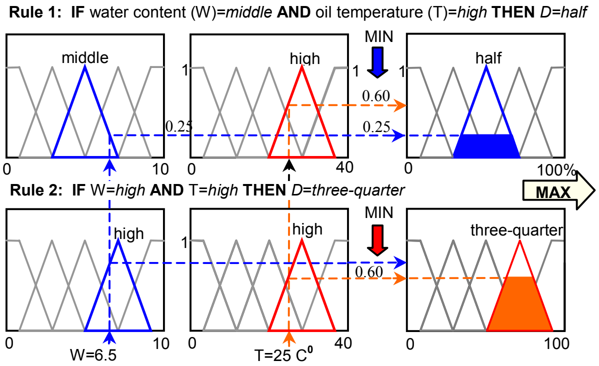
A high-level AMS should allow fast comparison of actual and expected asset performance (in terms of cost and risk) to confirm correctness of management decisions or to trigger an alarm, in case, when the risk profile of the system condition becomes dangerous.

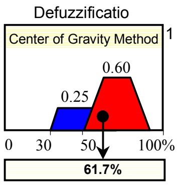
The major challenge is to apply available technology at low-cost, which is able to convert electrical performance data into information in demand-oriented form.

Provided, that the appropriate combination of condition data has been collected, the condition deterioration of system components can be derived using the fuzzy technology (FT) [5]. The example in Fig. 4 demonstrates the FT transforming the oil test data of transformer into value depreciation of the insulation oil (D). The expected maintenance budget for oil treatment (RC_{jE}) can be calculated through probability of oil "breakdown" (P_{ghij}) and its total repair or replacement cost (RC_{jT}) according to (5). Since the exact functional relation between D and P_{ghij} is unknown, it has been assumed that the direct positive correlation between D and P_{ghij} describes the mentioned relationship with acceptable accuracy in warning status. The assumption above which is always subject to individual component-oriented fine tuning has been applied in (5) below. MB_{iE} represents the currently required maintenance budget for repair on PE-level, where the oil is situated in the asset hierarchy.

In order to calculate the condition index (c) on equipment level, the procedure in example should be carried out for all relevant components of the transformer (see the aggregation for FC_t in Fig. 3).

$$MB_{iE} = \sum_{j=1}^{n} RC_{jE} \qquad \text{where} \Rightarrow \qquad RC_{jE} = P_{ghij} \cdot RC_{jT} \qquad (5)$$





Oil	MD and Output Data	case 1	case 2 after vacuum drying
W	water content [ppm	6.5	2.1
T	temperature [C°]	25	28
D	depreciation [%]	61.7	12.5
RC_j	currently expected budget for oil treatment [$]	12340	2500
RC_j	total maintenance cost of oil treatment [$]	20000 Rules 1-2 ⇒ active rules for case	

Figure 4. Fuzzy Logic based interpretation of oil condition data demonstrating the "bridge" function of AMS between physical and financial asset

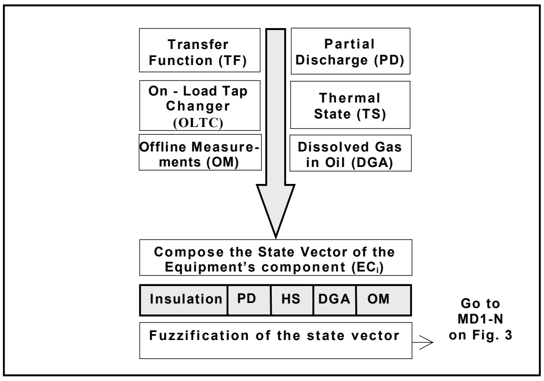


Figure 5. Composition of the component-oriented state vector from the measurement data delivered by monitoring units

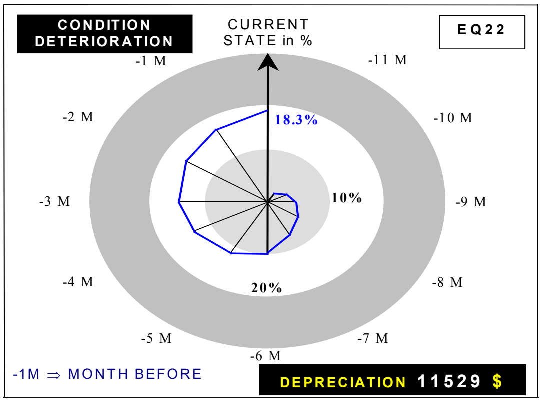


Figure 6. Visualization of condition development on equip ment level and of the currently expected budget sum for repair

Building the state vectors

The procedure of the equipment condition evaluation consist of the following phases:

1. Collecting the relevant outputs of monitoring systems (MS) characterizing the condition of the related equipment component (C) and set up its state vector (see Figure 5)
2. Fuzzification of the elements of state vectors [4] (see the simplified example in Figure 4)
3. Compute the depreciation (D) of the components (see defuzzification in Figure 3-4)
4. Aggregation of D for all C as proposed in [3]
5. Plotting the trend of condition development for EQs in monthly resolution (refer to Figure 6)

Automated reporting on assets

The automated reporting is the final step of the information management process linking up the physical assets with the relevant business processes.

Fig. 6 demonstrates a report sheet about condition development, which can provide up-to-the-minute computed information and as well as the trend of the condition deterioration to the plant operator.

7. Conclusions

The proposed concept describes the frame of a comprehensive asset management system aiming at automated, demand-oriented online reporting on the physical asset. It enables the decision makers to anticipate changes in network business and to develop appropriate actions for process optimization. In this paper has been shown that today's decision supporting tools do not take adequately into account the non-financial aspects in business process control and that this problem can be avoided using an AMS.

8. References

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