APPLIED HEALTH AND RISK ASSESSMENT ON A LARGE ASSET BASE

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ABSTRACT

The subject addressed is digitalization of asset performance management for a large asset base. This was done by implementing a tool for health and risk assessment, using only existing digitized information from available systems. The objective was to ensure uniform asset management decision making and to enable the line of sight in the decision making process according to the framework of ISO55000. The total time spent developing the tool was one year, and the tool is currently in operation. Results are used in asset management decision making, for instance monitoring of risk exposure and assessing maintenance needs.

INTRODUCTION

Demands on technical and financial performance of assets are high for electric power companies. Regulatory and economic pressure implicate the need for cost savings, meanwhile maintaining, or improving, high service and reliability standards [1] [2]. Understanding the impact of actions and the relation to cost and performance over time is therefore essential for efficient asset management [3]. One aim of asset management is to translate the organization's objectives into asset-related decisions, plans and activities as described in the ISO55000 standard. This involves the balancing of costs, opportunities and risks against the desired performance of assets [4]. Therefore optimal and transparent decision making is becoming increasingly important.

Vattenfall Eldistribution, hereafter Vattenfall, is one of the largest grid operators in Sweden, and operates a widely dispersed grid area in Sweden including apparatus with voltage levels spanning from 0.4 kV to 400 kV. Vattenfall is a company with a lot of legacy, and consequently technical and demographic variations between assets are large. This entails challenges regarding optimal decision making, which considers the state and criticality of all individual assets without overspending on decision support.

Many DSO's today aim to achieve a maintenance strategy where decisions are made based on the assessed condition of a specific asset and the estimated degradation time in order to ensure performance and functionality of assets [5], and thereby enabling that the assets are maintained based on need rather than time or other pre-defined interval [6]. Vattenfall is working active within this area, attempting to customise maintenance strategies and enable condition based methods for a larger portion of the asset fleet.

Historically, the maintenance approach at Vattenfall was primarily based on traditional concepts such as time based maintenance. Use of condition based maintenance was limited to specific subsets of asset types and risk exposure was performed on a "need-to-know" basis in specific cases. Maintenance decisions were primarily made by technicians locally and coordinated on a regional level. Due to this the line of sight of the decisions was impaired and in some cases, not uniform, i.e. different decision would have been made by different technicians based on the same data.

Common strategies to facilitate decision support for asset owners include various methods to asses asset health, reliability and criticality [2] [3]. Several methods and approaches have been presented in literature such as [1] [7] [8]. The challenge within this area is often associated to the availability of information, where information sometimes are unavailable, limited or stored in a non-structured way, especially when evaluating each asset in a large asset base individually. The matter is further complicated due to diverse asset stock both regarding demographics, age and technical aspect. This was also the case for Vattenfall. For instance, data has been collected using different methods depending on time period, technology and occasionally geographical area, i.e. all data is not necessarily available in a digitized format for all assets. Another identified challenge was the location of the data needed. Data was often dispersed across several different systems, sometimes with limited association to specific assets, which was also identified as a challenge in [3].

For larger assets bases, decisions of refurbishments and maintenance need to be optimized over the entire asset fleet. This entails requirements to define frameworks which enables comparison between assets or asset groups, often with large technical differences. In order to support decision making, processes need to identify potential failures in asset performance and evaluate the need for preventive actions. Individual evaluation of assets despite the quantity of assets and asset related data is therefore required. Consequently, to achieve optimal decision making for large asset bases the importance of digitalization is increasing.

This paper presents an approach to implement a tool for health and risk assessment for individual assets in a large asset base. An exploratory approach is used to enable data evaluation and decision making, based on available information which is gathered from currently existing data sources and merged in order to aggregate the information to the corresponding assets.

Objectives

The goal of the project was to enable the line of sight in the decision making process and to provide support according to the framework of ISO55000 [4]. In order to achieve this, a method for comparing different assets by using indices was developed. The intention was to enable comparison between different groups of assets and different geographical areas despite inherit differences, by creating an overview of asset overall performance and risk exposure, thereby enabling grid wide decision making based on a common framework. The method also aimed to allow evaluation of the result on different levels, such as type of station, voltage level or other relevant characteristics. Because of the size of the asset fleet, it was concluded that IT support would be required in accordance with what had previously been found in [3]. One goal was to aggregate data to individual assets and thereby making it available on demand. Furthermore the aim was to atomize as much of the evaluation and data collection process as possible. The developed method was implemented in an IT tool in which the necessary data was made available.

METHOD

An exploratory method was used, where the first step was to define asset groups based on asset properties and functions. The next step was to examine the available data and information, including possibilities to extract the data from the current systems, associating it to corresponding assets and make it available in the developed tool. Finally, the method for evaluation was designed and implemented. This is described in the following sections.

Asset groups

Selection of relevant asset groups for evaluation is essential in order to create useful indices. It is also relevant for the asset group population to have similar performance profiles [2]. To enable implementation together with the existing systems, the groups in this project were defined according to classifications in the maintenance system. This was motivated by the similarity regarding functionality as well as general maintenance and refurbishment strategies and budget. Furthermore, it reflects the current maintenance planning process and decision making, and therefore simplified implementation.

Data and information acquisition

To gather needed information in order to perform a reliability analysis, with results which resembles the actual end of life, can be complex, costly and time consuming [6]. One key success factor in developing a maintenance strategy is therefore to evaluate the potential in already existing data, which was also a conclusion in [2] and [6]. Evaluated data sources include information regarding demographics, condition, performance, functional criticality and costs. The categories are further exemplified in Table 1 and is commonly used for asset related decision making according to [6]. In order to connect different data sources an information model was developed, which was the most time consuming phase of the project. It was found that a lot of the data from the different information types both could be associated to individual assets and used for health and risk assessment.

Table 1. Different types of information used in the developed tool together with examples of different information in each group.

Information type	Example of content
Demographics	Location, manufacturer, type, capacity, age, voltage level
Condition	Inspection results, online monitoring, loading levels
Performance	Failure and interruption history
Functional	Safety compliance, obsolescence issues
Criticality	Number of customers, load, location, safety, environment,
Costs	Maintenance, replacement, spare parts, etc.

Evaluation method

In order to achieve both decision support and transparency it was decided to divide the evaluation of assets into four key performance indices (KPI:s) estimating asset condition, reliability, criticality and overall risk exposure. Each index is a value between 0 and 100, and the definitions are given in Table 2.

Table 2. The key performance indices used for evaluation and the corresponding definitions.

Index	Definition
Health index (HI)	depicts the actual asset condition based on current and historical condition information related to the specific asset. The main purpose of the index is to identify maintenance need.
Reliability index (ReI)	depicts the likelihood of failure. The main purpose is to estimate the reliability of the asset.
Consequence index (CI)	evaluates potential consequences of failures. The main purpose is to reflect the criticality of assets.
Risk index (RI)	depicts an estimate of the overall risk exposure related to malfunction of the assets. The main purpose is to provide an input to decisions of risk mitigation.

Using the available information, 230 useful performance indices (PI:s) were identified. Each PI is related to one of the four KPI:s. The relation between the PI:s and each KPI is shown in Figure 1. Some indices, such as interruption intensity, could be associated to all identified asset groups whereas other were specific to certain asset groups such as dissolved gas analysis (DGA) for transformers. Furthermore, some PI:s are evaluated for each asset individually whereas others, such as outage probability, is evaluated for subgroups of assets and assigned to individual assets based on group affiliation. The core method for calculation of indices is based on a generic framework. Selection of PI's is done by experts for each asset group, establishing trust in the method at an early stage.

Each PI is associated with an interval for accepted values and a weight to reflect the importance of the PI in the overall assessment of indices. Both intervals and weights were set by experts. The aim of using threshold values is to create transparency regarding which values or properties that are outside the accepted interval and therefore requires further attention. By using weights for each performance index, transparency is also achieved regarding how much each PI contributes to the overall evaluation for each asset. The weights also allows certain PI's to be excluded from aggregation without removing the PI for evaluation.

Calibrating the weight and threshold values for the interval requires expert judgements and iteration. Calibrating parameter evaluation settings according to experts judgments is considered crucial according to [6], and involvement of experts is also an important step in establishing trust in the method.

The framework allows aggregation of PI:s in several steps, where the final aggregation results in the key performance indices defined in Table 2. The purpose of this is to enable evaluation of specific functionalities or failure modes, or even information sources, and thus further improve comparability within asset groups. For example, several different technical solutions exists to ensure the manoeuvrability of a disconnector [9], but the system impact of failure to manoeuvre will not differ between the technical solutions. Therefore, the impact of manoeuvrability deficiency should have the same impact on the overall KPI. The aggregation of PI:s in several steps also allows for separate weight of sub evaluations, enabling different functionalities to be weighted separately and thus be defined as more or less important to the overall KPI. This functionality is used to add weights for specific data sources depending on usability of the source. For instance, DGA values are sometimes collected both online and during field inspections.

For substations and transmission lines an additional level of aggregation is added, which incorporates the KPI of the individual assets located in the substation or on the transmission line. The method also incorporates weight for the asset groups, thereby taking asset group importance into account.

The general steps for generating the KPI:s can be summarised as:

1. Define asset groups
2. Identify and collect digitized information
3. Define Performance measures
4. Evaluation thresholds and weights
5. Define KPI for decision support
6. Aggregate to desired entity, i.e. a substation or grid area

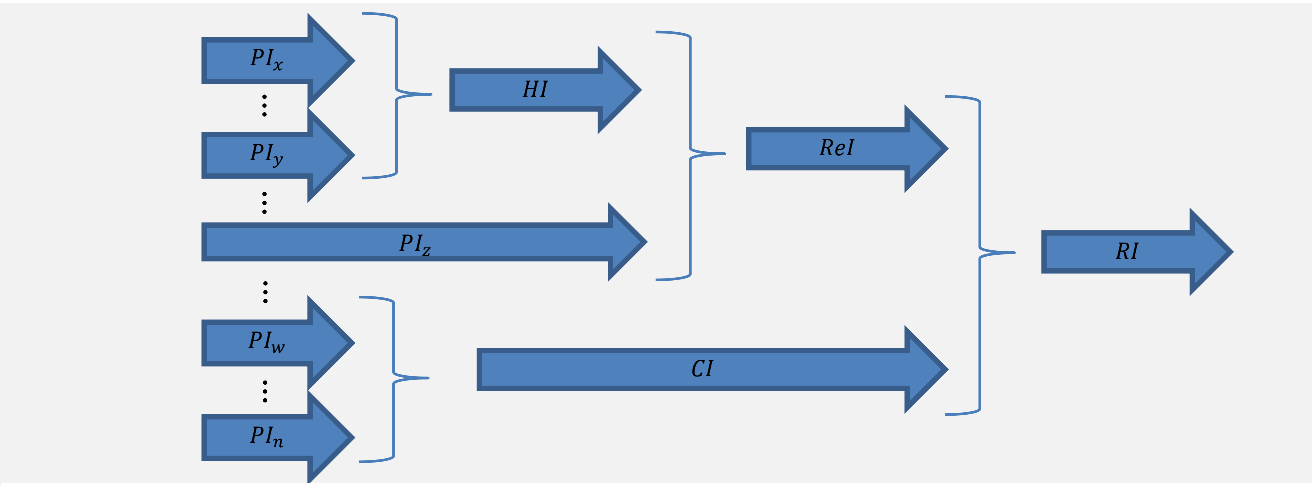

Figure 1. The relation between the initial performance indices and the resulting KPI:s.

RESULTS

The work has resulted in a flexible system where additional KPI values can be added on user demand and PI evaluation levels can be added or removed. The assessment includes more than two million individual assets belonging to 35 asset groups. For 28 of these asset groups, including both electrical assets, such as transformers, disconnectors and circuit breakers, as well as non-electrical assets, such as buildings, the available data was found to be sufficient for assessment of KPI:s. For these asset groups, health and risk indices are currently being exported to the maintenance system. The tool is currently utilising data from seven different sources and allows manual entry of inspection protocols, either through single entries or excel file import. This includes information regarding outages, maintenance, costs, assets and operations.

All settings including thresholds and weights can be adjusted by the users. The generated output identifies the assets in need of additional attention, such as additional maintenance activities, adjusted plans or controls, and also gives support in short- term planning and decision making regarding replacement or refurbishment of specific assets. The result has been made available in the maintenance system, enabling easy access to the evaluated information and possibilities to consider the result in the day-to-day O&M decision making. The tool is also used to follow up maintenance effects and to identify further need of activities to mitigate high risk values.

The total time spent developing the tool was one year, and the tool is currently in operation and results are being used in asset management decision making, for instance monitoring levels of risk exposure and assessing maintenance needs.

The result of the evaluation is aggregated to different entities, such as the individual asset, the substation containing the individual assets, or any other collection of assets based on attributes available in the system, such as voltage level, geographical area or specific types of the asset group, further enabling prioritisation of funds between different subsets of the asset fleet. These entities can also be used for visualisation in the system. One example is shown in Figure 2. Trends for specific PI:s and assets can also be visualized, as shown in Figure 3.

One example of an early benefit includes the prevention of a major tap changer failure, with estimated savings of 150,000 Euro. The incident was prevented during the development phase due to additional information being made available and visible. This resulted in in a new PI reflecting the identified amoralities in tap changer switching behaviour. Since then similar incidents have been identified and preventive measures withtaken.

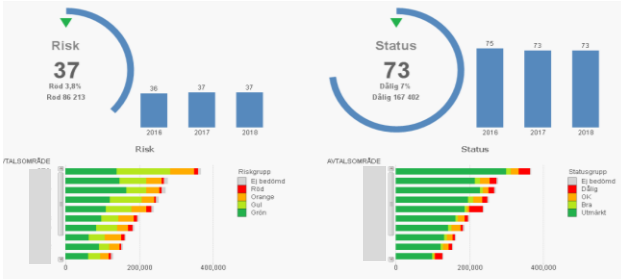

Figure 2. Example of visualization of health and risk indices on an aggregated level.

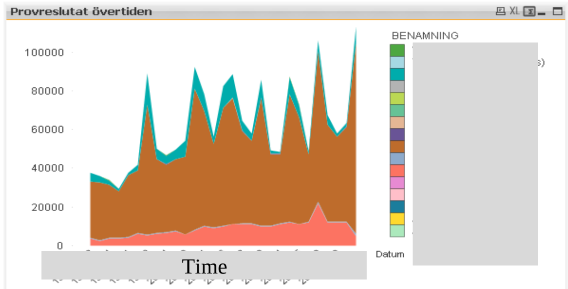

Figure 3. Example of how specific PI:s can be visualized over time.

DISCUSSION

Reliability models need to be sufficiently simple and at the same time sufficiently realistic [10]. The approach during this work was to reach an as simple and comprehensible model as possible to simplify roll out and end user engagement. This is an important step in understanding available data as well as identifying what additional data needs to be collected and made available. Because of the simplified method, the result does not depict absolute health or risk associated with each asset, it does however highlight anomalies and, hence both provides guidance in decision making and facilitates further analysis. The intention is to further develop and refine the method based on the lessons learned during the implementation.

In accordance with previous studies, insufficiencies in information was found to be the main obstacle. The extent of this issue varied from data being non existing to difficulties to associate relevant information to relevant assets, or even to the relevant asset classes. As described in [6], even when data is available it can be misleading to rely only on historical data. Sufficient failure data is not always available, and for newer types of assets, even if the data exists, it may not be sufficient for reliable failure analysis. Another identified challenge is the data volume, with the main challenges being related to storage, structure and computing power and time. However, this project shows that it is possible to make use of the currently available information to create value by making it accessible, structured, and transparent. The system output identifies assets in need of additional attention, which can therefore be further processed by experts.

Involving experts in the final analysis as well as the calibration of parameter evaluation settings, increased end user acceptance and understanding. Furthermore the knowledge of additional data needs has become more advanced within the organisation.

The achieved business values from the system includes cost avoidance due to both operational risk reduction and process improvement; by highlighting the asset with poor health or risk index, the possibility to attend to the asset with greatest need first is enabled. Another benefit being the aggregation of data facilitating analysis and eliminating the time consuming work of manually extracting data from multiple sources and manually merging data in order to enable further analysis. This has a positive impact on the overall business process.

CONCLUSIONS

The paper suggests a method where available information is gathered from currently existing data sources, and merged together such that all information is aggregated to corresponding assets and evaluated based on four indices; health index, reliability index, consequence index and risk index.

The work shows that even when access to information is limited and data is scattered between different sources, it is possible to collect and evaluate health and risk for the individual assets. The indices are used to identify assets in need of additional attention, and these assets can then be further analysed by experts to create the decision support needed. It is also possible to build an application that delivers the described functionalities in a short period of time, even for a large asset base. The full development time was less than a year for this project, and the added value could be realised in the early phases of implementation. The indices are currently being exported to the maintenance system in order to facilitate maintenance planning and decision making.

It should be noted that the main value added is the business knowledge, both regarding how to make use of already available information and how to plan for additional information to be collected in order to enable optimization of asset management.

The developed tool is an early step towards calculations of actual probabilities, that considers both the actual health of the asset and other characteristics as well as the historical data. The next steps consists of improving the accuracy of the method by further breakdown of failure modes as well as further refinement of the chosen asset groups, allowing subsets. This includes further development of asset health assessment in order to depict proximity to end of life and not only maintenance need, by implementing an additional KPI, In addition to this, additional data will be collected from other sources, both to enable a more precise analysis and to include new asset types. This also sets new requirements for the system and the infrastructure. This will require further expertise regarding big data management as data volumes are expected to increase over time,

REFERENCES

[1] T. Hjartarson and S. Otal, "Predicting Future Asset Condition Based on Current Health Index and Maintenance Level,", *IEEE 11th International Conference on Transmission & Distribution Construction, Operation and Live-Line Maintenance*, Albuquerque, USA, 2006.

[2] D. Hughes, "The use of "health indices" to determine end of life and estimate remnant life for distribution assets,", *CIRED, 17th International Conference on Electricity Distribution*, Barcelona, 2003.

[3] J. Schneider, A. J. Gaul, C. Neumann, J. Hogräfer, W. Wellßow, M. Schwan and A. Schnettler, "Asset management techniques," *Electrical Power and Energy Systems*, vol. 28, pp. 643-654, 2006.

[4] Swedish Standards Institute, "SS-ISO 55000:2014 Asset management – Overview, principles and terminology," SIS, Swedish Standards Institute, Stockholm, 2014.

[5] C. J. Wallnerström and P. Hilber, Reliability Analysis and Asset Management Applied to Power Distribution, Sweden: Edita Bobergs AB, 2014.

[6] G. Anders, S. Otal and T. Hjartarson, "Deriving Asset Probabilities of Failure: Effect of Condition and Maintenance Levels,", *IEEE Power Engineering Society General Meeting*, Montreal, Que., Canada, 2006.

[7] R. Heywood and T. McGrail, "Clarifying the link between data, diagnosis and Asset Health indices,", *Asset Management Conference 2015*, London, 2015.

[8] S. Miletić, "Asset condition assessment by health index benchmarking,", *CIRED, 20th International Conference on Electricity Distribution*, Prague, 2009.

[9] A. L. Brodersson, J. H. Jürgensen and P. Hilber, "Towards health assessment: failure analysis and recommendation of condition monitoring techniques for large disconnector populations,", *CIRED*, Helsinki, 2016.

[10] A. T. Holen, A. Høyland and M. Rausand, Pålitelighetsanalyse, Trondheim: Tapir Forlag, 1983.