LOOKING AT LARGE-SCALE UTILITY ASSET MANAGEMENT

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The trend for grid management is towards larger utilities, with owners, authorities and customers making heavy demands in terms of return on investment, efficiency, health, the environment, safety and quality. Typical characteristics include more stringent internal quality requirements, demands by the authorities for better documentation and reporting, and an increasing need for specialist evaluation to be documented and justified to management and decision-makers.

Utilities are, therefore, faced with important choices when it comes to prioritizing grid refurbishment, replacement, maintenance, and fault correction. The need for a holistic approach and more reliable decision support is now a reality in achieving desired goals.

In the present situation, this is not easy to implement in practice. It is still common that important information is only available in manual archives or only available as "silent" knowledge in the heads of experienced employees. A typical situation is meters of shelving with ring binders containing forms covering several years of line inspections, backed up by employees who remember where there have been problems. This type of knowledge could previously be used to make decisions at the local level, without much thought being given to the overall picture and main priorities at the utility level.

The challenge now is to use this type of information as a basis for making decisions taking into account the overall picture for the whole utility. Replacement of a line will not be appropriate if there are other needs which should be given higher priority. Furthermore, other changes are underway, with a new generation of employees

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replacing those with long years of service and extensive local grid knowledge. Younger project managers and technical personnel will be much more dependent on formalized information, as they do not have a corresponding background and local knowledge.

This article describes a concept to deal with the challenges described above. Currently, utilities should benefit from investments in key information systems, such as Network Information Systems (NIS), systems for Enterprise Resource Planning (ERP) and Customer Information Systems (CIS). Such systems have been available for many years and much effort has been put into data collection and data conversion from self-developed proprietary data systems. The situation today is characterized by key systems offering high performance functionality and vast amounts of information. The challenge is now to utilize the available information.

APPLICATION AREAS THAT REQUIRE COMPREHENSIVE GRID EVALUATION

Decision makers will need to rely upon different kinds of information, depending on what kind of decision is to be made. Typical situations are:

– Development of long-term maintenance plans
– Short-term plans for corrective maintenance
– Plans for refurbishment and replacements
– Dealing with current technical problems
– Grid dimensioning based on different prognoses
– Ensuring proper security level for employees and public
– Dealing with environmental issues

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– Meeting requirements from authorities
– Satisfying needs and demands from customers

These different situations require different kinds of information, which might be found in different kinds of data systems. Furthermore, decision-makers will definitely need to differentiate the importance of the data involved. There is no single answer to such questions, and each of the utilities will have to establish rules based upon utility philosophy, preferences, and availability and quality of information.

Maintenance and renewal

Decisions regarding maintenance and renewal play an important role for most utilities due to the fact that the average age of assets has become considerably high. Furthermore, the need for short-term cost reductions will often dictate strategies and solutions where little attention is paid to long-term consequences. A considerable amount of information needs to be taken into account when making such decisions. Typical needs for information are:

- Asset state and failures from condition monitoring and inspections
- Component age
- Component types
- Results from technical calculations
- Economic data such as historical maintenance costs
- Results from LCC analysis
- Cost benefit from different actions to be taken

Authority requirements

There are several authority requirements that must be met, such as annual inspections of components in the distribution network. Information from such inspections is often important when making decisions. Other authority requirements are upgrading or replacement of different technical solutions that are motivated by safety reasons. The time frame and importance of different authority requirements might be differentiated and the number of actions to be taken will often be extensive. This means that prioritizations must be made, involving complex decisions.

Technical requirements

Technical calculations are necessary to verify that current grid complies with existing regulations and to ensure optimum operation of the grid system. This includes load flow analysis to determine voltage drop, thermal load limits of cables and lines, transformer loads, etc. Further calculations must be performed for a period of time, normally 30 years, where future development of energy and power demand is estimated. Assumptions regarding demographic development, industry developments, etc, must be defined and taken into account.

Customer satisfaction

Customer vulnerability is very diversified with respect to interruptions, voltage fluctuations, etc.

For example, customer satisfaction based on complaints should be recorded and related to the occurrence of undesirable events. Availability of historical data for customer satisfaction could be useful for understanding trends in frequency and duration of both notified and non-notified interruptions.

Further, it may be of interest to analyze fault statistics, such as weather conditions and technical causes, to find out more about problem causes.

Personnel safety

An immediate menace to life, health, environment and safety should initiate immediate action.

However, not all observations call for immediate action as this could easily cause suboptimization.

It is, therefore, important to record such information and coordinate with other relevant information and use this to make the right decisions. Component information, such as age and type, will often be used to identify areas where safety needs to be improved.

Economic issues

Economic data is needed to understand how investments should be differentiated in the different components of the grid system. Both data describing labor expenses, asset investments, cost of losses and interruption costs must be taken into account. Furthermore, data describing planned investments and planned maintenance will be needed.

Environment/esthetics

It is necessary to evaluate environmental consequences. This implies both potential pollution problems and esthetic aspects. Public fear and uncertainty surrounding areas such as electromagnetic influence should be represented. This could, for example, determine the use of cable instead of line when crossing residential areas. Esthetic aspects could also motivate a similar conclusion.

METHODOLOGY

Low-voltage network structuring

A low-voltage cable network usually consists of the following components: LV distribution busbar, feeders, distribution pillars and service lines. In our model, the substation itself, the MV switchgear and the distribution transformers are also regarded as components of the "low-voltage" network.

It's important to note that not every single item is analyzed. In the model, all similar items, e.g. all service lines, are analyzed as one average "component".

Low-level indicators

For each component "i" in the low-voltage network, a set of low-level indicators is defined.

– Technical indicators comprise technical solution, age, technical condition (percentage value based on condition monitoring), degree of utilization, etc.

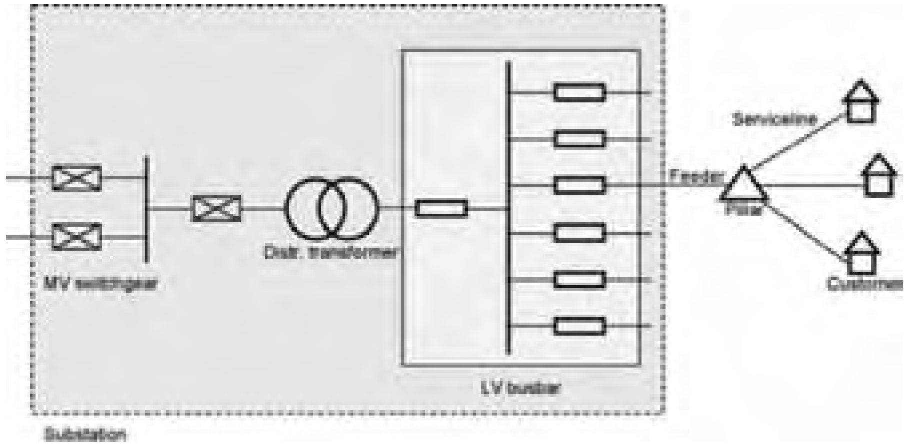

Figure 1 Example of a low-voltage cable network

– Economical indicators comprise historical investment costs, operational costs, maintenance costs, etc.

Most of the input parameters come from load flow analyses, short-circuit calculations and reliability calculations in the Network Information System (NIS). In addition, information like type, age, etc, and parameters for the technical condition, recorded failures and their consequences coming from the computerized maintenance management system (CMMS) are important parts of the analysis.

One of the main practical problems is to compare quantitative parameters (with different scales) with qualitative parameters. On way to overcome this obstacle is to transform each selected parameter into 1 out of 3 possible states by comparing the parameter value to a pre-defined set of criteria. It is important that these criteria are strongly related to the utility's philosophy and strategy. The 3 states are based on a traffic light analogy (Red, Yellow, Green), with a 4th White state added for inadequate input data. By following such a methodology the decision-maker may have a uniform and consistent analysis of all components in the entire network.

Table 1 Categorization of low-level indicators in one out of 4 possible states

State		Description	Criteria	Weighting
WHITE	-	Inadequate input data		α_{White}
GREEN	OK	No actions necessary	U > 218	α_{Green}
YELLOW	Warning	Fulfills functional requirements, but actions may be necessary	U < 218	α_{Yellow}
RED	Alarm	Does not fulfill functional requirements, actions required	U < 207	α_{Red}

U = Lowest measured (or calculated) voltage in the low-voltage network [V] (230 V system)

Table 2 Examples of low-level indicators for a transformer

Low-level indicator	Value	Red	Yellow	Green	Weight
1. Technical solution	Orient. core		Non-ori. core	Orient. core	$w_{i,1}$
2. Age	30 years	[illegible]	≥ 35 years	< 35 years	$w_{i,2}$
3. Technical condition	40	[illegible]	≤ 50 %	> 50 %	$w_{i,3}$
4. Degree of utilization	92	[illegible]	≥ 90 %	< 90 %	$w_{i,4}$

Component indicators

Each component in the network has several low-level indicators, and to be able to make a total assessment of each component, the indicators have to be aggregated to one component indicator.

The indicator for component "i" can be calculated based on all its low-level indicators "j" by the following formula:

$$PI_{Comp,i} = \frac{\alpha_{Green} \sum_{j,Green} w_{i,j} + \alpha_{Yellow} \sum_{j,Yellow} w_{i,j} + \alpha_{Red} \sum_{j,Red} w_{i,j}}{\sum_{j,Green} w_{i,j} + \sum_{j,Yellow} w_{i,j} + \sum_{j,Red} w_{i,j}}$$

Relative weighting of the low-level indicators

These different low-level indicators may have varying importance (weight) when assessing the actual component. The weighting can be based on a subjective assessment. Another, more formal, weighting principle may be based on e.g. the Analytical Hierarchy Process (AHP) method. The type of customers connected to the network may also influence the weighting of the indicators, e.g. the availability or outage time is much more important in an industrial/service area than in a residential/farming area.

Network Name	Network	White	Green	Yellow	Red	Network	Sub-station	MV Switchgear	Trans-former	LV busbar	Feeders	Pillars	Service lines
<Average>	0,1	9	72	5	14	0,1	0,0	0,0	0,0	0,0	1,0	0,0	0,0
<Worst case>	14	9	72	5	14	13	100	100	100	100	33	100	100

Table 3 Results presentation examples from the prototype

Relative weighting of the four possible states

Based on an intuitive assumption that "red" indicators are more important that "yellow" and "green", the four states have been given different relative weight (white indicators are not included, and have ?White = 0).

The main purpose of aggregating low-level indicators to the component level before they are aggregated to the low-voltage network level is the possibility to separately assess similar components throughout the system, e.g. to compare component indicators for all the distribution transformers in the entire network, and to analyze whether the same components most often cause the "bad" indicators.

Low-voltage network indicators

The low-voltage network indicator is, in addition to the component indicators, calculated based on a set of indicators with aggregated values for the LV network:

– Technical indicators comprise network losses, lowest voltage, number of outages per year, annual outage time, annual outage cost, etc.

– Health, environment and safety indicators comprise safety, noise problems, esthetics, etc.

– Other indicators comprise demographic information, customer categories, etc.

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The low-voltage network indicators can be calculated using a formula similar to that on page 35. As with the weighting of low-level indicators, different components may have different importance (weight) in the network. The weighting principle can be based on the replacement cost for each component. This can be justified by the fact that the alternative to overall renewal of the LV network is replacement of faulty or overloaded components. Also, for the low-voltage network, the weighting principle may be based on the Analytical Hierarchy Process method. Table 3 presents examples of result presentation from the prototype.

<Average>

The result from the <Average> calculations gives a "Green" indicator for this LV-network. In addition to the overall indicator, a weighted percentage value for each of the states White, Green, Yellow and Red is calculated. By inspecting these values, the decision-maker can find that an overall "green" network still may have potential "red" problems. For this particular network, the result shows that 9% of the indicators are "White" (data missing), 72% are "Green", 5% are "Yellow" and 14% are "Red". The detailed results for the different components show that it is only the feeders that are not "Green".

<Worst case>

In addition to the overall weighted average, the prototype also gives the possibility to calculate and present aggregated indicators where information about the worst low-level indicators is maintained. The result from the <Worst case> calculation shows that 33% of the low-level indicators (1 out of 3 indicators with equal weight) for the feeders are "Red", which results in the 14% "Red" for the whole low-voltage network. Notice that in this case the color of the worst-case indicator is presented as the network indicator.

In this example the results are presented for only one low-voltage network. However, the prototype can simultaneously calculate indicators for all low-voltage networks the user selects.

Presentation of low-voltage network indicators in NIS/GIS

The one single weighted indicator representing the state of the entire low-voltage network indicators can be presented in the NIS/GIS (Graphical Information System). Figure 2 shows the results from an analysis in the prototype. The lines represent the medium-voltage network, while each dot (located at the geographical position of the sub-station) represents the low-voltage network indicators. In this grey-scale figure dark grey = Red, grey = Green, light grey = Yellow and white = White. This kind of graphical presentation may give the decision-maker an indication on geographical areas with several "bad" low-voltage networks.

Figure 2 Example of visualization of indicators in a network

It is impossible to have an exact and perfect large-scale utility asset management model. The real challenge is, therefore, to establish a model that is not so complex that it cannot be implemented, but still complex enough to present results that are "good enough", although not "optimized".

Maynard Keynes once stated: "It is better to be roughly right than precisely wrong". Using high-precision values in the result presentation only gives the impression that the calculations also are very precise, which they are not.

It is therefore emphasized, as the name implies, that the indicators only give an indication of current problem areas, or areas where future problems are most likely to occur. For the "Red" and "Yellow" low-voltage networks more detailed analyses must be carried out in order to identify the actual problems and the proper solutions.

INFORMATION AVAILABILITY

Currently, most utilities have established systems for documentation of assets, including geographical information. In a modern NIS (Network Information System), asset information is integrated with geographical information, network topology, maintenance information, making considerable amounts of information available for users within various levels of the organization.

The trend seems to move from integration between several stand-alone applications towards fewer integrated solutions where NIS (Network Information System), ERP (Enterprise Resource Planning), CIS (Customer Information System) and SCADA are the core systems. The advantage of few core systems in this context is that information is made easily available to those who need data to make decisions. Stand-alone applications may seem advantageous when just looking at the need for information for specific tasks, e.g. applications for recording data when doing line or substation inspections. However, such information is far more valuable if it is possible to relate this information to other relevant grid data such as results from network calculations and historical maintenance costs.

CONCLUSION

Traditionally, most of the maintenance and renewal planning and decision-making have been carried out in local departments, where in-depth knowledge about the condition of the network was background for many important decisions. Due to centralization, more of the planning and decision-making is transferred to central offices where the planners do not have a similar local knowledge about the network condition. Furthermore, decisions now have to be made upon a broader set of information, including economical data, technical analysis, environmental and safety data. Therefore, making decisions now has to be based on "formal knowledge" stored in different information systems.

Distribution networks are characterized by a large number of geographically dispersed components, and the opportunities for decision-makers to get detailed information about the network is limited. This fact calls for a methodology to help decision-makers in screening the entire network to decide what is likely to be the most cost-effective solution for maintenance and renewal.