ASSET MANAGEMENT ARGUMENTS FOR SMART GRIDS

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ABSTRACT
This paper describes how Essent Netwerk has developed a strategy for the automation of its medium voltage network. Using Asset Management techniques, it was demonstrated that the application of a new distribution automation concept results in an improvement of network reliability and enables the temporisation of asset replacement programs. Both these benefits were quantified and appeared to outweigh the cost of the new strategy by far.

INTRODUCTION
In the past the design and operation of the medium voltage (MV) grid has been optimised for the main function of transmission of power from the high voltage grid, where large-scale power plants feed in, to the low voltage grid, where mainly power consumption takes place.

Nowadays a number of trends can be identified that will result in a different use of the power grid (e.g. distributed generation) and different demands of stakeholders (e.g. information requirement of customers and regulator). These trends may lead to different requirements on the design and in particular on the operation of the MV-grid.

Being aware of these changes, Essent Netwerk has analysed the different trends and their effect on design and operation of the MV-network. In order to meet the future requirements, a new strategy for operation of the MV-grid had to be developed. This paper describes how the risk analysis and the development of the mitigating strategy was carried out, using Asset Management principles that are incorporated in Essent Netwerk’s Risk Based Asset Management (RBAM) process.

ASSET MANAGEMENT
Since 2004 the RBAM process is being used and further developed at Essent Netwerk. In 2006 full certification of this process according to the standards ISO 9001:2000 and PAS 55-1 was reached.

The Asset Management Organisation Model
In the Asset Management organisation model three different roles can be distinguished, namely the Asset Owner, who is responsible for budget and target setting, the Asset Manager, whose task is to formulate policies and resulting workload, and finally the Service Provider, whose task is the execution of the work.

Risk Based Asset Management
In the RBAM-process, as depicted in figure 1, the Asset Manager fulfils his task by identifying and analysing risks that threaten the performance of the networks as expressed by the business values of the Asset Owner. Next the Asset Manager formulates strategies to reduce these risks. The strategies with the highest expected yield, in terms of risk reduction per Euro spent, are selected to be implemented. After implementation the effectiveness and efficiency of the strategies are evaluated.

FUTURE DEMANDS ON MV-NETWORK
In order to explore the future demands (at about 2020) on the MV-network, first some general social trends of today that might be of influence here, were listed. The most relevant trends are mentioned here:

General trends
  • Increasing shortage of (fossil) energy sources because of continuous growth of global population and new growing economies. This shortage results in an increase of energy cost.
  • Increasing social awareness that energy availability is no longer unconditional. This awareness results from the energy shortage and common recognition of the negative environmental and climatological effects of energy consumption.
  • Further increase of computerisation and automation of society. People are getting used to the easy accessibility of data and will claim the same easy access in fields where this is not yet available now.
  • Persistent and maybe even increasing lack of qualified...
technical personnel.

**Future demands**

These general trends are enabling or promoting factors for some more specific developments that directly influence the demands on the MV-network. These developments are:

- Strong growth of distributed generation is expected. This type of generation often utilises sustainable energy sources and economically mostly depends on governmental subsidies. Because of the high cost of conventional energy, distributed generation will become profitable by itself and will more and more replace centralised production. The MV-grid then should be capable of facilitating bi-directional power-flows, balancing local power surpluses and deficits. The function of the MV-grid will thus shift from power distribution to power balancing.
- Society is becoming more demanding as to network reliability, as the dependence on electricity is growing. Power interruptions are no longer accepted as inevitable or inherent to the supply of electricity. Today, as appears from figure 2, the major part of the customer minutes lost (CML) originate from power interruptions in the MV-network. This is not a desirable situation when the MV-grid will gain importance in its new role of power balancer.
- Public information supply during power interruptions is getting more important. Because of the dependence on electricity on the one hand and the ease of public availability of information in other sectors at the other, a more complete and fast information supply on the size and expected duration of interruptions will be demanded.

From this analysis it appears that mainly the business values 'Reliability' and 'Reputation' are affected. Reliability is affected because the information on power-flows in the MV-network is not sufficient to facilitate the variable flows that come with distributed generation. This can for instance result in unnoticed overloading of electrical components. Reputation is at stake when the demands of society concerning reliability and information supply are ignored and not incorporated in network operation.

Using the Risk Matrix of Essent Netwerk the categories of the effect and the frequency of occurrence of the risk can be determined. Figure 3 shows an example of a simplified version of the Risk Matrix, including only the business values 'Reliability' and 'Finance'.

<table>
<thead>
<tr>
<th>Category</th>
<th>Probability</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serious</td>
<td>MH</td>
<td>VH</td>
</tr>
<tr>
<td>Considerable</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Moderate</td>
<td>N</td>
<td>L</td>
</tr>
</tbody>
</table>

**STRATEGY DEVELOPMENT**

The new functions of the MV-network ask for a more flexible operation at even higher reliability and enhanced information availability, while at the same time labour-intensity of network operation needs to be reduced. These demands quite logically lead to some form of automation.

**Distribution automation**

The MV-networks of Essent Netwerk typically consist of a transmission part, that is redundant in design (n-1 secure), and a distribution part, that has a ring-configuration, but is operated as a radial grid. In case of a failure, the fault is cleared automatically, however the isolation of the faulty section and the restoration of power is executed manually.

This implies a great potential for improvement of both reliability and labour-intensity by applying distribution automation. Moreover, distribution automation will also facilitate information supply. Therefore, a concept of remote control switching and fault location in the MV-network is developed. Many variants of remote control are possible: in theory all circuit breakers and...
switch-disconnectors could be equipped with remote control, but at a certain point the additional reliability improvement is no longer worthwhile, i.e. the additional investment does not pay off.

**Alternatives**

For several alternatives the yield (risk reduction per Euro spent) can be calculated in order to find the optimal degree of remote control. This will be illustrated here for two alternatives.

![Figure 4: Two alternative concepts for remote control](image)

As can be seen in figure 4, in alternative 1 only the circuit breakers at the origin of the distribution ring are remote controlled. Alternative 2 additionally includes remote control of the switch-disconnectors at the splitting point and halfway each distribution feeder.

**Risk reduction**

The reduction of risk normally is determined for each business value separately and then added to obtain total risk reduction. For the sake of brevity, in this paper only the risk reduction for the business value Reliability will be explained.

In alternative 1, in case of an outage of a feeder, fault isolation is still carried out manually, but power restoration can partly be executed remotely (only the first part of the feeder towards the faulty section). This saves time and reduces total CML in the MV-grid by approximately 10%, i.e. a decrease of SAIDI by 1.5 minutes.

In alternative 2, supply to half of the outaged distribution feeder can be restored at once, as the fault is located in the other half. After the fault has been isolated manually, power to the remaining part of the feeder is also restored remotely. This alternative will reduce total CML in the MV-grid by at least 40%, which means a SAIDI decrease of 6 minutes.

**Yield**

To be able to judge whether the risk reduction of the different alternatives outweighs the cost of each alternative, it would be useful to express the risk reduction of the non-financial business values (in this case only Reliability) in Euro as well. In that way reliability improvement can be compared to investment cost. In the Risk Matrix in figure 3, it can be observed that each row represents one effect-category for all business values. This means that the CML-effect is equivalent to the financial effect in the same row, in other words: 1 CML equals 0.5 Euro.

Table 1 now shows the annual risk reduction for both alternatives, expressed in SAIDI, CML and Euro.

**Table 1: Annual risk reduction**

<table>
<thead>
<tr>
<th>Reliability</th>
<th>Alt 1</th>
<th>Alt 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAIDI</td>
<td>1.5</td>
<td>6</td>
</tr>
<tr>
<td>CML (x 1000)</td>
<td>3,800</td>
<td>15,000</td>
</tr>
<tr>
<td>Euro (x 1000)</td>
<td>1,900</td>
<td>7,500</td>
</tr>
</tbody>
</table>

Because these are monetarised annual risk reductions, it is possible to translate the future annual risk reductions to the present, using the net present value (NPV) technique. The values that are acquired in that way represent the economic value of the total risk reductions of both alternatives. These values can be divided by the total investment cost (also NPV) of both alternatives to deliver the yield, expressed as risk reduction in Euro per Euro spent, as shown in table 2.

**Table 2: Yield of each alternative**

<table>
<thead>
<tr>
<th>Yield</th>
<th>Alt 1</th>
<th>Alt 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk reduction in Euro per Euro invested</td>
<td>1.3</td>
<td>2.5</td>
</tr>
</tbody>
</table>

The yield of both alternatives exceeds 1, which means that both alternatives are attractive investments, but alternative 2 has the highest yield: for each Euro spent, 2.5 Euro of risk reduction is returned. Also in comparison with other possible variants, that have not been discussed here, alternative 2 proved to be the most profitable one.

**INTERACTION WITH OTHER STRATEGIES**

Because many risk mitigating strategies already exist, one needs to check to what extent a new strategy influences the effect of existing ones. In this case a strong interaction with Essent Netwerk’s strategy for long term asset replacement exists, which will be discussed in the following.

**Replacement wave**

The major part of the assets in the electricity networks of
Essent Netwerk have been installed within a short period of
time, with a peak in the 1970's. It is expected that these
assets will also reach end-of-life within a short time span.
This may affect future network reliability and additionally
the necessary replacement of these assets may result in a
huge workload, while a lack of technical personnel exists.

To determine the expected size and steepness of this
replacement wave, simulations were carried out, based on
asset failure models. The simulation model was used to
assess different replacement strategies, to find an acceptable
balance between network reliability and the workload
involved with the replacement activities.

Figure 5 shows the investment volume in the past and a
prognosis for the future. With this rate of replacement future
network reliability is expected to stay at approximately the
same level as today.

![Figure 5: Investment volume over time (1970 = index 100)](image)

**Effect of distribution automation**

The improvement of network reliability through the
application of distribution automation in the MV-networks
directly influences the balance between reliability and
workload that has been established in the long term
replacement strategy.

This reliability improvement enables a delay of replacement
activities, thus flattening the replacement wave and
reducing the peak-workload.

Simulations show the expected development of network
reliability as depicted in figure 6. The red line represents the
deterioration of reliability when no active replacement
strategy is put in place. The green lines represent a
preventive replacement strategy, the upper without and the
lower with the application of distribution automation, as
from a certain point in time. The possible delay in
replacement programs also delays the investments involved
and in that way saves money. When this is also taken into
account in determining the yield of distribution automation,
it will be even more profitable.

![Figure 6: Reliability prognosis](image)

**CONCLUSIONS**

This paper presents the development-process of a new
strategy for operation of the MV-network. Application of
the RBAM-process has lead to the following conclusions:

- Distribution automation in the MV-network has proven
to be profitable, using Asset Management techniques.
- Remote control switching in distribution grids will
result in a significant reduction of customer minutes lost.
- Because of this enhancement of network reliability,
future replacement programs, that are anticipated to
maintain the reliability level, can be delayed.

The concept of distribution automation that has been
presented in this paper is the basis for a new strategy for
operation of the MV-network. This strategy will, in addition
to changes in the network itself, also lead to changes in
other areas. It for instance also involves adaptation and
integration of IT-systems and changes in working processes
that are related to network operation. An important result of
this strategy is that network operation, which can now be
characterised as 'network surveillance', in the future will
shift to 'network control'.

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