RISK BASED ASSET MANAGEMENT – DECISION SUPPORT AND COMPARISON OF SOLUTION ALTERNATIVES

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ABSTRACT

The Distribution System operators (DSO) of Berlin and Hamburg have applied the method of Risk Based Asset Management (RBAM) for about a year for decision support as well as for the comparison of solution alternatives. The present paper will describe this approach and the concrete procedure using the example of a cable type only sporadically employed (internal gas-pressure cable) with high failure risk and very long corrective maintenance time.

1. INTRODUCTION

1.1 Background

All German distribution network operators with more than 100,000 customers are regulated by the Bundesnetzagentur (*German Federal Network Agency*). All other network operators are subject to control by the federal state regulation authorities. If a federal state has no regulation authority of its own, the control of the network operators also falls to the Federal Network Agency as an “agency loan”. The main tasks of the regulation authorities consist in ensuring that every market partner has fair and equal access to the energy supply network, and creating incentives for the network operators to improve their efficiency. The associated cost reductions must be passed on to customers via the network usage charges.

The Asset Management of the two distribution network operators Vattenfall Europe Distribution Berlin and Hamburg is responsible for the sustainable management of the distribution networks, and pursues the following main business objectives:

- Compliance with all legal obligations
- Compliance with work safety standards
- Protection of the environment
- Achievement of appropriate supply quality
- Positive company image
- Ensuring financial success

These objectives may come into competition in individual cases, so that, with fundamentally limited resources (e.g. required specialists), decision conflicts had to be resolved over the past years with regard to the planning and initiation of replacement and maintenance measures.

For the tasks described, Vattenfall Europe Distribution Berlin and Hamburg developed the method of RBAM in 2009 and used it for the first time in the regular planning process in the year 2010. It is now being successively extended to all investment and cost projects.

Even under uncertain framework conditions, Risk Based Asset Management provides an objective comparison between different measures, and therefore the basis for optimum decisions. The efficiency of the required decisions can be further improved by the systematic, impartial assessment of the asset-related measures with regard to the defined business objectives.

1.2 Method

The idea of the RBAM method is based on two fundamental principles.

1. The assessment of the asset-related measures with regard to the defined business objectives
2. The prioritisation of the measures under the condition of limited resources

The method runs through the following 4 phases:

1. Risk analysis and solution development
2. Assessment and solution selection
3. Resource comparison and prioritisation
4. Monitoring

In the first step of the risk analysis, the facts and the resulting consequences are prepared, and the assignment made to the defined business objectives. The results of the analysis are visualised in a graphic overview, the so-called bubble diagram (Figure 3), in order to systematically prepare and support the development of different possible solution alternatives.

In the second step, the solution variants are developed and assessed. In practice, it has proven itself expedient to examine the variants with respect to a reference variant (status quo). The effect of the measures on the different business objectives is thereby converted into a commercial variable (e.g. Euro), so that costs and benefits may be compared objectively. By means of this standardisation, the usually multi-dimensional effects on several business objectives can be cumulated directly year-on-year. The calculated total in Euro shows the benefits directly, i.e. the concrete effect of the assessed measures with respect to the defined business objectives in the relevant year. The annual totals of the calculated benefits and costs of the measures are converted at cash value to the base year. An additional advantage of this standardisation is its easy adaptation in the event that business objectives are extended, omitted or changed. Such adaptations can be carried out very easily and directly, i.e. without the use of otherwise necessary weighting factors.

The quotient η_w from the expected benefit and the forecast costs of a solution alternative is referred to as the efficiency (Figure 1).

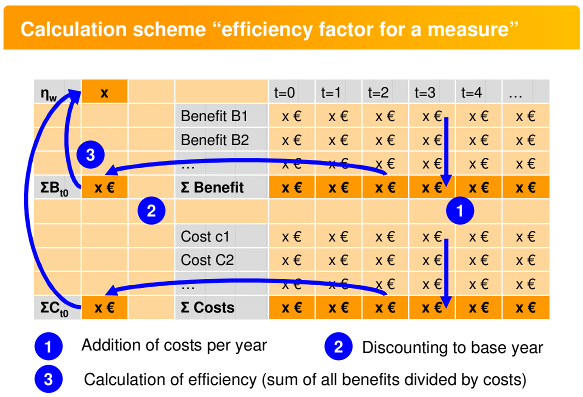

Figure 1: RBAM calculation schematic

If the benefit of the measures predominates (efficiency η_w>1), it is then seen in itself as more profitable than the reference variant (the status quo is maintained). In the case of problems which have several solution alternatives with an efficiency factor of more than 1, the solution possibility with the greatest efficiency is selected as the best solution. If the risk analysis results in all solution alternatives showing an efficiency of less than 1, no measures are implemented for this risk field, the status quo is maintained and the risk consciously accepted, since the costs for the risk minimisation or avoidance are higher than the resulting benefit.

Since the resources required for the implementation of the measures are not available to an unlimited extent in individual cases, the prioritisation of all efficient measures with respect to the available resources is required in the third step, should the case arise. For this purpose, a resource limit is introduced, which ensures that the available resources can only be used by the most efficient measures. In practice, the assessed solution measures are sorted according to the calculated efficiency factors in descending order of size and selected in turn for implementation, until no adequate resources are available for further measures. The most complete possible utilisation of the available resources by variants assessed as efficient can be further improved by mathematical optimisation processes [2].

In the fourth step, the efficient measures which are not implemented because of possible short-term resource restrictions are noted in a risk memory, in order to include these measures systematically, when new resources become available, e.g. in the following business year, in the new RBAM process which will then be started. The documentation of the efficient measures not implemented because of resource restrictions enables the systematic monitoring of the risk development, combined with the resulting and possibly necessary initiation of resource increases.

2. APPLICATION USING THE EXAMPLE OF AN INTERNAL GAS-PRESSURE CABLE, YEAR OF INSTALLATION 1963

In this chapter, the method presented will be described by means of an actual example.
The distribution network in Hamburg covers the voltage levels from 110 kV to 0.4 kV. The anticipated service life of the components, depending on the relevant operating material, is in practice between 20 and 70 years. Due to this long service life, the supply network will necessarily consist of operating materials with different technologies and different technical conditions.
In 1963, in the west of Hamburg, a new 7 km-long 110 kV cable was brought into operation for the supply of a substation. A three-conductor internal gas-pressure cable manufactured by the firm of Felten&Guilleaume was used. This cable type has functioned reliably in the past. A spare cable section is available, although the manufacturers have announced for the future that they will be discontinuing the support for all types of internal gas-pressure cables. A transitional technology (cable junction box) between the internal gas-pressure cable and the XLPE cable used today has not yet been developed by the manufacturers. In addition to the increasingly difficult repair possibilities brought about by the age of the cable and the lack of specialist personnel, this creates an increasing risk of a long-lasting, extensive power failure.

Figure 2: internal gas-pressured cable junction box

A risk assessment therefore had to be carried out for the affected substation and especially for the internal gas-pressure cable connection. This required the identification and analysis of potential supply interruptions and their causes (operating equipment failures). The developed solution alternatives were then examined and assessed using the RBAM method.

2.1 Risk analysis

The risk of the further operation of internal gas-pressure cables consists in the long non-availability in the event of a fault. If the spare system also fails at the same time, several tens of thousands of customers will be without power for a relatively long time. The risk of occurrence of a failure must therefore be considered particularly on the basis of the probability of occurrence and the effects of possible fault events.

The following possible failure scenarios of the specified cable type were identified:

- Lacking integrity of cable junction box
- Cable faults (electrical / mechanical)
- Damage of cable seating end
- Cable sheath faults

The probability of occurrence, the repair costs and the time required for repairs were estimated for all failure scenarios. These constitute the input values for the probabilistic examination analysis.

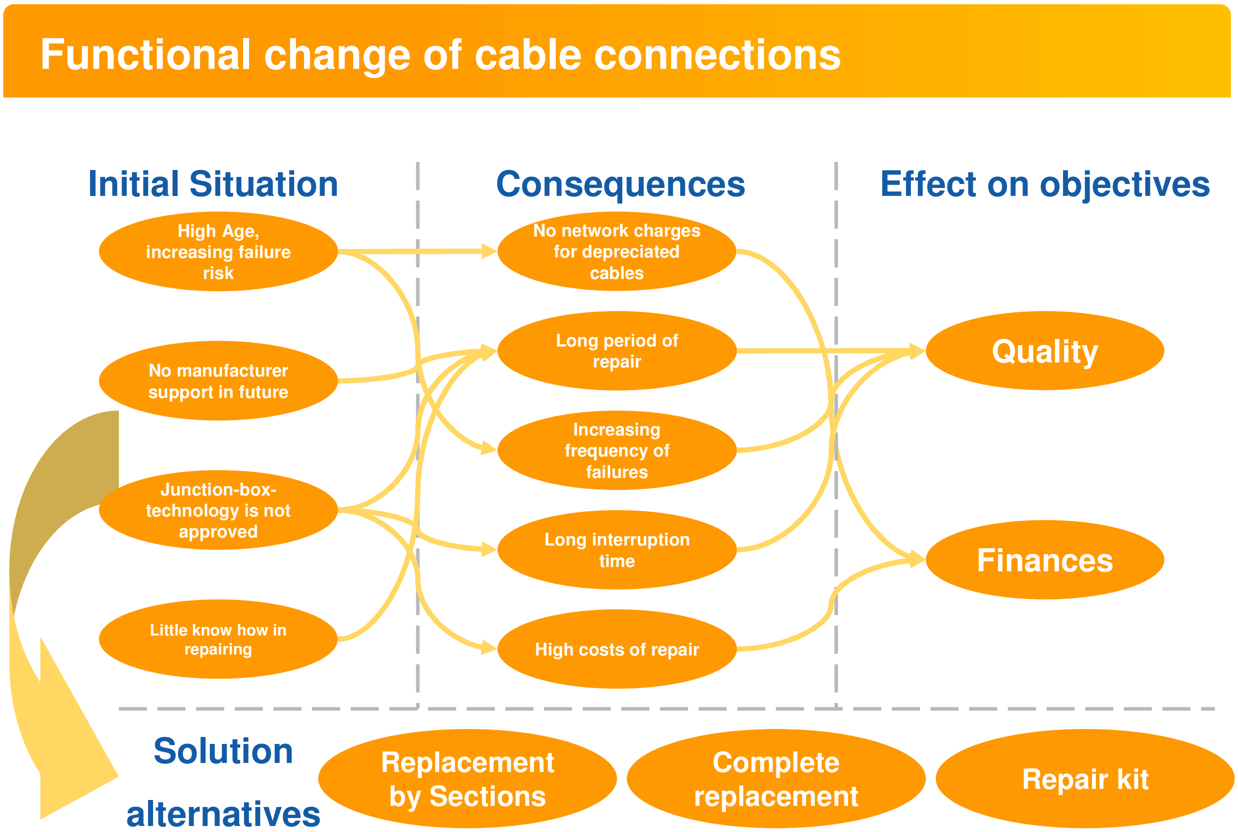

Figure 3: Bubble diagram for internal gas-pressure cable

2.2 Solution development

In order to minimise the risk of a complete failure of a Hamburg city district, various solution possibilities were developed for the existing situation. Three solution approaches appear here to be advisable:

(1) Replacement by sections:
The cable is replaced in sections along the same line, the probability of a failure of the internal gas-pressure cable is reduced with every replaced section.

(2) Event-oriented repair with provision of special repair sets:
Repair sets are ordered before damage occurs, consisting of cable junction box for connection to the current cable technology. This reduces the repair time in the event of a failure.

(3) Complete replacement:
Before the end of the service life and the decommissioning of the internal gas-pressure cable, a new XLPE cable is laid along a new line. The old cable is shut down on completion of the new connection.

The event-oriented repair without provision of special repair sets and correspondingly long repair time (ordering and supply **after** failure) is the reference variant.

2.3 Assessment

In the next step, the identified solution alternatives for improvement of the situation are assessed. To do this, the relevant expected differences in the costs and benefits of the variants under assessment are determined in comparison to the status quo.

The concrete resulting benefits of the variants include:

1. Finances

These include a reduction in the forecast operating costs after implementation, together with higher revenues from the network usage charges (assessment of investment in accordance with German network charge regulations).

2. Quality
The solution alternatives provide a higher forecast service reliability (reduced frequency and duration of supply interruptions) and thus improved key figures (H_U, T_U, Q_U) for the supply quality. In the future, these key figures will be included in the quality regulation. They determine a reduction or bonus on the network usage charges to be applied. This results in a positive effect on the business objective of "quality", which is therefore assessed with a bonus amount.

Quantitative risk analysis

For the reference variant "Repair without provision of repair sets" and the solution approaches "Repair with provision of repair sets" and "Complete replacement", a probabilistic reliability analysis was carried out as the basis for quantitative risk analysis. The input figures included the failure frequencies and repair durations of the network components, the durations of operational switching and measures and the performance requirements of the affected customers. The results include the frequency and duration of the interruption of the system function "Supply of the sub system HV/MV substation" (incl. the high-voltage cable connection) and the energy not supplied on time as a result of the interruption. The reliability data of the network components were provided by the VDN fault statistics, and the durations of operational measures and switching by the DSO Hamburg. The stationary Markov process [3] (see Figure 4) was used for the enumerative analysis, since simpler processes were not suitable for the current task.
One particular challenge was posed by the modelling of the failure behaviour of the internal gas-pressure cable and the complex repair strategy. The stationary Markov process was also the suitable method for this modelling (see Figure 5). As a result, failure and repair rates were obtained for the internal gas-pressure cable. In the course of this modelling, it was already clear that replacement by sections, due to the repeated long non-availability (10 times in about 5 years, each time several weeks) of the internal gas-pressure cable connection is not an expedient solution alternative, since it provides only a moderately reduced failure risk, at least for the first replacement sections.

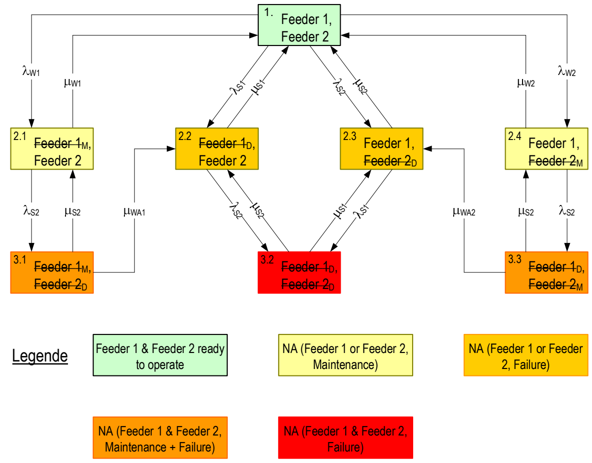

Figure 4: Markov diagram, substation reliability

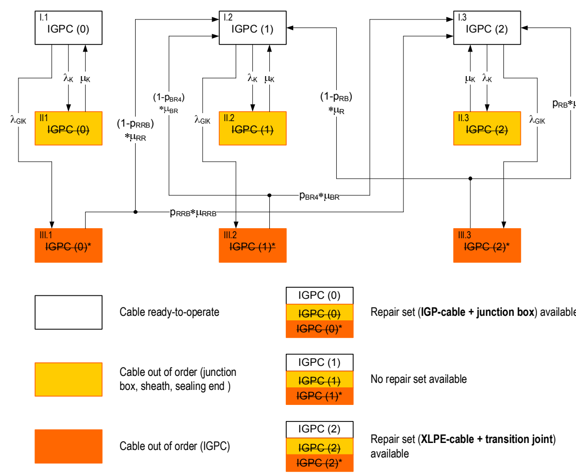

Figure 5: Markov diagram, internal gas-pressure cable

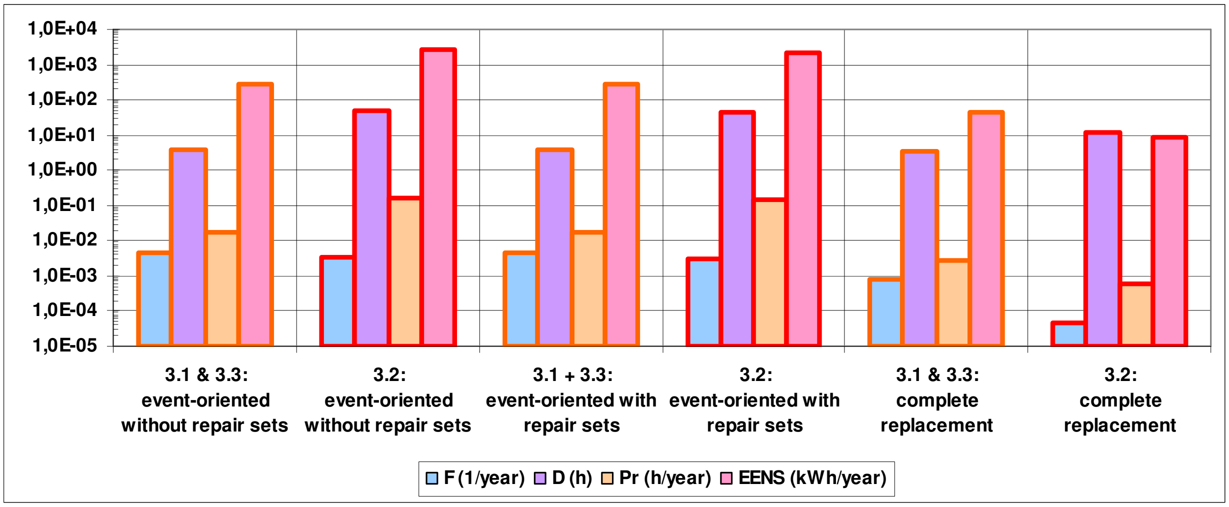

Figure 6: Reliability of the substation

The comparison of the results provides clear conclusions (see Figure 6):

- The non-availability of the internal gas-pressure cable essentially determines the reliability of supply of the substation, irrespective of the repair strategy. The customer-orientated reliability criterion is clearly infringed [4].
- The provision of repair sets brings about no significant improvement.
- Only complete replacement provides an acceptable reliability level (EENS ≤ 500 kWh/year),
- The efficiency values ηw for the solution variants under consideration are calculated in accordance with the presented schematic (Figure 1).

2.4 Solution selection

The result of the concrete investigation is that the efficiency factor η_w for the variant “Complete replacement” is > 1, and shows the highest value in the benefit/cost comparison of the alternatives under consideration.
The variant of “Complete replacement” is therefore selected for further implementation.

2.5 Resource comparison, prioritisation and monitoring

The high efficiency value of the variant (3) “Complete replacement of the internal gas-pressure cable” leads to a high prioritisation in comparison to other assessed measures. The comparison of the resources required for the project implementation with the available resources resulted in no conflicts, so that this project is contracted for implementation. In the event of inadequate resources, the project would be noted in the risk memory and re-prioritised in the following year. This monitoring ensures that no risks can remain unidentified and uncontrolled.

3. CONCLUSIONS

The RBAM method has proven itself to be successful in practice in the Asset Management of the distribution networks.
Through the method of RBAM, a wide range of technical questions can be assessed with regard to their impact on defined business objectives. Due to the use of the same reference unit (Euro), the efficiencies of different projects can be easily compared with each other, and the best possible variant identified. Through the reference to the commercial variable EURO, all those involved obtain a very plastic impression of the extent of possibly existing risks in the handling of the supply task.
The RBAM method thereby helps in developing very systematically creative solutions and producing transparency for the communication processes necessary prior to the relevant project implementation.

REFERENCES

[1] Lücking, 1981, *Energiekabeltechnik,* Vieweg Verlag, Braunschweig, Germany, 106-109.
[2] Berthold Vöcking, 2006, Das Rucksackproblem – Die Qual der Wahl bei zu vielen Möglichkeiten, RWTH Aachen
[3] Hans-Dieter Kochs, 1984, Zuverlässigkeit elektrotechnischer Anlagen, Springer Verlag, Berlin, Germany.
[4] Th. Nippert, 1997, Improvement of the (n-1) criterion introducing a probabilistic failure-related reliability criterion, CIRED 1997, Birmingham