SUMMARY

The Dutch utility ‘Eneco Utrecht’ (part of the ENECO group) was faced with increasing financial risks due to increasing risks of failure of their ageing infrastructure. The challenge was, to mitigate these risks in the most cost-effective manner. KEMA developed a practical methodology for identifying and ranking these measures on the basis of maximum risk mitigating for minimum costs. The methodology was based on a quantitative risk assessment (QRA) with input from data-analyses and staff knowledge. Results were very encouraging, as the structured methodology not only ensured optimum use of available knowledge but also initiated open communication between the different participating departments. Also, the quantified results in some cases proved the anticipated results wrong.

PREPARATION

In January 2003, Eneco implemented an organisational change to achieve the unbundling of the Asset Manager and the Service Provider. The tasks of the new departments were directly related to the Eneco business drivers and hence, included clearly defined accountabilities [1]. To fulfil her task adequately, the Asset Management department of Eneco Netbeheer needed to have a good understanding of the risks Eneco was exposed to due to their ageing Medium Voltage (MV) distribution network. Both qualitative and quantitative valuations were required to manage the risks and retain optimum power quality in a cost-effective manner.

To achieve this, KEMA developed a step-wise planning as depicted in figure 1. The first 2 steps have been completed and Eneco is now working on development and implementation of the mitigating measures (steps 3 and 4).

APPROACH

To control the operational and financial risks in a utility, it is essential to inventorise all relevant existing risks, assess their potential consequences and develop risk-mitigating actions. The risk-mitigating actions are to be verified for their economic viability. Therefore, a quantitative risk assessment (QRA) was considered the most appropriate approach. A short introduction to a QRA is described below.

Quantitative Risk Assessment

In principle, a QRA consists of answering the following five questions:
- What are the hazards / what can go wrong?
- What are the consequences / costs, if it goes wrong?
- How often is it expected to happen?
- Is this acceptable?
- If not: what could we do about it?

After having answered the above questions for any (group of) component(s) and organisational issues, a cost/benefit analysis is undertaken. Hereby the estimated costs of the mitigating measures are compared to the prevented costs of a failure. If economically viable, a measure could be implemented. It should always be considered however that more than one solution could be available to solve the problem!

If a measure is not economically viable, the risk should be accepted or some other means of risk mitigating should be developed. When an accepted risk-mitigating measure is implemented, it becomes part of the overall risk management system. A graphical representation of risk management principles is depicted in figure 2 overleaf.
Information requirements

All risks in relation to the MV grid are related to the performance of the separate components in the grid and their functionality. To quantify the risks, information is required from all levels of the grid: from component-level up to system-level. To obtain this information, several workshops were organised in which Eneco staff were interviewed for their perception of the problems.

Different sessions were held with representatives from the management teams, planning, design and operations departments. The representatives were selected on the basis of their knowledge of the particular issues. The sessions resulted in a list of most-feared risks, supplemented with potential mitigating measures and their rough cost estimates.

BASIC DATA AND ESTIMATES

To verify cost savings from implementing risk-mitigating (control) measures, a limited amount of numerical data is required.

To obtain this data, each risk ‘block’ in figure 2 was treated as a separate entity and discussed in detail with the relevant groups. As the study commenced in the year 2003, the only complete outage figures and statistics that were available, were from 2002. Although some improvements had already been made, these were the figures that were used throughout the study. The entire QRA process, as executed, is depicted in figure 3.

Costs of failure

From statistics and verbal information from Eneco, the average cost of an outage failure was calculated as follows: Average cost = the total costs paid to recover from the failures, divided by the total number of failures. In the Eneco 2002 case: (€ 2.2 Million) / (201 failures) = € 11.000 per failure. This € 2.2 Million comprised € 1.4 Million of time-depending costs and € 0.8 Million of fixed costs (e.g. component costs). Obviously, if recovery times could be reduced, a cost saving could be obtained. Saving one percent in total time for recovery from the problems would yield a cost saving of: € 1.4 Million / 100 = € 14.000. The 201 failures accounted for approximately 9 million customer minutes lost.
Estimates of mitigating measure quality and costs

To assess the improvement potential of mitigating measures, estimates are required of their costs, benefits and anticipated service life duration. To facilitate providing these estimates, four categories were developed, each with a different rating of severity: L (Low), M (Medium), H (High) and VH (Very High).

For outage duration reduction, the following categories were used: L = 0-2%, M = 2-6%, H = 6-14% and VH = in excess of 14%.

Analogous categories for costs [units: € x 1000]:
- 0-150
- 150-750
- 750-1500
- in excess of 1.5 Million.

Analogous categories for anticipated minimum service life [years]:
- 0-2
- 2-6
- 6-14
- in excess of 14 years.

To estimate the service life of mitigating measures, the following assumptions were made:
- New equipment lasts at least 20 years
- Modifications and upgrades last at least 10 years
- IT and organisational upgrades last 4 years
- Inspections, plans, etc. are only valid for one year

To compare investments, all costs and benefits are expressed on a 'per year' basis. The approximation was made that new investments were written off linearly over the anticipated service lives of the particular investments. This is not as accurate as working with Net Present Values (NPV’s), but the difference lies well within the uncertainty of the other input parameters and therefore has not much added value (at this stage).

RESULTS

Due to the fact that several independent workshops were held, many risks appeared more than once on the list. After screening for duplication and combining similar risks, a total of 40 essentially different risks remained, with in total 50 potential mitigating measures. These measures were sorted by their nature of influence, i.e. reducing the frequency of the failures (SAIFI) and reducing the recovery (repair) time of the failures (SAIDI). Another sub-division was made to group the timing of their influence; short term or long term. The measures that are merely effective on the long term mainly addressed new construction projects. These were left for later study, as the goal of this exercise was to focus on 'quick results' only.

Outage duration (SAIDI) reduction

The risks that are of influence on the outage duration are mainly proces-related. This is illustrated by the fact that remedial action is required when an outage occurs and the efficiency of this action mainly determines the time the outage persists. Improving the related business processes therefore can reduce the average outage times. Some (random) examples are:

- Hazard: Increased traffic delays repair crews
  - Potential mitigating measure: Spread out home bases of crews so travel distance becomes shorter
- Hazard: Small stations are difficult to find in the cities due to new buildings covering or hiding them
  - Potential mitigating measure: Equip all vehicles with GPS location finders
- Hazard: Equipment expertise and area knowledge is disappearing through retiring of staff
  - Potential mitigating measure: Hire and train new staff prior to old staff leaving the company

The above are just a few examples of the many proces-related risks and mitigating actions that were identified. At this stage, i.e. prior to the cost/benefit analyses, it was by no means certain that any of the above mitigating measures would actually be implemented.

After the cost-benefit analyses were carried out, the following four mitigating measures appeared to be economically viable:
- Install GPS equipment in each repair crew vehicle
- Review protection philosophy and procedures
- Readjust protection relay settings
- Earth the isolated neutral system (i.e. earthing the ‘floating neutral’ across the grid)

Further investigation with more accurate data would have to prove whether these four projects indeed are economically as good as they appear. Some of these studies have been, and others are currently being carried out.

Outage frequency (SAIFI) reduction

The risks that are of influence on the outage frequency are mainly related to the components and their operating environment. This is illustrated by the fact that the condition and/or the environment of a component basically determine when it fails [2]. Improving the condition or environment of the components therefore can reduce the average failure frequencies. Some examples are:

- Hazard: Some types of circuit breakers are well overdue for replacement
  - Potential mitigating measure: Replace breakers soonest
- Hazard: Cables become damaged by unsupervised digging activities
  - Potential mitigating measure: Supervise digging activities
- Hazard: Some types of old cable joints are of poor quality
  - Potential mitigating measure: Replace cable joints pro-actively
The above are just a few examples of the many component-related risks and mitigating actions that were identified. At this stage, i.e. prior to the cost/benefit analyses, it was by no means certain that any of the above mitigating actions would actually be implemented.

To obtain an estimate of the costs of each particular failing component type, the failure database was analysed. After correcting for some obvious input-errors, the failure statistics were divided in surface equipment (i.e. substation component) failures and subsurface component failures (cables and joints). Note: It should be borne in mind that there are no overhead lines in The Netherlands at MV distribution level; only underground cables.

In the analyses, estimates were made to distinguish between unknown slow degradation processes of cables (and joints) for which no particular cure or prevention method was available. The quantity thereof was estimated to be 30%. For the remaining 70% of the cable and joint failures, some form of prevention would have been possible. Figure 4 shows the results of this analysis in graphical format.

Several mitigating measures were proposed for each of the five component-types that had caused problems. Several of the proposed measures actually complemented each other or would tackle more problems than just the one they were proposed for. The list of mitigating measures therefore was combined into a smaller list of measures. When a mitigating measure mitigates multiple risks, the economical attractiveness obviously increases, representing the convergence of the methodology.

After assigning monetary values to each risk and mitigating measure (with the L, M, H, VH categories, as described above), a cost/benefit analysis was carried out.

After the cost/benefit analysis, (only) the following two mitigating measures appeared to be economically viable:

- Develop and implement a pro-active cable joint replacement strategy, relating replacement priority to joint type and soil conditions
- Develop and implement procedures for handling of cables and joints at excavation sites

Again, further investigation with more accurate data would have to prove whether these projects indeed are economically as good as they appear. Some of these studies have been, and others are currently being carried out.

**UNCERTAINTY**

To obtain insight in the sensitivity of the calculated cost/benefit ratios that are close to ‘1’ (i.e: the mitigating measure cost is comparable to the risked cost), statistical uncertainty distributions were added to input parameters. Therefore, probability distributions were added to estimated costs, perceived benefits and anticipated service lives.

With a probabilistic software program (an add-on to MS Excel), the cost/benefit ratios were calculated 10,000 times with each time a (nearly) random value being picked from the input distributions. These calculations resulted in a spread on the outcomes that were initially calculated as fixed values.

An example of two resulting probability distributions can be seen in figure 5 overleaf. The distribution on the left has a certainty of only 60% that the mitigating measure would be economical while the mitigating measure represented on the right has a 92% chance of being cost-effective.
The results of the exercise for Eneco Utrecht yielded many distributions with no red color at all (in black & white print: the lightly shaded right-hand side of the distributions), implying that those measures would be economical, regardless of the uncertainties of the input.

The same software application also provides sensitivity analyses in the form of a tornado diagrams (see figure 6). From these diagrams, it can be seen which factors are of most influence on the cost/benefit ratios. In essence, it indicates that improvements made to the top items on the list yield much more benefit than improving the ones at the bottom of the list. Each item in the list represents an input parameter like costs, times, improvement assumptions etc.

CONCLUSIONS

Upon completion of the above exercises, the following conclusions could be drawn with respect to the QRA process:

- The QRA has clearly identified the hazards with the highest impact on ‘customer minutes lost’ originating from component failures as well as organisational imperfections.

- The first cycle of the QRA has proven that, even with very rough input estimates, some very useful conclusions can be drawn. The differentiation between ‘most likely uneconomical’ and probably economical’ mitigation measures could easily be made. Even with significant refinement of the input parameter values at a later stage, none of the ‘most likely uneconomical’ measures became economical!

- Because of the multi-disciplinary approach, this exercise has proven to work as a catalyst in achieving good communications between the different participating departments.

In addition to achieving the primary objective, each implemented mitigating measure also has a positive effect on power quality and grid capacity. These benefits were not included in the QRA, hence they are the ‘hidden extras’ that will become available when implemented.

Other ‘hidden extras’ are available because of the simplified accounting method (linear depreciation and Money of the Day [MOD]). When calculations are repeated with Net Present Values (NPV) and realistic depreciation times, the projects with a longer service life tend to become even more economical.

In summary, the QRA has proven to be a valuable tool in achieving cost-effective SAIFI and SAIDI reduction. To obtain more accurate budget figures for the proposed (and selected) mitigating measures, the process can be repeated for each measure in more detail. In this manner, obtaining detailed information is only required for the selected solutions, not for all solutions as identified in the beginning of the QRA process.

REFERENCES
