# Balancing spares investment to minimize revenue loss

– A utility scale sparing concept for step-up transformers based on risk of lost production and investment in spare units.

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## Abstract

This paper presents a tool based methodology for optimizing a spare transformer concept using the investment cost, risk of lost profit, transformer reliability, and the downtimes in case of failure as the prime analysis parameters.

In the case presented in this paper an energy utility uses the software OPUS10 by Systecon, a spare parts inventory and logistic support optimization tool, to analyze and develop a spare transformer concept for its fleet of step-up transformers.

The results from the analysis detail which transformers that it is profitable to keep spares of, and at which power plants the respective spare units should be stored for optimal operations.

By conducting the analysis the utility stands prepared for failures on the critical sub systems that the transformers are, and at the same time the company rests assured that it has not overinvested in spare units. The methodology used by the utility ensures that the spares investment is well balanced with the economic risk of losing generation.

Furthermore, the case presented in this paper shows how the OPUS10 tool can be successfully employed, and deliver fact based results in cases where the systems have low failure frequencies.

## Background

A large energy utility has identified a need to develop a sparing concept for the company's step-up transformers.

The utility wants to investigate and analyze if additional investments in spare transformers can be economically motivated, and in that case which they should purchase?

## Systecon AB

Systecon AB is a consultancy company and a software provider specialized in systems and logistics engineering. Systecon's Opus Suite consists of the following software tools:

- OPUS10 – an optimizing tool for spare parts supply and logistics support solutions.
- SIMLOX – a system, and system support, performance simulation tool.
- CATLOC – a tool for Life Cycle Cost modelling and evaluation.

Systecon delivers services to both suppliers and operators of technical systems, and the suite of software, which has been developed over 40 years, is used in several different industries, e.g. defense, rail, energy, aviation, and telecommunication, throughout the world.

## The Case

The transformers included in the analysis are of the type that connects power plants to the grid. In case of failure of a transformer included in the concept the affected power plant is left unable to deliver electricity to the grid and hence the revenue from that power plant will be lost until the transformer is replaced or repaired.

The utility has decided that repairable transformer failures will not be allowed to drive the need of spare units since replacing a transformer for the duration of its repair is not considered profitable. Therefore, only total breakdowns of the transformers that will require a new unit are considered in the analysis.

The company wants to investigate and analyze if there are investments in spare transformers that can be economically motivated, and in that case for which power plants?

## Data sources

The utility had the following data (Table 1) available:

**Table 1: Available Transformer data**

| Parameter | Description |
|---|---|
| Power Plant | Name of power plant |
| Manufacture | Manufature of transformer |
| Apparent Power | The magnitude of the complex power [VA] |
| Voltage Ratio Max/Min | Ratio between LV and HV side |
| Vector Group | Winding configuration of 3-phase transformers |
| Existing Spare Transformer | If spare units exist and its location |
| Quality/Reliability | Reliability of transfomer |
| Transformer Price | Price of transformer [EUR] |
| Downtime in case of spare | Time duration required to replace if spares exist |
| Downtime in case of no spare | Time duration required to replace if no spares exist |
| Expected annual gross margin of block | Expected gross margin per annum if no unavailability |

The data concerning down times with and without spare units, and the data concerning the expected margin, enabled the utility to assess what possible down times would imply in terms of lost profit. Together with the reliability data and the price of each transformer the risk of losing profit could be evaluated against the risk mitigation of investing in spare units.

## Methodology

The utility used the spare part and logistic support optimization tool OPUS10 to model and analyze their transformer case. The basics of the methodology is depicted below in Figure 1.

OPUS10 is an analytical tool that uses turn-around-times, reliability, and price data together with other logistics, maintenance and technical data to calculate the optimal assortment and allocation of spares from a system cost-efficiency perspective.

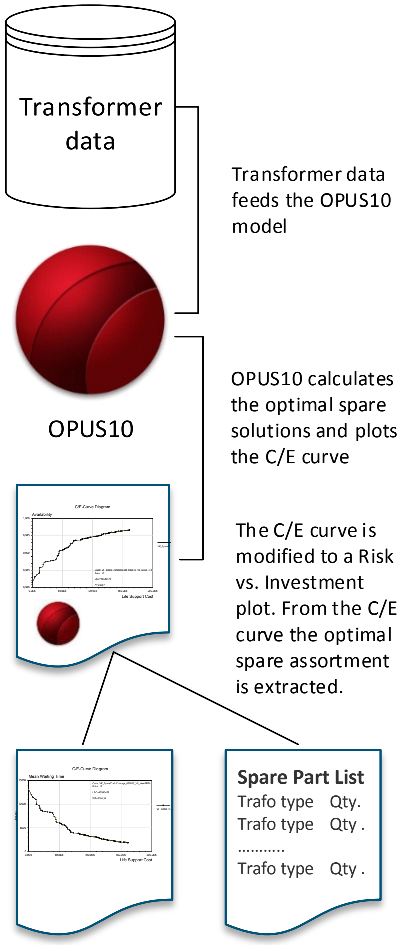


**Figure 1: Overview of the analysis methodology.**

The C/E curve that the utility generated using OPUS10 plots the spares investment against the availability of the whole system, i.e., the average availability of all transformers. Each point on the C/E curve represents the optimal sparing solution for a specific budget frame, and as one progresses to the right in the C/E curve the spares investment increases as OPUS10 invests in more transformers. As a consequence of the larger spares investment the resulting availability also increases.

As the value of availability can differ between transformers in this case the utility took advantage of the possibility to prioritize the plants in the OPUS10 model, and used the expected annual gross margin as the priority factor in the input model.

Once the C/E curve had been established the utility extracted the availability for each and every transformer in the case, and for each point on the curve. Together with the information about the expected annual gross margin the C/E curve was modified to a Risk vs. Investment curve.

## Results

Figure 2 shows how the investments in spares influence the lost profits due to down time caused by transformer failures. Naturally, lost production, and hence lost revenues, decreases with higher investment levels in spare transformers.

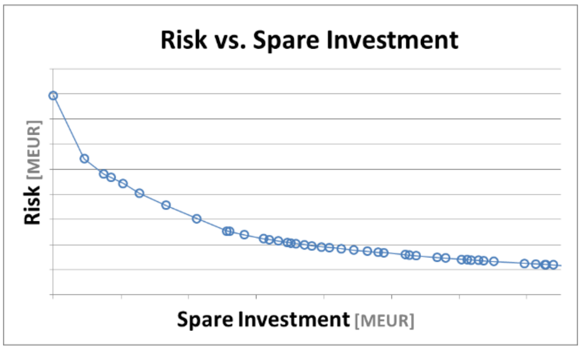


Figure 2: Risk vs. Spare investment.

The utility was interested in evaluating how many, and which, transformers that could be economically motivated to purchase as spares. Therefore, the delta risk reduction was divided with each respective spares investment to create Figure 3 below.

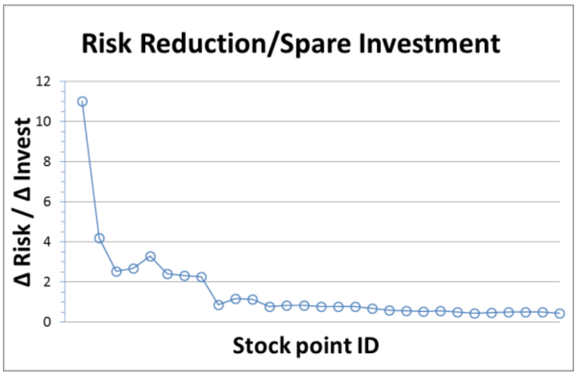


Figure 3: Delta risk/delta investment.

In the plot above the dimensionless ratio between risk reduction in MEUR and investment in MEUR is depicted. If this ratio is below one (1) the investment is inevitably not profitable. However, all ratios above one (1) will not necessarily prove themselves profitable since there are some uncertainties built in to the risk value.

The utility opted to vary different input parameter, e.g. the failure frequencies of the transformers, in order to study the sensitivity of the results. Results from three scenarios with different failure rates are shown below in Figure 4.

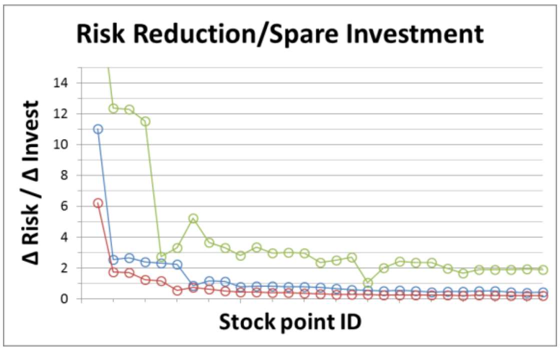


Figure 4: Delta risk/delta investment at different failure scenarios.

Properly investigating the sensitivity of the results was an integral part of the analysis. To find the absolute availability level was not the priority of the analysis, more so was formulating a short list of transformers to invest in. After evaluating the case in different scenarios the utility could select a ratio between risk reduction and spare investment with good judgment and formulate a short list of transformers for their investment program.

Furthermore, OPUS10 also specifies the optimal allocation of the spare units, i.e. at which power plants the different spare transformers should be stored at to achieve maximum efficiency.

## Summary

This paper has presented a tool based methodology for optimizing a spare transformer concept using the investment cost, risk of lost profit, transformer reliability, and the downtimes in case of failure as the prime analysis parameters.

The results from the analysis detail which transformers that it is profitable to keep spares of, and at which power plants the respective spare units should be stored for optimal operations.

By conducting the analysis the utility stands prepared for failures on the critical sub systems that the transformers are, and at the same time the company rests assured that it has not overinvested in spare units. The methodology used by the utility ensures that the risk reducing spares investment is well balanced with the economic risk of losing power generation.

Moreover, the case presented in this paper shows how the OPUS10 tool can be successfully employed, and deliver fact based results, also in cases with low failure frequency systems.