ASSET SIMULATION IN DISTRIBUTION NETWORK USING TOOLS FOR EVALUATION OF TECHNICAL CONDITION

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ABSTRACT

The need of proper investment planning in mid and long-term horizon and lifecycle observation comes out from stakeholder's requirements. Asset simulation helps management in their strategic decisions and supports negotiations with stakeholders. In certain countries, asset management tools are required by their national regulatory body.

For long-term simulations of maintenance and renewal costs in AM it is important to have consistent data records in terms of quality and range, apply correct way of asset data collection and evaluation and use these data to objectively determine individual asset's condition. After simulated and real condition comparison (feedback from the field) is done it is possible to enhance the model and proceed to tasks from operation (OPEX) and investments (CAPEX), which are important for money allocation. In the article higher detail is focused on parameter collection with workforce on low voltage level and asset condition visualization in GIS.

INTRODUCTION

ČEZ Distribuce, a.s. is one of 3 DSOs operating in Czech Republic. It supplies energy in area of 52.001 km^2 for 3,6 mio customers. Annual distributed energy equals 43,3 TWh, total length of lines is more than 160.000 km and total number of distribution stations is more than 58.000. Internally ČEZ Distribuce, a.s. is divided into 5 regions.

Fig. 1 – area of ČEZ Distribuce, a.s. operation in Czech Republic

TECHNICAL CONDITION INDEX AND COST OPTIMISATION

The tool for evaluation of technical condition used in ČEZ Distribuce, a.s. is divided into two main parts. First one is "Technical condition index evaluation", whose results are input for the second part called "CAPEX/OPEX cost optimization".

Technical condition evaluation (TCE) index defines technical treatment of individual asset, whereas Cost optimization defines economical treatment. It determines time, when it is appropriate to reduce maintenance and repairs and focus on modernization or renewal of individual device. Key attributes for evaluation of TCE index are collected data. The longer time window of gathered data is available, the better results you get for your final TCE.

TCE is based on multi-criterial calculation. Each attribute (for low voltage see below) is assigned with weight, which contributes to total technical condition of asset. Some attributes refer to technical condition of an asset, whereas the others refer to importance of an asset. Final TCE is a value between 0 and 100, where 0 is new device and 100 is device unable to operate. Technical condition is divided into 4 states (A, B, C and D). For each type (segment) of device the borders between states are different.

In general, definitions of each state are:

A - Good state – new device, regular maintenance, **B - Middle state** – few repairs, corrective maintenance, regular maintenance, **C - Poor state** – increasing number of repairs, corrective maintenance, regular maintenance, device is planned to be renewed, **D - Critical state** – immediate reconstruction needed.

CAPEX and OPEX costs are allocated for assets with highest score of TCE. Cost predictions needed for asset renewal are created according to current prices. If it is not possible to renew more assets than simulated in one year due to technological or suppliers' limits, the renewal is postponed to next year. Mid and long-term criteria prediction is defined for each type of asset through probability curves such as aging curve and demand change curve. The asset management strategy of ČEZ Distribuce, a.s. is to have no devices in D - Critical state

EVALUATED ASSETS

For simulation purposes, the distribution network is divided into 12 segments (see Table 1). Data for asset condition evaluation is collected in GIS, SAP PM, SAP

AM and Dispatching Control System (BI in preparation).

Table 1 – segments of asset simulation in ČEZ Distribuce, a.s.

High voltage	Overhead lines
	Transformers
	Stations
Medium voltage	Overhead lines
	Underground cables
	Distribution stations
	Distribution transformers
	Section / pole switches
	Substations
	Coils
Low voltage	Overhead lines
	Underground cables

PROBABILITY OF FAILURE CURVES

For long-term cost prediction we created probability of failure curves using Weibull distribution. Failures considered are only those related to useful life and mechanical deterioration (it means without 3rd parties influence and weather calamities). We determined Reliability R(*t*), Failure Probability F(*t*), Failure Intensity λ(*t*), Failure Probability Density f(*t*) functions and MOTTF (mean operation time to failure) (see examples Fig. 2 and Fig. 3). MOTTF is a time value, when 50 % of failures occur before this point, 50 failures after it. It is interesting, that MOTTF is higher for low voltage overhead line and lower for low voltage underground cable. It shows, in general, that underground cable (MOTTF = 39,4 years) has shorter useful life than overhead line (MOTTF = 45,3 years).

Fig. 2 – R(t), F(t), λ(t), f(t) and MOTTF for low voltage overhead line

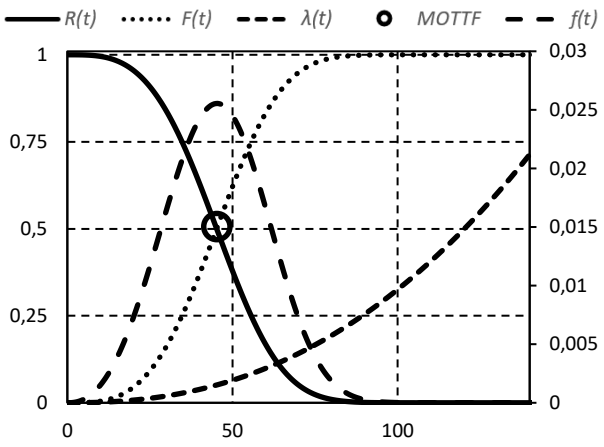
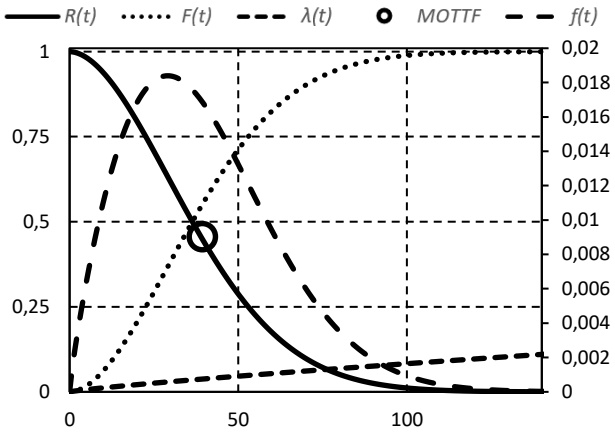


Fig. 3 R(t), F(t), λ(t), f(t) and MOTTF for low voltage cable



With these results we can even think of changing scheduled maintenance to dynamic period of regular inspections.

LOW VOLTAGE ASSET SIMULATION MODEL

This paper is also focused on parameters and data for low voltage level, because the simulation model of low voltage was missing in ČEZ Distribuce, a.s. and it creates 40 % of all renewal investment costs. Low voltage network of ČEZ Distribuce, a.s. consists of 100.000 km of both cables and overhead lines incl. 1.600.000 poles.

The smallest unit registered in GIS is "**Technological unit**" – usually gathering similar technologies (line or cable between two cabinets).

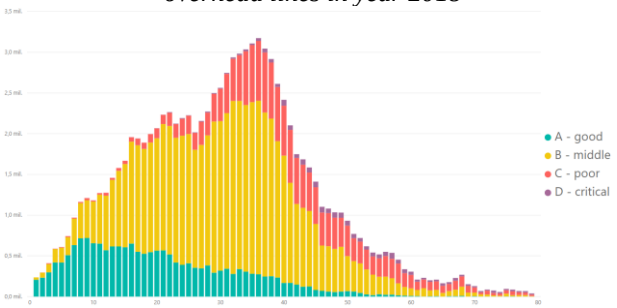
"Dispatching unit" is also registered in GIS and it gathers assets in view of dispatching control (smallest switchable part of network).

"Maintenance unit" is registered in GIS with its image as functional location in SAP PM and it corresponds to the size of regular inspection would be done in one day by one technician, typically a street in a town or a small village.

Main data sources for low voltage modelling are GIS (geographical information system) and SAP PM. Parameters and attributes used for low voltage simulation model are:

Age (technological unit), number of customers (dispatching unit), length (technological unit), cost and number of repairs, cost and number of damages, result from last regular inspection (maintenance unit), impedance, type of cable (technological unit), depreciation and accounting (maintenance unit).

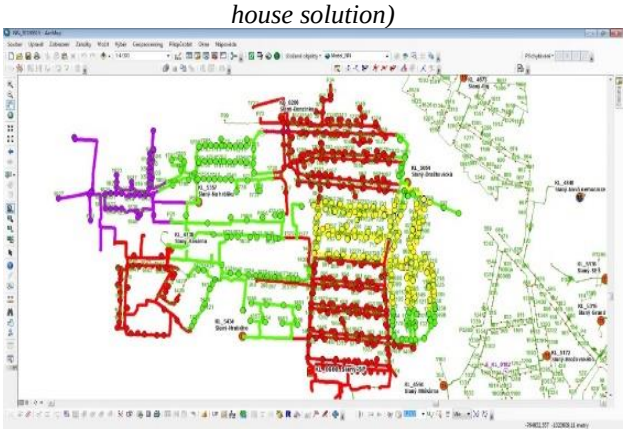
Fig. 4 – age distribution of low voltage cables and overhead lines in year 2018



CONDITION VISUALIZATION IN GIS

The aggregation of technical condition at low voltage level is nowadays made for "maintenance unit" of network.
Data for technical condition evaluation are collected from the field (with workforce terminals). The maintenance unit is as big as regular inspection of network would be done in one day and consist of several lines, poles and cabinets. The aggregated condition of this maintenance unit is then visualized in an in-house solution (A – green, B – yellow, C – red, D – purple) in GIS. In the future, we prepare extension of workforce project for collecting data in higher detail, especially years of constructions and failures are collected/gathered at maintenance unit level today and should be collected at technological unit level. The most logical aggregation for evaluation of technical condition is then the dispatching unit.
Systematic collection of feedback from the field, which means comparison of simulated results and real condition subjectively determined by local asset owners improves results of the model. Furthermore, using statistical tools like R Studio or Python with programmed self-learning benchmarking algorithms it is possible to get similar results after collection of feedback for only a fraction from total number / length of devices.

Fig. 5 – visualization of technical condition in GIS (in-house solution)



CRITERIAL FUNCTION

Another approach of economical treatment can be done by criterial function. Inputs for criterial functions are current reproduction value (Fig. 6 and 7 – orange colour), cost of preventive inspection and cost of failure repairs (blue colour). The minimum of criterial function (grey colour) shows the best time to renew existing asset. This approach also showed that low voltage cable has shorter useful life (42 years) than low voltage overhead line (48 years).

Fig. 6 – time of optimal renewal of low voltage overhead line

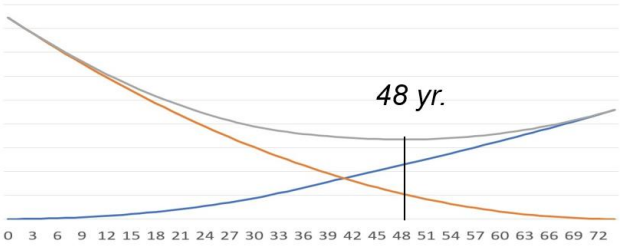
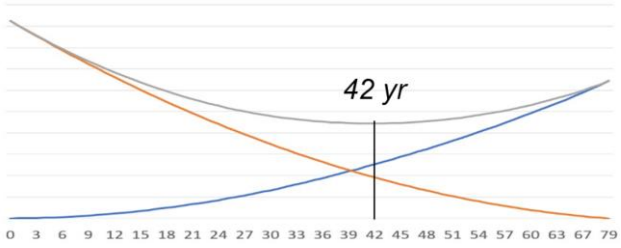


Fig. 7 – time of optimal renewal of low voltage cable



STRATEGIC AM VS OPERATIONAL AM

Very important part of strategic simulations is organisation of asset management. In ČEZ Distribuce, a.s., AM is divided into two units: Strategic asset management (SAM) and Operational asset management (OAM). Organisationally process of SAM is in Strategy Department, whose responsibility is to create mid and long-term OPEX/CAPEX asset strategies (5-30 years), shift budgets between voltage levels and regions, closely communicate with controlling department and create prediction curves. OAM is then in Asset management department, each group of assets has its own data analytic and specialist, who are responsible for handover OAM results to the local asset managers, and they are responsible for investing money into assets in the worst condition. List of assets in the worst condition could be named as tactical (1-5 years) part of strategic simulations.

CONCLUSION

Originally, the expert knowledge of asset managers was crucial in investment planning process. Each asset manager applied own experiences in order to identify grid needs within the region and these partial requirements

were prioritized and consolidated in overall company's level. Nowadays, digitalization of processes and novel SW tools allow DSOs to establish more transparent budget planning and evaluation process fulfilling company´s KPIs.

The other benefit of long-term asset simulation is elimination of fluctuations in budget and at the end of the day sustainable OPEX and CAPEX costs considering reliability of network (number of repairs). Moreover, the in-house created visualization of technical condition in GIS helps technicians in the field to better identify devices prepared for renewal and mitigate operational risks.

"Asset management is a journey, journey from reactive decisions to optimized decisions." (source: The Institute of Asset Management, UK)

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