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STRATEGIC EVALUATION OF THE RAILWAY TRACTION ENERGY SUPPLY DEVELOPMENT ON THE HUNGARIAN RAILWAY NETWORK

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Abstract

Transformer substations are hidden elements of the railway infrastructure, they have a long service life and reliable operation. On this reason reconstruction of substations are often left out of railway development projects. The board responsible for railway development in the Ministry of Innovation and Technology has decided to set up a project dedicated to substation development. The purpose of our work was to assess, examine and supervise the current technical status, network role and future sustainability of railway substations in order to choose a set of substations to be reconstructed in the given cost framework. We completed traction energy simulations to explore the weak points of the traction energy supply system and to provide basic data for the planning process. In our feasibility study we chose 20 of 38 substations to be reconstructed in a multi-step decision process. On Level 1 we assessed professional and operational aspects with multi-criteria analysis (MCA) regarding capacity shortages, energy efficiency, existence of remote control, characteristics of environmental protection and climate resilience, age-related failures, unit performance and network assessment. Based on the multi-criteria analysis we formed feasible technological options. To quantify and compare their long-term financial effects, on Level 2 we have chosen cost-effectiveness analysis methodology considering investment cost and the operational costs incurred during the estimated evaluation period. After option analysis we conducted cost-benefit analysis (CBA). Savings at social level are considered benefits in economic terms. As the type of the intervention did not fit the relevant CBA guide, we had to elaborate a special methodology for the assessment of economic benefits of the project. After all we have set up three project packages (6 or 9 or 20 substations) depending on available funding sources – and all three project packages can be regarded as economically viable and eligible for financing and implementation.

Keywords: project evaluation, railway, power supply

1 Introduction

Main beneficiaries of the EU funds available for transport in the 2010s were railway lines. With the expansion of the electrified railway track sections and the increase in the number and performance of the electrified traction vehicles, the demand for electricity supplying the traffic is growing steadily. The accumulating effect of the increasing power requirement within the feed section of a traction transformer station may easily lead to local overload.
The figure below shows the network of the traction substations of the Hungarian State Railways Plc. The 38 orange discs stand for the sub-stations.

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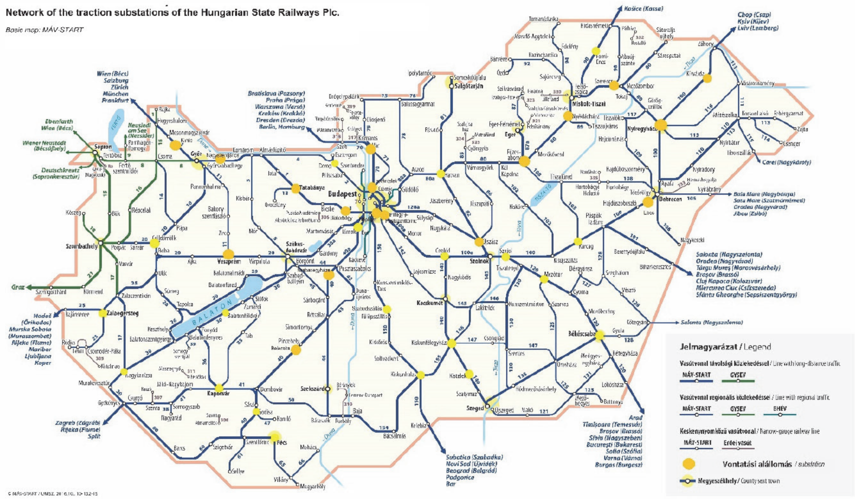

Figure 1 Network of the traction substations of the Hungarian State Railways Plc.

Although transformer substations are invisible elements of railway infrastructure, their proper technical standard is essential for the high-quality operation of rail transport. In our paper we present a comprehensive study covering the national railway network, that sought intervention points for rail traction energy supply network and suggested a prioritization of investments.

Our paper is based on a feasibility study with the title “Development of railway traction energy supply on the network of the Hungarian State Railways Plc.” [1].

The targeted financial resource of the implementation project is provided by the Integrated Transport Development Operational Program (ITOP) [2], so we have followed the methodological guidelines of the ITOP program [3].

Now, the project is already in the implementation phase. Due to the developed project packages, growing number of substations can be financed by redeploying resources released on other projects.

2 Objectives and goals of the project

Significance of rail transport projects is emphasised in the European strategic documents like EU White Paper [4] and other studies and reports [5]. Furthermore, the project is in line with the goals of the National Transport Development Strategy [6], as it is promoting resource-efficient ways of transport and improving the quality and the efficiency of the transport services.

2.1 Main problems and the baseline scenario

The main problems stem from the age of the equipment and the obsolescence of the technology. On 10 sub-stations out of the 38 there is no remote-control system. These locations are sub-stations functioning with an operator. Three of them can be remotely controlled on the spot, so they are not connected to the power SCADA control panel. The age of the substation equipment is extremely high and most of the tools have exceeded their life expectancy. If not only active but passive components have to be improved as well, the reconditioning only extends the operating time of the transformer by 5 to 10 years, but the costs of the repair approximate the price of a new transformer.

The number and severity of age-related failures is expected to increase significantly in the future without infrastructure development, therefore the increased consumer demand can no longer be satisfied reliably. In addition, the operating, maintenance and replacement costs are also expected to increase.

2.2 Objectives of the project

The purpose of this project is to provide development suggestions and implementation for the selected substations by means of traction energy supply testing of the substations and their associated energy routes (i.e. normal and emergency power lines). Aiming to improve the inappropriate traction energy supply, we were looking for technical solutions that can provide the right quality and quantity of traction energy to comply with the relevant standards of the EU Regulation 1301/2014. In order to guarantee the proper utilization of the capacity and the safety of operation, we will also determine which traction energy supply development tasks need to be performed, including all the environmental intervention related to development.

3 Option analysis

3.1 Demand analysis

In railway infrastructure development projects, peak demand needs to be met, so the modelled traffic is also assessed for the heaviest traffic period. This was the summer workday afternoon. The traction energy simulation model considered a current timetable (A), a future timetable (B), and a “theoretical maximum” load (C). The model covers the entire electrical transmission path (overhead power line network) belonging to the power supply section of a given substation.

3.2 The method and process of option analysis

In Level 1 analyses, we examined the main features (i.e. the technical status, the network role and the load conditions) of the power supply network that currently comprises 38 sub-stations and their powered sections. The purpose of the Level 1 analysis was to select the 20 development sites. Based on the network characteristics we have performed a multi-criteria analysis (MCA) of the present network at the 38 substations. The MCA revealed professional and operational aspects: capacity shortages, energy efficiency, remote control, environment protection and age-related failures, unit performance and network assessment. When determining the weight of the certain aspects, we also sought to ensure that the evaluation criteria reflect the network role in addition to the technical and performance characteristics. Substations that reached the highest total score were selected based on this evaluation. On the selected substations and their powered sections – based on their technical parameters, scheduling structure and the traction vehicle flee – traction energy simulation was used to determine the electrical capacities required for future loads and expected improvements, as well as to specify the technical content of the project. After traction energy simulation two technical variants (option “A” and “B”) were worked out at each location. Although the option features vary by sub-station, the following considerations have been prioritized:

- aspiration to complete refurbishment
- in the case of common buildings with other special services, only renovating the substation part
- development in own territory, without land acquisition
- enhancing environment protection: developing transformer bases

The following three areas of intervention were specified:

- Placement of the equipment of 25 kV fields (outdoor / indoor)
- Placement of the equipment of 120/25 kV fields (new place / original place)
- Placement of the equipment of 25 kV test resistor (outdoor / indoor)

At Level 2 option analysis we conducted a cost-effectiveness analysis of the two feasible technical options. In the cost-effectiveness analysis we considered the investment cost and the operational (maintenance and replacement) costs incurred during the estimated evaluation period. To support the decision process and to provide flexibility in the financing, three project packages were formed:

- ITOP Basic package: with 6 substations
- ITOP Extended package: with 9 substations
- Full package: with 18 substations

4 Environmental and climate effects

The impacts of the project on the environmental compartments were examined, namely: impacts on soil, water base, ground water, protected natural environment, populated areas, and noise. From a soil, surface water and groundwater quality perspective, the relevant environmental load of the substations may be due to the water pollution caused by regular or occasional oil spill. Nevertheless, it can be stated that the planned technologies, utilities and equipment do not allow the possibility of contamination risk based on the oil- and water sealing indicators. From noise protection aspect, the impact of the construction and operation is acceptable, not significant, thus noise protection measures are not required.

Based on the preliminary studies, it can be concluded that in case of any planned development on the site, the extent of the load on the nearabout environment is not expected to be significant in terms of land protection, water protection, air quality and landscape protection. In the case of those substations selected for the implementation, a separate plan for approval and environmental study has been prepared, which was submitted for a construction authorization procedure. The environmental study is intended to identify and record the environmental protection measures required during the implementation.

As the effects of the climate change, it can be stated that the vulnerability of the planned investment and the level of risk posed by climate change are moderate. [7] Furthermore, the impact of the planned investment, due to its climate change volume, has a neutral effect. Appropriate measures to decrease the effects of the climate change can significantly mitigate the expected negative impacts.

5 Financial and economic analysis

5.1 Financial analysis

The project's financial plan (i.e. the cost of project activities) was broken down into the main cost categories for the investment period (2017-2025) referring to the different project sizes. If the planned substation developments are implemented, the net investment cost without financial reserve:

- for the ITOP basic package: 38,655 million EUR,
- for ITOP extended package: 58,575 million EUR,
- for the full project package: 103,812 million EUR.

The project has not any non-eligible activities. Investment costs were determined partly based on the executive and framework contracts already signed and on the investor's cost estimates. The investment period ends in 2025, so the year 2026 is the first full year of the operating period.

Future operational and maintenance costs were calculated from the actual data of recent years, i.e. the 2014-2016 period. Our assumptions are that permanent fixed costs will not change. For running and maintenance costs we have set the percentages for two periods: between 2017-2025 (% change in value compared to 2014-2016 average), and % after 2025. With the addition of more powerful, more modern transformers, the energy loss also changes. After replacing the existing 2x6, 6 or 12 MVA capacity transformers up to 16 MVA transformers, the idle loss values are reduced but short-circuit losses are increased. Table 1 contains the overall values and the additional operating costs of the replacement of the transformers.

Table 1 Energy losses and additional operating costs [1]

Project package	Idle losses (kWh)	Short-circuit losses (kWh)	Total losses (kWh)	Additional operating cost (EUR)
ITOP basic	-402 960	1 752 000	1 349 040	49 401
ITOP extended	-911 040	2 479 080	1 568 040	57 421
Full	-1 200 120	4 140 560	2 940 440	107 678

In the baseline case, it is inevitable that major refurbishment activities will start in 2025, due to accelerating degradation processes, as further aging equipment is expected to require substantial intervention by then. It was assumed that renovations will also take place in 2030 and 2035, during which only the most inevitable repairs and equipment replacement works are performed. If the equipment in obsolete technical condition cannot be repaired during the maintenance operation, it can only be maintained by the replacement of larger units and thus a significant replacement cost. In case of realizing the project, replacement costs were taken into account, based on the life expectancy and the investment costs of the built-in infrastructure elements. The revenues of the Hungarian State Railways originate mainly from infrastructure charges (network access charges), but the implementation of this project does not affect these charges.

5.2 Economic analysis

For the determination of economic costs, the financial costs have to be adjusted by the following factors:

- fiscal adjustments
- the correction of market price
- external impacts.

Savings at social level as a result of the project are considered benefits in economic terms. The quantified economic benefits of the project are the differences between ”with” and “without” project costs of the change in travel time and the environmental cost savings.

In addition to the inputs provided by the simulation model, unit costs set out in the Hungarian CBA Guide [8] were also taken into account to quantify the benefits. In terms of manifesting time saving in money, train delays, potential time savings for the model trains of the simulation, percentages of current overloads, passenger counts, and unit value of travel time (VOT) were used. Time-saving is due to downsized train delays caused previously by short-circuits and substation errors, as well as the impact of the timetable adjustments on passenger hours. The performance limit constantly affects the trains on the affected line: it has constant timetable effect by evolving a sort of electric slow-motion signal. The decisive part of all social benefits comes from travel time costs.

Based on the facts above, development of the substations may result in saved travel time costs during the 30-year evaluation period.

Changes in environmental impacts were performed by a detailed estimation methodology in which the impacts on climate change were quantified in accordance with the relevant guidelines [8], [9]. The calculation of the environmental costs was based on determining the effect of GHG on energy use resulting from the change in idle and short-term losses.

Based on the results of the economic analysis of the project, it can be stated that the economic net present value (ENPV) of all three project sizes is positive, the economic internal rate of return (EIRR) is higher than the applied social discount rate (5 %) and the cost-benefit ratio is also higher than 1. Thus, the project can be regarded as economically viable and eligible under the initial conditions. The best return is made by ITOP-basic packages, but the ITOP expansion, as well as the implementation of the entire development package is equally effective.

6 Conclusion

Energy supply system (including substations) is a special segment of the railway transport infrastructure with long service life and reliable operation, but reconstructions of these elements are often left out of railway development projects.

The purpose of our work was to assess, examine and supervise the current technical status, network role and future sustainability of railway substations in order to choose a set of substations to be reconstructed in the given cost framework. We used multi-level assessment for strategic and technical option analysis; and we have set up three project packages (6 or 9 or 20 substations) depending on available funding sources.

After option analysis we conducted cost-benefit analysis (CBA). As the type of the intervention did not fit the relevant CBA guide, we had to elaborate a special methodology for the assessment of economic benefits of the project. Based on the financial and economic analysis all three project packages can be regarded as economically viable and eligible for financing and implementation.

As a conclusion it can be stated that sustainability and viability of the project are affected by the relevant technical requirements, the results of the traction energy simulation, the social-economic background, and the availability of the funding sources.

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