



APPLICATION OF NEW TECHNICAL SOLUTIONS FOR THE NEEDS OF MODIFICATION OF THE ELECTRIC TRACTION SYSTEM ON THE RAILWAY LINES OF CROATIAN RAILWAYS

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Abstract

Modification of the electric traction system on railways Moravice – Rijeka– Šapjane, Škrljevo – Bakar and Sušak Pećine – Rijeka Brajdica (ISEV Project) is an investment project which actually represents reconstruction of a part of the existing 3 kV DC electric traction substations and construction of new substations and devices necessary for transition to 25 kV, 50 Hz single-phase electric traction system. The project is a continuation of the modification of the system started in the 80s of the last century. The modification of the electric traction system is a pioneer task of Croatian experts, because until now such an intervention has not been done anywhere in Europe, except in Croatia. Having learned from our experience, Polish and Slovak railways are starting similar interventions on their railways, and our experience will start to be applied also in some other countries which still have DC electric traction substations. Except for a general presentation of the overall project, this paper especially treats the latest technical solutions in the network of Croatian railways applied for the first time: connection of railway electric power substations to different pairs of phases of the 110 kV transmission network, building in of the equipment for compensation of reactive energy, creating of technical preconditions during construction for later implementation of recuperated energy and construction of 110 kV block units of a compact design.

Keywords: electric traction system, reconstruction, modification

1 Introduction

Modification of the electric traction system on the railway lines Moravice – Rijeka – Šapjane and Škrljevo – Bakar (ISEV Project) is an investment project of rebuilding of a part of the existing 3 kV DC electric traction plants and construction of new equipment required for shifting to the 25 kV, 50 Hz single-phase electric traction system. The ISEV Project is continuation of replacement of the electric traction system completed on the part of the Zagreb – Moravice line in 1987.

2 Reasons for launching the ISEV project

Reasons for launching the above mentioned investment project, as well as benefits of its implementation are detailed in the feasibility study of modification of the electric traction system and in Investment Study with data and applied calculation methods of justifiability of the project. Only main facts enabling justification of the ISEV Project in simple way are presented briefly herein:

- a The Project implementation provides a unified system of electric traction in the territory of HŽ Infrastructure, including all accompanying benefits (absence of confrontation of two systems and replacement of locomotives, unified traffic technology, improved utilisation of electric locomotives by longer traction sections and more efficient use of shifts of the staff).
- b It enables to increase throughput capacity of the railway line, especially in the most difficult mountain section of the line from Rijeka to Moravice.
- c Maintenance costs of stable electric traction plants (SPEV), as well as maintenance costs of locomotives are lower with the 25 kV, 50 Hz, AC ,single-phase electric traction system than with the 3 kV DC electric traction system.
- d Investments in maintenance of the existing the 3 kV DC electric traction system have not been sufficient for years, because the second phase of the system modification has been expected. The DC traction system plants are obsolete and worn out, procurement of spare parts becomes more difficult because some parts have not been manufactured any more. If it was decided to keep this system, revitalization of the plant would be required; however, such investment would be classified as unjustified investment because of high cost and inappropriate benefits.
- e Locomotives of 1061 series (for traction at the 3 kV DC voltage) are, in average, over 40 years old; the last new locomotive was purchased in 1969. The average age of the 6011 series electric motor trains is over 40 years. In case the 3 kV DC electric traction system remains in use, revitalization and procurement of new traction plant would be required.
- f Together with modification of the electric traction system thorough renovation and improvement of stable electric traction plants (SPEV) will be made, with a series of interventions which involve additional technical and economic benefits, such as conversion of the partially compensated contact network into compensated one (which improves the current collection at pantograph and cuts costs of contact conductor), introduction of remote control system, which enables to eliminate permanent crews in electric traction substations and faster and more efficient identification and separation of the failure spot.
- g Number of employees is reduced, i.e. labour ratio is improved.
- h Costs of electricity are reduced significantly, because the unit price of electricity is much lower in AC traction system than in DC traction system and it goes down with increase of electric traction substations having the same voltage level (110/25 kV, 50 Hz).

3 Scope of intervention in the project

Plants rebuilt, i.e. constructed within the investment project are the following: transmission lines and fields, 110 kV; electric traction substations (DELNICE, VRATA, PLASE, SUŠAK, MATULJI); sectioning facilities (SKRAD, LOKVE, DELNICE, SV. KUZAM, RIJEKA); contact network between open track and service tracks, 135.4km; building of maintenance units in Delnice; telecommunication cables and TC systems; signalling and interlocking subsystem (adaptation).

4 New technical solutions applied

4.1 New “electrical engineering” design solutions

Electric traction railway plants, 25 kV, 50 Hz, are connected to two phases of power supply system and represent, in this sense, unsymmetrical load of the power supply system. So far, for the sake of simplicity in utilisation, all EVPs in Croatia (except EVO Opuzen) have been connected to the same phases of the power supply system (phases 4 and 8). The study of influence of electric traction on asymmetry in the power supply system (FER Zagreb) has shown that current and voltage asymmetry, which would be generated in the power supply system

by use of electric traction on the line Moravice– Rijeka– Šapjane, with use of the same phase, would be intolerable high. Therefore, as the part of the Project, the load balancing will be made for the first time by connection of the stable electric traction plants to different pairs of phases. Parallel operation of electric traction substations on the network, 25 kV, 50 Hz, will be used for the first time by construction of ISEV plant, which will additionally increase reliability of supply of electric traction vehicles and improve power parameters (more stable voltage, use of higher power trains). Further specific property of the Project is that facilities for compensation of reactive power are built in all EVPS. In addition to known benefits from compensation of reactive power (lower losses, better voltage conditions, lower expenses for consumed electricity), better power factor, resulting from built-in facilities for compensation of reactive power and energy, negative impact to voltage and current asymmetry is reduced.

4.2 Tunnel adjustment to requirements of KM 25 kV, 50 Hz within the ISEV project

Modification of voltage level of contact network (25 kV, 50 Hz AC instead the present voltage of 3 kV DC) is especially specific due to technical solutions applied in tunnels. Namely, according to the size of their clear openings, built tunnels are at the lower threshold value which enables electric traction. In addition, the mentioned modification of the voltage level requires special solutions, because the height of contact conductor is 5,350mm in 3 kV DC system compared to 5,500mm in 25 kV, 50 Hz system. So, on the section Moravice – Rijeka of the Zagreb- Rijeka line, Rijeka – Šapjane – Board line, and on the line Škrljevo – Bakar and Sušak Pećine – Rijeka Brajdica, the present electric traction system is 3 kV DC system with normal height of contact conductor is 5,350mm above GRT (minimum 4,950mm). Works of modification of tractions system on the mentioned sections of the line/lines (ISEV Project) and use of electric traction, 25 kV, 50 Hz AC, with standard height of contact conductor above GRT of 5,500mm (min. designed 5,100mm) are underway. Accordingly, geodetic survey of tunnels and other structures located at the mentioned section of the line/lines has shown that clear opening of 7 tunnels (Sljeme, Kobiljak, Baudine, Sopalj, Pajca, Brajdica and Rukavac) and 2 overcrossings do not meet requirements for KM 25 kV, 50 Hz and they have to be adjusted to new criteria for heights of contact conductors, safety distances of contact conductor according to load profile and contact network and according to the structure height. The following has to be met for the mentioned structures: to provide minimum height of contact conductor of 5,100mm; to ensure safety distances for the 25 kV AC system pursuant to the standard HRN EN 50119; to ensure ballast prism with min. 30cm of crushed stones below the bottom sleeper edge measured beneath non-elevated tracks.

4.2.1 Replacement of wooden sleepers with steel sleepers

Wooden sleepers will be replaced by steel trough-shaped sleepers (in accordance with the standard HRN EN ISO 6305-3), length of 260cm, whose basic cross section shall meet the following conditions: minimal height (h)=10cm, minimal width on bottom surface (b =25cm, minimal width on upper surface (a)=13cm, minimal sleeper wall thickness (d)=0.0cm (Figure 1). Such solution, i.e. difference in the wooden and steel sleeper of approx. 15cm enables the level reference line to be lowered in the mentioned tunnels, i.e. on the section of the railway line below overcrossings.

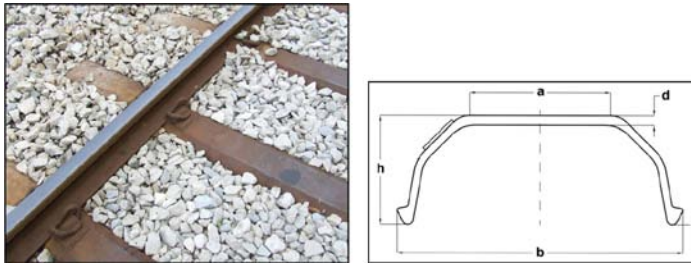


Figure 1 Railway track on Šapjane station and cross section of steel sleeper

4.2.2 Compact tunnel consoles (KTK) with contact track (KT) in the system of tunnel contact network (KM)

One of main reasons for introduction of KTK and KT is much improved utilisation of the tunnel space which is schematically shown on the figure 2. By better utilisation of space in tunnels and tunnel profiles, 5 to 30% of the tunnel profile can be saved in designing of new tunnels, which are then, in fact, limited only by the train speed, i.e. hydrodynamic conditions of running the train along the tunnel. It results in significant savings in excavated cubic meters of earth. The figure 3 shows significant difference in size of standard tunnel console and compact tunnel console with contact track. It can be easily noticed that we use one insulator instead of two or three. Furthermore, it can be seen how much the height of KTK console is smaller compared to standard console in vertical direction. Such geometry of KTK console provides minimum height toward the tunnel ceiling, and it can also be seen that positioning of KTK console toward the tunnel ceiling is much simpler. The figure 4 show required minimum distances.

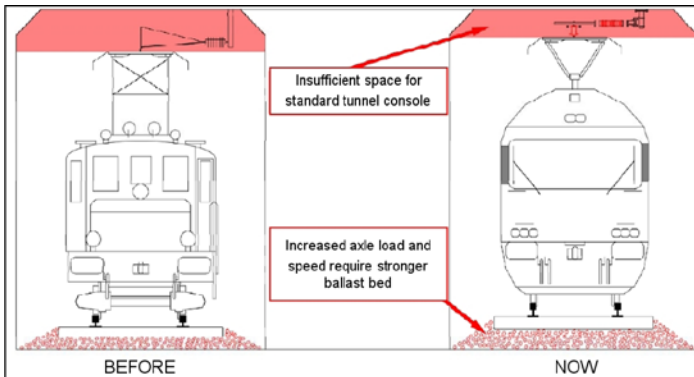


Figure 2 Utilisation of the tunnel space.

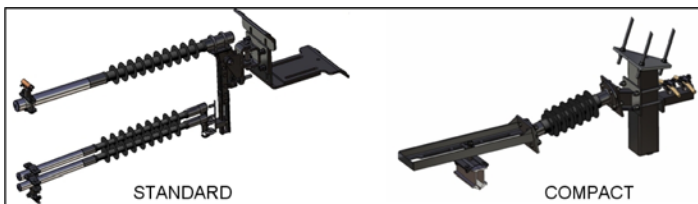


Figure 3 Standard and compact tunnel console with contact track.

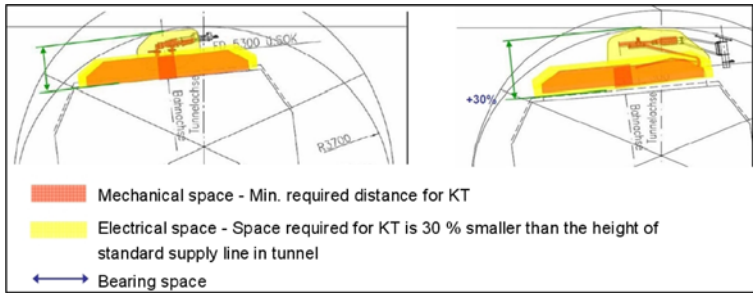


Figure 4 Required minimum distances.

The figure 5 shows the profile of contact track (KT), together with geometric elements, i.e. advantages in comparison with standard AC 100 contact conductor (100mm²) which is normally used by railways and HŽ. The cross section surface of KT is 22 times larger than the one of standard KT. In electric terms, effective cross section is, in fact, 12 times larger than standard copper conductor AC 100. This is important for two reasons - electric load (capacity) of KT and safety in case of fire in tunnel. No straining is needed in designing of KTK with KT as it is required with standard solutions of contact network in tunnel. Instead of automatic straining (as in standard solutions) expansion or dilatation joints are built in.

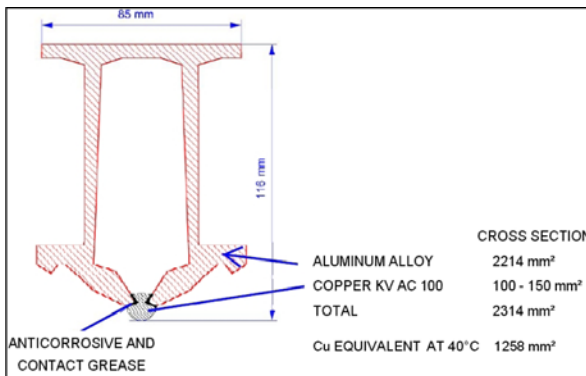


Figure 5 Profile of contact track (KT) with geometric elements.

Due to significant construction advantages compared to standard solution, dependence of permitted over-temperature on time of flow of large currents enables this new solution to show significant advantages in tunnels, taking into account that in a tunnel, due to specific conditions, possibility to reduce over-temperature by dissipation into space is limited, figure 6. Fire testing shows that compact tracks with bearing structures function represent reliable elements of the contact network, even in case of fire. The fact that during fire power supply was not interrupted much longer than time required for vehicles to exit tunnels is of the utmost importance. The figure 7 shows fire testing of KT in a tunnel.

Performed comparative tests of various designs of contact network in tunnels show that thermal resistance of KT is 3- 4 times higher compared to standard solutions in tunnels, figure 8. From the safety point of view, such thermal resistance of KT can save many lives. The figure 9 shows standardized designs of joints, transferable buses and fastening of supports to the tunnel ceiling.

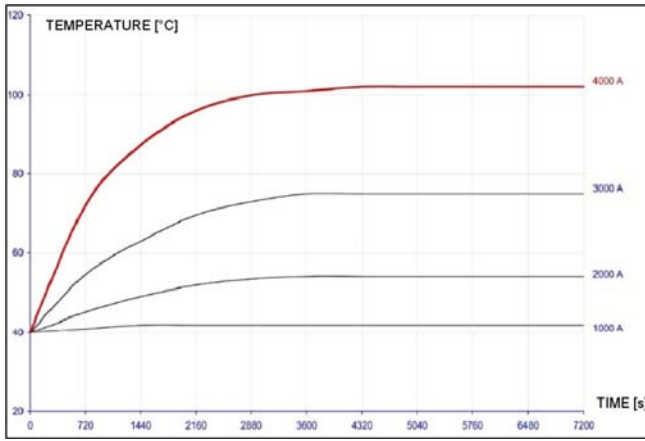


Figure 6 Dependence of permitted over-temperature on time of flow of large currents.



Figure 7 Fire testing of KT in a tunnel.

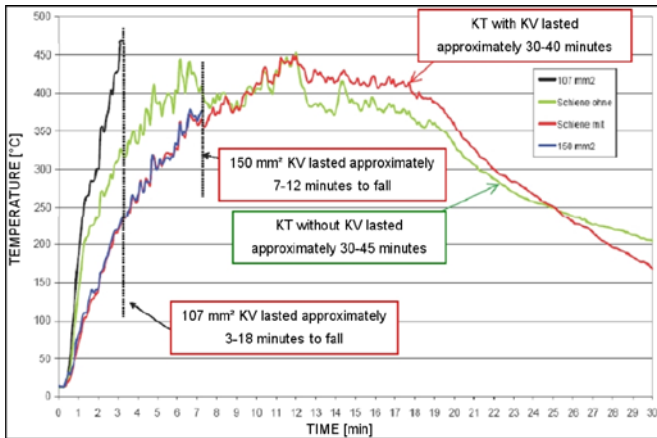


Figure 8 Comparative tests of various designs of contact network in tunnels.

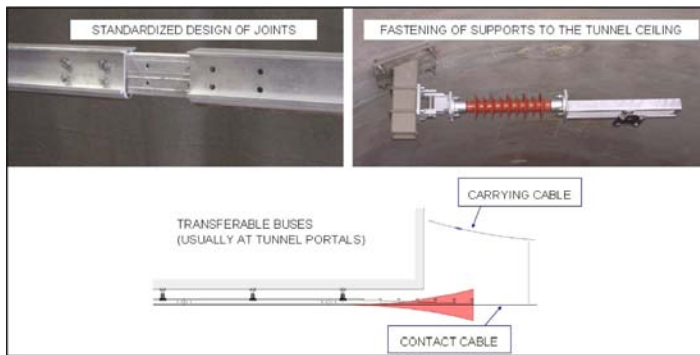


Figure 9 Standardized designs of joints, transferable buses and fastening of supports to the tunnel ceiling.

5 Conclusion

This article is intended to present, at one place, the reasons for launching the ISEV Project (Modification of Electric Traction System), as well as some new technical solutions implemented within the Project. The ISEV project classified under more complex project, not only because of significant interventions in space, but also because the fact that building of structures for modification of electric traction currently represents the largest (or one of the largest) project in building of power plants in Republic of Croatia (five new transformer stations, five sectioning plants, transmission lines and fields, 110 kV, new remote control centre, tunnel rehabilitation...).

This paper presents short description of the project and therefore some simplifications have been made. Our wish is that new solutions applied in the ISEV project find their place in the railway infrastructure in future period.

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