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Innovative Power Supply System for Conventional and High Speed Trains

Abstract. *The paper presents the new idea, developed in Military University of Technology and Railway Institute, for the development of a power supply system for high speed trains that will be soon implemented in the Polish railways system. The power supply will consist of two parts: methane combustion energy and hot dry rocks heat. The system will be reliable and adapted to the Polish railway system.*

Keywords: traction power supply system, hot dry rocks,

Introduction

Modernization and construction of new railway lines satisfying requirements of interoperability [1] involve building new traction substations, frequently in the places where supplying the power lines is difficult or even impossible (e.g. in the case of areas environmentally susceptible), and their length may reach several dozen kilometres.

Moreover, in accordance with European Union "Green Document", Poland is in the last place considering the amount of coal used for the trains supply system [2]. That fact causes a need to look for a new power supply system limiting the coal usage. In Poland there are numerous problems with train substations supply resulting in a necessity to prepare the systems for high speed trains.

The paper deals with a new innovative system of power supply designed for conventional and high speed trains that will be soon implemented in Polish railway system.

Railway power supply system and its modernization

The electric traction power system is the most extensive system included in the railway. It involves tens of thousands of kilometres of traction networks, tens of thousands of power supplies objects (traction substations and sectioning cabins) as well as thousands of kilometres of power supply lines of different voltage values, transformer stations, electric power substations and, in certain cases, even generators in power plants.

Parameters of the traction power supply systems are dependent not only on characteristics of devices assigned to the railway, but also on the whole electric power system, starting with generators in power plants, through the lines of the highest voltage, transformer stations, ending with the lines supplying the traction substations.

In Poland, almost 100% of electrified railway lines are powered in the 3 kV DC system. The 3 kV DC traction power supply system is interoperable when the distances between the traction substations are not longer than 15 km; on the average it is 10 - 12 km. The power of each of the substations exceeds the value of 12 MVA, whereas the voltage of power supply from the electro-energetic system is in the range from 15 to 110 kV.

In order to power the high speed lines, it is planned to create a 2 x 25 kV 50 Hz system. According to PN-EN 50388 standard [3], the substations should be equipped with a minimum of two transformers with the power of 20 – 60 MVA , and the distance between the substations should not exceed 45 km. Due to not sufficient transmission capabilities of 110 kV lines and not sufficient short circuit power , the traction substations located on this lines should be powered with the voltage of 220 kV or 400 kV.

Modernization or construction of traction power supply system often requires building of new traction substations located in the place of already existing sectioning cabins or in the other place resulting from the analyses of a voltage drop in the overhead contact system. In numerous cases, it results from the technical analyses that new traction substation should be located in the place surrounded by the environmentally susceptible area, as shown in Figure 1. Conveying the supplying lines directly from GPZ is impossible without environmental intrusions, and the only solution is supplying the new substation with the cable lines laid in the railway track, powered from the neighbouring substations.

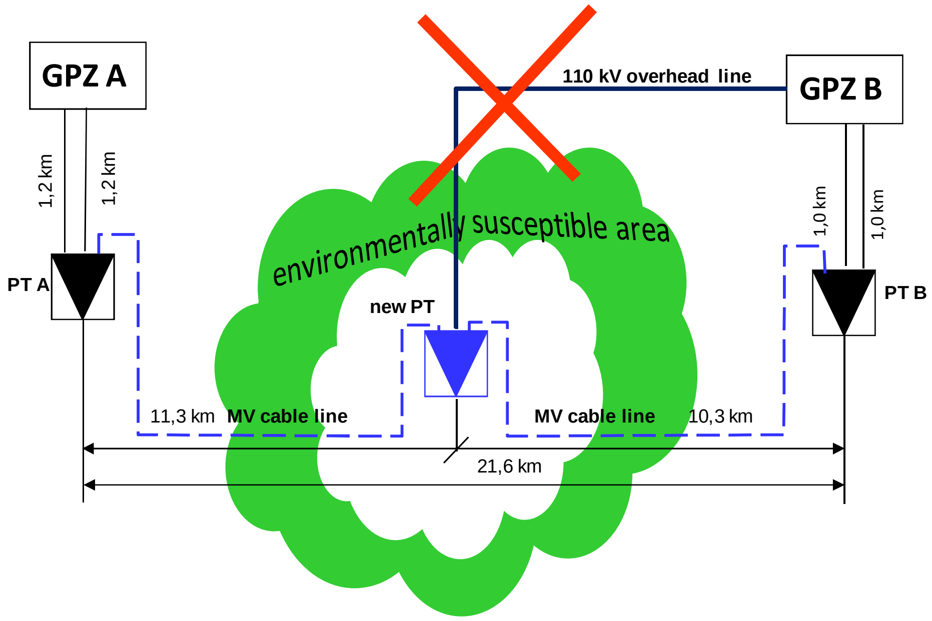

Fig. 1.Supplying a new substation surrounded by the environmentally susceptible area

The presented solution is not energetically effective. Long power supply lines cause significant values of voltage drops in the traction power supply system, what results in a great value of inner substitutive resistance of a new substation. Taking into consideration the fact that each of the traction vehicles is able to retrieve electricity of 2500 A value on conventional interoperable lines, each 0,1 Ω of substitutive resistance causes an output voltage drop by 250 V. As a consequence, a new substation output powered as it is shown in Fig.1, the voltage may drop significantly below the nominal value of 3300 V, what further results in limitation of the power supplied to the traction vehicles.

Regardless of the fact that the process of railway line electrification has been conducted in Poland on and off since 1936, there are the lines of national and international importance which are still not electrified.

It can be exemplified with the case of E75 line being a part of a transport corridor Via Baltica. The studies [4] proved the necessity of construction of, among others, two substations between Suwałki and Lithuanian border – PT Kaletnik and PT Trakiszki.

The main problem in the case of these traction substations is a lack of source of their power supply in the area of their location. The only solution of this problem is construction of a double-track line 110 kV from GPZ Hańcza of total length of almost 27 km, what is illustrated in Figure 2.

In Poland, there are many such areas (mainly in the region called ”eastern wall”) where the electric power system does not allow for supplying of large consumer of electricity, namely traction substations, without the necessity of its upgrading, frequently to the large extent. Additionally, such investments, despite their high cost, are utilized only by railway due to a lack of other consumers of electricity – the industry.

Fig. 2. Supplying of new traction substations on E75 line [4]

Railway lines of velocity over 250 km/h require power supply with alternate voltage. In Poland, construction or modernization of railway lines of driving speed over 250 km/h (”Y” line and modernization of CMK line) will be accompanied by implementation of a power supply system 2 x 25 kV 50 Hz.

As it was mentioned, power supply for a substation in the 2 x 25 kV 50 Hz system should be realized with the voltage of 220 or 400 kV. Since the course of 220 and 400 kV lines in the national electric power system does not correspond to the course of railway lines, implementation of high speeds will be related to, among others, the necessity of construction of several hundreds of kilometres of lines of the highest voltages. For instance, modernization of CMK line to the driving speed over 250 km/h will require construction of an power line of 220 or 440 kV on the whole distance of the railway line.

Innovative power supply system

The solution of the above described problems is an application of electric energy generating directly in the traction substation, also with the use of renewable sources.

The proposed system for supplying traction substations is presented in Figure 3. The system can be dual: it uses both the methane combustion and hot dry rocks (HDR) heat for energy production, or only one of these methods. The main part of the system is a turbine that can be driven either by methane combustion or steam from HDR.

The generators in the substations work in the idle state supplying internal loads of the substation and railway non-traction loads; and after receiving information, from the railway traffic control system, about the approaching train, it reaches the required power. It is estimated that the time of reaching the full power by the generators should not be longer than 5 minutes.

The "methane part" of the system consists of the wellbores drilled about 20 m below the railway and connecting substations with local gas suppliers. It will assure the ongoing energy supply for the trains. In the case of the higher energy consumption, e.g. a high speed train passing through the station, the energy taken from deep wells (5 000 – 10 000 m below the ground), drilled to hot dry rocks beds, will be used.

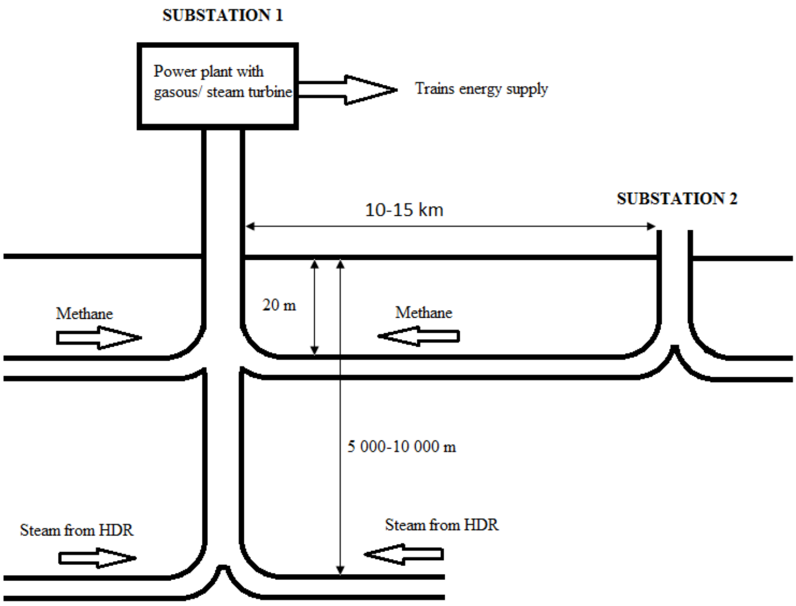

Fig.3. Scheme of power supply system for high speed trains.

Hot dry rock geothermal power is a specific type of geothermal power. Geothermal power generation depends on capturing the heat produced naturally by the earth and transforming it into a more useful form of energy. In the case of hot rock geothermal power generation, that more useful form of energy is steam. To approach generating the steam that is needed, boreholes are drilled into the earth to gain access to hot rocks**.** Water is then fed into these boreholes and comes into direct contact with the hot rocks. Contact between water and the hot rocks produces high pressure steam. This steam is returned to the surface to be utilized in a steam turbine as one of the cleanest forms of power production known to date [7].

This form of power generation has the potential to be very beneficial for several different reasons. The miniscule quantity of adverse impacts it has on the environment is one benefit that cannot be over-emphasized. When a hot dry rock geothermal power plant is operating at a steady state there are virtually no emissions. No adverse elements are returned to the environment aside from a small amount of waste heat [8]. The emissions of dry rock geothermal power are negligible when compared to, for example, the thousands of tons of sulfur dioxide and millions of tons of carbon dioxide released into the environment by coal power plants. Another advantage of this form of power production is that it is a very sustainable process. Hot water used in the process of power generation can be re-introduced into the boreholes to produce more steam. These qualities allow hot dry rock geothermal power generation to easily adhere to the demands of a world yearning for a greener future. Lastly, there is the matter of location convenience. A hot dry rock geothermal power plant can be located anywhere that it is possible to access hot rock within the earth by drilling. This allows for large freedom of choice with regards to location and may even allow for more power production in areas where it is inconvenient for other methods to be implemented.

In Poland, there are very good geological conditions allowing implementation of HDR technology to produce electric energy for traction purposes. Figure 4 presents the maps of temperatures distributions in the area of Poland depending on the depth.

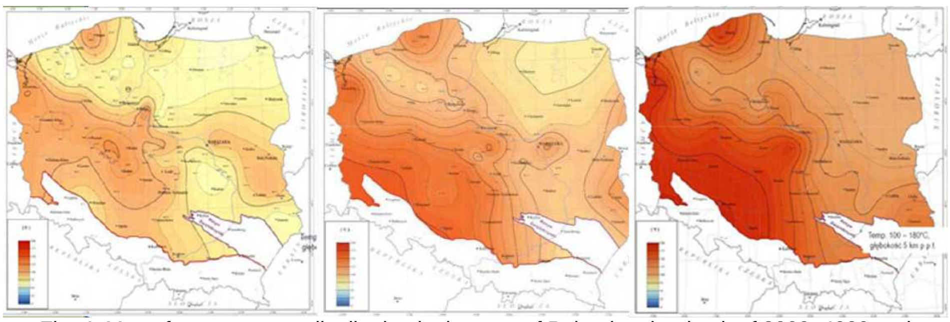

Fig. 4. Map of temperatures distribution in the area of Poland at the depth of 3000, 4000 and 5000 m below ground level. (source: AGH)

The presented technology of electric energy generating on the basis of HDR energy has been already successfully introduced in Europe and in the world. It is exemplified with a generator, presented in Figure 5, using HDR technology of 2.6 MW power.

Fig.5. 2,3 MW generator using HDR technology in Landau, Germany.

The advantage of the described solution for power supply of traction substations is lack of necessity to build power supply lines of medium or high voltage, frequently longer than 10 km, what results in shortage of protection zones for these lines.

Besides the place of the substation localization, the system does not occupy the ground as gas transfer between the substation may be accomplished through the gas pipes placed under a railway track.

Owing to generating the energy at the place of its transferring to the overhead contact system, the wastes of energy transfer are minimized, and the elimination of part of voltage drops in the system improves its voltage-current characteristic.

Application of HDR technology for generating of electric energy does not cause the emission of contamination to the atmosphere or any other negative effects for the natural environment. It also increases share of the renewable energy in the grand total of electric energy generated in Poland, that is compatible for reducing emissivity of Polish economy national programs

An innovative traction power supply system makes, to some extent, the railway system independent of the national electric power system as well as improves its reliability and availability in case of blackout.

The drawback of the presented system are costly drillings, however the constant progress in this field favourably influences the drop in costs of the investments of this type.

Conclusions

1. Modernization of the electric traction power supply system repeatedly requires construction of new substations located in the places where conveying the supplying lines is impossible due to environment protection.
2. The innovative electric traction supplying system is independent of power supply sources from the national electric power system. It allows for supplying traction substations without the necessity of upgrading the national electric power system, frequently to a large extent. The solution improves also the extent of electric traction supplying reliability.

3. The innovative electric traction power supply system does not require construction of the electric power lines or does not causes occupation of ground by these lines.
4. The innovative electric traction power supply system is ecological – HDR technology does not cause the emission of greenhouse gases to the atmosphere.
5. In the system, the energy transfer wastes are minimized, what positively influences the voltage-current characteristic of the electric traction power supply system.

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