RENEWABLE ENERGY IN RAILWAY TRANSPORT

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ABSTRACT

The advantage of using electric energy for rail passenger transport has long been evident. But because of this, more and more importance is paid to saving energy, searching for cheaper and more affordable sources. From this point of view, the author of the article approaches the analysis of the growing opportunities in recent years for the use of renewable energy sources in rail transport and the trends in their development, distinguishing hydrogen fuel cells, photoelectric installations, wind, solar, and our planet. A special place is given to the problems of energy storage, to variants of its rational redistribution on the network. At the same time, research, design and implementation practices of a number of countries are shown.

Keywords: railways, power supply, renewable energy sources, search, development, energy culture.

Background. *The use of renewable energy sources (RES) in industry and transport and their further development is today an urgent need in terms of ecology, energy efficiency and consumer attractiveness of rail transport.*

Increasing the efficiency of the use of energy resources and, first of all, renewable energy sources open immense opportunities for the railway. In public passenger traffic (ÖPNV), about 66 % of the transport work, expressed in passenger kilometers, falls on electricity. On the Deutsche Bahn AG (DB AG), more than 90 % of energy for traction is electricity. This indicator for railway long-distance traffic has already reached 98 %. The advantage of using electric power for rail passenger transport is obvious. That is why energy saving is given special significance, and also because its cost increases.

It should, however, be borne in mind that the vehicle № 1 in Germany and the countries of the European Union is a car. And for DB it is a strong factor of competition. In addition, other railway companies that have their own rolling stock and carry out freight and passenger transportation on the DB network, strengthen their positions in the transport market and present increasing competition for the company.

It is planned that by 2050 the emission of carbon dioxide will have decreased practically to zero, and the railway transport will be completely freed from CO_2 – i.e. «green zero» will be reached. This is possible also because the DB operates its own power supply network (for example, it has its own hydroelectric power plants and some of them supply contact networks with a frequency of 16.7 Hz) and itself regulates the purchase of electricity.

Nevertheless, a complete transition to RES is a difficult task also for the reason that different energy sources do not always have a sufficient quantitative and uniform energy production factor.

The German government, in formulating the energy concept in 2010, set the goal of reducing energy consumption in transport by 2020 by 10 % and by 2050 by 40 % compared to 2005 [1].

It is known that rail transport in comparison with other modes of transport is characterized by lower specific energy consumption and has proved more environmentally friendly. Countries with limited own fossil resources in recent years have been intensively investing in technological development and the introduction of renewable energy sources. Thus, dependence on oil and gas decreases, and in addition, dependence on energy imports also decreases. Germany actively uses various alternative energy sources (wind, solar, hydropower, biomass).

DB sees itself as a favorite in the field of environmentally organized transport and energy saving. It was recognized by the respectable international organization CDP (Carbon Disclosure Projekt) as the world's best railway in the field of environmental cleanliness, ranking first in the rating.

The application of RES is supported in Germany by the law on renewable energy (EEG), which has a positive effect on rail transport, which is a major participant in energy policy, where, as elsewhere, the direction of future development depends on the position of the «arrow» [2, 3].

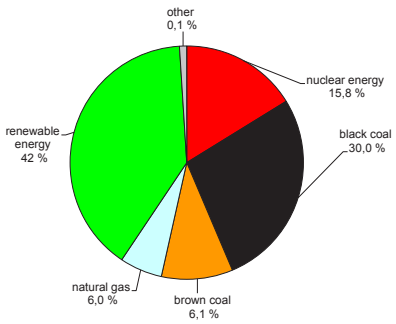
Objective. *The objective of the author is to consider prospects of renewable energy sources application in the field of railway transport.*

Methods. *The author uses general scientific methods, comparative analysis, scientific description.*

Results.

Energy on the roads and in the rolling stock sector

According to DB, the share of renewable energy in power consumption for traction would have been increased to 35 % by 2020, but this figure has already surpassed and reached 40 % in 2015 [4] (Pic. 1). For comparison: in 2010 the share of renewable energy sources in railway transport was 19.8 %. The possibilities of using alternative energy sources on the railway are very diverse. From today's perspective, it is: energy for train traction, operational work, infrastructure, rolling stock (the work of auxiliary units, lighting, air conditioning systems), a network of computers, maintaining external functions, accumulating energy, lighting buildings, etc. Other possibilities for increasing energy efficiency are the transition to lightweight rolling stock designs, the production of more economical locomotives and motorized rolling stock, as well as the optimal method for controlling trains. It should be noted that decisions on increasing energy efficiency on the railroad receive very noticeable returns. Up to 8 % of the total energy



Pic. 1. Sources of energy production for DB in 2015, (revised by the author).

Pic. 2. Photoelectric installation on the roof of the station in Berlin. Photo: DB.

consumption, for example, can be returned to the AC contact network by recuperation during braking or can be accumulated.

Power supply for air conditioning systems, auxiliary units and lighting is carried out mainly in the usual way, and can also be supplemented by renewable energy sources (hybrid drive concepts in combination with photoelectric modules, hydrogen fuel cells, etc.). An energetically optimal way of controlling train traffic also creates an additional saving potential. However, stationary generation of energy remains in the foreseeable future an important method of its production. Moreover, it is successfully supplemented by intelligent management methods (Smart Grid), especially with increasing requirements for energy networks and in connection with the growth of the share of renewable energy in railway transport.

Manufacture of lightweight rolling stock and the use of composite materials with first-class properties (on glass and carbon fiber basis GFK and CFK) is another energy saving resource, design weight is reduced and production costs are reduced by 20–30 %. New horizons are also opened by the use of nanotechnology on the rolling stock and infrastructure facilities.

Science provides many different technical capabilities and products, which, however, cannot always be used so far, because they are not yet economically efficient (profitability), nor have they reached market maturity.

Practical use

Hydrogen fuel cells

The use of the drive on hydrogen fuel cells for traction of trains instead of diesel or electric traction in the near future is hard to imagine. The fact is that for traction, not only the high power of hydrogen fuel cells is needed, it is equally important to have a large amount of generated energy. For the needs of auxiliary units this is possible already today. But in all cases, the technical and economic task is also a significant increase in the profitability of this environmentally friendly energy source.

Below there are some examples for traction rolling stock, where hybrid power plants using hydrogen fuel are used.

• Alstom signed an agreement at the international fair «InnoTrans 2014» in Berlin on the delivery of a traction rolling stock on hydrogen fuel to four Federal States of Germany. The same company supplied hybrid locomotives for cargo transportation in 2015–2016 for the plant of the Audi automobile concern in Ingolstadt. As it is known, work in the plant's workshops is allowed only for locomotives that do not generate exhaust gas.

• The completed project within the framework of the Public Private Partnership, in which a number of companies participated, confirms the activity in this direction in the USA. In 2009, a test trip of the locomotive on hydrogen fuel was successfully carried out. This, perhaps, is the largest locomotive of this kind for today (firm BNSF). Its power with a long operating mode is 240 kW. The peak power of 1 MW is enough for a few minutes [5].

• Research on the use of hydrogen fuel cells for the shunting locomotive of the shunting locomotive of the marshalling yard is carried out on the Russian Railways (JSC RZD). At the same time, the production of hydrogen is carried out by conversion from natural gas transported on board the locomotive. Other projects are aimed at the use of hydrogen fuel for railcars, rail buses and cars with an energy installation to provide electricity for tunneling.

Photoelectric installations, wind power

The use of solar energy in rail transport has many advantages. It is suitable for the power supply of on-board equipment, air conditioning devices, for power supply to low-capacity stations and areas, it should be considered as an economically viable alternative, especially where the connection to the power grid (if any is near) is expensive. The share of wind energy in sources of energy production is also constantly growing.

• In Florence (Italy), in 2004, a completed project was presented, within which a car with solar panels (Photovoltaik Train) was designed. This is the project of Italian Railways (Trenitalia), which was funded under the EU program (1.25 million euros). Rolling stock with solar panels on the roof is in operation. The generated energy is sufficient for lighting, air conditioning and operation of onboard systems. It should be noted that for a number of years in Italy there has been a «solar boom», because the state, through financial incentives, has increased the attractiveness of projects in the field of using solar energy sources.

• Solar power has been used in the field of signalization on the railway for many years. The power supply of global positioning systems (GPS) in freight cars is also carried out with the help of solar current. Examples of the use of solar panels in soundproof walls on transport are known.

• Roofs play an important role for solar energy. Since 2003, a photovoltaic system has been in operation on the south side of the main station in Berlin (Pic. 2). Such installations on the roofs of the stations are already available in a number of countries.

• For the Geneva Canton transport company (Switzerland), Höft & Wessel more than 700 ticket machines have been supplied that are installed in the sunniest places.

• The Chinese firm JinkoSolar produced and supplied solar modules for the roof of the high-speed tunnel between Paris and Amsterdam on the Belgian railroad track (Pic. 3). Solar panels installed on the roof of a 3.6 km long tunnel generate 3,300 mW•h of energy per year. Electric energy is used for trains and infrastructure. The emission of CO_2 decreases by 2400 tons per year [6].

• The metro of Mexico city uses the energy of the airflow of moving trains. The current generated by the wind generators installed in the mines is used to illuminate the metro stations.

Accumulation of energy

The production of energy must necessarily be combined with the possibilities of its accumulation.

This is foreseen in the energy complex today. Effective management synchronizes energy consumption and its production from fluctuating sources and provides the necessary profitability. The inconstancy of energy production from renewable energy creates at the same time a stimulus to the search for reliable and economical storage devices. The combination of sources with energy storage provides sufficient energy for periods of weak solar or wind activity.

The advantage of generating electricity and heat is also that these sources are decentralized. In the case of excessive production of energy, there is a need of its return to the energy network with payment, its accumulation and to creation of reserves. There are examples where excess energy is simply «gifted» to other neighboring countries, since the suspension of energy production is sometimes more expensive.

Accumulation of heat

There are various possibilities for accumulating heat and transporting it. An innovative way is to use latent thermal energy storage devices, when everything is determined by the change in the aggregate state of the accumulating medium when heat is applied or removed. Transportation of the container «with heat» is carried out on the highway, and in the presence of access roads can be made by rail. Latent storages are used for heating or cooling buildings. For transportation, tank containers are used. One example of the mobile heat transport system that already operates since 2013 is in Augsburg, Germany, where the tank containers are «charged with heat» at the heat station of the «AVA» garbage processing plant and transported to heat the school center of the neighboring town of Friedberg. Such an option gives about 2500 kWh • h of energy. The system efficiency is 85 % [7].

Condensation of electricity

The results of using supercondensers (Supercaps) for the accumulation of electrical energy are impressive. Today such solutions are not original when collecting energy, for example, from wind power and solar installations. These systems are able to accumulate electrical energy in large volumes. Supercondensers with a capacity of up to 5000 farads are already known, although the voltage values are small. The efficiency is 90–95 %, and the application potential is very high. Modularization on the rolling stock is possible and gives the desired effect.

Examples of their use in combination with batteries are available in several countries. Let's say that the Siemens concern is putting into operation a tram line in Doha (Qatar). In this rail system without a contact network, there is a hybrid system for accumulating electrical energy: two-layer supercapacitors are supplemented with lithium-ion batteries. Charging, if necessary, takes place literally in seconds at any of the stations of the tram network [8].

Energy of the Earth

For the movement of trains, the smooth operation of turnout switches is important. Their heating in winter conditions is possible not only with the help of electricity, but also with the use of the energy of the Earth. These systems also use the heat of underground water, air or sewage. Modern heat pumps save at least 40 % of energy.

• The first example of the use of geothermal heating of switches on a DB refers to 2007 in Holzminden. In 2010, the geothermal heating of the switches without the use of a current was commissioned on the Hamburg port railway.

Pic. 3. The roof of Paris-Amsterdam route tunnel. Photo: JinkoSolar.

• Since 2005, in Bad Lauterberg–Barbis, a heating system for the railway platform is also in operation on the Göttingen–Nordhausen line, also using the heat of the Earth.

• «Triple-S-GmbH» has a number of completed projects for equipping turnout switches, platforms, transport areas and bridges with geothermal heating systems. It received an admission to the work on the DB and, in particular, the permission of RZD to install a new generation pilot system at two switch points in St. Petersburg. The devices are serviced remotely from Germany. Today, the number of geothermal systems on the railway grows after their successful testing.

• At individual metro stations in Vienna, heat pumps and heat of tunnels are included in everyday use.

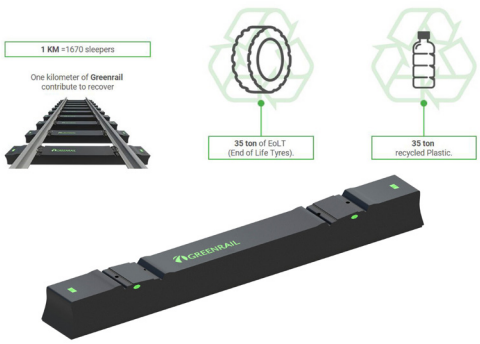
Solar thermal energy and sanitation of buildings

• The comprehensive use of renewable energy sources is demonstrated in Cologne by the DB project of Germany's first environmentally friendly train service company ICE, where it is planned to show the most advanced technology in the field of environmental protection. Here, geothermal energy, photovoltaic installations, solar thermal energy are envisaged and other innovative solutions will prevail. The company will be equipped with a conditioning system based on heat pumps and heat exchange with underground water. Solar thermal collectors will provide heat supply to the public building, delivering warm water for domestic needs. The total capacity of 1200 photovoltaic modules located on a roof 433 m long will be 300 mW.

Naturally, under peak loads, energy will come from other environmentally friendly energy sources. To recharge the electric motor road transport «solar» refueling stations will be built. A number of other modern solutions is provided, construction of additional noise-protective walls with solar batteries, soundproofing of buildings, etc. As early as 2017, high-speed trains, including the future generation of ICE4 (IC), will be inspected here.

The total energy savings will be 15 %.

• Warming of facades, roofs and walls of railway stations, as well as other buildings is an integral part



Pic. 4. Sleeper with piezoelements. Photo: Greenrail.

of the energy efficiency program DB. In addition to thermal insulation, old windows and heating systems are being replaced. Over the past years, more than 30 buildings, mostly under the protection of the state as monuments of the past, were energetically sanitized. Annually in Germany three railway stations are modernized, which receive a new energy passport.

Scientific researches and projects

The newly founded Italian firm «Greenrail» (greenrail.it) produces new sleepers, which produce current due to the pressure produced by trains passing over them. Integrated piezoelectric elements, which are generators, give up to 150 kW•h / km of energy when passing up to 15 trains. Together with Polytechnic University of Milan and other partners, the company promotes this product to the market (Pic. 4). In 2016, it is testing 1 km of track with these new sleepers.

• Within the framework of the «Next Generation Train» project at the National Research Center of Germany DLR, using the methods of system analysis the effectiveness of new technologies and solutions (including RES) is studied in the projection on the entire integrated railway system. This major project represents a look into the future of rail traffic [9].

• In 2015, an innovative shunting gas-turbine locomotive TEM-19, built at the Bryansk machine-building plant «Transmashholding» under the order of Russian Railways, was presented in Moscow within the framework of the 5th international railway salon «Expo-1520». The locomotive passed the necessary tests and is scheduled for serial production. The gas turbine locomotive has a gas piston engine with a power of 880 kW and operates only on liquefied natural gas. This is an excellent example of the implementation of the Railways program for the implementation of resource-saving technologies.

• The final study of the railway energy project (7th EU-funded research program) analyzes the results for a number of countries for different types of rolling stock on the use of energy-efficient technologies and examines options for making investment decisions from the standpoint of the need for energy, CO_2 emissions and profitability.

• The Augsburg University of Applied Sciences together with the MIIT regularly organizes internship, conduct joint research. About 300 specialists from Russian Railways and teachers took part in the training programs.

Conclusion. *The orientation of railways to the use of renewable energy plays an important role in ensuring the efficiency, long-term and reliable energy supply and characterizes the epochal trend of its development. In this process, there are many «actors»: politics, industry, railways, science, universities, society and people. And the running mechanism will function well only with full interaction of all participants in the process. The use of new energy sources, resource-saving technologies should affect the entire railway complex, which has a huge potential for saving energy, and then the efficiency of energy supply will be significantly higher. A new energy culture has received a great deal of development in the society and in rail transport today. The transition to decentralized energy supply ensures greater autonomy, independence and security of the industry sector.*

The energy revolution is a process that should be accompanied and corrected on time by institutional policy. This is not only an abandoned challenge, but also a great chance to be used.

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