Energy-Efficient Electric Drive of Multifunctional Turnout

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Summary

Along with the improvement of the existing switchgears by replacing unreliable elements, global companies create its new types in order to improve the reliability, operating speed and to achieve high speeds of motion on pointers. Therefore in this work the way of modernization of the existing turnouts is offered based on switched reluctance electric motor, and also the design of direct-drive turnout on the basis of linear electric motor.

Keywords: switched reluctance electric motor, linear electric motor, turnout

1. Relevance of the Study

The development of railway automation technique and the improvement of its service work technology greatly contribute to the improvement of traffic safety and economic factors of the railways. A special role is given to the station automatic and tele automatic systems, as the main technological operations of receiving, sending and processing of trains are run on stations. The effectiveness of these systems operation depends largely on the quality of actuators, the most important of which are turnouts. For example, railroads in North America annually spend 300 million US dollars to replace the elements of turnouts and crossings at grade and 500 million US dollars on their current maintenance and repair. The costs associated with delays of trains due to turnouts failure are 200–600 million US dollars, and with the elimination of the consequences when railway equipment comes off the rails – 16 million US dollars. This situation explains the scale of the expenditure of funds in order to extend the operating life of turnouts. Therefore, more relevant is the improvement of the existing types of switchgears, the development of the new one, as well as the improvement of their reliability.

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2. Material and Results of the Research

A turnout is a device used to transfer railway equipment from one track to another. Such systems are an integral part of the railway infrastructure, but at the same time represent one of the weakest track elements. They are complex, subject to deviations of geometrical parameters and damage in operation, since their design includes moving parts that are affected by high dynamic loads. This increases the price of their maintenance and repair, leading to high costs for routine maintenance of tracks. Frequent violations of train movements are connected with the failure of turnouts. Turnouts may limit the operational availability and train-handling capacity of the railway lines, if the allowed speed of train does not match the speed of both the main and side roads. The general concept of new turnouts for both ordinary and high-speed traffic is to ensure the maximum safety and security, whereby the cost of routine maintenance is minimal, reduce of power consumption, the extend of functions of the drive such as automatic return and smooth tongue to point rail.

First turnouts appeared in Italy in 1873. Depending on the purpose and conditions of the connecting tracks, turnouts can be single, double and cross. Single turnouts are divided into ordinary, symmetric and asymmetric. Ordinary turnout is most common. It consists of pointer, frog with check rails, connecting part between them and crossing sleepers (Fig. 1).

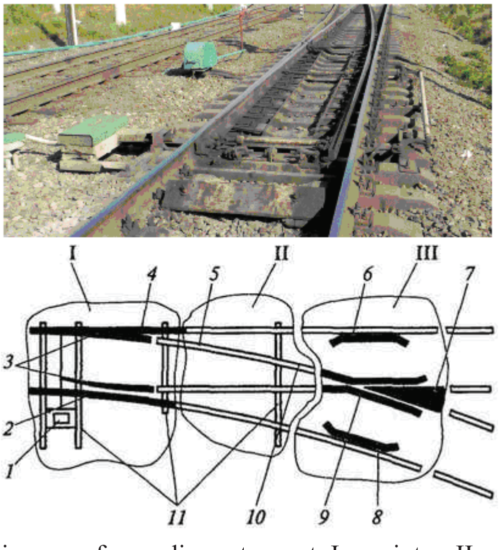

Fig. 1. Photo and diagram of an ordinary turnout: I – pointer; II – connecting tracks; III – set of frog part: 1) shift mechanism; 2), 4) point rails; 3) tongues, 5) backing-up strand of turnout curve; 6), 8) check rails; 7) point of crossing; 9) counter-rail; 10) the end of the turnout curve; 11) crossing sleepers

One of the main elements of pointer is switchgear. The railways of Ukraine applied electric drives series СП, previously series of СПВ were also used. For the moment all automatics of The State Administration of Railway Transport of Ukraine „Ukrzaliznytsia" as part of the element base СЦБ has gears type СП-3 и СП-6, as well as modifications based on them (СПГБ-4М, ВСП-150, СП-12У), which changes radically didn't affected main structural assemblies, developed in the USSR in 1972 and 1983. Fig. 2 shows a general view and drawing of switchgear type СП-6. This electric drive consists of three main units: the electric motor 2, reduction gear 4 with clutch 3, automatic switch 6, located in the body 1.

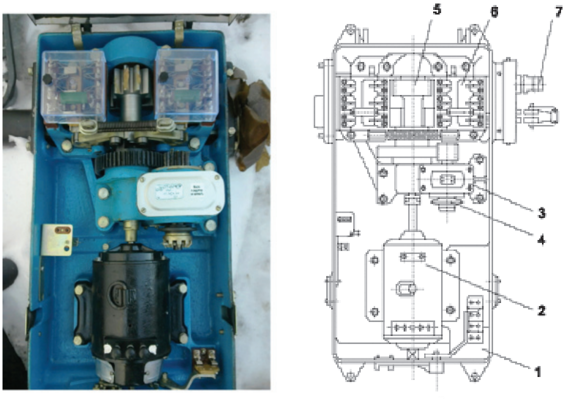

Fig. 2. General view and drawing of switchgear type СП-6; 1) body of switchgear; 2) electric motor; 3) reduction gear; 4) clutch; 5) main shaft; 6) automatic switch; 7) control lines

On the previously discussed types of turnouts two types of electric motors are used in Ukraine – DC motor and AC (asynchronous) motor. Despite the use of such motors they have a number of disadvantages. Electric power diagram of electric drive type СП-6 (Fig. 3) represents the ratio of losses in its various parts and net capacity at nominal load on gate valve.

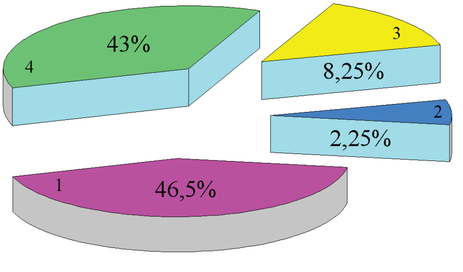

Fig. 3. Electric power diagram of electric drive type СП-6; 1) losses in engine and reduction gear, 2) losses in automatic switch, 3) losses in gate pair, 4) net capacity

As shown on the diagram, net capacity of the existing domestic electric drives is only 43%. A significant part of the energy (almost half of the total power consumption) is spent in reduction gear and motor, the last of which (DC motor, asynchronous) has its own disadvantages. Despite of this, such systems in many years' practical work showed itself in a positive way, but today they cannot cope with the new challenges, functions and tasks that are set in other countries.

Switchgear manufacturing companies are searching for ways to improve them in different directions. Some of them are working on the improvement of the remote computerized direction of turnouts and monitoring of their condition, while others explore the possibility of promotion to the market switchgears with power supply from solar battery.

In our view, the most promising today are shift mechanisms built in railway sleepers, which are designed to reduce their costs and increase the life cycle during the whole operating life (as an example, Hydrostar system – Figure 4 or Switch 2000 – Figure 5).

Global Signalling company, sector of automatic and tele automatic equipment of the division of railway engineering of corporation General Electric (GE Transportation System, GETS), has developed a switchgear type Hydra-Switch 3000LP (Fig. 6). This gearless shift mechanism can be adapted to remote control by radio facilities or by using a global communications network and its application allows the railways to increase the level of automation of the station. It has electro-hydraulic gear, servomotor that can be powered by solar batteries.

Fig. 4. Hydrostar System

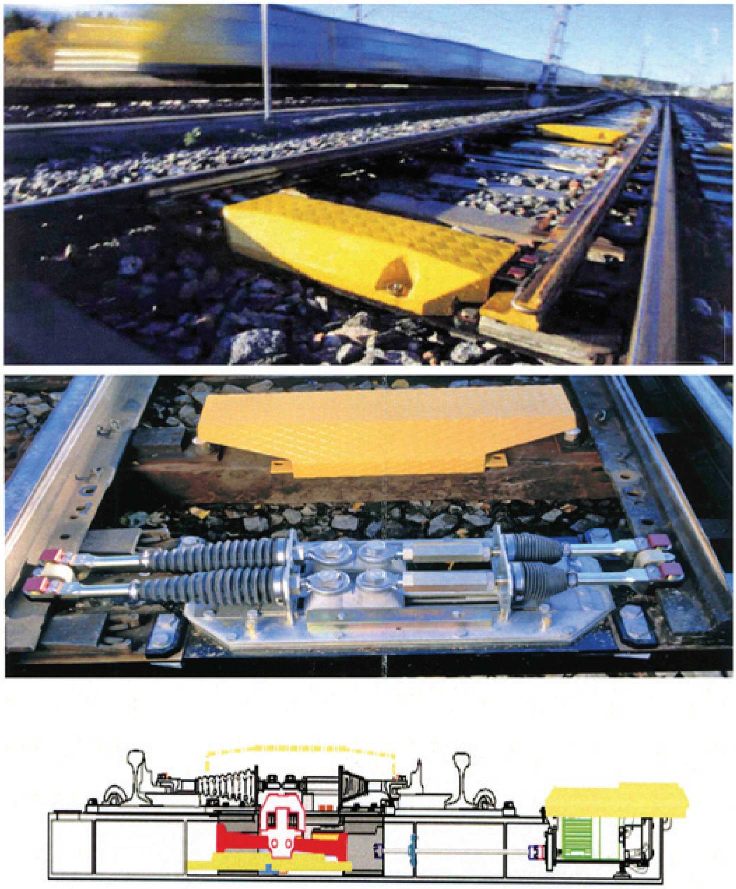

Fig. 5. Switchgear with frequency regulation EBI Switch 2000

Fig. 6. Switchgear type Hydra-Switch 3000LP

In such systems, it is efficient to use new types of electric motors – switched reluctance electric motor (SRM) or linear electric motor (LEM) shown in Figs. 7 and 8. SRMconsists of a rotor and a stator with identical double-slotting. On cog-tooth of the stator concentrated single pole winding is placed. Toothed rotor is passive; this means it doesn't contain elements that create a magnetic field (windings, magnets). An integral part of the motor is rotor position sensor that can be used as a sensor of tongues position. SRM for switchgears of Magnetic Control Switch (MCS) type (Fig. 7) are designed by Ltd. ETZ „GEKSAR". Control system of such motor provides the possibility of synchronous operation of two or more electric drives, which makes it promising for the use in turnouts of speed railways.

The principle of operation of electromechanical converters of induction type (Fig. 8) is based on the interaction of the magnetic field generated by alternating periodic, pulse or aperiodic current of inductor winding with impressed current in the disc of armature that moves linearly. An example of it can be a cylindrical LEM, the concept diagram of which is shown in Fig. 9. A special feature of its structure lies in the fact that the windings 2 are arranged around permanent magnets 1 that is formed into a cylinder and the point of crossing is absent.

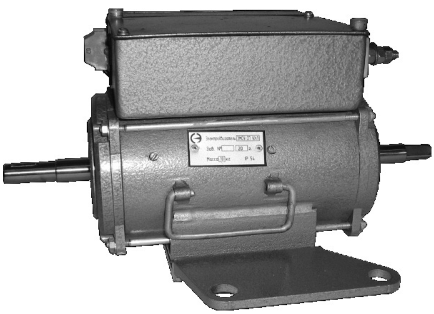

Fig. 7. Physical configuration of SRM MCS-0,25-160V

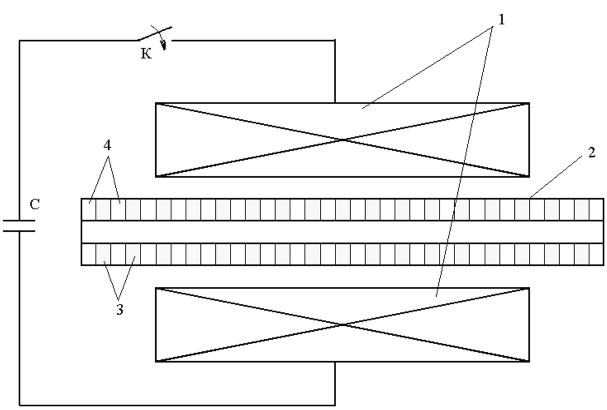

Fig. 8. Linear electromechanical converters of induction type:
1) inductor; 2) armature;
3) copper discs;
4) ferromagnetic disks

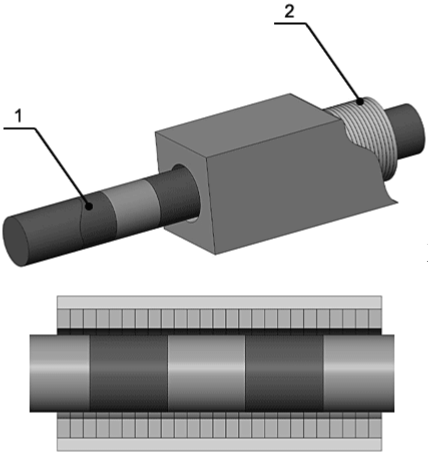

Fig. 9. Linear Electric Motor:
1) permanent magnets;
2) winding

Today developments are made in partnership with the „Department of electric vehicles” of *Rostov* State University of Transport Communication in order to create sleeper type switchgears by using SRMand LEM. Aside from that the development of microcircuit techniques enables the creation of microprocessor control systems, as well as the expansion of the drive functionality, the use of a new generation contactless sensors, the application of electronic converters and the protection of motor during the operation without the use of a friction clutch.

As a control object switched reluctance four-phase electric motor designed by the „Odessa National Polytechnic University” has been selected (Fig. 10). Physical configuration of breadboard model of sleeper type switchgears is shown in Figure 11. Reduction gear of such electric drive is a pair of „crew set” (Fig. 10) which serves to convert rotational motion into linear. Such transfer is primarily has a higher efficiency and produces a greater force and, moreover provides accurate movement.

Realized control system as a part of SRMis shown in Figure 12. During its development one of the goals was maximum simplification of the circuit design by reducing the number of components to a minimum by combining individual nodes of circuit.

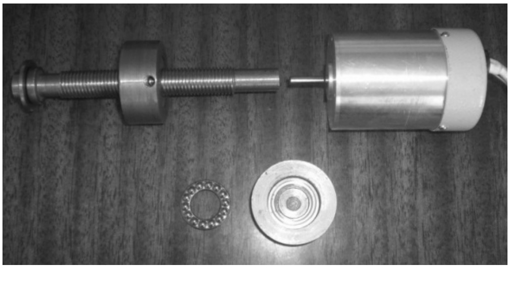

Fig. 10. SRMcombining with reduction gear type of „screw set”

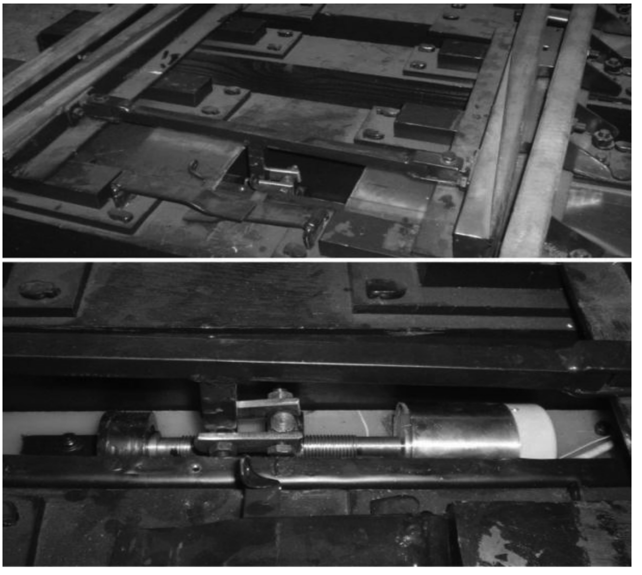

Fig. 11. Sleeper type switchgear

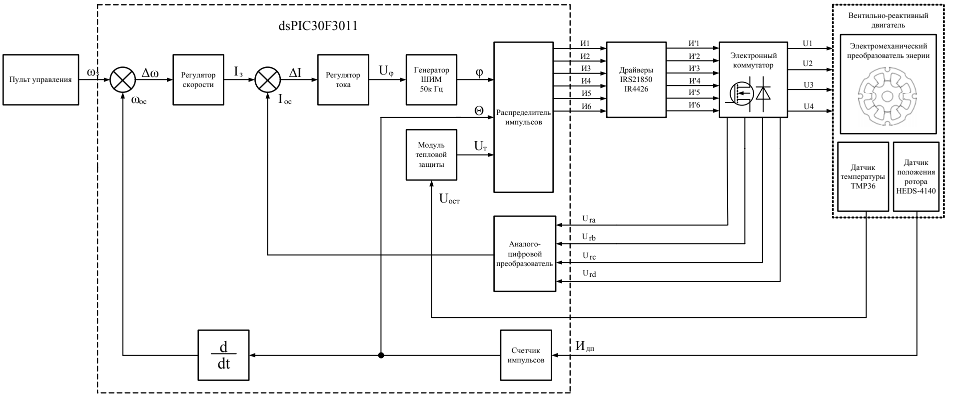

Fig. 12. Functional scheme of SRMcontrol system

An example is the use of a microcontroller dsPIC30F3011 of Microchip firm, specifically designed to address this kind of problems, and for digital signal processing. Many elements of the scheme, such as ADC, PWM with six outputs (pulse distributor), quadrature encoder module (pulse counter) are already a part of the microcontroller, thereby main program solving tasks were given to hardware, that allow to relieve the central processor and give the rest of the time for the implementation of different control methods, including the use of complex mathematical calculations.

To control the position of the rotor (at the same time the location of tongues – as one method of control), as well as the speed and direction of its rotation the built in SRMoptical incremental sensor HEDS-4140 is used, which allows to get 360 pulses per one revolution of shaft, connected directly to a quadrature encoder microcontroller.

As current sensors serve low-resistance precision resistors, their voltage is preliminary filtered out and measured by ADC. Information about the temperature of SRMwindings is received by sensor type TMR36. Conducted researches have confirmed the high accuracy and speed of the new drive, and much higher energy efficiency compared to turnout systems.

3. Conclusions

Positive results from the creation of drives using the switched-inductor motor allow, in our view, to make a prediction that such machines can not only simplify the mechanical part of the drive and windings control system, but also improve its reliability and performance, and the use of linear electric motor can create gearless switchgears of a new generation. The high energy efficiency allows using these electric drive systems with alternative sources of electric power, that will increase the overall reliability of the system of railway automation.

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