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EXAMPLES OF USE OF ELECTRONIC AND POWER-ELECTRONIC SOLUTIONS IN MULTIMODAL TRANSPORT

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Abstract: The paper discusses examples of the application of new technological solutions in the field of automation, IT, and electronics in multimodal transport. In the 21st century, electric vehicles and electronic systems that accelerate the delivery process are becoming increasingly important. The purpose of the article is to show examples of the application of electronics and power electronics in road, rail, and sea transport. The functioning of selected devices and systems used in specific modes of transport is also described.

Keywords: electronics, power engineering, information technology, automation, multimodal transport.

1. INTRODUCTION

Nowadays, one of the most valuable resources in the functioning of companies and of the society is information. It ensures that companies are managed in an efficient and optimal way. With the emergence of the need to optimize companies' management systems, a demand appeared for new technologies in the field of automation, electronics, and electrical engineering. The new solutions have helped to speed up international transport and trade. This need has strongly influenced the improvement of transport. This is particularly evident in multimodal transport. Thanks to the efficient functioning of systems and equipment used at transport companies, terminals, logistic centers, and seaports, cooperation between different modes of transport has become possible. In order to deliver a specific cargo, it is possible to carry it in stages, where part of the journey is carried out with a road tractor or a train and another part is carried out using a ship. Computerization has also contributed to electronic transmission of documents, which has had a positive impact on the growth of international trade.

2. MULTIMODAL TRANSPORT CHARACTERISTICS

Transport is the movement of goods or persons from the place of origin to the place of destination. There are several basic modes of transport:
- maritime;
- inland waterway;
- railroad;
- road;
- air;
- pipeline [Koźlak 2008].

Cargo or persons may be carried using one or more of these modes along the entire route. Over time, the frequency of the use of different means of transport for one journey has increased. The reason for this situation globally is the development of international trade caused by globalization [Transport Europejski 2013].

Multimodal transport is most often used in intercontinental transport operations or in situations where it is conditioned by geography. In order to transport cargo by sea, land, or air, transshipments are performed. They may be performed from means of road transport to means of rail, maritime, or air transport. This method of transport is referred to as multimodal transport.

Multimodal transport takes place when:
- a minimum of two modes of transport are used;
- one contract for multimodal transport has been concluded;
- there is one transport organizer;
- the cargo is unitized, i.e. appropriate packaging of the cargo is provided, which is assumed to be a unit. This makes transshipment easier and protects the cargo along the entire transport route.

An example of cargo unitization is containerization. Containers are the basic loading equipment used in road, maritime, and rail transport. Many groups of goods are transported in containers of different types. Standard 20-foot or 40-foot rectangular containers are used. This facilitates the process of cargo delivery, as it is possible to reload the same container onto different means of transport [Stankiewicz 2011]. In the intercontinental and intracontinental transport operations, containers with electronic circuits are used. One of the most commonly used container types is refrigerated containers. They contain chillers that allow the right temperature to be maintained for the cargo during transport. A constant temperature inside such a container is ensured by a thermostat controlled by means of electronic circuits. The microprocessor controller adjusts the operation of the chiller depending on the weather conditions. The set temperature is entered and controlled on the operator panel located at the unit or remotely at the terminal in the tractor cab. In most cases, this is done wirelessly.

3. EXAMPLES OF APPLICATION OF ELECTRONICS IN ROAD TRANSPORT AS A LINK OF MULTIMODAL TRANSPORT

In road transport, the use of electronics is evident not only in transport of cargo, but also in payment of tolls for national roads and motorways. Intelligent Transport Systems (ITS) are playing an increasingly important role.

The viaTOLL electronic toll collection system belongs to this group. It is obligatory for buses and trucks. A special device is installed in the vehicle that sends a signal to the gantries installed above the roads. The driver at most gas stations can check his or her account balance in the system and find out if he or she has to pay for the use of the road infrastructure [viaTOLL 2019].

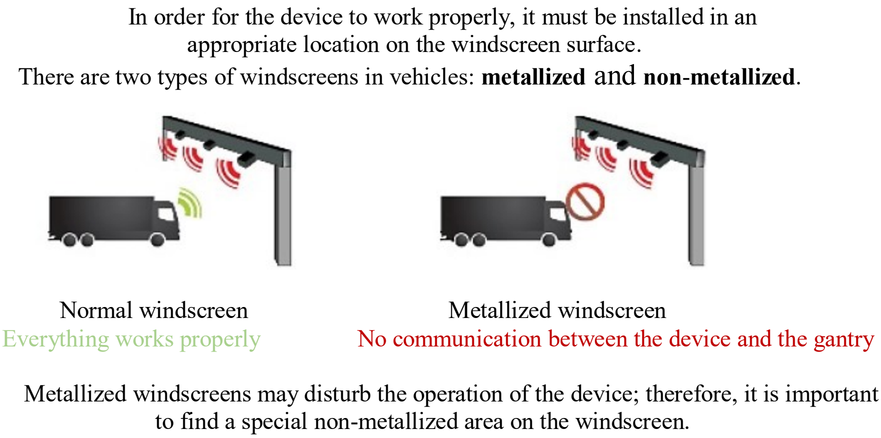

Fig. 1. Operation of the viaTOLL system during the passage under a gantry

Source: [viaTOLL 2019].

The viaTOLL system operates on the basis of the DSRC *(Dedicated Short Range Communication)* technology, which is used for uninterrupted exchange of information between vehicles and the infrastructure. It is mainly used for automatic toll collection. The system operates by sending radio waves from transponders (called viaBOX) to sensors located on gantries.

The vehicle data sent from a viaBOX at the microwave frequency of 5.8 GHz and the rate of 500 kb/s is received by the sensor in the toll gate without the need to slow down or stop the vehicle [RFID-Lab 2019]. The transponder must be attached to a windscreen that is not metalized, as otherwise the radio signal may be disturbed.

Fig. 2. ViaBOX

Source: [viaTOLL/viaBOX 2019].

Another example of electronic devices used in road transport is smart tachographs. They calculate the working time of the driver and improve the claim process in the event of traffic accidents. After 9 or 11 hours of driving, the driver may pay a penalty. “The new functions make full use of advanced digital technologies, such as satellite positioning, short range communication for law enforcement agencies, and links to other telematic applications, through a harmonized smart transport system interface. This will allow, among other things, automatic recording of the location of the start and end of the journey, as well as remote access to certain tachograph data via wireless data transmission to control authorities” [Polityka Organu Państwa Członkowskiego 2019].

In road transport, attempts are made to introduce electric tractor units. In May 2019, ABB and E – Force One presented such a vehicle. It is equipped with batteries with the capacity of 310 kWh, which makes it possible to cover 300 km on one charge. The charging time of the installed battery is 6 hours, using a 50 kW DC charger. The engine of the unit has 360 kW (489 hp) and 2,700 Nm of torque. The maximum speed of the vehicle is 85 km/h [Elektrowóz July 2019].

Fig. 3. Electric tractor unit

Source: [Elektrowóz 2019a].

4. EXAMPLES OF APPLICATION OF ELECTRONICS IN RAIL TRANSPORT AS A LINK OF MULTIMODAL TRANSPORT

Another example of use of electronic circuits in multimodal transport is connecting trains to the overhead contact line, as well as connecting trains and/or cars to each other by means of couplings. Control-command and signaling equipment is the basis for the operation of trains. An electric multiple unit (EMU) is a train that is directly attached to the overhead contact line. Diesel locomotives are not connected to EMUs due to the mutual exclusion of their operation. Electric locomotives are used in freight and passenger trains.

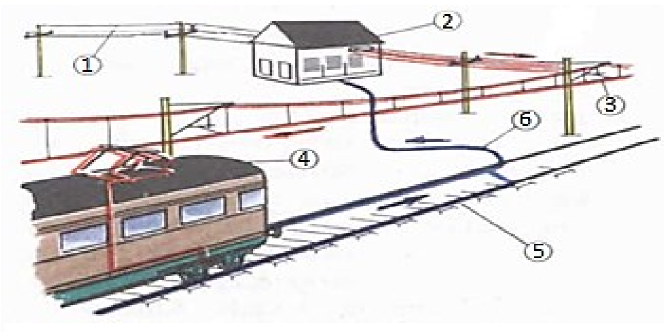

Fig. 4. A DC traction power supply system:
1 – AC line, 2 – substation, 3 – overhead contact line, 4 – multiple unit, 5 – track, 6 – return line

Source: [Świderek 2019].

Electric traction systems are supplied from an external EE network and, thanks to the high power of the electric motors used in locomotives, it achieves much higher speeds than diesel vehicles. The disadvantage of electric traction systems is the need to build a very costly railway infrastructure, as well as to ensure failure-free signaling and control systems, as failure results in delays in transport. Single-phase DC and AC, 50 Hz and 16.7 Hz systems are used most commonly. Polskie Koleje Państwowe S.A. (Polish State Railways, PKP) use a DC system where the current flows from the power plant to the substation with systems of traction rectifiers that supply the overhead contact line with DC power. The voltage between the conductor above the railway track and the rails is 3,000 V [Świderek 2019].

Electric multiple units in rail transport have a number of advantages over other means of transport when accounting for the use of electric motors compared to diesel engines. Electric vehicles are environmentally friendly because they do not emit exhaust gases. The air quality does not deteriorate during their operation and, therefore, they are in ever-more common use in urban, suburban, and subway transport [Karwowski 2018].

Electric motors can also operate in a generator mode during vehicle braking to produce electricity. This energy is most often transferred through the overhead contact line to another vehicle. This mode of operation significantly improves energy efficiency in rail transport. Electric motors produce their rated torque as early as at zero angular speed and do not need to maintain idle gear, as is the case with combustion-engine vehicles [Multon 2016; Karwowski 2018].

Another advantage of electric machines is the use of multi-engine distributed drives, in which separate electric motors drive multiple axles of the vehicle.

The use of power-electronic systems is also visible in the connection of cars and trains using couplings. A distinction is made between electric and mechanical couplings. In an electric coupling, the connection is made by means of so-called "electric housings." These devices raise their lids as they approach each other and a connection is made of the female and male contacts between the two devices. The electric couplings are sent for analysis and maintenance after about 4 years of operation. Spark and insulation resistance of cables to 2.5 kV are then performed. These couplings transfer energy after transformation from a 3 kV DC overhead contact line.

Railway traffic is controlled with relays and computers. The former are the intermediary element between the control circuit and the controlled circuit [Zalewski, Siedlecki and Drewnowski 2004]. For example, pressing the button on a control panel blocks the switch. Computer control is carried out by means of appropriate software [Zalewski, Siedlecki and Drewnowski 2004]. Many of the automatic devices are used in railway transshipment points and seaports. Automation of transshipment was possible thanks to the use of electronic systems that enable the correct flow of information.

5. EXAMPLES OF APPLICATION OF ELECTRONIC SYSTEMS AND AUTOMATION IN MARITIME TRANSPORT AS A LINK OF MULTIMODAL TRANSPORT

Gantry cranes are used in seaports as well as at transshipment points. They are used to move containers from a platform (a special type of car for transporting containers) onto a ship or other storage facility. Gantry cranes can be controlled by operators, or are automated. Automated gantry cranes have such advantages as:

- shorter reloading times;
- lower operating costs (due to the elimination of employee wage costs);
- development of new technologies.

An Electrical Rubber Tyred Gantry Crane (eRTG) is fully powered by electricity, in contrast to the older version of the RTG with a diesel engine. Electricity is supplied to the crane by means of a cable reel. It is equipped with a system for automatic control of the crane and side shifting of the container holder [Gospodarka Morska 2014; Miler 2019].

Fig. 5. An eRTG automatic crane

Source: [Gospodarka Morska 2014].

Automatic vehicles facilitating the storage and loading of containers are also used in ports. These are:

- Automatic Guided Vehicles (AGVs);
- Automated Lifting Vehicles (ALVs);
- Automated Rail Mounted Gantry Cranes (RMGs), which used for handling containers from trains to ships, and Automated Stacking Cranes (ASCs), which work as cranes [Matczak 2016].

The Robotic Container Management System (RCMS) system is a concept that automates terminals by controlling devices from a building. Containers are handled and stored in a framework structure. Behind STS cranes, there is a building with seats for storing containers. Refrigerated containers are placed on the sides of the terminal to provide employees easier access to the chillers. In a two-stage system, quayside gantry cranes are operated. A container picked up by a manual crane is placed on a lashing platform. Then the container connectors *(twistlocks)* are removed. An automatic crane loads the container onto an AGV, which puts the container in the building's seats. The movement of a container loaded on an AGV up or down inside the building is done by means of elevators. Omni wheel carts, which can move in different directions without turning, can are also used. Overhead Bridge Crane (OHBC) machines are used to operate land transport vehicles [Matczak 2016]. The whole system is controlled by a complex IT system that automatically manages individual components of the port infrastructure with the use of electronic control and monitoring devices. Its greatest advantage is its scalability, i.e. the ability to adapt to current needs and expand by adding more modules in the future.

The share of hybrid ferries in maritime transport is increasing. They are particularly suitable for multimodal transport, as they are most often used by truck drivers with semi-trailers – containers to travel the sea. Due to the tightening of the regulations on the protection of the marine environment, maritime vessels must have environmentally friendly drives. An example of a ferry powered partially by electricity is a hybrid unit of the Norwegian company Color Line. It is 160 m long and can accommodate 2,000 passengers and 500 cars. The Color Hybrid ferry is equipped with an electric drive with internal combustion energy generators. The battery capacity of the unit is 5 MWh. These batteries weigh 65 tons and can be charged from generators or by connecting to generators in the port. This unit has a *plug-in* system, which means that it can run in an electric-only mode or with internal combustion engines working [Elektrowóz 2019b].

Fig. 6. The Color Hybrid ferry

Source: [Elektrowóz 2019b].

6. CONCLUSIONS

Multimodal transport is becoming increasingly important in modern times. Some types of cargo require special conditions during transport. Thanks to appropriate use of electronic circuits, it has been possible to develop special containers in which cargo is transported at certain temperatures. Such containers are used along the entire transport route by road, rail, and sea without the need for reloading. Electronic systems and computerization have also been useful in designing electronic toll collection systems, an example of which is the viaTOLL system. The use of power electronic systems supports the development of environmentally friendly means of rail transport which are not driven by diesel locomotives. Automation is also used to improve delivery efficiency. Its use is particularly evident in seaports, where automatic cranes and vehicles move containers from ships to terminals. In multimodal transport, a relationship can be observed between the use of electronic, power-electronic, and telematic solutions. The technical data of the examples shown are not generally available. The English-language literature presents the basis for the functioning of electronic systems. Not all detailed technical information is provided in articles on specific examples, as these are in most cases patents of individual manufacturers.

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