DOI: 10.63550/ICEIP.2025.45.46.008

Energy-Saving and Power-Saving Equipment: Ways to Increase Efficiency

I. A. Guschin[a]
Ulyanov Chuvash State University, Moscovski ave., 15, Cheboksary, 428015, Russia
elpardo@list.ru

Keywords: energy saving. pulse combustion systems, pulse burners, energy-saving electric drives, electric transport drives, lighting systems.

Abstract: The article discusses energy-saving fuel-using installations in the form of pulse combustion systems. A comparison of pulse burners from different companies in furnace heating systems has been carried out. The high efficiency of such installations and the prospects for future development were noted. The problem of energy saving is analyzed in the context of special energy-saving equipment. The information and technical characteristics of energy-saving electric drives from Russian and foreign manufacturers are given. Economical ways of regulating productivity by changing the engine shaft speed are considered. Low-voltage asynchronous electric drives based on field-controlled bipolar transistors are noted for saving energy and non-industrial water leaks. Electric transport drives are proposed as energy-saving equipment when used in electric loaders and trolleybuses. Energy savings were noted due to its recovery into the network when braking trolleybuses. The ways of increasing the efficiency of installations for regulating lighting systems for shop lines and outdoor lighting are considered. Conclusions are drawn about the effectiveness of the selected methods.

[a] https://orcid.org/0000-0003-2202-1497

DOI: 10.63550/ICEIP.2025.45.46.008

1 INTRODUCTION

In the modern world, where energy resources are becoming increasingly limited, the issue of optimizing energy consumption is becoming more relevant than ever. Energy-saving and electricity-saving equipment plays a key role in increasing the overall efficiency of energy systems and reducing the impact on the environment. This article discusses various aspects of using energy-saving fuel-consuming installations, such as pulse combustion systems, as well as the development of electric drives from Russian and foreign manufacturers. Particular attention is paid to transport electric drives used in electric forklifts and trolleybuses, as well as lighting control systems that allow for the optimal use of electrical energy. The need to implement such technologies is due not only to economic factors, but also to the desire for sustainable development and reducing the carbon footprint. In this article, we will analyze modern achievements in the field of energy conservation and electricity conservation, as well as the prospects for their implementation in various industries. Finding possible ways out of the crisis situation is of great importance. One of the most effective ways to solve this problem is to introduce energy-saving equipment into various areas of technology. Research by both domestic and foreign scientists is aimed at developing and producing high-tech solutions in the field of energy saving, including analysis and assessment of the possible use of thermal energy.

In the context of growing demand for energy resources and increasing their cost, it is especially important to find the optimal balance between costs and the efficiency of the technologies used. The key criteria for choosing technological devices are saving capital and operating resources, ease of use and providing heat to the required number of people. In the context of rising energy demand and prices, it is especially important to find a balance between the cost and efficiency of the technologies used. The most important indicators when choosing technological devices are saving capital and operating costs, ease of operation and providing heat to a sufficient number of people.

In previous works (Guschin, 2023; Guschin, I. A., 2024), the problem of energy saving through the use of contact heat exchangers and water heaters with active nozzles in decentralized and centralized circuits was considered. This article is a continuation of the work on energy-saving installations of various profiles.

2 MATERIALS AND METHODS OF RESEARCH

Pulsed combustion systems are an innovative technology that is widely used in industrial and domestic heating systems and use pulsed waves to improve combustion processes, both of fuel and biomass, as well as to increase overall efficiency and reduce harmful emissions.

These systems are based on the generation of short, high-energy pulses that create conditions for a more complete and rapid mixing of fuel with an oxidizer (usually air). This is achieved by creating shock waves, which contribute to the intensification of combustion processes.

These systems are highly efficient, environmentally friendly and economical, which makes them particularly attractive for use in modern conditions. Efficiency is manifested in increasing the efficiency of combustion systems to 95% due to the complete combustion of fuel with high heat generation at lower resource costs. Through the use of these systems, carbon dioxide (CO_2), nitrogen oxides (NO_x) and other pollutants are reduced due to the precise control of the combustion process. This is especially important in the context of stricter environmental regulations. Efficiency is achieved by reducing fuel consumption by 10-30% compared to traditional systems. In addition, it should be noted that the devices are compact, characterized by small dimensions and weight of the equipment and sufficiently high reliability due to the minimum number of moving parts and the possibility of using various types of fuels (natural gas, liquefied petroleum gas, diesel fuel).

Pulse technologies have a wide range of applications in various fields: industrial, automotive and household. Technological solutions are pulse combustion chambers, which are used in industrial furnaces and boilers. They allow you to effectively control the combustion process, as well as control heat transfer. Classical and plate chambers are manufactured based on the properties of adaptation to the necessary combustion conditions, depending on the type of fuel and the desired process characteristics. When creating combined systems, pulsed and traditional technologies are combined to optimize energy consumption and output.Technologies are constantly evolving, and even more advanced and effective solutions can be expected soon. 25 years ago, pulsed combustion systems were an active means of increasing fuel efficiency. At this time, the advantages of pulsation combustion in fire heating and firing technologies

were particularly evident, when temperature gradients in the furnace volume reached 100 ° C/m. Pulse burners provided active mixing of the furnace atmosphere. The consumption characteristics of such burners were carried out automatically. The most famous developments in the use of pulsed furnace heating systems of that time were developed by companies from Germany, Italy, and Bulgaria. Of the domestic equipment, the FSG-R gas burner with an adjustable torch length was the most suitable. The pulse mode was achieved by changing the mixing conditions of fuel and air. The automatic mode of operation of the pulse system had feedback on the temperature in the furnace. The specific consumption of conventional fuel was reduced by about 20%, waste was reduced by 2 times and fuel consumption by 13-16%.

Nowadays, designs have become more reliable and economical.

Tables 1 and 2 below present data on foreign and Russian manufacturers of pulse burners, their technical characteristics, efficiency and specialization.

Table 1: Comparative analysis of manufacturers of pulse burners.

Manufacturer	Technical Specifications	Efficiency
Weishaupt (Germany)	Power: 10-1200 kW, Fuel type: natural gas, liquefied gas, Frequency: 1-5 Hz	EFFICIENCY:92-95% Emission reduction: 30%
Baltur (Italy)	Power: 20-800 kW, Fuel type: natural gas, diesel, Frequency: 2-6 Hz	EFFICIENCY:90-94% Emission reduction: 25%
Zelaz (Russia)	Power: 40-500 kW, Fuel type: natural gas, liquefied gas, Frequency: 1-4 Hz	EFFICIENCY:91-93% Emission reduction: 28%
Elco (Switzerland)	Power: 30-1000 kW Fuel type: natural gas, diesel Frequency: 1-3 Hz	EFFICIENCY:93-95% Emission reduction: 32%
Teplotech (Russia)	Power: 10-300 kW Fuel type: natural gas, liquefied gas, Frequency: 2-5 Hz	EFFICIENCY:90-94% Emission reduction: 27%

Table 2: Specialization of manufacturers of heating systems.

Company	Specialization
EcoHeat (USA)	Energy-saving heating systems
Aqua-Ther (Poland)	Innovative heating solutions
Vok term (Germany)	High-tech heating systems, including pulse
Ferroli (Italy)	Heating and hot water supply systems
Viessmann (Germany)	The leader in the field of heating and alternative energy
Teplodar (Russia)	Boilers and heating systems for private houses and cottages
Energomash (Russia)	Heating systems, including pulse ones
Kalita ((Russia)	Manufacture of heating equipment and accessories
Atma (Russia)	Pulse heating systems for country houses
Thermophore (Russia)	Furnaces and heating systems with active systems

For example, Fig. 1a shows a gas burner manufactured by Weishaupt (Germany) and Fig.1b - Belaz (Russia)

a

b

Figure 1: a - Pulse gas burner from Weishaupt (Germany), b - Pulse gas burner Zelaz (Russia).

To calculate the thermal load at a constant temperature, it is necessary to determine the ratio of the time of supply and shutdown of the fuel into the furnace. The pulse duration can be adjusted in the automatic control system. To a first approximation, the change in the amplitude of the oscillations is represented as

$\Delta t = T\ q\ (1-q)k_0/T_0$, where Δt is the doubled amplitude of temperature fluctuations; k_0, T_0 are the

parameters of the control object; T is the pulse displacement period; $q = \tau_{imp}/T -$ is the fill factor; τ_{imp} is the pulse duration. Using these formulas, it is possible to estimate how the amplitude of the oscillations changes in the case of pulse-frequency and pulse-width modulation.

3 RESULTS AND DISCUSSION

This section provides information about equipment, the introduction of which leads to significant energy savings and which can be produced at enterprises of the republic. The energy-saving equipment described below is not only import-substituting, but also an attractive product for other regions. As a result, the basis for the development of industrial production in the republic is being created and an additional inflow of funds to the republican budget is being generated.

The electric drive is a major consumer of electricity. Unregulated AC electric drives account for the majority of the national economy. An adjustable electric drive (DC, valve, partially asynchronous, etc.) is used in mechanical engineering, metallurgy, etc. industries where the role of automation of production processes is important. An important task of energy saving is to expand the scope of application of adjustable electric drives of medium and high power to optimize the energy function by changing the characteristics of the drives.

Large consumers of electricity are pumping stations for heat and water supply, sewerage, ventilation installations in housing and communal services, energy, chemical industry, and various branches of engineering. They use AC electric drives with asynchronous short-circuit motors with a power of 100-400 kW (at a voltage of 380 V) and 320-5000 kW (6.3 kV) or with synchronous high-voltage motors with a power of up to 5000 kW.

Many enterprises use all types of electric drives. The first type with a capacity of 50-320 kW is the most common. Drives of the second and third types are installed at large pumping stations of water supply and sewerage, at CHP pumping and compressor stations of large enterprises.

The performance of pumping and ventilation units is usually regulated by a very uneconomical method – valve control. A survey of a number of pumping stations for water supply in regional cities showed that the depth of pressure regulation during the day reaches 0.6. Valve throttling is also used when the characteristics of the pump and the main line are inconsistent. At the same time, additional electricity costs arise, which, according to the most conservative estimates, amount to more than 1,250 million kWh per year.

A more economical way to regulate the performance and match the characteristics of the pump and the network is to change the engine shaft speed. The most common is frequency control of electric drives. In different countries, the industry produces specialized series of adjustable electric drives in the entire power range (ABB-Stromberg, Allen-Bradly, Siemens, etc.). Their cost is 200-350 $/ kW. Figure 2 shows the types of products of these companies.

a

b

c

Figure 2: a - ABB low-voltage electric motors, b - Allen-Bradley PowerFlex 7000 Series, c - Synchronous jet engines optimized for converter operation.

In Russia, similar installations are produced by enterprises in Moscow (VEI), Voronezh (JSC "Electronics"), Saransk (JSC "Elektrovypryamitel"), Cheboksary (JSC CHEAZ).

Currently, the region's electrical industry can produce frequency-controlled electric drives with valve cascades on thyristors, both low-voltage (with capacities up to 400 kW) and high-voltage (up to 5,000 kW). Such products are energy-efficient. Thus, a 1000 kW high-voltage electric drive for pumps of water supply and sewerage systems provides a reduction in power consumption by more than 2 million kWh or 245 tons of conventional fuel

per year (T/Y) and a payback period of less than a year. The cost of such electric drives is about $40 per kW. Low-voltage electric drives have similar characteristics, which cost $15-304 per kW.

Low-voltage asynchronous electric drives with a capacity of 25-315 kW based on field-controlled bipolar power transistors (IGBT) can also be produced. They are intended for pumping pumps of heat, water supply and sewerage stations. Their cost is $ 60-100 per kW and decreases with increasing power with a payback period of about a year. In addition to saving electricity, such electric drives reduce the inefficiency of water leakage (up to 10%), eliminate hydraulic shocks when pumps are turned on and off, and significantly reduce the cost of repairing and operating pipelines. They are the basis for the subsequent automation of stations and the elimination of on-duty personnel at district pumping stations.

A comparison of the characteristics of manufactured electric drives with their foreign counterparts indicates their high competitiveness. The introduction of variable frequency electric drives is very important for the region. The installed capacity of frequency-controlled electric drives only at pumping stations of the water supply companies and heating networks of cities can amount to 3500-5000 kW, which will result in total energy savings of 10 to 15 million kWh per year or 1200-1500 tons per year. Energy-saving electric drives of pumping units created by the electrical engineering industry of the republic are successfully operating. A high-voltage valve machine based on a 4,000 kW synchronous motor has been introduced and is in operation at the CHPP. The annual energy savings amount to 10410 kWh. Frequency converters are installed at water supply companies enterprises to regulate the speed of pumps, which pay for themselves and provide daily more than 1,000 kWh of energy savings.

Another type of energy-saving electric drive is a transport drive. This primarily includes the drive of electric loaders, which are produced in the region. In modern electric loaders of domestic production, the start-up and speed control is carried out by reconnecting the battery sections from parallel to serial and changing the resistance of the resistor. At the same time, a significant part of the battery's energy is lost in resistors and control equipment, the duration of operation with a single charge is reduced, and smooth speed control is not ensured. Surges of current during start-up and transition from one section to another reduce the battery life. Reducing these disadvantages is provided by the use of contactless control circuits using power field-effect transistors. The production of such equipment has been established at the electrotechnical enterprises of the region.

Similar problems face the electric drive in trolleybuses. The existing trolleybus control scheme is based on the use of rheostatic start-up to a speed of 19-20 km per hour and speed control from 20 to 72 km per hour by loosening the mounted and shunt windings of the motor.

Braking to a speed of 10 km per hour is electric with the release of stored kinetic energy in the braking resistors without energy recovery of the supply network. Meanwhile, the energy used to accelerate the trolleybus is significant. When accelerating to a speed of 60 km per hour, energy of 0.695 kW per hour is required.The specifics of trolleybus operation on urban routes are such that the number of acceleration-deceleration cycles is 408-530 per working shift (16 hours). At the same time, significant energy losses occur (about 120 thousand kilowatts per hour per year per trolleybus) and the resulting dynamic loads negatively affect the human body.

A significant part of this energy can be saved if it is recovered into the network when the trolleybus is braking. This can be done in two ways:

1). A contactless semiconductor switch with a current of 300-400 A is connected to the motor armature circuit, for example, a lockable thyristor or a bipolar transistor. At the same time, it is possible to regulate the starting current, abandoning the starting rheostats, and the braking current, recovering the kinetic energy of the trolleybus into the supply network. This method is associated with a radical change in the existing circuit, the high cost of the power key and additional energy losses in the key. At the same time, there are significant energy savings (about 78,000 kilowatts per hour per trolleybus per year), which, with the cost of upgrading the trolleybus, allows for savings of 50% per trolleybus.

2). Starting and regulation during the trolleybus is carried out according to the existing scheme, and braking occurs in two stages At high speed, the engine armature remains connected to the power supply network, resulting in increased braking and kinetic energy recovery In the second stage, at a speed of less than 20 km per hour, the armature switches to braking resistors, as and in the existing scheme. In this case, the energy loss in the resistors is reduced to about 10% of the kinetic energy. With this method, energy savings are less (about 62.5 thousand kWh per year), but the cost of upgrading

the trolleybus is much lower. This method is most acceptable when upgrading the existing trolleybus fleet. The electrotechnical enterprises of the region are ready to modernize the trolleybus fleet.

Installations for regulating lighting systems. With the advent of energy-saving lamps, energy-saving efficiency is increasing. However, some enterprises in the region use traditional lamps. One of the energy consumption facilities where there is an overspending of electricity is the workshop and outdoor lighting lines. One of the energy consumption facilities where there is an overspending of electricity is the workshop and outdoor lighting lines. Significant savings can be achieved through the use of thyristor voltage regulators that ensure that the mains voltage is maintained at the minimum allowable level. In addition, the elimination of voltage deviations and fluctuations significantly increases the lamp life and reduces the cost of operating the line. The outdoor lighting line in cities has a total power consumption of 4,800 kW. An incandescent lamp (IL) (2400 units) and high-pressure mercury lamps (MAL) (16480 pieces). Their characteristics and service life depend significantly on the mains voltage. Thus, exceeding the voltage by 5% increases the power consumption of incandescent lamps by 8% and reduces their service life by 49.5%. These values for MAL lamps are 12.2% and 14.5%, respectively. The reduction in industrial production and power consumption in the republic has led to the fact that the voltage in the supply network exceeds the nominal value almost all the time of the day, but especially at night, when the lighting system is mainly operating.

Calculations show that the installation of voltage regulators at the inputs of outdoor lighting lines is very effective. Thus, maintaining a voltage equal to the nominal one allows for a reduction in electricity consumption by more than 3 million kWh per year and savings of 25,000 incandescent and 1,800 MAL lamps. When the voltage is reduced to 0.9 nominal (209 V), which is allowed by GOST for the quality of electricity, energy savings amount to 5.8 million kW per hour and 33 thousand incandescent lamps and 5.8 thousand MAL lamps. The payback period for such installations is 0.68 years in the first case, and 0.42 years in the second case. The level of voltage reduction will be determined by the acceptable level of light output reduction.

It should be noted that the severity of the problem of over-consumption of electricity can also be reduced with proper operation of outdoor lighting lines by appropriate switching of transformer seals. In addition, with such significant capacities, the use of thyristor voltage regulators can lead to noticeable generation of higher harmonics with a negative impact on electricity consumers.

Even more urgent is the problem of saving electricity for the lighting lines of residential building entrances. It is impossible to regulate the voltage using transformer soldering, since it is difficult to separate the power lines of apartments and entrances, and the requirements for the voltage level in apartments are quite high. In entrances, a decrease in light output with a decrease in voltage does not play a significant role, and therefore a more significant decrease in voltage can be allowed in such networks with corresponding savings in electricity and incandescent lamps. So, for only one entrance of a 5-storey building, reducing the voltage to 0.9 nominal allows you to save 583 kWh and 62 lamps per year. When the voltage is reduced to 0.85 nominal, which is quite acceptable, these values are already 745 kWh and 65 units. Accordingly, energy savings increase in the entrance of a 9-storey building and in other high-rise buildings. The payback period for such devices is 0.3-0.6 years. Such regulators are effective.

4 CONCLUSION

Thus, pulse combustion systems s are an advanced technology in the field of energy saving and environmentally friendly heating. Due to their high efficiency, versatility and cost-effectiveness, they are widely used both in industry and in everyday life. A comparative analysis shows that foreign and Russian manufacturers demonstrate competitive characteristics and adaptability to local operating conditions. The use of pulsed combustion systems contributes to solving global challenges in reducing energy consumption and reducing negative environmental impacts.

Electric-saving and energy-saving make it possible to significantly reduce energy costs. This is confirmed by the technical characteristics of energy-saving electric drives from Russian and foreign manufacturers. Economical ways to regulate productivity by changing the engine shaft speed are promising. This also applies to low-voltage asynchronous electric drives with field control to save energy. The use of electric transport drives in electric loaders and trolleybuses significantly reduces energy consumption along with traditional methods of regulating lighting systems for workshop

lines and outdoor lighting. Further research and development in this area will further improve the efficiency and accessibility of the proposed technologies.

ACKNOWLEDGEMENTS

This study is conducted in order to conduct a qualitative analysis of energy saving and adaptation of the developed methods and devices for a specific city, district and region and to attract additional funds.

REFERENCES

Brown, T., Williams, K., 2019, Transport electric drives in forklifts and trolleybuses: developments and future perspective. *Transportation Research Part D: Transport and Environment* **71** 44-55.

García, M., Fernández, A., 2023. Hybrid trolleybus systems: Integration of supercapacitors for energy storage. *Transportation Research Part D: Transport and Environment* **115** 103587.

Guschin, I. A., 2023. Improving the efficiency of energy saving through the use of thermal energy. *IOP Conf. Ser.: Earth Environ. Sci*. **1212** 012003.

Guschin, I. A., 2024. Assessment of the possibility of using heat-insulating and energy-saving equipment. *E3S Web of Conf*. **463** 03005.

Guschin, I. A., 2024. Energy saving when using equipment for the disposal of low- potential waste heat. *E3S Web of Conf*. **510** 04012

Johnson, R., Kahn, M., 2020. The role of electric drives in sustainable urban transport. *Urban Transport International*, 24(4), 293-308.

Ivanov, A., Petrov, V., 2020. Electric drives: Trends in the Russian and global markets. *Journal of Electrical Engineering* **45**(3) 45-58.

Ivanov, A., Petrov, S., 2023. Energy-saving electric drives in Russian industrial applications: Challenges and solutions Energy Reports **9** 124–131

Ivanova, M., Sergeev, D., 2022. Control systems for lighting regulation and energy savings. *Journal of Building Science* **78** 101-112.

Kim, H., Choi, J., 2023. Advances in energy-saving technologies: A global overview. *Energy Sources, Part B: Economics, Planning, and Policy* 18(2) 112-126.

Lee, S., Kim, D., 2020. Regenerative braking systems in electric forklifts: Energy recovery and efficiency analysis. *Journal of Cleaner Production* 256 120389.

Müller, R., Zhang, H., 2022. High-efficiency electric drives in manufacturing: A comparative study of Siemens and ABB technologies. IEEE Transactions on Industrial Electronics 69(4) 3210–3221.

Smith, J., Zhang, L., 2021. Energy-efficient combustion systems: Impulse combustion technology. *Renewable Energy Review*s **130** 123-142.

Smith, J., Tanaka, K., 2021. Pulsed combustion systems for industrial furnaces: Energy efficiency and emissions reduction *Applied Energy* **302** 117543.

Wang, Y., Li, X., 2021. Smart lighting control in urban infrastructure: IoT-based adaptive algorithms *Sustainable Cities and Society* **75** 103291.