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EXPERIMENTAL STUDIES OF BURNING PELLETS IN A BURNER UP TO 30 KW

Abstract: *Given the world trends in the use of biofuels of agricultural origin, Ukraine has considerable potential to develop this direction at the expense of a significant resource base. Solid biomass is mainly used for heat production in large or medium-sized district heating boilers and in domestic wood, pellet boilers, in furnaces and in fireplaces.*

The work is devoted to the research of burning of wood pellets and agropellet (from rape straw) with the purpose of improvement of operational and ecological indicators of household boilers with capacity up to 30 kW. Results of experimental research of burning of mentioned pellets are given on the basis of data of experiment characteristic features of temperature conditions in heating volume of boiler and burning at burning of pellets are defined.

Keywords: *bioenergy, biomass, agrobiomass, straw, crop residues, by-products of crop production, agropellet, rape straw*

Introduction. Brief analysis of recent publications

Almost one-third of the fuel needs of municipal heat power engineering Ukraine is satisfied by imported natural gas. Part of it can be replaced by using biofuel of agricultural origin [1]. It is important to realize this in conditions of economic crisis, necessity of import substitution and the most severe economy of fuel and energy resources, especially in military time.

Biomass, including commercial agricultural waste, plays an important role in achieving the EU target [2] of 32% renewable sources in total energy consumption by 2030. According to [3], biomass, in combination with solar thermal and wind energy, has the greatest potential in the energy goals of the EU until 2050 (full coverage of energy needs for heating and cooling, reduction of greenhouse gas emissions by 80-95%).

Currently, Europe accounts for more than 50% of the world demand for pellets. As of 2020, pellet use in European countries included residential heating (40%), power plant needs (36%), commercial heating (14%) and cogeneration (10%). Heating system held a significant market share in 2020 and is likely to dominate in the near term (Fig. 1). In addition, pellets are also used in projects to replace coal in buildings owned by local authorities or public administrations, such as: schools and offices. As of 2020, most co-fired power plants have either closed or converted, with some switching entirely to wood pellets as fuel. The largest of these is the Drax power station in North Yorkshire (UK), which has converted four of its six 65 MW units to run exclusively on biomass and is currently evaluating options for the remaining two coal-fired units.

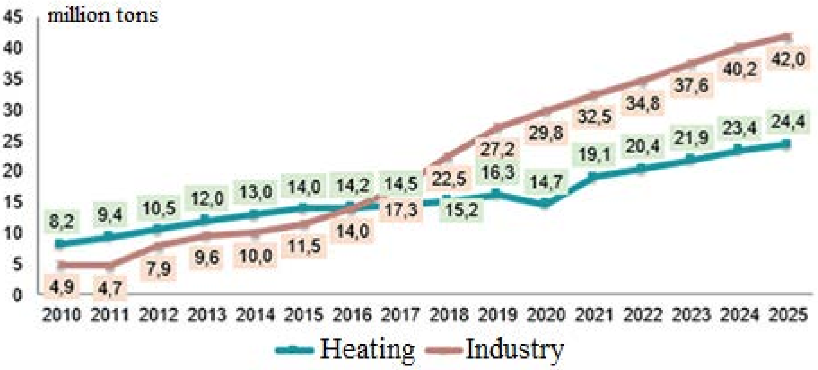


***FIGURE 1.** Dynamics of world consumption of pellets in 2010-2018 forecast for 2019-2025, million tons [4]*

The sales volume in the European pellet market in 2020 reached 8.92 million dollars. It is expected to grow by 15% between 2021 and 2027. The demand for pellets will be driven by the increase in the number of facilities generating energy from alternative sources.

Another factor in the increase in demand was the properties of the wood pellets themselves. They have lower moisture content and less ash residue than traditional fuels such as coal. Despite the difficulties with transportation, pellets have their stable demand in the USA and Europe. In particular, the expected demand for pellets in Europe will reach 70 million tons by 2027. The industrial sector will consume about 35% of the total volume of manufactured pellets, because there is a trend for the construction of heat and power generating plants and their conversion from coal consumption to pellets [5].

In addition to wood, solid biomass can also be taken from agriculture (to produce agricultural pellets) [6]. Currently, the main sources of biomass in Ukraine are agricultural waste and residues (straw of cereal and technical crops, stalks and stalks of corn, stalks, and husks of sunflower), as well as in the future – energy crops (willow, poplar, miscanthus, etc.) that are specially grown [7].

Rape residues are characterized by several disadvantages, so they cannot be used in animal feed and bedding. Therefore, rape began to be used as an effective and inexpensive source of energy. In the conditions of constantly rising energy prices, this opens more and more benefits, new types of fuel are being developed on the basis of rapeseed and existing ones are being improved.

The possibility of producing pellets from rapeseed straw is under consideration. According to the volume of cultivation and export of rapeseed, Ukraine is firmly in the top ten world leaders. In particular, last year Ukraine harvested almost 2.8 million tons of rapeseed and was in 7th place among the leading producing countries. Over the past two years, the area under rapeseed in Ukraine has increased by as much as 62%: from 0.8 million hectares in 2017 to 1.3 million hectares in 2019. During this time, the average yield of rape increased from 2.5 t/ha to 2.76 t/ha, and the productivity of rape straw was approximately the same.

It is worth noting that Canada, the EU, China, Japan, and India are among the TOP-5 world producers of rapeseed (Fig. 2). This year, production indicators may change significantly. This was affected by the prolonged drought in several European countries. Experts claim that the area sown under rapeseed has significantly decreased in the EU. Production estimates are down for France, Romania, and Hungary, but up slightly for the UK and Slovakia, as the overall water balance in the EU worsens, despite a slight improvement in Southeast Europe. The situation on foreign markets can significantly affect economic forecasts for Ukrainian farmers [8].

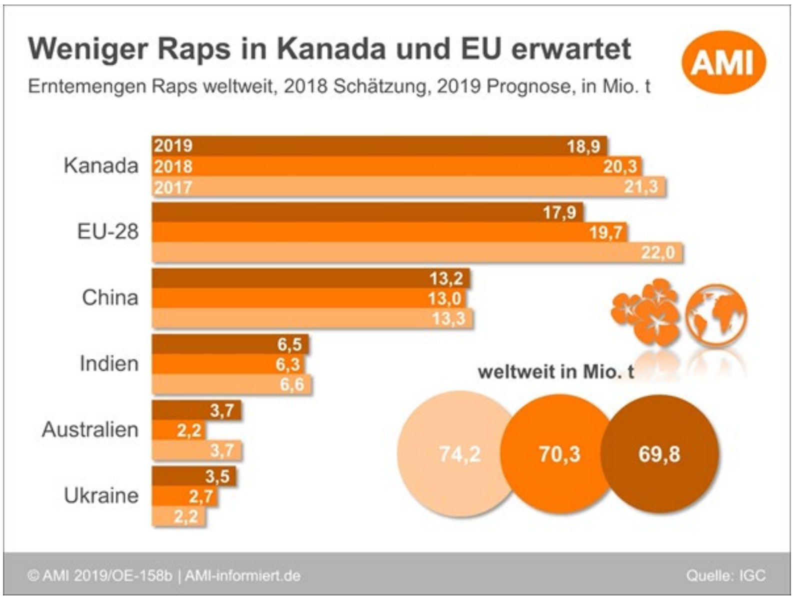


FIGURE 2. *Sown areas under rapeseed in the world*

The use of biomass as a fuel in the production of thermal energy to meet the needs of heating and hot water supply provides significant economic advantages, because it will reduce heating costs, as well as reduce greenhouse gas emissions by more than 8.0 million tons of CO_2-eq.

The successful technical implementation of the pellet burning process relates to the choice of rational technical solutions and operational parameters of the corresponding equipment. Therefore, the improvement of technologies and equipment for burning biofuels of agricultural origin is an urgent task, which is due to the ecological state of the environment and the need to involve alternative and renewable energy sources in the energy industry in connection with the depletion and constant growth of prices for fossil energy carriers.

Considering the relevance of the study of the process of burning biofuel, the Institute of Engineering Thermophysics, National Academy of Sciences of Ukraine developed and tested an experimental installation of a solid fuel boiler with a pellet burner for heating an experimental house of the passive type [9, 10]. The main goal of this study is to determine the main regularities of the combustion process of agropellets of agricultural origin and to study the influence of regime parameters on the temperature distribution in the combustion chamber, as well as to study the productive characteristics of biofuel raw materials.

Object, subject, and methods of research

The developed experimental installation based on a solid-fuel boiler of the Viadrus type with a thermal capacity of 30 kW with an original pellet burner allows for a thorough investigation of the burning characteristics of various plant-based fuels for home heating (Figs. 3, 4).

The temperature is measured using a comb of Chromel/Alumel thermocouples with an open junction, located at different distances from the initial cross-section of the burner (Fig. 5). The temperature measurement error was no more than ±0.5 K. During all tests, the water supply temperature from the boiler stabilized at 65°C ±1°C.

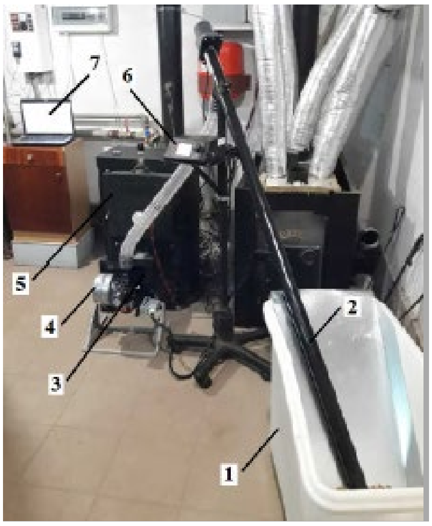


FIGURE 3. Experimental installation of a pellet burner for burning vegetable pellets: 1 – loading hopper; 2 – external auger for transportation of biofuel; 3 – pellet burner; 4 – fan; 5 – solid fuel boiler; 6 – boiler control unit; 7 – unit of measurement and archiving of experimental data

FIGURE 4. Automatic burner with a movable scraper

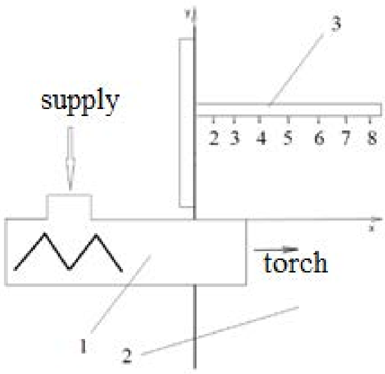


FIGURE 5. Temperature measurement scheme: 1 – pellet burner; 2 – furnace space of the boiler; 3 – comb of thermocouples located above the burning torch

The fuel supply rate is set in manual mode to obtain continuous operation with a small amount of combustible elements in the remainder. The consumption of pellets coming from the hopper to the combustion chamber is regulated by the electronic control unit of the solid fuel boiler. It can also be used to adjust a number of boiler operation parameters: boiler operation power, maximum and minimum fan performance, operating time of the internal auger in the burner when feeding pellets into the high-temperature zone, parameters for cleaning the burner floor with a movable scraper.

The residues collected after the heating plant tests were also analyzed to determine their composition and carbon content (representing the unburned carbon content of the bottom residue).

During each test period (for the same type of fuel), the feed rate is constant, which is determined by the duration and frequency of the screw conveyor.

Measurement of emissions. After reaching stable operating conditions, CO, NO_x concentrations expressed on a dry basis were measured using a TESTO type 330-1LL gas analyzer. NOx emissions during combustion are formed mainly in the form of NO, the content of nitrogen dioxide is on average 5%.

Study results and their discussion

The article focuses on the following types of pellets: wood pellets and rapeseed pellets.

When burning wood pellets, ignition occurred within the first 300 seconds. The fuel is ignited by a special igniter. After ignition, the pellets begin to burn, and the temperature value in the volume of the boiler begins to gradually increase. The largest increase in temperature occurs near the front wall of the boiler, which is opposite to the burner. At the moment of time 2550 s from the beginning of the experiment, the maximum temperature values reach 680°C (Fig. 6, thermocouple No. 8).

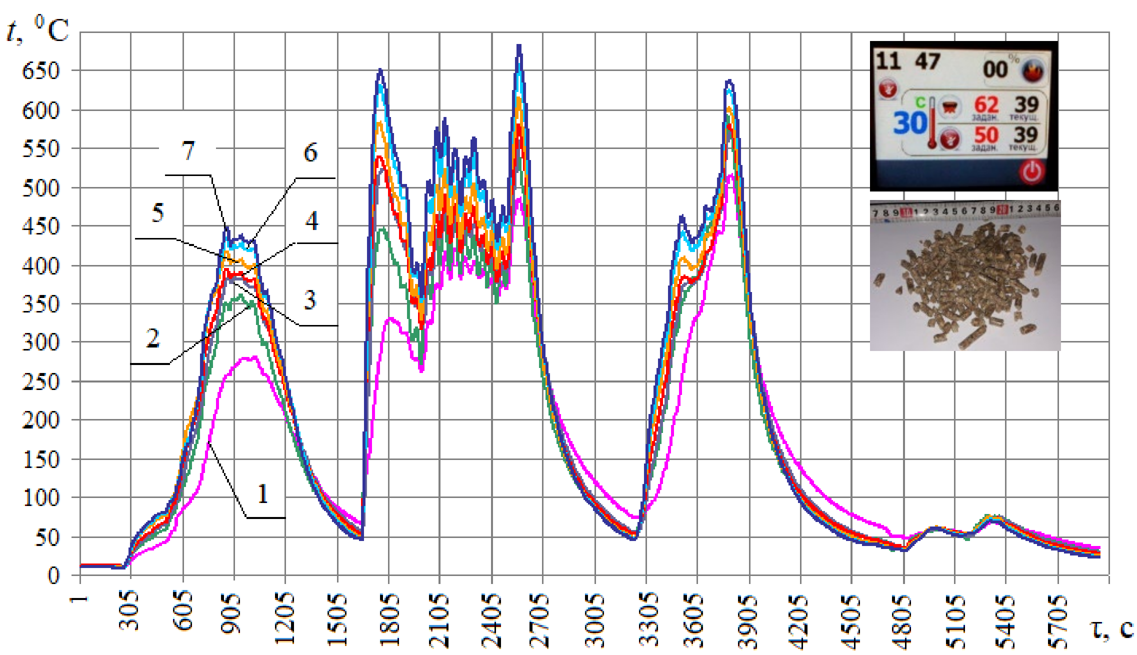


FIGURE 6. *Temperature of combustion products in the high-temperature zone of the combustion chamber when burning wood pellets: 1-7 – temperature values measured by thermocouples No. 2-8, respectively (see Fig. 5)*

From 2105 s to 2500 s of the experiment, a stable burning process of wood pellets takes place. The average temperature of flue gases is 260°C. During this time, there was an automatic periodic supply of pellets from the bunker according to a programmed algorithm. At the same time, the temperature fluctuated within the following limits:

- thermocouples No. 4-8 – 400...590°C;
- thermocouples No. 2-3 – 350...450°C.

Temperature fluctuations occur as a result of the periodic burning of a portion of biofuel in the burner and the arrival of a new portion of pellets from the bunker. The burner is extinguished by selecting the "Extinguishing" menu item in the controller. As can be seen from the graph, a gradual decrease in the temperature in the boiler chamber and flue gases begins. After extinguishing, the corresponding symbol appears on the controller display.

In a similar way, as in the previous experiment with the burning of wood pellets, the results of the study of the burning of agricultural pellets from rapeseed straw were obtained (Fig. 7). In this case, a lower temperature level is realized (thermocouples No. 2-6) compared to wood fuel. The measured values are in the range of 120...250°C at a steady burning mode (720-2000 s).

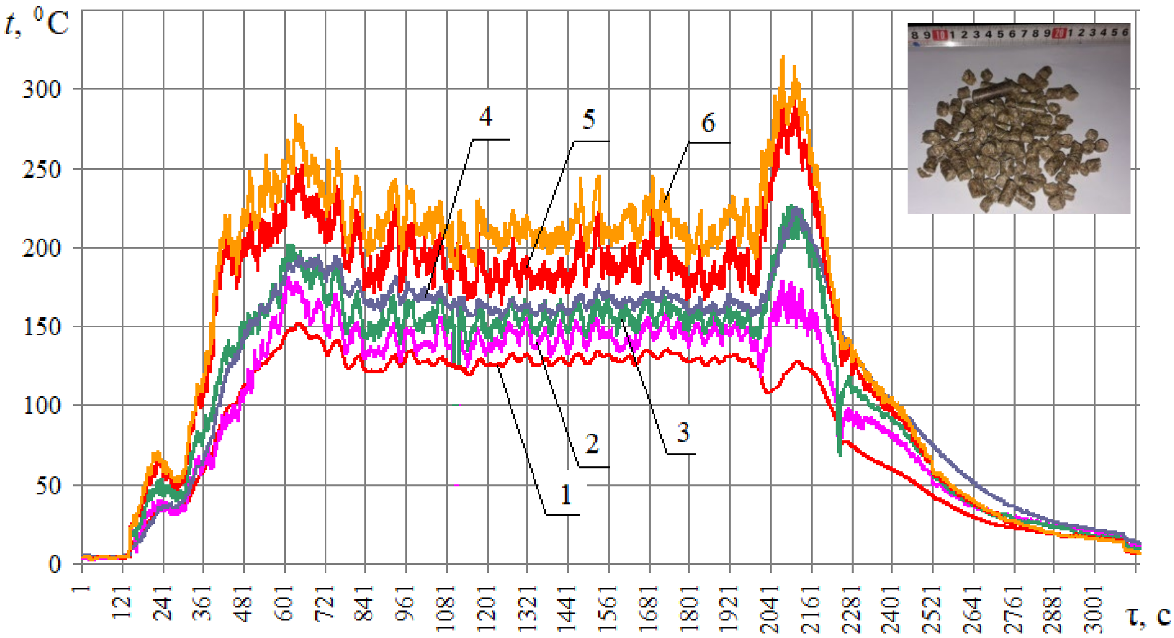
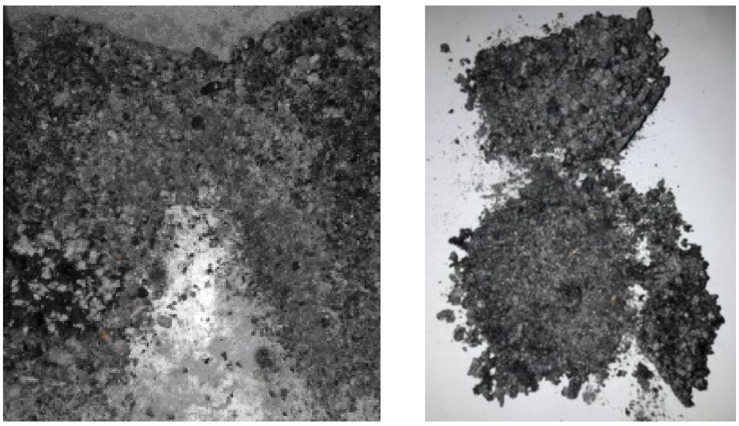


FIGURE 7. *Temperature of combustion products in the high-temperature zone of the combustion chamber during rapeseed burning: 1 – flue gas temperature; 2-6 – temperature values measured by thermocouples No. 2-6*

At the end of each experiment, the remains of fuel ash were photographed (Fig. 8).



a) b)

FIGURE 8. *Ash residue during burning: a) wood fuel pellets; b) pellets from rapeseed straw*

The gas analysis was carried out during the burning of wood pellets. The selection of combustion products was carried out in the chimney immediately after the boiler. As a result, the NO_x and CO concentrations of the corresponding temperature at the sampling site were obtained. The change over time in the concentration of these substances in flue gases is shown in Figure 9.

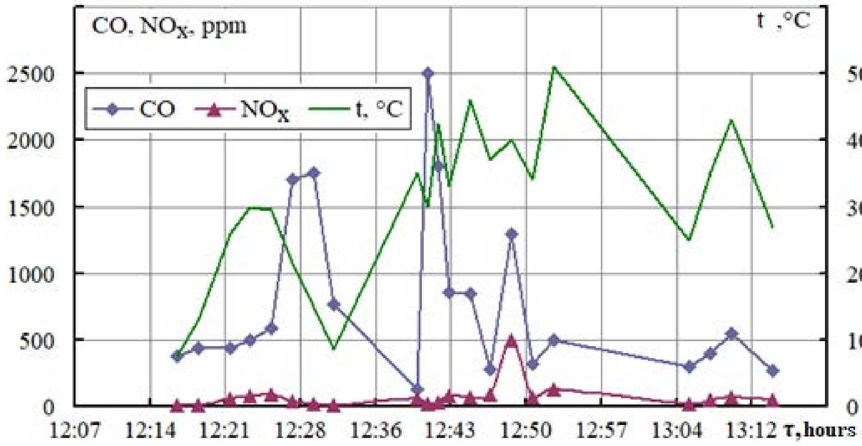


FIGURE 9. Concentrations of NO_x and CO in waste gases during burning of wood pellets

The values of concentrations of nitrogen oxides should be considered moderate, which cannot be said about the concentration of carbon monoxide. Such a picture is characteristic of the process of low-temperature combustion with the presence of significant chemical underburning. It was found that a significant concentration of CO is realized in the transitional phases of fuel supply, its ignition and extinction. Concentration maxima correspond to transitional processes between ignition and steady burning. In general, concentrations of CO as the main component of chemical underburning have an inflated level and require further correction by adjusting the operating modes of the burner system and, if possible, implementing additional constructive measures.

It should be noted that the reduction of CO emissions due to incomplete combustion can be achieved by extending the residence time of combustion products (especially in parts with a sufficiently high temperature >550°C), by additional turbulence of the flow or by achieving higher temperatures of combustion products in certain parts of the water heating boiler. Since the residence time of products is determined by the speed of fuel supply and the design of the combustion chamber, it is almost impossible to significantly influence it. One of the options for solving the given problem can be proposed measures that cause a local increase in the turbulence of the flow or an increase in the temperature of the flue gases. As an option, the authors of [11] (Fig. 10). The recommended location is in a region of high enough temperatures to potentially support relatively high CO burning rates.

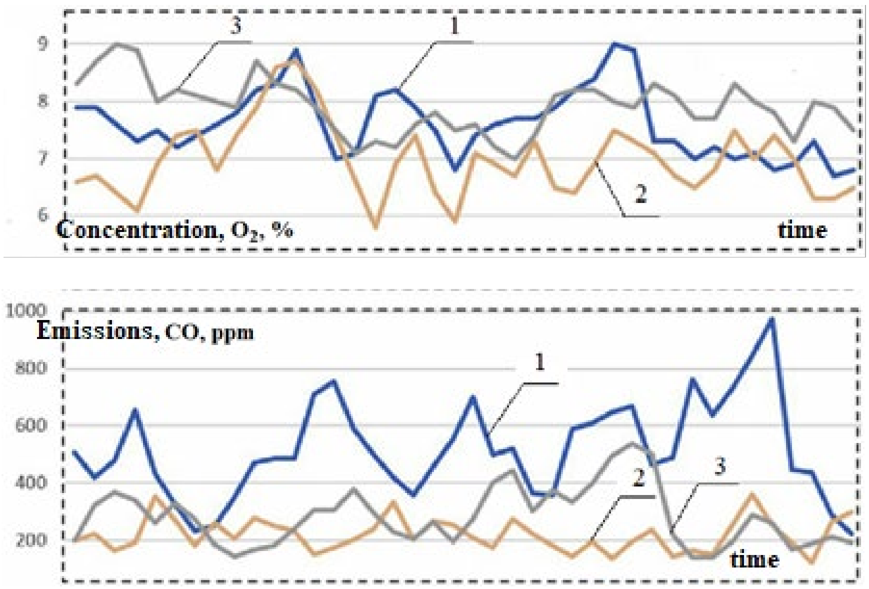


FIGURE 10. Concentrations of CO and O_2 in the waste gases during the combustion of agricultural pellets (1) when using grid combustion turbulators of a honeycomb shape (2) and V-shaped turbulators (3) [11]

Conclusion

It has been established that when combining a solid fuel boiler and the proposed burner (low power – up to 30 kW), it is possible to burn a wide range of pellets of plant origin.

Variations in physical and chemical properties among the pellets used are relatively large. It was established that the mechanical strength and bulk mass are lower than the limit values. This can cause pellet transport problems and burner clogging. The latter can cause problems with burner control.

The ash content for agricultural pellets ranged from 4.4% to 7.6%.

During the research, optimal combustion mode maps were established depending on the completeness of combustion, emissions of harmful gases (NO_x), ash structure, and coolant temperature. The composition and concentration of the components of waste gases, as well as possible regimes in which condensation of water vapor occurs, were studied.

In the future, the results of the research can be used to increase the efficiency of the combustion process when burning biofuel and to modernize fuel-burning systems of low-power boilers of communal and industrial heat energy, the social-budgetary sphere, the individual-household sector, etc.

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FEATURES OF THE HEAT AND MASS TRANSFER OF THE UNDERGROUND STRUCTURES OF THE KIEV METRO WITH THE GROUND MASS AND AIR ENVIRONMENT

Abstract: *On the basis of the experimental values of temperature and absolute humidity of the tunnel air and the temperature of the walls of the rim of the deep tunnels of the Kyiv metro, the features and mutual influence of the earthen massif, the supply air environment and the operating modes of the mechanical system of reversible tunnel ventilation during the year are considered. On the basis of the CFD model, which takes into account the above processes of heat and mass transfer, ventilation modes have been determined that have made it possible to reduce the humidity of a group of tunnels of the Kyiv metro as much as possible.*

Keywords: *subway, tunnel, humidity, air, ventilation, modeling*

Introduction

In today's world, the subway is a popular form of underground public transport in any major city with heavy street traffic. In the capital of Ukraine, this function is performed by the Kyiv Metro, in addition, during martial law, the underground part of the metro additionally serves as a shelter for the population. In general, the Kyiv Metro system consists of 46 underground and 6 surface stations on three branches with a total length of 67.6 km. The underground part of subway lines consists of tunnels of shallow (to a depth of 10-12 m), medium (12 to 20-25 m) and deep (more than 25 m) occurrence. There are the following forms of cross-sections of tunnels: rectangular (shallow tunnels), circular (tunnels constructed by mechanized method), vaulted (walkers and ventilation tunnels).

Experience in the operation of subways shows that the well-being of passengers and the performance of maintenance personnel are significantly affected by hygienic conditions, as well as the state of the air and microclimate in tunnels and structures. It has been established that the main harmful components in the subway are heat, moisture and carbon dioxide, released from the transformation of energy spent on the movement of trains and the operation of equipment, from the vital activity of passengers and maintenance personnel, as well as various gases that can enter the tunnel with outside air, from soils, communications crossing tunnels and located next to them. In addition, dust generated in the tunnels and arriving with ventilation air, oil mist and microbiological air pollution are harmful to the subway. As a rule, the outside air supplied to the tunnels is not processed (due to the high costs of this process) [1].

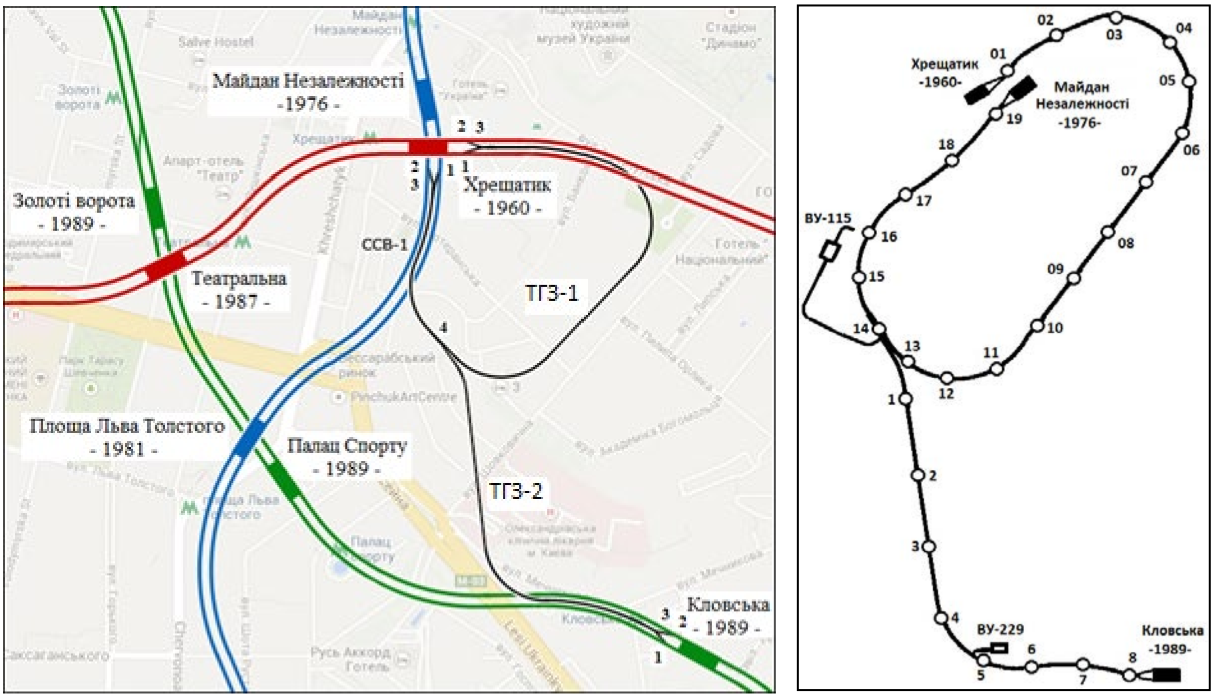
The objective of ventilation in stations and tunnels is not only to maintain specified meteorological conditions (air temperature from +5°C to +28°C, relative humidity less than 75%) and chemical composition of the air, which meet hygienic requirements, but also to create necessary modes of ventilation in case of malfunction of subway devices and smoke formation in places of passengers and staff [1]. Components of the mechanical system of reversible tunnel ventilation of the Kiev subway are ventilation units (VU), located directly near the stations and in separate ventilation shafts (VSh). The operation of the tunnel ventilation system is regulated by a work schedule throughout the year, depending on the temperature and humidity of the environment. The reversibility of the mechanical ventilation system of subways consists in the fact that during the warm period of the year outside air is forced into the tunnel through the station ventilation shafts and/or inclined escalator tunnels and is removed to the surface through the distillation ventilation shafts, and vice versa during the cold season [1].

Defining the goal and objectives of the study. Analysis of peculiarities and regularities of changes in heat and mass transfer characteristics of deep tunnels by the example of the Kiev subway as a result of mutual influence of the earth mass with the air environment depending on the modes of operation of the mechanical system of reversible tunnel ventilation during the year.

The geometric, physical, and mathematical models are described in detail in [1].

Research results

From September 2017 to December 2018, the authors, together with the staff of the electromechanical service of the Kiev subway, conducted experimental studies of the temperature and absolute humidity of tunnel air and the temperature of the walls of the rim of deep tunnels (Figs. 1-4).



a) b)

FIGURE 1. *Scheme of the subway tunnels (ST): a) schematic location of ST between the metro stations (m. sta.): 1-4 – numbers of track switches; Khreshchatyk – 1960 – name of the subway station and year of construction, respectively; b) marking of subway tunnels pickets: 01-19 – numbers of ST-1 pickets; 1-8 – numbers of ST-2 pickets*

Experimental studies were carried out during metro working hours, taking into account the “pumping” effect of train traffic, using the testo 835-T1 pyrometer and testo 435-T1 thermoanemometer in accordance with the recommendations of V.Ya. Tsodikov [2].

During the trial period from September 22, 2017 to August 15, 2018, station ventilation units and VU 229 operated in steady state with a flow rate of 108000 m^3/hour, and VU 115 – 215000 m^3/hour. Injection of air in the tunnel was carried out by VU of stations and VU 229, and removal of tunnel air through VU 115. It should be noted that this mode of operation of VU has remained unchanged over the past 20 years. As a result of a complex and ramified tunnels network, the distribution of air flow in tunnels directions is as follows: from the Khreshchatyk metro station to the junction – 7 m³/sec; from the Klovska metro station to the junction – 29 m³/sec; from the Maidan Nezalezhnosti metro station to the junction – 23 m³/sec.

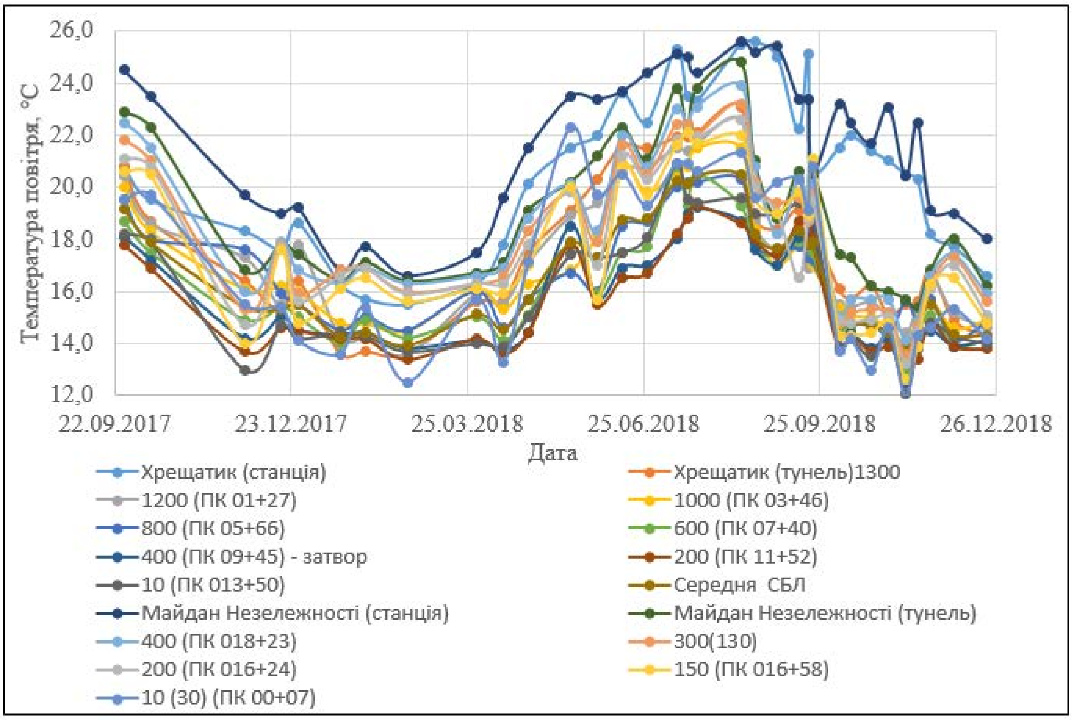


FIGURE 2. *Variation of tunnel air temperature during 2018 for different pickets on the ST-1 section from Khreshchatyk m. sta. to Maidan Nezalezhnosti m. sta.*

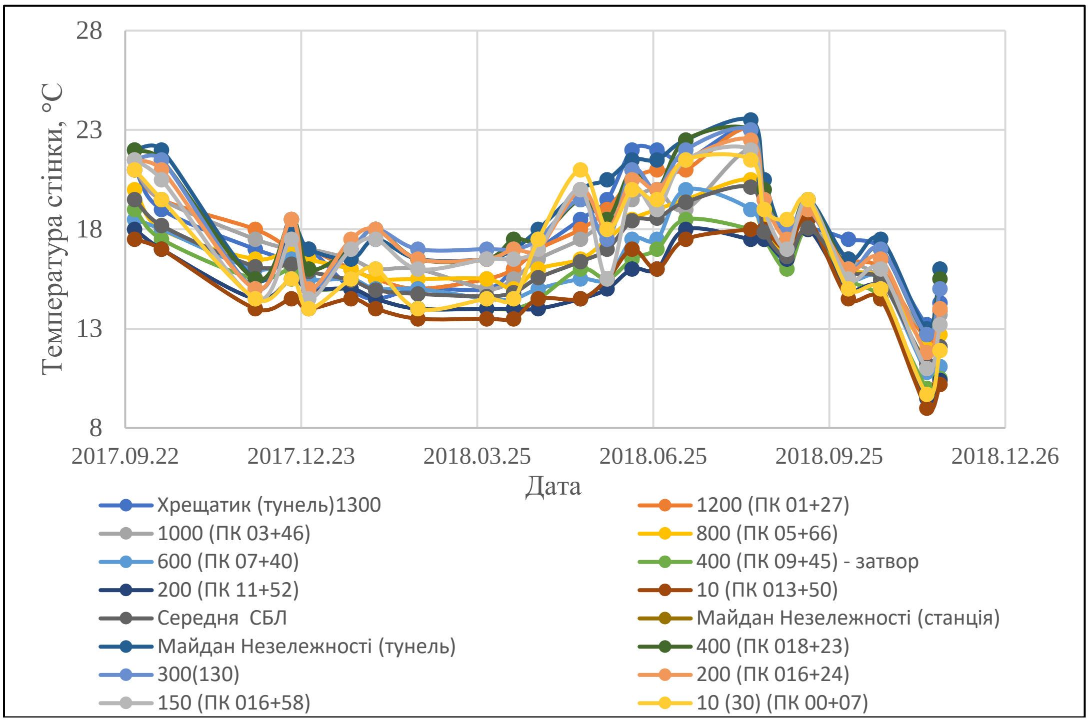


FIGURE 3. *Changes in the temperature wall of the tunnel rim walls during 2018 for different pickets on the ST-1 section from Khreshchatyk m. sta. to Maidan Nezalezhnosti m. sta.*

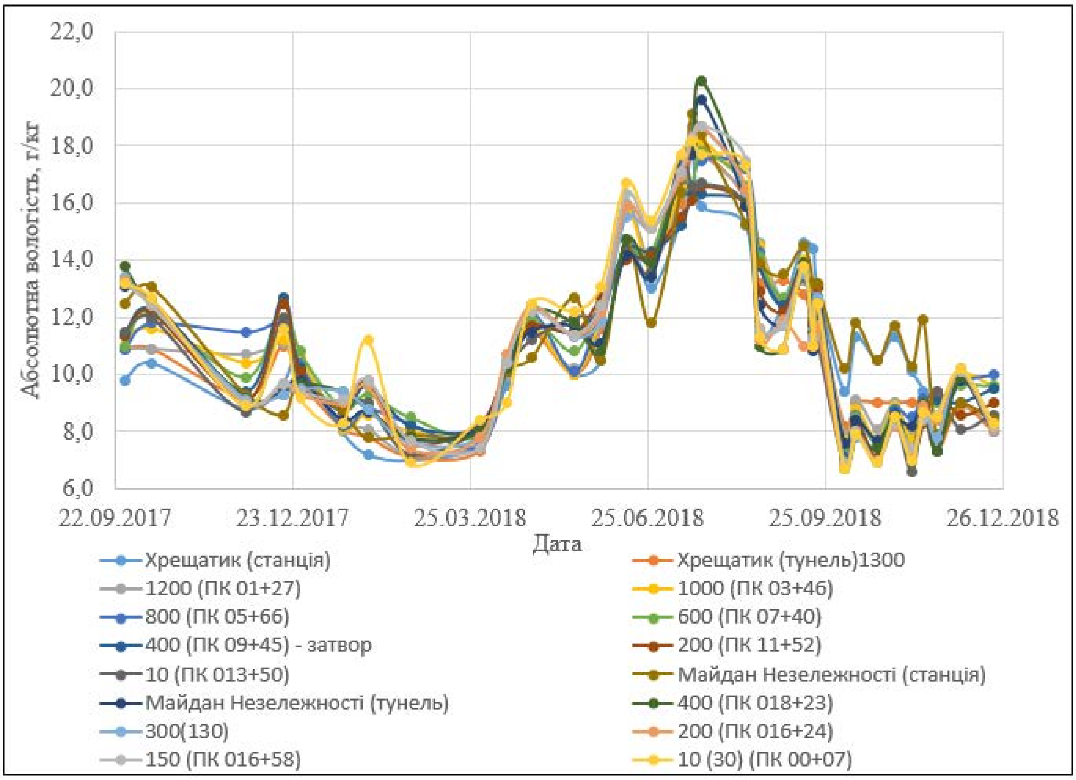


FIGURE 4. *Changes in the absolute humidity of tunnel air during 2018 for different pickets on the ST-1 section from Khreshchatyk m. sta. to Maidan Nezalezhnosti m. sta.*

As can be seen from Figures 2 and 3, the temperatures of tunnel air and tunnel rim wall are characterized by the fact that at stations are always higher than in tunnels, this is due to the heat input from passengers at stations during the winter period and the injection of warm air at stations during the summer period. Also, Figures 2-4 shows that the temperature and absolute humidity of tunnel air and the temperature of the tunnel rim wall change cyclically throughout the year according to the summer and winter modes of operation of the mechanical system of reversible tunnel ventilation: the lowest values are characteristic of the winter mode, and the highest ones of the summer mode, the extreme values are characteristic of the middle of modes. Since the air movement in the ST did not change during the year, so in the summer period the closest sections of the ST to the stations are heated first by convection and begin to accumulate heat by thermal conduction into the soil layer around the tunnels. By the end of the summer period, sections of ST from the stations Khreshchatyk and Maidan Nezalezhnosti in the direction of the junction warm up to 500 m: from PC 19 and from PC 01 to PC 14 and to PC 06, respectively. There is no heat accumulation in the summer period on the section of ST-1 from PK 06 to the junction. During winter mode, these sections of ST-1 from the stations and Khreshchatyk and Maidan Nezalezhnosti begin to cool by convection, resulting in changes in temperature and absolute humidity of tunnel air provides relative humidity close to the normative value of 75%. On the section of ST-1 from PK 06 to the junction the tunnel air is not heated (even at speeds of 0.5 m/s, the maximum value of 4 m/s) and the relative humidity is 95-98%, sometimes in May-July it reaches 100% (the phenomenon of fog). Due to the large mass of building structures of the tunnel mandrel walls and the soil layer around them (large inertness) there is no significant accumulation of heat in summer, so the temperature of the tunnel air and tunnel mandrel walls differ by 1-2°C at most.

For this period by engineering method of Tsodikov [2] accounting for the movement of subway trains and CFD modeling of heat and mass transfer of thermal energy from 10 m layer of soil around the tunnels determined the duration of the summer period of soil heating around the tunnels, which for Kiev is 153 days. The calculated air temperature during the cold period of the year at the stations of the Kiev subway located at a depth of about 60 m, where the amplitude of fluctuations of outside air temperature with natural soil temperature of +10°C does not affect, is +13°C. The calculated duration of heat transfer into the ground for 153 days is 5088 hours. During the summer period, the final air temperature in the tunnel will be close to +23°C, which is confirmed by experimental data for sections of ST-1 up to 500 m long from the stations. The depth of ground warming is 2.8 m. The resulting calculations depend on the intensity of train traffic in the tunnels. Taking into account in the calculations, the correction for the schedule of train traffic, we determine the average annual temperature of the soil around the ST-1 tunnels, equal to +15°C.

Switching the operating modes of the ventilation system is carried out when comparing the ambient temperature and the average temperature of the tunnel air of the ST: switching to the summer mode (forcing VU115 and VU229, removing tunnel air through the VU of stations), when the ambient temperature is equal to or higher than the average temperature of the tunnel air; switching to winter mode (reverse to summer mode) when the ambient temperature is equal to or lower than the tunnel air temperature.

The implementation of the proposed mode of operation of the mechanical reversible tunnel ventilation system in the Kiev subway was carried out from 15.08.2018 to 15.11.2018. From Figures 2-4 we can see that during this period the temperature and absolute humidity of the tunnel air along the length of ST-1 leveled off, which led to a decrease in the relative humidity of the tunnel air to the level of 75%. In addition, according to the experimental values of the temperature of the ST-1 rim wall, the section from the connector to PC 07 started to accumulate heat.

Conclusions

On the basis of analysis of experimental values of temperature and absolute humidity of tunnel air and temperature of the tunnel lining wall of deep-flowing tunnels at steady-state operation mode of tunnel ventilation during a calendar year with injection of air in the tunnel from the stations side it was found that a 700 m long tunnel section (with total length 1400 m) does not accumulate heat from tunnel air in summer and leads to high humidity of 95-98%, sometimes 100%. In order to reduce humidity in deep tunnel sections longer than 500 m, it is necessary to install an additional ventilation shaft with a ventilation system. If the tunnel air temperature does not comply with +15°C, the air should be heated by local electrical installations in order to avoid damage to the equipment.

Thanks to the CFD model for deep tunnels, a reversible tunnel ventilation mode was defined and proposed, the implementation of which led to a decrease in the humidity of tunnel air in the problem area to 75-80%. The peculiarity of tunnel reversible ventilation in summer is the injection of air by the overrun VUs and removal by the station VUs, and vice versa for winter period. This solution is due to the complex geometry of the metro tunnels.

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COMPARATIVE COMPUTATIONAL ANALYSIS OF THE SELECTION OF BATTERY ENERGY STORAGE FOR CIVIL OBJECTS AND PARKING WITH PHOTOVOLTAIC PLANTS

Abstract: *One of the disadvantages of solar power plants is that they do not produce electricity at night, so they cannot support the load of consumers. One of the reliable methods of increasing the efficiency of the use of photovoltaic power station (PPS) for consumers is the installation of energy storage. This study aims to investigate the efficiency of using a battery energy storage system (BESS) that is designed to power a civil facility and a parking lot. This study presents a feasibility analysis of BESS using System Advisor Model (SAM) software. The following objects were chosen as objects of research: a cottage; 19-story residential building with built-in non-residential premises (BNP); 9th floor parking lot for 979 cars. These facilities have solar power plants installed on the roof. BESS is planned to be used for power supply of the entire facility and power consumers. For the existing PPS, taking into account the peak load, the selection of the storage energy and modeling of the system operation modes was performed.*
The modes of use of the usage accumulator have been studied. The most effective mode of operation is mode 1, which involves charging the electricity storage during the day, and feeding the load in the evening. It is advisable to use this mode throughout the year. Mode 2 should be used to cover the load only during the spring-winter-autumn period, when the electricity generation from the FES is not sufficient.
The simulation results showed that BESS has the highest economic efficiency for the electricity supply of BZB with a payback period of 10.5 years with a battery utilization efficiency of 96.49%.

Keywords: *PPS; BESS; System Advisor Model; battery energy storage*

Introduction

Energy production from PPS has a number of advantages and disadvantages. One of the disadvantages is that PPS does not produce electricity at night, so they cannot support the load of consumers. To solve the problem of stability of electricity supply at night battery energy storage (BES) are used [1]. BES in combination with a solar power plant is called a battery energy storage system (BESS). This system absorbs and releases energy in different periods. There is no doubt that the additional investment and operating costs of BESS will affect the cost-effectiveness of the PPS. The purpose of this work is to develop the BESS design methodology of civil objects and parking.

Materials and Methods

In this study, the selection of the BES and the simulation of the operation modes of the PPS, which is installed on the roof of civil facilities and a parking lot, are carried out. The system consists of PPS, charge controller, inverter and BES. SAM software was used for research.

The structural diagram of the power supply system with PPS and BES is shown in Figure 1.

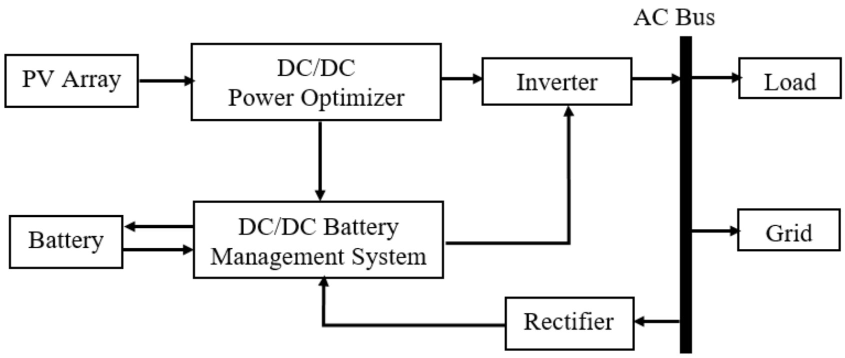

FIGURE 1. *Model of BESS [2]*

The principle of operation of BESS is that the energy produced in the PPS charges the BES, and then, when there is no solar insolation, the storage is discharged. At the same time, energy can be used to supply electricity to public housing facilities (parking lots) or can be fed into the electrical grid [3].

The selection of an EE storage unit for an existing PPS involves the following stages:

1. Determining the load capacity of public transport facilities (parking lots).
2. Based on the data on the installed capacity of the PPS, the forecast of the annual EE generation.
3. Calculation of the peak annual load in the SAM software.
4. Calculation of the power and capacity of the BES based on the peak annual load.
5. Choice of BES type: lead-acid or lithium-ion.
6. Selection of the mode of use of the BES.
7. Modeling of BESS operating modes in the SAM software to determine the value of the generated energy of the PPS and evaluate the efficiency of using the BES.
8. Economic analysis and evaluation of the economic performance of the hybrid system using the SAM software, taking into account the daily, monthly and annual volumes of electricity generated by the PPS, BES data and electricity consumed by the facility.

Results and Discussions

In this work, calculation studies of efficiency using BES for power supply of objects using PPS were carried out. The research objects are located in the city of Kyiv (latitude: 50.4; longitude: 30.45). Weather data was selected for 2021 from (https://energyplus.net/weather).

TABLE 1. *Deviation of air temperature in the room from the average. Design loads and parameters of PPS with peak load (option 1)*

Type of house	Nominal power of the existing PPS, kW	Estimated power of consumers (AC), kW	Estimated power of power consumers (AC), kW	Peak annual power of consumers (AC), kW	Peak annual power of power consumers of BZHB (AC), kW
K	60	25	–	40	–
B	124.95	–	16.32	–	26
A	676.2	398	–	151.49	–

For comparison, a BES for half the peak load was selected.

TABLE 2. Design loads and parameters of the PPS with half the peak load (option 2)

Type of house	Nominal power of the existing PPS, kW	Estimated power of consumers (AC), kW	Estimated power of power consumers (AC), kW	Half of the peak annual power of consumers (AC), kW	Half peak annual power of power consumers (AC), kW
K	60	25	–	20	–
B	124.95	–	16.32	–	13
A	676.2	398	–	75.75	–

K – cottage; B – 19-story residential building with built-in non-residential premises (BNP); A – 9th floor parking lot for 979 cars. The cottage is powered only by PPS. The PPS of a residential building is used to supply energy consumers. The parking lot is powered only by the PPS.

Using the calculated parameters of the peak load, the capacity of the BES is determined. The storage was selected taking into account the condition that the peak load should be less than the nominal power of the PPS. A Vipow lithium-ion (lithium-iron-phosphate) battery with a capacity of 50Ah and a voltage of 3.2 V was selected for the designed PPS. For each object of research using the SAM software, the selection of the choice of BES, the time of operation at maximum power and the capacity BES. The results of the calculations are presented in Tables 3 and 4.

TABLE 3. Selection of BES and capacity (option 1)

Variant number	The power of the BES consumers (DC), P1	Time of operation at maximum power, t1	Capacity of the BES of consumers (DC), Q1 = P1 · t1
K	32	2	64
B1	21	4	128
B2	21	8	258
B3	21	12	384
A1	152	4	608
A2	152	8	1216
A3	152	12	1824

TABLE 4. Selection of BES and capacity (option 2)

Variant number	The power of the BES of consumers (DC), P2	Time of operation at maximum power, t2	Capacity of the BES of consumers (DC), Q2 = P2 · t2
K1	20	2	40
B4	13	4	52
A4	76	4	304

With the use of SAM software, the following modes of operation of the BES were simulated by programming the drive dispatch controller:

1. Mode 1: BES charge during the day, feeds the load in the evening.
2. Mode 2: At night (11:00 p.m. – 7:00 a.m.) it does BES fully charge from the power grid (low electricity tariff), in the morning (7:00 a.m. – 8:00 a.m.) it gives electricity to the electric grid, and then charges from the PPS.

Such working periods are BES defined:

Period 1. All energy from the PPS is directed to battery charging.

Period 2. Discharge of BES and power supply of consumers.

Period 3. Charging of the battery from the electrical grid and subsequent return of energy from the BES to the electrical grid.

The BES discharge is carried out gradually: the BES will be discharged every hour by 20% of the total 80% depth of discharge. This will allow for an even discharge of the battery system during each hour of peak time. The minimum state of charge is 20% and the maximum state of charge is 100%, giving a depth of discharge (DOD) of 80%. This ensures the highest battery life.

The results of BESS modeling for various research objects are presented in Figures 2-10.

1. Cottage. Similar graphs are obtained for other variants of the cottage study.

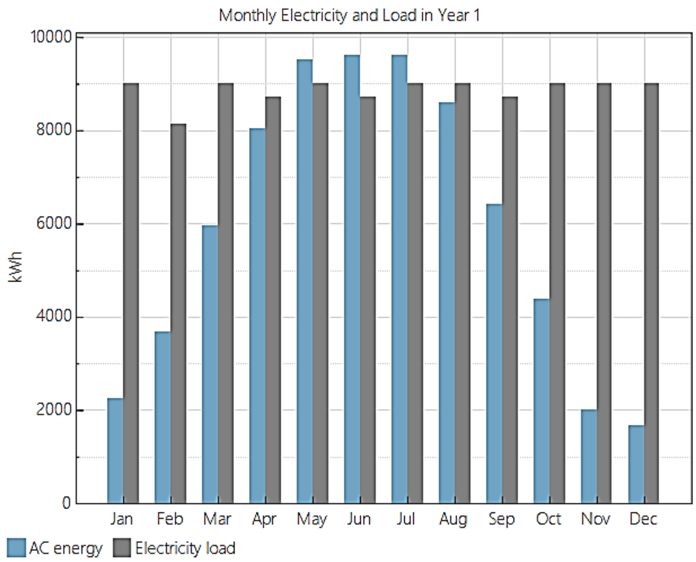

FIGURE 2. *Schedule of average monthly electricity production of the PPS and consumption of the facility K*

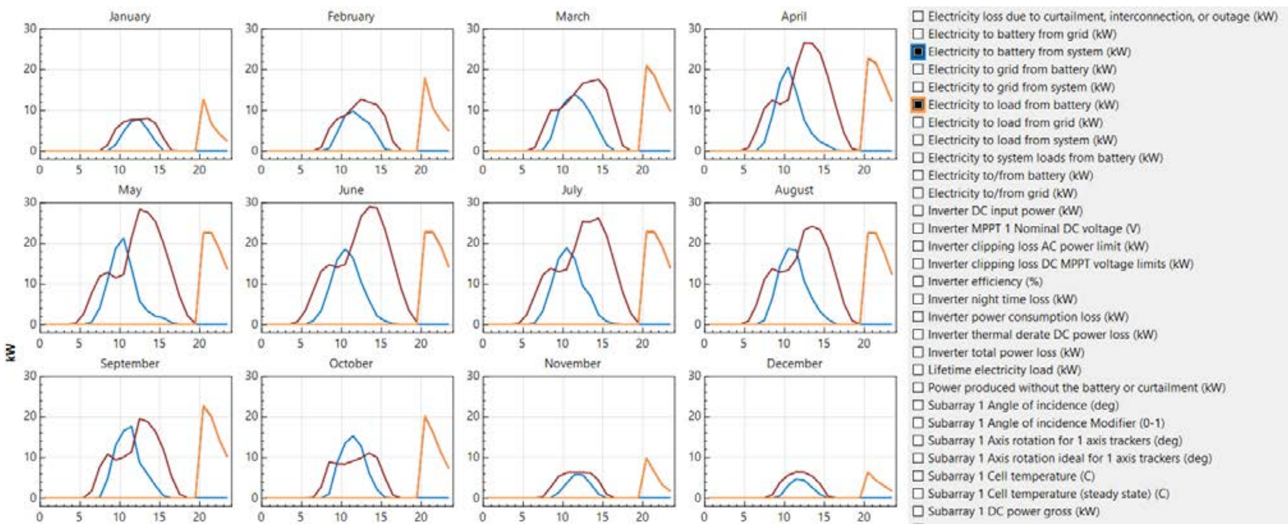

FIGURE 3. *Graphs of the average monthly electricity generation of the PPS, the electricity that is stored and the electricity that is delivered to the consumer according to mode 1*

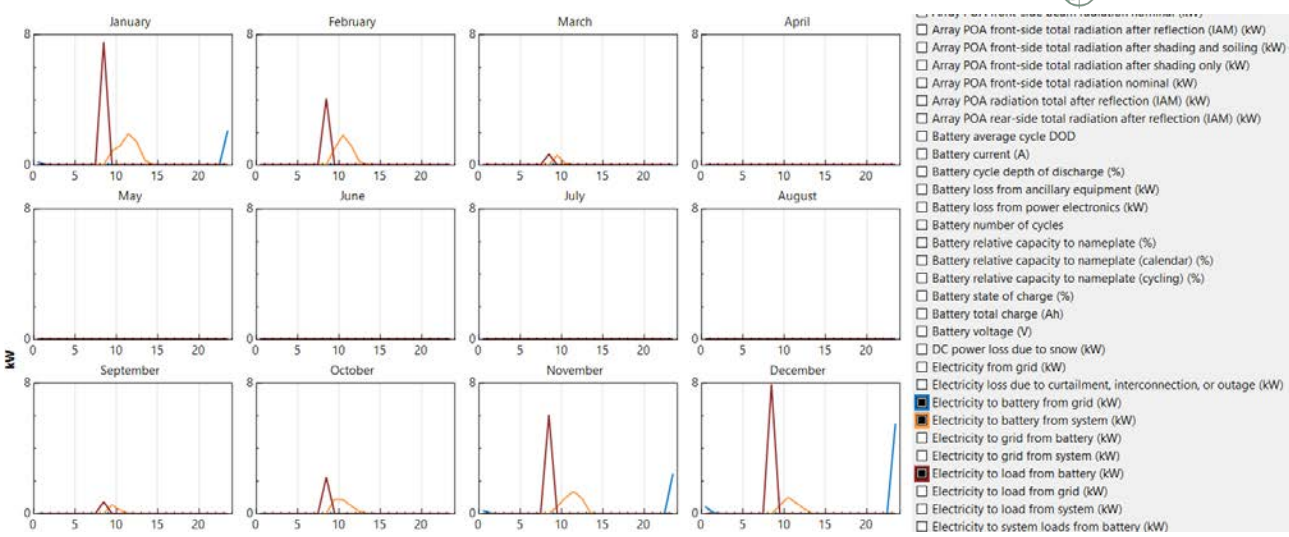

FIGURE 4. Graphs of electricity accumulated from the PPS and the electrical grid and electricity delivered to the consumer in mode 2

2. ***19-story residential building with built-in non-residential premises (BNP). Similar graphs were obtained for other variants of the BZH study.***

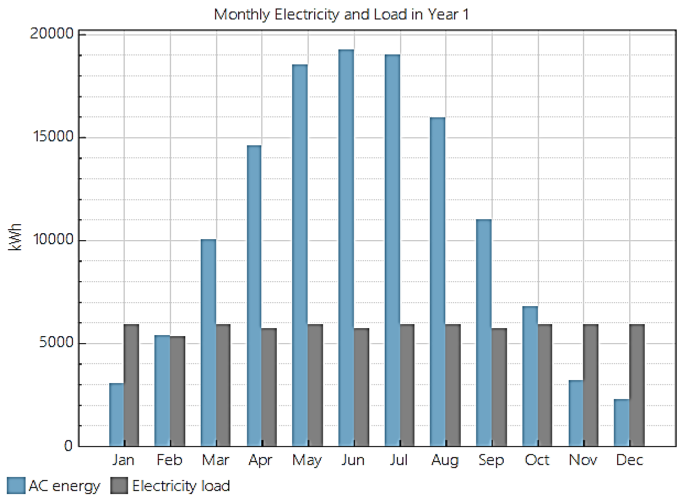

FIGURE 5. Schedule of average monthly electricity production of the PPS and consumption of facility B

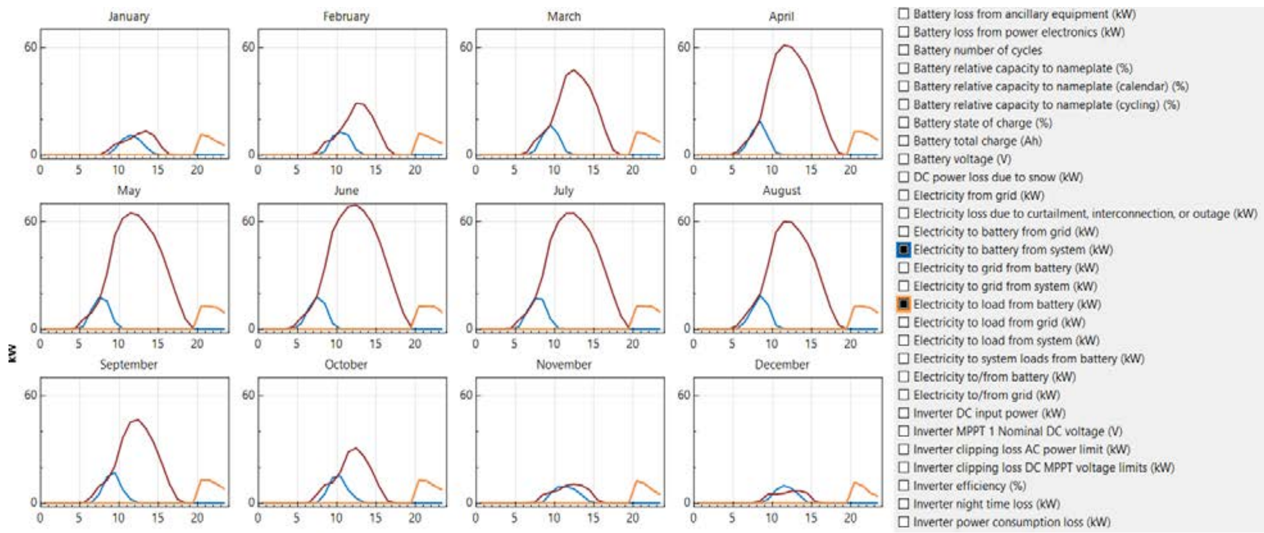

FIGURE 6. Graphs of the average monthly electricity generation of the PPS, the electricity that is stored and the electricity that is delivered to the consumer according to mode 1

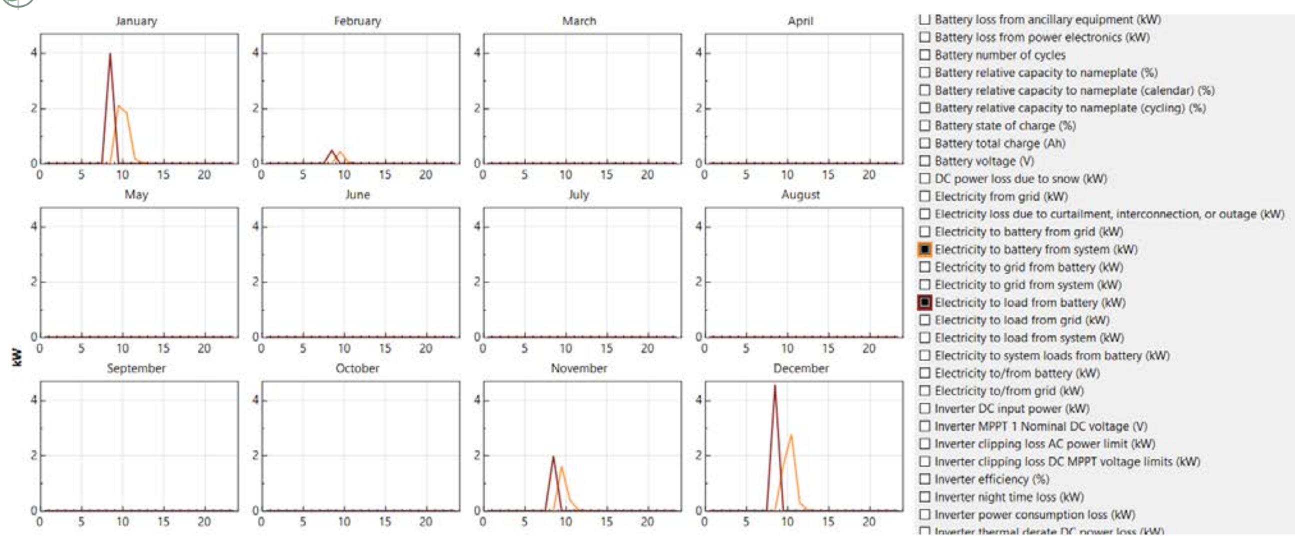

FIGURE 7. Graphs of electricity accumulated from the PPS and the electrical grid and electricity delivered to the consumer in mode 2

3. 9th floor parking lot for 979 cars. Similar graphs are obtained for other variants of the parking lot study.

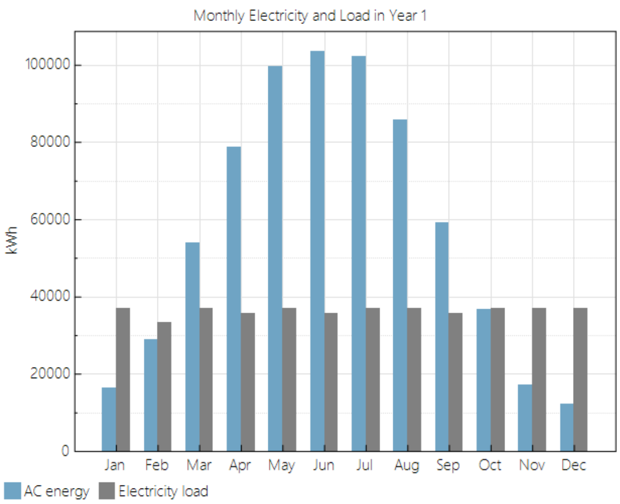

FIGURE 8. Schedule of average monthly electricity production of the PPS and consumption of object A

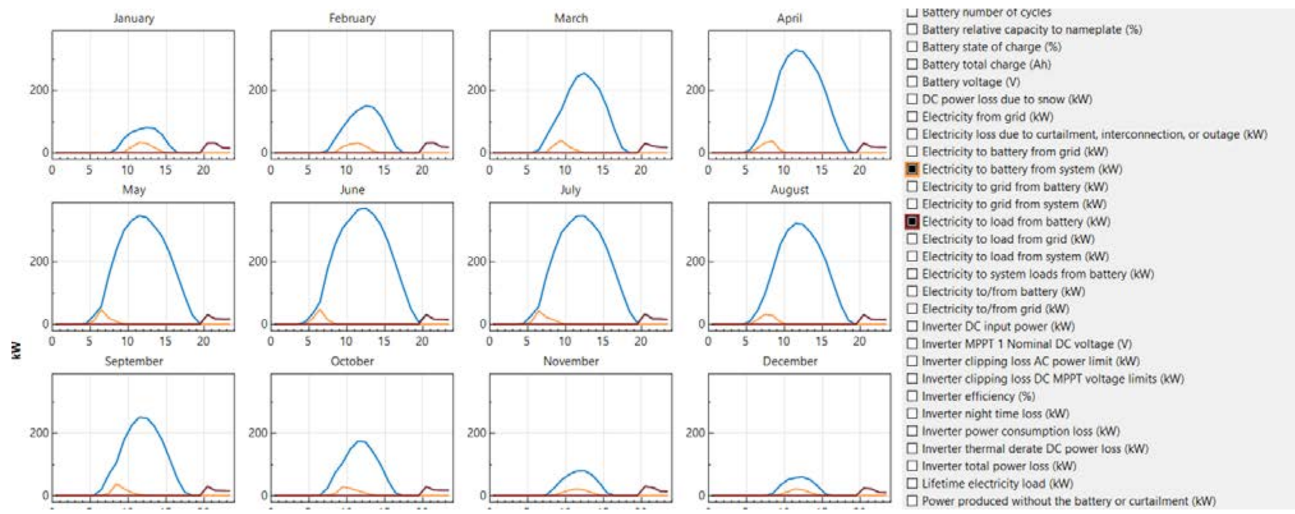

FIGURE 9. Graphs of the average monthly electricity generation of the PPS, the electricity that is stored and the electricity that is delivered to the consumer by mode 1

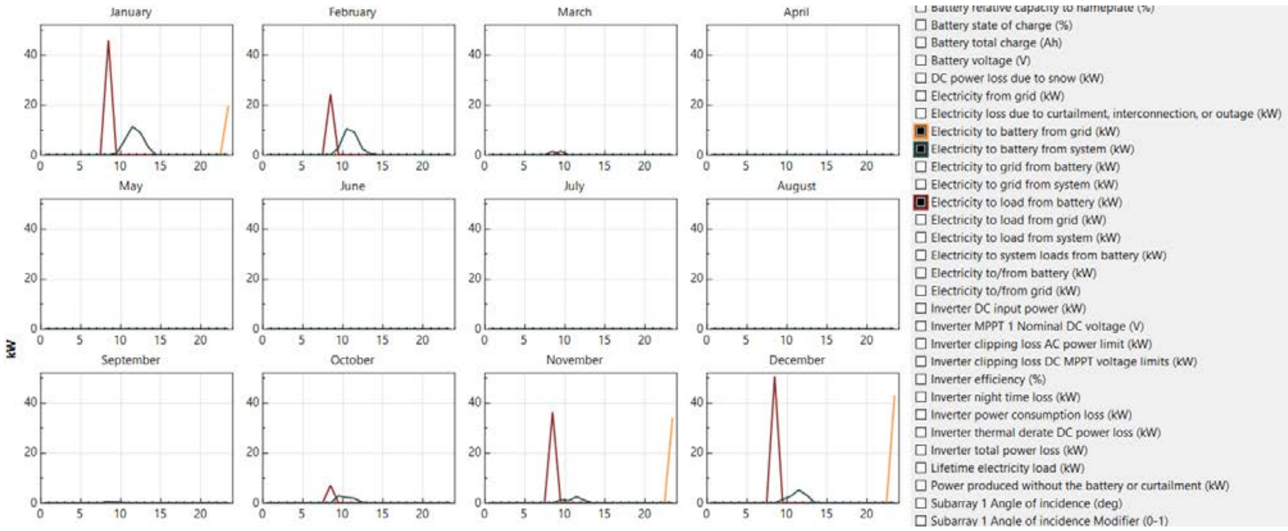

Figure 10. *Graphs of electricity accumulated from the PPS and the electrical grid and electricity delivered to the consumer in mode 2*

Comparing Figures 2, 5 and 8, it can be concluded that the energy of the PPS is not enough to cover the load during the spring-winter-autumn period. Using mode 1 shown in Figures 3, 5 and 8 BES is charged during the day, in the evening it supplies the load for a year. Mode 2, shown in Figures 4, 7 and 10, the BES, is used only to cover the load during the spring-winter-autumn period, when there is not enough electricity.

Using the calculated parameters of BESS, an economic assessment of projects of electricity supply of research objects with the use of PPS was performed.

The results of the economic assessment of BESS design for various research objects are presented in Table 5.

Table 5. *Results of the economic evaluation of the BESS project*

Mode of use of the electricity storage	Total cost of BESS construction	Battery efficiency	Battery charge energy from PPS	Payback period
Mode 1 for K	$133763	94.60%	100.0%	13.2
Mode 2 for K	$133763	95,48%	71.9%	13.1
Mode 1 for B1	$230152	94.98%	100.0%	12.5
Mode 1 for B2	$254415	96.01%	100.0%	14.6
Mode 1 for B3	$278238	96.28%	100.0%	17
Mode 2 for B1	$230152	96.44%	100.0%	12.5
Mode 2 for B2	$254415	96.61%	100.0%	14.6
Mode 2 for B3	$278238	96.67%	100.0%	16.9
Mode 1 for A1	$1359378	94.44%	100.0%	11.6
Mode 1 for A2	$1488894	95.58%	100.0%	13.7
Mode 1 for A3	$1618411	95.8%	100.0%	16.1
Mode 2 for A1	$1359378	92.12%	45.4%	13.2
Mode 2 for A2	$1488894	94.12%	45.8%	15.9
Mode 2 for A3	$1618411	94.88%	45.9%	19
Mode 1 for K1	$127464	94.2%	100.0%	12.7
Mode 2 for K1	$127464	94.98%	100.0%	12.5
Mode 1 for B4	$219431	94.5%	100.0%	11.7
Mode 2 for B4	$219431	95.85%	99.7%	11.7
Mode 1 for A4	$1264194	92.62%	100.0%	10.5
Mode 2 for A4	$1264194	96.28%	52.0%	11.3

Analysis of the data given in the Table 5 showed that the project with the use of PPS for powering the parking lot in mode 1 for A4 with a payback period of 10.5 years has the highest economic efficiency. For civilian objects, the most effective project is a B4-19-story residential building with a payback period of 11.3 years and a cost of $219,431.

Conclusions

1. For the most efficient use of the power supply system with PPS and storage throughout the year, it is advisable to use mode 1, which involves charging the BES during the day, and feeding the load in the evening.
2. Mode 2 should be used to cover the load only during the spring-winter-autumn period, when the generation electricity from the FES is not sufficient.

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MODELING OF THE DISTRIBUTION OF WIND PRESSURES OF THE BUILDING OF THE NEW SAFE CONFINEMENT OF THE CHERNOBYL NPP

Abstract: *Distribution of wind pressures on the outer surface of the New Safe Confinement (NSC) is necessary to determine the unorganized air exchange from the NSC (outward or inward) with radioactive aerosols to the environment, since it is not hermetically sealed. The results show the discrepancy between the wind pressure distribution on the NSC outer surface in the small-scale 1:300 physical model of the NSC tested in the wind tunnel and the literature data. The computational CFD model of the NSC external air flow was developed to determine the distribution of pressures on the NSC surface at different wind directions and speeds. The adequacy of the calculated model is confirmed by the proximity of calculated and literature data, as well as calculations according to the European standard.*

Keywords: *ChNPP, New Safe Confinement, CFD modeling, external wind flow, surface pressure distribution, wind loads, building aerodynamics*

Introduction

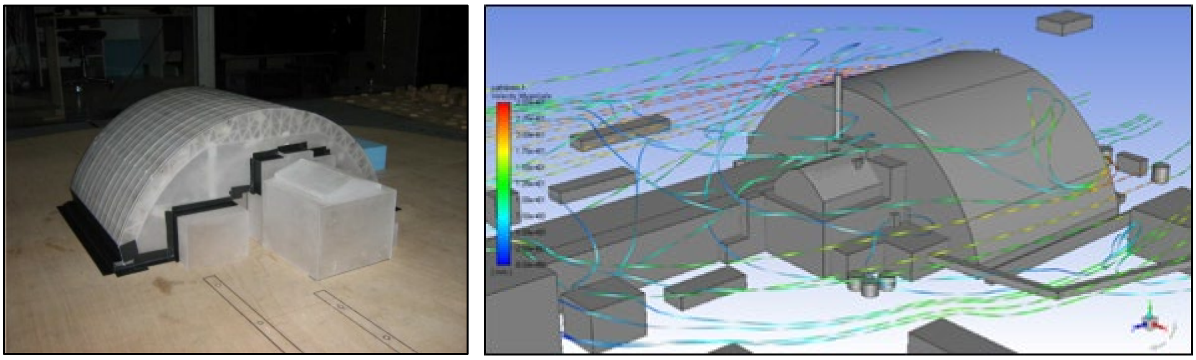
Determination of the distribution of pressure maps in buildings is necessary to determine the resistance of buildings to winds with high air velocity, the mutual influence of buildings in densely built-up areas for the design of the supply ventilation system of premises, for emergency buildings with particularly valuable or hazardous substances inside it, the air exchange of which depends on the pressure distribution maps on the outer surfaces of buildings through a large number of small gaps. Because due to the difference in pressure inside and outside, air from the windward side enters the building, and from the in 2016, the NSC was built over the destroyed ChNPP Unit 4, which was built using modern technologies and design standards, but it could not be completely sealed. There are many small gaps between the NSC walls and the rest of the ChNPP Unit 4 structures through which air can flow both inside and outside the NSC, therefore, to analyze and control the release of unorganized air exchange and radioactive aerosols (RA) from the main volume (MV) of the ChNPP NSC into the environment (EE), information on the distribution of wind pressures on the NSC outer surface and on the Shelter building structures is required. Such maps of pressure distribution on the NSC outer surface can be obtained by means of full-scale or computational experiment.

For this purpose, a small-scale physical model of the NSC at a scale of 1:300 (Fig. 1a) was tested in a wind tunnel during NSC design and maps of wind pressure distribution on the outer surface of the NSC model were obtained for all directions of air blowing from 0° to 360° with a step of 10 degrees [1] in order to determine the stability of NSC arch structures against wind with a wind speed of 23 m/s, both during construction and during NSC operation.

The pressure maps are the values of pressures in 197 separate sections of the western, eastern and cylindrical surfaces of the NSC of the small-scale physical model of the NSC (Fig. 1a), which did not include all structures under the walls and near the NSC. During operation, these wind pressure distributions were used to perform the above task, the results of which showed that these pressure maps qualitatively and quantitatively do not correspond to the literature experimental and calculated data. An alternative way to obtain pressure maps is to build a computer model using CFD (Computational fluid dynamics) technology (Fig. 1b).

Defining the goal and objectives of the study

The purpose of the work is to build a three-dimensional full-scale 1:1 computer CFD model of the NSC external air flow (Fig. 1b) for arbitrary rotation angles and wind speeds and to pre-tune the model according to the literature and experimental data of the ChNPP, which includes all structures under the walls and near the NSC to obtain the pressure distribution on the NSC outer surface and building structures of the Shelter during air flow.



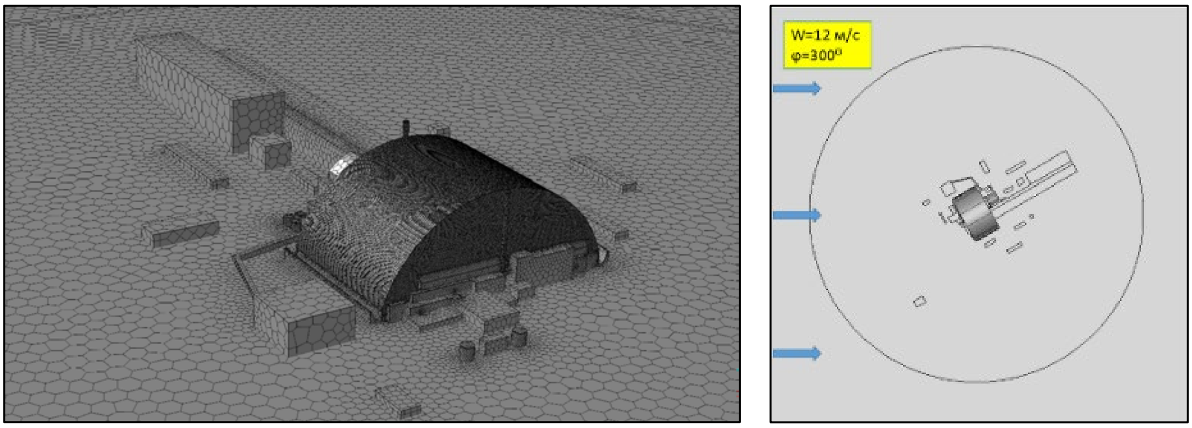
a) b)

Figure 1. *The NSC and the Shelter: a) photo of a small-scale physical model in the wind tunnel channel from the southeast angle; b) full-scale modeling of the external aerodynamic flow of the NSC and adjacent buildings from the northeast angle*

The geometric, physical, and mathematical models

The paper considers a three-dimensional full-scale 1:1 computer model of the NSC external airflow (Fig. 1b) for the same rotation angles and arbitrary velocity range, which was pre-tuned according to the literature and experimental data of the ChNPP, containing all structures under the walls and near the NSC. The geometric model has dimensions of 3.5x3.5 km, up to the upper limit of 800 m. The computational grid of such model consists of about 4 million cells (polyhedral mesh). Thickening of cells (Fig. 2a) was carried out to obtain the result of acceptable in time and stable calculation results in the CFD model of the NSC external flow.

To properly take into account the wind flow, the distance from the NSC to the lateral edge of the computational domain was chosen to be at least 1.0 km, taking into account the NSC height of about 110.0 m, as well as the atmospheric pressure at the remote $P_\infty = 10^5$ Pa and the air temperature T_∞ = 15°C. The wind direction was taken into account by rotating the internal volume of air with the geometry of the NSC with a radius of 1.0 km (Fig. 2b), the dimensions of which are selected in accordance with the literature [2-4] to simulate the external air flow around the buildings. At the input boundary of the computational domain, the wind direction and speed are set, the distribution of which in height corresponds to the power law for the terrain of type III with the power law index m = 0.31.



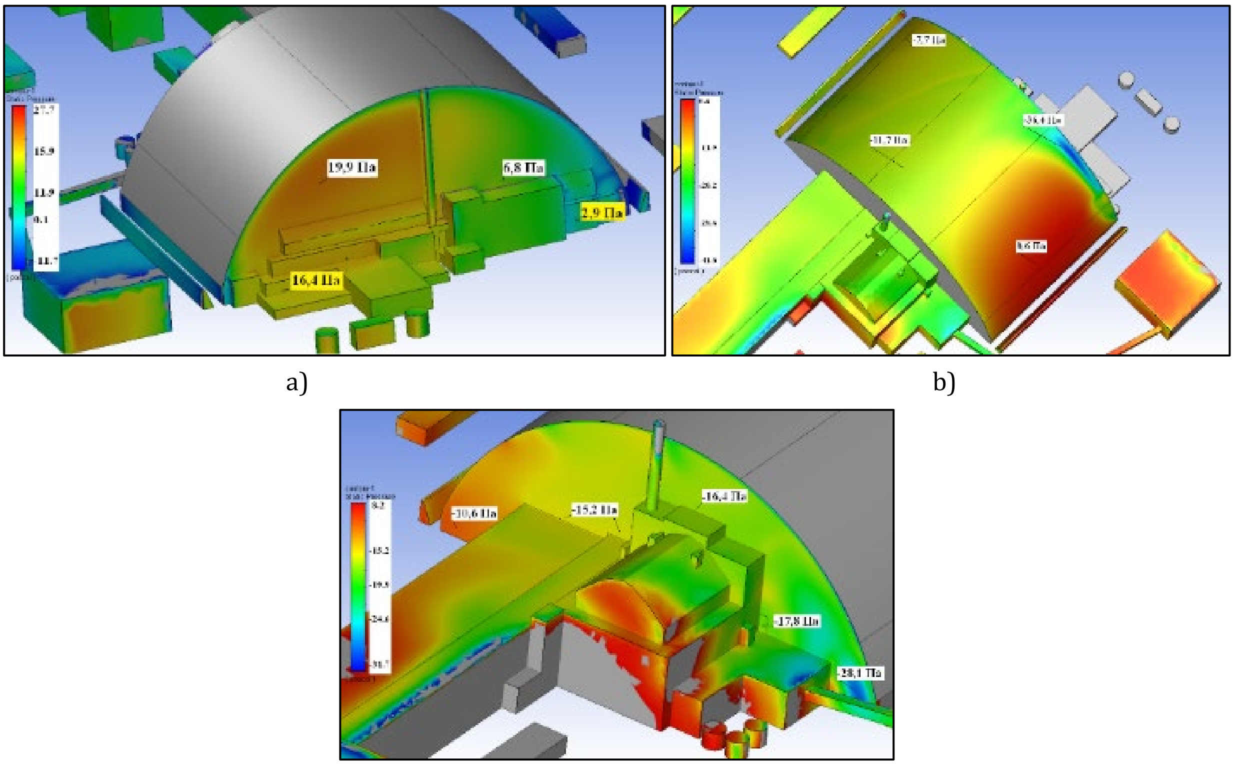
a) b)

FIGURE 2. Computational grid of the NSC air flow model and the area of the computer model of the NSC and the environment that is rotated relative to the wind direction (direction 300 ° is indicated)

When setting up the CFD model of the NSC, the variable profile of wind speed in height, surface roughness, intensity and scale of turbulence at the entrance to the computational domain, turbulence model and its parameters, ground temperature, as well as the geometry of buildings at the ChNPP industrial site were adjusted.

Research results

In contrast to the small-scale physical model, the full-scale computer model allows obtaining continuous pressure distributions over the entire NSC surface (Fig. 3), which is 87.6 thousand m^2, as opposed to 197 values in individual sections of the small-scale physical model of the NSC.



a) b)

c)

FIGURE 3. Distribution of static pressure on NSC surfaces and Shelter structures

Maps of pressure distribution on the outer surface of the NSC and building structures of the Shelter were obtained for different wind directions, which qualitatively and quantitatively coincide with the literature data [2-4] on the external flow of buildings and greenhouses.

The obtained pressure distributions on NSC surfaces were calculated for all wind directions from 0° to 360° through 10° at wind speed of 3.8 m/s. For other wind speeds, the pressures obtained with the help of physical and computational models are recalculated using dependence (1) [1]:

$$P_c = P_b \cdot \left(\frac{V_c}{V_b} \right)^2 \tag{1}$$

where P_c is the pressure for the current (c) value of wind speed; V_c is the current value of wind speed; P_b is the pressure for the base (b) value at the base wind speed V_b = 3.8 m/s.

As a result, the obtained maps of wind pressure distribution on the NSC outer surface and Shelter building structures can be used during scientific support as information support, monitoring and forecasting of air flow rate Q (m^3/s) of radioactive material outlet to and inside the NSC and control of the NSC ventilation system in order not to exceed the maximum permissible level of radioactive material release from the NSC [5].

Conclusions

The paper presents a three-dimensional full-scale 1:1 computer model of the external air flow around the New Safe Confinement (NSC) for different rotation angles and an arbitrary range of wind speeds. The results of calculations of wind pressure distribution on the NSC outer surface are in good agreement with the literature and ChNPP experimental data. Wind pressure distributions on the NSC outer surface are used to solve an important task of controlling the release of unorganized air exchange with radioactive dust from the NSC into the environment.

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INCREASING THE EFFICIENCY OF THE FUNCTIONING OF INDUSTRIAL ELECTRICAL NETWORKS THANKS TO THE INTEGRATION OF VACUUM RECLOSERS

Abstract: *Topical matter of power supply for today is effective increase in the reliability of power supply in medium voltage overhead power systems by sectioning of lines with switching devices, such as disconnectors, controlled disconnectors or sectioning points. In such schemes, the manual approach to emergency management is used. This kind of schemes can be used where the overhead power lines are. Protective device on the outgoing feeder is switched off as soon as damage occurs in any area. As a result, all consumers of the line lose power for a long time. Remotely operated disconnectors or remote controlled sectioning points can also be installed instead of manual line disconnectors. This process of damage localization differs only in that all switching operations are performed remotely. Decision on switching is made by the dispatcher, constant communication with each controlled element of the network is necessary, otherwise it becomes virtually uncontrollable and the entire effect of remote control of disconnectors is eliminated.*

Keywords: *recloser, vacuum switch, dispatching, emergency processes, power lines, switching control*

Introduction

According to the analysis of the operation of distribution electric networks of Ukraine, it is necessary to note the following. Losses in distribution networks range from 12% to 17% (25-33% in individual power stations):

1. Energy losses for 2012-2020 – UAH 44 billion.
2. Volume of investment programs for 2012-2020 – UAH 15 billion.
3. Reduction of e/e losses 2012-2020 – UAH 0.2 billion or only 0.54%.

All these are the consequences of: Inefficient configuration of networks; Low level of network automation; Problems with connecting new subscribers, in particular distributed generation, electric heating and electric transport infrastructure; Low quality of electricity supply to consumers; Low level of automation electricity metering systems.

Proposals for a comprehensive approach to promotion energy efficiency of distribution networks:

1. Changing the network configuration – approximation high voltage networks to the consum.
2. Transition to medium voltage level of 20 kV – decreasing degrees transformation.

3. Level up network automation – Telemechanization of PS, sectioning distribution networks (using reclosers).
4. Changing the operating mode relay protection – safety of people, removal of overvoltage from equipment.
5. Level up equipment automated accounting systems – decrease commercial losses.

The goal of this paper

Propose a technical solution to significantly reduce the time to eliminate emergency shutdowns; to offer opportunities for reducing power losses in power supply networks; consider variations in improving the quality of energy supply to consumers.

Presentation of the main research material

Reclosers of E.NEXT-Ukraine Company and "Igor Sikorsky Kyiv Polytechnic Institute" are self-contained small-sized complete switchgears with great functionality (Fig. 1).

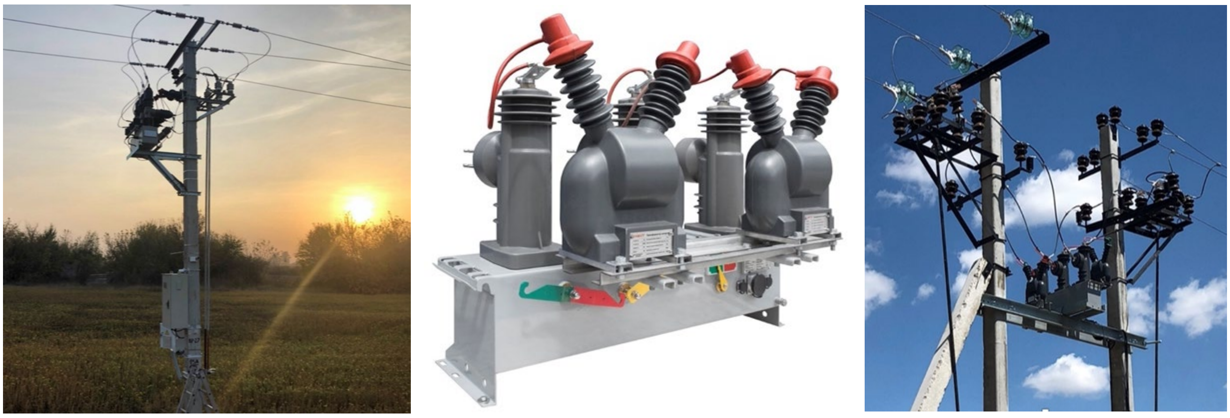

***FIGURE 1.** Installation example for reclosers, switching module and control unit*

The main idea of using reclosers is the following [1, 2]:

1. One of the main problems of today's electric power industry is the frequent emergencies on medium voltage overhead lines. This is due to their considerable length and high wear and tear of the equipment of consumers connected to them. Therefore, power supply companies require the installation of sectioning devices on the overhead power lines of consumers, automatically separating this line from the general power grid in case of emergency situations on it. This kind of devices are the reclosers.
2. In case of short circuits on the power line protected by the recloser, the fast-switching vacuum circuit breaker protects the fuse link of the tap-off fuse. And only on the 2nd or 3rd automatic reclosing cycle (depending on the setting of the microprocessor protection of the recloser), when it is already possible to talk about the stability of the circuit, the device allows this insert to burn out.
3. In addition to the protective and sectioning functions, the reclosers of the E.NEXT-Ukraine Company and "Igor Sikorsky Kyiv Polytechnic Institute" can be used for remote monitoring and logging of the quality of supplied electricity, metering its consumption, including it being a part of automatic metering and telemechanics systems. It is possible to enter automatic transfer switches and backup power system with help of them.

Using of reclosers of E.NEXT-Ukraine Company and "Igor Sikorsky Kyiv Polytechnic Institute" significantly increases the reliability of the network, reduces the costs of its maintenance and losses from possible undersupply of electricity to the consumer, and allows keeping electricity metering at the border of consumers balance inventory. Currently, about 40% of overhead lines (OHL) have reach the end of its service life and more than 80% are in need of technical re-equipment.

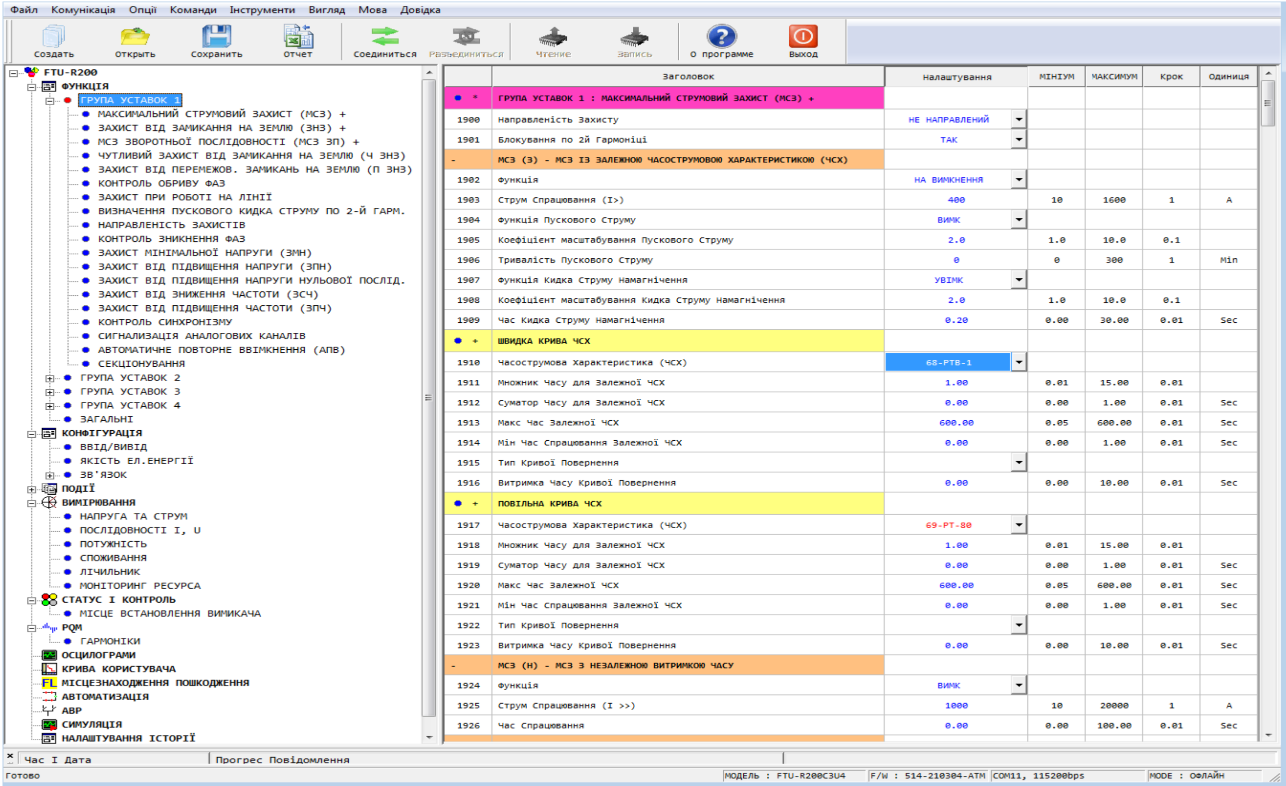

FIGURE 2. *Mnemonic frame from SCADA system*

The weakest link in the power supply system is 6 (10) kV overhead distribution networks. However, this requires large costs during the construction phase, and sometimes is not feasible due to the complexity of the placement [2, 3]. Also, in order to increase the safety of power supply to consumers, it is possible to repeatedly reserve and section the lines with manually operated disconnectors. But this method also has disadvantages. Therefore, the reliability of power supply of such power lines is increased by sectioning it into several relatively short sections with the installation of intermediate automatic protective switching devices-reclosers. Reclosers of E.NEXT-Ukraine Company and "Igor Sikorsky Kyiv Polytechnic Institute" are small circuit breakers located at the top of distribution poles and are usually used on very long distribution feeders.

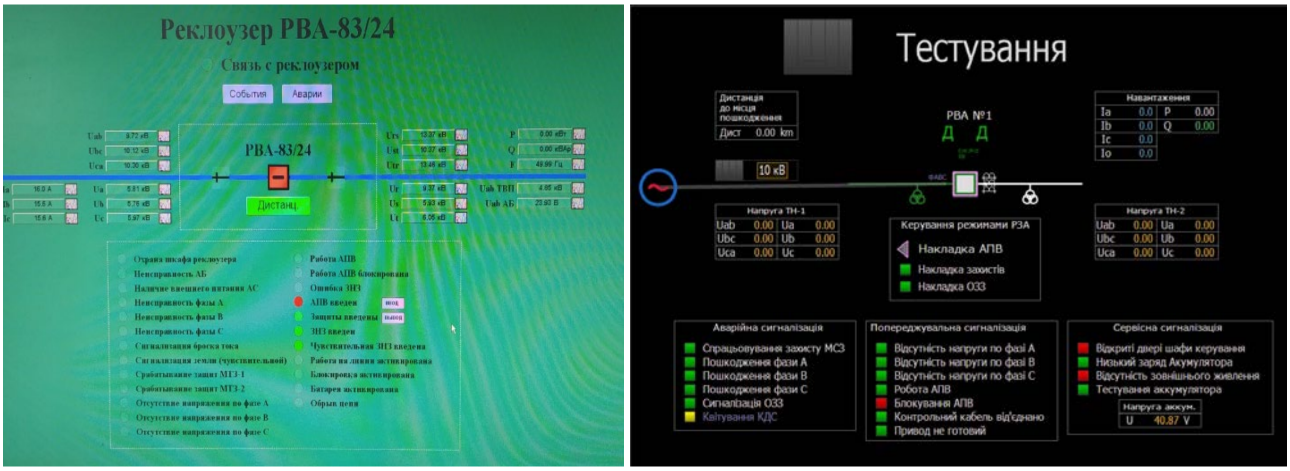

FIGURE 3. *Mnemonic frame from SCADA system*

Their function is to isolate the feeder section in the event of a malfunction or overload and thus minimize the number of unattended customers. Because they act like small circuit breakers, they have the ability to automatically restore power in situations of temporary failure, hence the name “recloser”. This device is remotely controlled and allows the electrical network manager to detect a fault on the overhead line directly at the time of the fault, make decisions quickly and send the emergency repair team to the right area.

Recloser of E.NEXT-Ukraine Company and “Igor Sikorsky Kyiv Polytechnic Institute” includes: vacuum (SF6) switching device; system of primary current and voltage converters; autonomous operational power supply system; microprocessor relay protection and automation system with the ability to connect telemechanics systems; a system of ports for connecting telemetry devices; software complex. The advantages of the developed recloser [3, 4].

Installation of poles. Reclosers have external (external) pole installation, and due to this:

Increased level of insulation – the insulation of the poles of the switching module is made of epoxy resin, which has high insulating properties, resistance to ultraviolet radiation, and the ability to self-cleaning from precipitation and pollution.

No risk of internal short circuit – in the event of an internal fault or lightning strike in the switching module, a short circuit will not occur, since the poles are insulated with solid insulation without the risk of explosion. On the other hand, reclosers with indoor poles have a high risk of explosion.

Maintainability – in the event of a malfunction of one of the poles, it is possible to quickly replace the recloser pole, which is cheaper and more practical with a long service life, in comparison with the internal version, where this is not possible, in case of a malfunction, the entire switching module is replaced.

Drive mechanism. In the proposed reclosers, a spring drive mechanism is installed, which makes it possible to manually turn on and off the recloser in the presence of voltage on the line, while it does not need the presence of an auxiliary power supply, which cannot be done with a magnetic drive mechanism. Also, the latter requires frequent checking of the capacitor, which may lose capacity, which is likely under unfavorable climatic conditions (high temperature). The spring-loaded mechanism of the drive provides a higher mechanical pressure on the power contacts, which minimizes the risks of contact welding, and also withstands a higher short-circuit current compared to a magnetic drive. The spring-loaded drive mechanism is used at high-voltage switchgear/substations, which confirms the reliability and durability of this drive mechanism.

Current measurement. Reclosers use built-in current transformers (CTs) to measure current, which provide a whiter class of accuracy than Rogowski coils. The error in measuring the phase currents for CT and Rogowski coil is 0.1% and 1%, respectively, when measuring a single-phase earth fault, the error for CT and Rogowsky coil is 0.01% and 0.2%, respectively, which is a very important factor in networks with an isolated neutral LEP 6-35 kV, where earth fault currents are small compared to phase-to-phase short-circuits.

Body material. The recloser body is made of expensive 304 stainless steel, 4 mm thick, powder coated, this will ensure a long service life even in the most aggressive environments, compared to the low grade stainless steel body.

Auxiliary transformer (TSN). Complete with reclosers, single-phase TSNs with built-in fuses are used, with the ability to mount on the recloser body, which minimizes the time and material costs for installing the recloser on the power transmission line support.

Practical implementation of a technical solution

An example of the use of a recloser in power lines is presented in Figure 4.

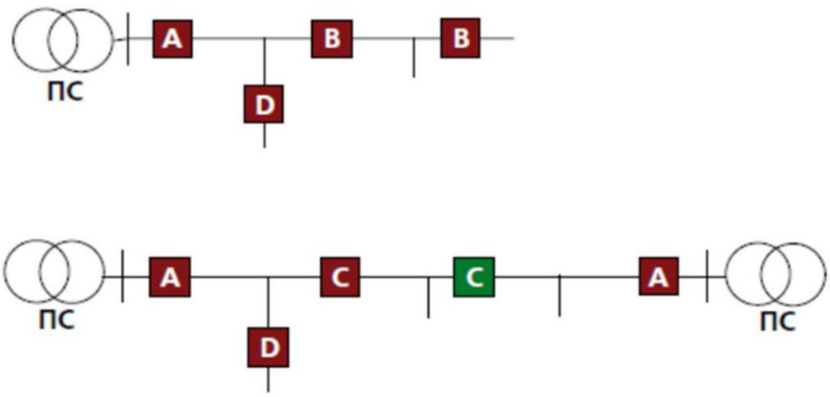

FIGURE 4. *Recloser installation options: A – device on the outgoing line; B – sectioning point in the network with 1-way power supply; C – sectioning point in the network with 2-way power supply; D – protective device on the branch line*

An example of a classic use of a recloser in radial diagrams is presented in Figure 5. Unstable short circuits are eliminated in the process of disconnection of the overhead line (up to 80-85%) and automatic reconnection inclusions of automatic reclosing – this inclusion of reclosers reduces the number of hours of disconnection. In addition, with this use, it is possible to arrange a classic relay protection redundancy scheme – zoned sensitivity, time exposure depending on the short-circuit current.

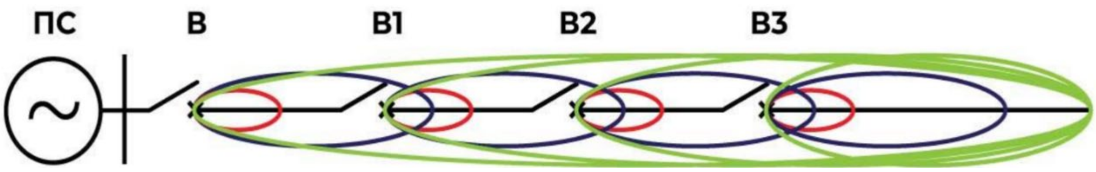

FIGURE 5. *ПС – feeder substation. B, B1, B2, B3 – reclosers. The colors show the zones of protection*

The main difficulties in installing reclosers:

1. When choosing a recloser installation point, it is necessary to take into account the payback period and/or technological period expediency.
2. In hard-to-reach places, it is necessary to organize the access of technical means to the support for the installation of power module – the weight of the structure can reach 100 kg, and despite the simplicity of the structure, it is necessary to use it installation techniques.
3. When choosing the installation point and model of the recloser, it is necessary to take into account the readiness of the system management of operators of the distribution system before working with the recloser: availability of technical measures – SCADA, control room, etc. In otherwise, the functional equipment of the recloser will not be used to its full extent.
4. Correctly determine the operating mode in which the device will be used: automatic operation, operation.
5. By centralized commands with a control room, semi-automatic – execution of automatic reactivation algorithms with expectations of further commands of the central management body.

If there is an opportunity to establish stable communication with the control room at the location of the recloser, then functional equipment allows its use as a SMART-GRID element in the collection and data transfer regarding network operation mode:

- current voltage values;
- currents;
- frequencies;
- remote control of switch position, etc.

Conclusions

The use of a vacuum switching device at the base of the recloser makes it possible to switch currents load without the risk of personal injury and equipment damage – use a recloser for switching networks both remotely from the control room and directly on site installation by personnel using a remote control, which significantly speeds up execution switches in networks. The recloser functionality allows a group of reclosers arrange full protection of the overhead line section, separation of the damaged area, preservation power in the damaged area due to time-current settings, ensure compliance nominal parameters of the network in terms of voltage, frequency, or limit the flow of power beyond the norm value in automatic mode without intervention person in the process of restoring the regime after liquidation accidents.

Further development of the technical improvement of vacuum reclosers of the ENEHT-Ukraine Company together with the Ihor Sikorskyi KPI has prospects for improving the efficiency of the functioning of the power supply system in Ukraine.

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