Energy-saving Technologies for Construction in Extreme Climatic Conditions

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Abstract. The aim of the study is to identify the main features and correlation of the organization of construction building site in extreme climatic conditions by modeling organizational and technological solutions applied energy-saving technologies. A model of a mobile wind, electric, diesel station consisting of separate blocks: solar panels, wind turbines and a diesel power plant is developed. Recommendations on energy saving, which will increase energy efficiency during the construction of buildings and structures in extreme climatic conditions are proposed. The importance of the results for the construction industry is the possibility of improving the quality of construction of buildings and structures in extreme climatic conditions with reducing work force, material-technical and fuel-energy resources and adverse environmental impacts.

1. Introduction

As it is commonly known, energy efficiency is a significant reduction of utility costs and resources saving for the population. Also, it is increasing construction productivity and competitiveness for the country. The use of energy-saving technologies in temperate latitudes is partially reduced utility costs. In addition, energy-saving technologies must be accessible, environmentally friendly, safe for human life and do not affect on lifestyle [1-4].

In present requirements for the construction of buildings and structures in a section of must-use energy-saving technologies in process of construction new energy efficiency conditions are imposed.

In Russia, like in other countries, there was a time when the importance of energy efficiency was not appreciated enough. Currently, the construction industry is creating and introducing energy-efficient technologies, and this is one of the main lines of construction industry development [5-7].

Unfavorable conditions for human life and work are required non-standard solutions to the problems of providing heat and electricity to the construction site. It follows the development of innovative construction energy-efficient technologies [8-10].

Interest in energy-saving technologies and alternative energy was caused by the efficient allocation of resources and reduction costs. The literature data analysis of energy-saving technologies has shown that the main goals and objectives were partially solved, and the application of energy-saving technologies during the construction of buildings and structures in extreme climatic conditions have never been thoroughly studied or designed at all. In this regard, the purpose of the work is the developing a model of a mobile wind, solar- and diesel power plant [11-16].
2. Research methods

Today, mobile diesel power plants are the main power source in regions without electric transmission lines. For distant villages and the construction of buildings and structures, it is practically the only source of electricity, whereas isn’t a central electricity supply. In this work a model of a mobile wind, solar- and diesel (Hybrid) power plant for providing energy for buildings and structures in extreme climatic conditions is developed.

In the development of the Hybrid power plant model, the diesel model was adopted as a prototype manufacturer "Company Diesel". The diesel power plants in Russia have a high demand in the work of emergency, repair crews, in watch settlements for exploration, construction, maintenance and repair of oil and gas industry facilities. Mobile diesel power plants (DPP) were occurred widely because of their undoubted positive advantages: high reliability and safety, maximum mobility, applying in extreme weather conditions, etc.

It is necessary to take into account the potential energy provided by solar panels and wind turbines together when designing a mobile Hybrid power plant. It well known that hybrid power plants using renewable and traditional sources of energy have a special economic effect. The most appropriate option is a system that contains several sources of electricity generation - solar, wind power, and a traditional (backup) - diesel power plant. The typical structure scheme of Hybrid power plant is shown in the fig. 1, which works on the following principle: all the solar power converted by panels (batteries) and wind turbines - wind energy is supplied into the electricity system through a controller. Controller is regulated the charge process of battery from wind generator and solar panels, protected it from recharging and provided a long life duration.

The inverter is designed to convert the energy accumulated in batteries. In the case of low-level of battery, the inverter protects it from deep discharge by disabling consumers.

In addition, a three-phase diesel generator is connected to the system, which will work only in force majeure situations.

Moreover, such a system requires quite a large investment at the construction stage, therefore, it leads to a long payback period, but in comparison with the conventional diesel, generator Hybrid power plant is economically more efficient.

Mobile Hybrid power plant is able to supply power to all current customers who need emergency power, as well as to facilities located in distant areas without power lines.

The Hybrid power plant is fenced off from the construction site to create the necessary space for solar modules and to avoid blanking them. They should keep the south side and have a slope equal to the latitude angle of the site. Wind generators should have a free space without nearby trees, buildings and structures. Fig. 2 shows 3D-model of the Hybrid power plant, which was designed in the Autodesk Revit software complex.
3. Results and discussion
The main and essential solar radiation characteristic is the daily, monthly and annual amount of solar radiation on the horizontal site in cloud conditions. All the necessary information is obtained for the expended period from weather observing and forecasting system.

In accordance with SP 131.13330.2012 "Building climatology" in Russia the highest insolation is observed in Makhachkala. The average daily and average monthly amounts of solar radiation for all months with the optimal tilt of the site for Makhachkala and Kazan are listed in the table. 1.

| Table 1. Daily and monthly average of solar radiation in Makhachkala. |
|-----------------|--|--|--|--|--|--|--|--|--|--|--|--|
| Month           | Jan| Feb| Mar| Apr| May| June| July| Aug| Sept| Oct| Nov| Dec|
| Daily solar radiatio n kWh/m² | 1,5| 2,75| 4,13| 5,42| 6,45| 6,13| 6,71| 6,32| 5,2| 4,26| 3  | 2,5 |
| Monthly solar radiatio n kWh/m² | 0,82| 2,04| 3,7 | 4,5 | 5,7 | 5,5 | 5,7 | 5  | 3,7 | 2,2 | 1,2 | 0,8 |

Figure 1. Structural operation scheme of Hybrid power plant.

Figure 2. 3D-model of Hybrid power plant.
The analyzed data in table 1 indicated significant difference in insolation values between two cities in different regions.

Accumulating solar energy can be used to work power tools on a construction site. The energy consumption of electrical instruments required for the construction of buildings and structures in extreme climatic conditions (table 2) are described below.

**Table 2. Energy consumption of electrical instruments.**

| Consumer description         | Consumed power (W) | Quantity | Operation hours, h | Total capacity (kW) |
|-----------------------------|--------------------|----------|--------------------|---------------------|
| Electric drill              | 800                | 4        | 4                  | 3.2                 |
| Hammer drill                | 1400               | 4        | 4                  | 5.6                 |
| Rotator saw                 | 1600               | 4        | 4                  | 6.4                 |
| Electric jointer            | 1000               | 4        | 2                  | 4                   |
| Electric fret saw           | 700                | 4        | 2                  | 2.8                 |
| Grinder                     | 2200               | 4        | 5                  | 8.8                 |
| Chain saw                   | 1700               | 4        | 2                  | 6.8                 |
| Compressor                  | 2500               | 4        | 2                  | 10                  |
| Welding machine             | 3500               | 4        | 5                  | 14                  |
| Other equipment             | 10000              | 2        | 3                  | 20                  |
| **Total per day**           |                    |          |                    | **81.6**            |
| **Total per month**         |                    |          |                    | **2529.6**          |

For calculation the required electricity, several types of power plants were chosen. Among most common solar power plants (SPP), wind power plants (WPP), diesel power plants (DPP) relying on parameters: generated power and cost we selected: SPP R-SOLAR 017 (7 items), WPP- SAV 15 kW (7 items), and DPP - AD-100 (YaMZ-236BE) (1 item). The parameters are listed in the table 3.

**Table 3. TEI of various power plants.**

| PP                    | Description          | Power, W | Quantity | Cost, min. rub. | Consumption of fuel, l/h | Operation hours per day, h | Consumption of fuel, l/d | Cost of fuel, rubl | Cost of fuel per annum, min. rub. | Amount for 5 years, min. rub. |
|-----------------------|----------------------|----------|----------|-----------------|-------------------------|---------------------------|---------------------|-----------------|---------------------------------|-----------------------------|
| DPP                   | AD-100 (YaMZ-236BE)  | 100      | 1        | 1,0             | 22.3                    | 24                        | 535.2               | 45              | 8,79                           | 44,95                       |
| SPP                   | R-SOLAR 017 Sokol    | 15       | 7        | 1,7             | 0                       | 24                        | 0                   | 0               | 0                              | 11,9                        |
| WPP                   | Air Vertical         | 15       | 7        | 1,0             | 0                       | 24                        | 0                   | 0               | 0                              | 7                           |

In Russia there are regions where wind power plants can become the main source of energy, for example: the islands of the Arctic Ocean, large areas of Eastern Siberia and the Far East. In this areas it is quite expensive to conduct power lines.

A comparative study of several variants of power plants has been performed:

1 option is to use only DPP, 100 kW. The total expense consist of: purchase of power plants and supplying fuel for 5 years (the price for liter of fuel is constant for 5 years).
2 option is to use DPP+SPP. The parameters of DPP are: power 40 kW, cost of 0.52 million rub. and a consumption 9.6 (l/h). The second component is SPP, consist of 4 items, with a production capacity of 15 kW and cost of 1.7 million rub.

3 option is to use the DPP+WPP. DPP is similar with 2nd variant, the second component is a wind power plant, consist of 4 units, with a production capacity of 15 kW and a cost of 1.0 million rub.

4 option is to use the DPP+WPP+SPP. 3 items of DPP and SPP, with a production capacity 15 kW and additional DPP with a production capacity of 10 kW, consumption of 3.5 (l/h) are chosen.

The results of the power grid suggested that the optimal solution simultaneously includes all 3 energy sources. The cost of electricity supply will increase by a factor of 2.5 after discarding one of them (1 and 4 options).

4. Conclusions
1. The Hybrid power plant model for the construction of buildings and structures in extreme climatic conditions, which includes DPP, WPP, SPP was proposed.
2. The efficiency of the electricity system, consisting of solar, wind and diesel power plants was shown.
3. The technical economic indicators (TEI) of various power plants were displayed.

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