

# Efficiency of using solar electric panels with grid-tie inverter for public buildings

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**Abstract.** It is shown that the operation of solar electric panels in the Republic of Khakassia of the Russian Federation should be carried out without power output to the grid. The scheme of connecting a solar power station to an existing building network and power station equipment were selected. A methodology for calculating the power of the inverter and solar panels was developed and applied based on the building's electric load schedule. Electricity rates for public buildings were analyzed. The discounted payback period for the use of a solar power station in parallel with the power grid was calculated. The applicability of solar panels operating in parallel with the power grid for public buildings of the Republic of Khakassia of the Russian Federation was revealed. Conclusions are made based on research results.

## 1. Introduction

Since 2014, in the Russian Federation there has been a steady increase in the installed capacity of solar power plants. The total capacity of such power station plants in August 2019 reached 957 MW. Basically, these are power station plants with capacity of 5-60 MW connected to the electric power system.

The use of solar panels by private households, companies, public buildings in the Russian Federation is not common. This is due to the fact that individuals and companies are legally prohibited to transfer electricity to the power grid. Thus, all generated electricity must be guaranteed to be consumed without being delivered to the electric power system.

In the main, the use of solar electric panels is the extent of remote power grid objects. In this case, an autonomous system with batteries and redundancy with a gasoline or diesel generator is used [1, 2].

However, trends in increasing the electricity rates and lowering the cost of solar panels in some cases make it advisable to use solar panels for parallel operation with the power grid [3, 4]. In particular, it is of interest to use solar panels for public buildings of educational, medical institutions and public authorities. The load curve of such buildings is in good agreement with the solar panels production schedule, and an increase in electricity rates reduces the payback period of solar panels [5, 6].

Thus, research on the use of solar panels in parallel with the power grid for public buildings in the Russian Federation is important today.

## 2. Calculation methods

The rated power of the selected inverter  $P_{inv}$  must not exceed the average value of the maximum power of the electrical load in the daytime  $P_{max}$

$$P_{inv} \leq P_{max}. \quad (1)$$

According to [4], the rated power of solar panels  $P_{SP}$ , taking into account the efficiency of the grid-tie inverter  $\eta_{inv}$

$$P_{SP} = P_{inv}/\eta_{inv}. \quad (2)$$

Investments in a solar power plant, taking into account installation works:

$$K = 1,3 \cdot (K_{SP} + K_{inv}), \quad (3)$$

where  $K_{SP}$  – cost of solar panels;  $K_{inv}$  – inverter cost.

Total electricity generated by a solar power plant per year

$$W_Y = \sum W_M, \quad (4)$$

where  $W_M$  – electricity generation for each month of the year under review.

Annual economic effect of installing solar panels

$$E = \sum(C \cdot W_M), \quad (5)$$

where  $C$  – electricity rate in the month under review.

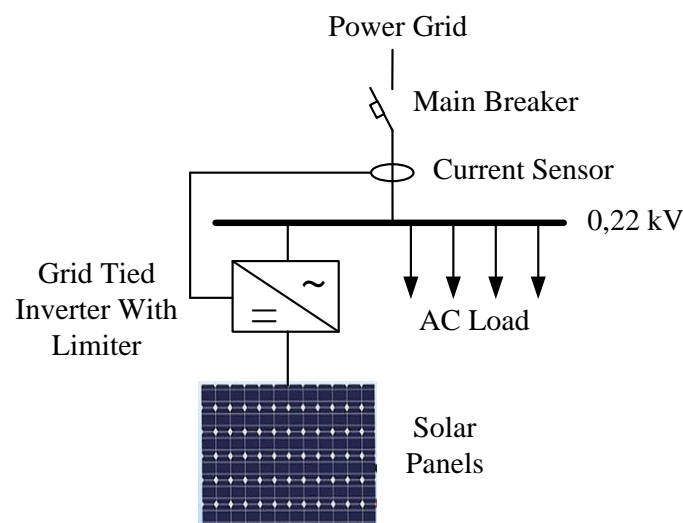
Discount payback period in view of the growth of electricity rates

$$T = \left[ \ln \left( 1 + \frac{K}{E} \cdot \frac{r-i}{1+i} \right) \right] \cdot \left[ \ln \frac{1+r}{1+i} \right]^{-1}, \quad (6)$$

where  $i$  – discount coefficient;  $r$  – average annual increase in electricity rates.

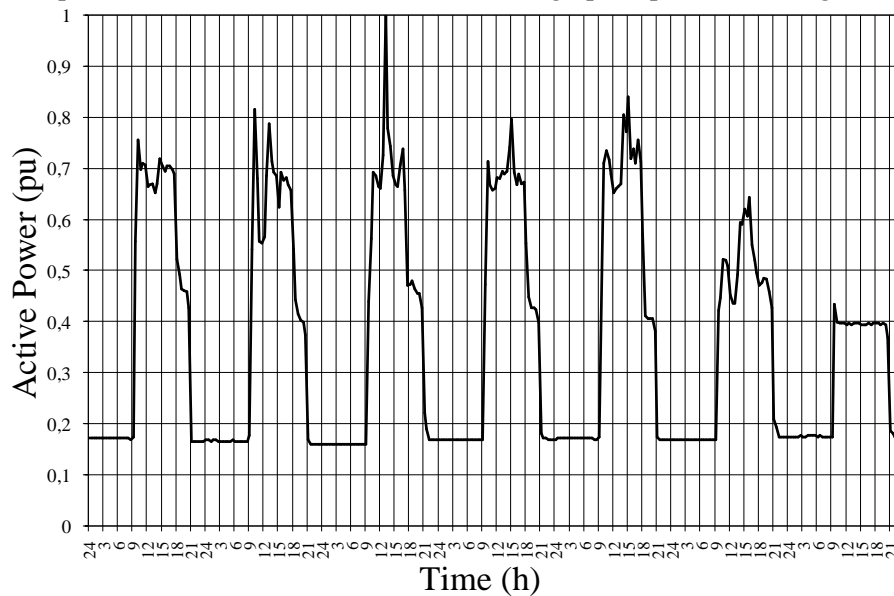
### 3. Research results

As the object of use of solar panels, consider the block of buildings of the Khakass Technical Institute - a branch of the Siberian Federal University, located in the city of Abakan of the Russian Federation. The suggested installation diagram is shown in figure 1.



**Figure 1.** Scheme of connecting a solar power station to the electrical grid of the academic building.

In studies, active power measurements were recorded. The graph is presented in figure 2.



**Figure 2.** Weekly chart of hourly values of active power of the facility.

The selection of the rated power of equipment is based on the analysis of the active power graphs of the facility concerned.

The graph is obtained for one phase, since it is planned to use a single-phase inverter. The graph has a base part and a daily peak load. The topping power is consumed every day from 9 am to 9 pm, which is well within the schedule of energy generation with solar panels. On weekends, there is a decrease in the daily peak, because on Saturday part of the staff is not working, and on Sunday the building is closed.

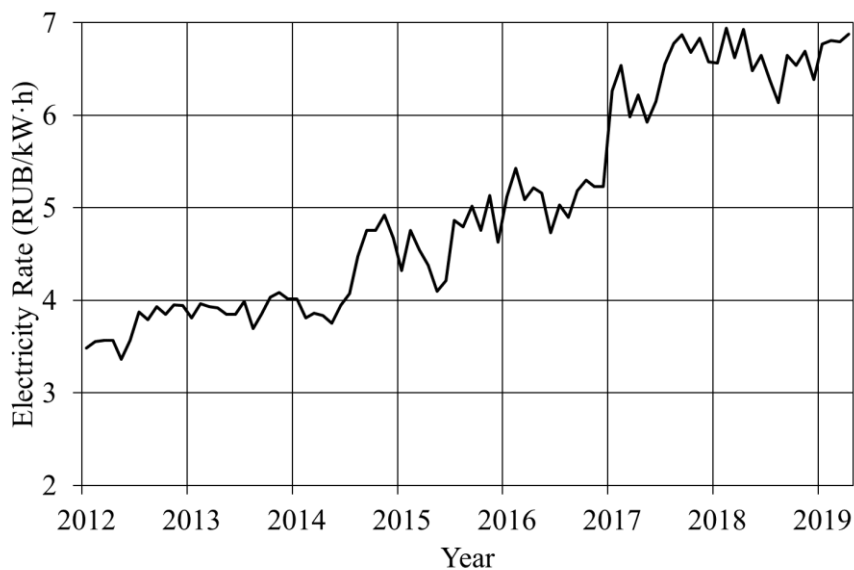
The average value of the phase power of the object concerned was  $P_{max} = 2.2$  kW. Using (1) the nearest standard inverter power value  $P_{inv} = 2$  kW is chosen. The cost of such a grid inverter with a power limiter is  $K_{inv} = 22,000$  rub. The inverter contains a power limiting device to prevent the transfer of excess power to the power line [7, 8]. The device monitors the load power and adjusts the inverter power to it.

The efficiency of the selected inverter  $\eta_{inv} = 0.92$ . Then, according to (2), the nominal power of solar panels is  $P_{SP} = 2.17$  kW.

Nine solar panels made of single-crystal silicon with a rated power of 250 W, with a total cost of  $K_{SP} = 9 \cdot 14,100 = 126,900$  rub. are selected. The rated power of the selected solar panels is  $P_{SP} = 2250$  W.

Investments in a solar power plant according to (3) will amount to  $K = 193,600$  rub.

The electricity rate for the facility concerned is  $C = 6.88$  rubles / kWh for April 2019. The rate is unregulated and reviewed every month. Over time, there is an increase in tariff (figure 3). For 2012-2019, the average annual tariff increase amounted to  $r = 10.3\%$ .

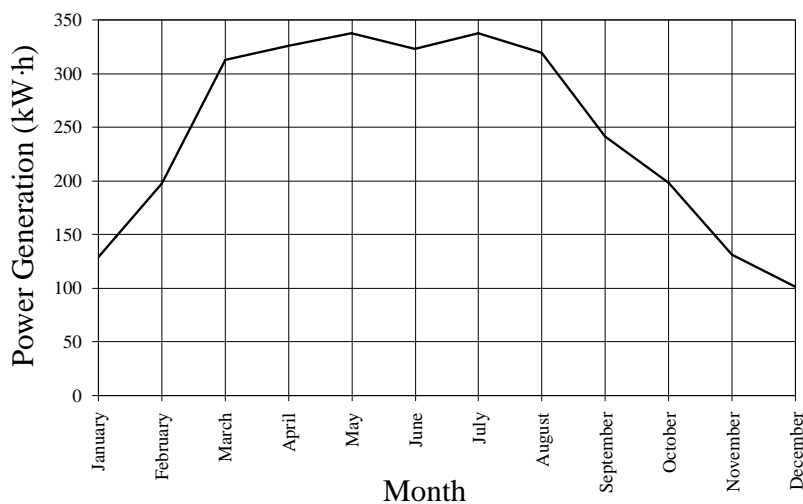


**Figure 3.** The dynamics of the electricity tariff.

The estimated electric generation by solar panels in the city of Abakan is presented in figure 4. The total electric generation by panels for the year (4) will be  $W_Y = 2954$  kWh.

The value of the economic effects for 2018 according to (5) will be  $E = 16,023$  rub.

Taken  $i = 0$ , since it is not planned to use borrowed funds. Then the discounted payback period (6) will be  $T = 7.9$  years.



**Figure 4.** Graph of electricity generation by solar panels during the year.

#### 4. Conclusions

As a result of studies, the applicability of solar panels operating in parallel with the power grid for public buildings of the Republic of Khakassia of the Russian Federation was identified.

A survey of equipment and schemes for the implementation of solar power plants operating in parallel with the network was performed. The scheme of connecting a solar power station to an existing building network has been selected. Single-crystalline solar panels with high efficiency and a service life of up to 30 years have been selected. The inverter used in the calculations has a power limiting device, since energy generation into the electricity supply company grid is prohibited.

A methodology for calculating the power of the inverter and solar panels was developed and applied, taking into account the real schedule of the building's electrical load. For the facility concerned, an analysis of the electricity rate for the last five years has been performed. A steady increase in tariff has been identified.

The discounted payback period for the use of a solar power station in parallel with the grid for the object concerned is calculated. The calculation takes into account the increase in the electricity tariff, as well as the interest rate when using a loan for the purchase and installation of a solar power station.

Based on the studies, the following conclusions are made:

1) The use of solar panels for the object concerned is appropriate, the payback period is significantly less than the service life of the power plant equipment.

2) The considered systems can be used for public buildings even in the absence of special "green" tariffs that allow selling electricity to the grid.

3) The use of solar power plants for public buildings makes it possible to replace from 30 to 70% of the energy consumed from electrical grids on sunny days. This helps to reduce electricity bills and reduce the environmental impact of traditional power plants.

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