параметры существующей системы энергоснабжения здания. На основании этих данных определяется количество и тип применяемых ГКУ, а так же необходимый набор приборов учета и контроля параметров ГКУ.

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ENERGY SUPPLY OF AN ADMINISTRATIVE BUILDING UNDER USING THE SOLAR ENERGETIC INSTALLATION

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Abstract. The analysis of the efficiency of the solar power plant for integrated power supply on the example of the building of mechanization and transport service (MTS) of the branch of PJSC “Kubanenergo” of the Sochi electric network in Sochi, provided partial replacement of energy received from existing networks of centralized heat and power supply. The calculation of parameters of heat and hot water supply system for a building MTS was made. There was estimated the economic feasibility of using agg hybrid solar power plant for integrated power supply of an administrative building in climatic conditions of Sochi.

Keywords: renewable energy sources, solar energy, hybrid solar collector, energy supply, energy saving.

Introduction

Rising energy prices are forcing consumers to find alternative sources of heat and electricity, one of which is solar energy, which can be converted into a used by a man form with the help of solar collectors and photovoltaic panels.

The economic feasibility of construction of a solar power supply system is mainly determined by costs of equipment and renewable energy.

The analysis of efficiency of solar energy system for integrated power supply is made on the example of the construction of mechanization and transport service (MTS) of the branch of PJSC “Kubanenergo” of Sochi electric networks, the appearance of which is shown in Figure 1, it operates under the partial replacement of energy received from existing networks of centralized heat and power supply.

Figure 1. The building of mechanization and transport service (MTS) of the branch of PJSC "Kubanenergo" of Sochi electric networks in Sochi

Object of location

For calculation there was used the climatic data for Sochi according to Building Codes and Regulations (BCR) 2.04.05-91 [1]:

Estimated summer temperature + 28 °C;

Estimated winter temperature + 4 °C;

Temperature of the coldest five-day period is 6 °C;

The heating period lasts 126 days.

The building of the mechanization and transport service (MTS) of the branch of PJSC "Kubanenergo" of Sochi electric networks in Sochi is made of reinforced concrete with insulation, the roof of the building is made of reinforced concrete slabs (1.5 x 6.0 m) with a heater made of claydite and several layers of roofing felt (Figure 2), this design has sufficient bearing capacity to accommodate solar collectors of the power supply installation.

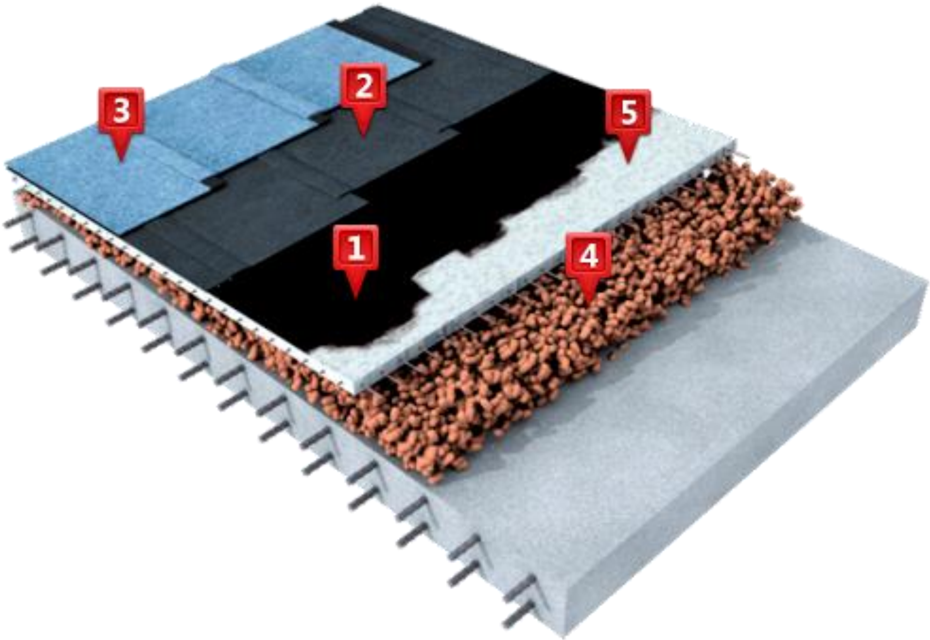

Figure 2. Roofing pie

The temperature inside the building during the heating period should not fall below + 18 ° C.

Parameters of heat supply system

The calculation of parameters of heating and hot water supply system for the MTS building. According to Table 1 the data of energy survey of the MTS building are used for it.

Table 1

DATA OF SPECIFIC INDICATORS OF HEAT ENERGY CONSUMPTION FOR HEATING, VENTILATION AND HOT WATER SUPPLY PER 1 M²

№	Qот (кВт·ч)/м2	Qвен(кВт·ч)/м2	Qгвс(кВт·ч)/м2	Q(кВт·ч)/м2
1.	20,18	20,18	1,095	41,45

When calculating the solar heat supply system (SHSS) and hot water is taken into account the year-round operation. The heating capacity of solar heat supply system and hot water annual period of its operation (QS) is determined by the equation:

$$Q_c = f \cdot Q \quad (1)$$

where f - share of total average annual heat load from solar energy 2.5%; Q – total annual load of heat supply, kW/h, so Qc=0,025x41,25=1,095k/Wh, with regard to the area of the MTS building; S=825,4m ^{2} , Qc=903,81kW/h or Qc=0,777 Gcal:

Specific annual heat supply is determined by the formula

$$g = \frac{Q_c}{F} \quad (2)$$

where F – area of the solar collection unit surface, the area of one solar collector F=2,049 m^2, so the area for 16 units is F=32,79 m^2

$$g = \frac{903{,}81}{32{,}79} = 27{,}56\ kW \cdot h/m^2 \text{ per year}$$

The specific annual heat capacity is a function of following parameters: geographical and climatic characteristics (φ, H, $t_{нв}$); features of solar collector (UL, (τα), Fr, ε); controlled parameters (t_r, t_x, g); parameters of the system (ε1, Va, f).

Solar collector characteristics of different designs are generalized in three types - I, II, III, which are used in finding the specific annual heat output SHSS q and are given in [5].

In our case, the solar collector refers to the II type of solar collectors. It is recommended to use a single-glass selective collector (type II) and a two-glass non-selective collector (type III) for SHSS. For heat water supply systems - single-glass collectors (types I, II). The schematic diagram of solar heating system is shown in Fig. 1 and provides the operation of the installation in different modes of heat supply.

The main parameter SHSS is the annual specific heat capacity determined for the equation

$$q = a + b\cdot(I - 1000),\ kW/h\ /m^2, \quad (4)$$

where I – average annual total solar radiation to horizontal surface, kW · h/m^2; we obtain it from [5] for Sochi, I=1365 kW · h/m^2; a, b – parameters determined from the equations (4) and (5)

$$a = (\alpha1+\alpha2r+\alpha3r2) + (\alpha4+\alpha5r+\alpha6r2)f + (\alpha7+\alpha8r+\alpha9r2)f2; \quad (5)$$

$$b = (\beta1+\beta2r+\beta3r2)+(\beta4+\beta5r+\beta6r2)f + (\beta7+\beta8r+\beta9r2)f2; \quad (6)$$

The r - characteristic of heat-insulating properties of the building fenced structures at a fixed load value of a solar collector presents the ratio of daily load of heating at external temperature of 0 °C to daily load of the solar collector. The greater the *r*, the larger the share of heating load compared with the share of load of a solar collector and the construction of the building in terms of heat losses is absolute; *r* = 0 is taken when calculating only the hot water system of the solar collector.

Define parameters a and b:

$$a = (607{,}0-1340+1900) = 1167;$$

$$b = (1{,}177-2{,}6+3{,}35) = 1{,}927.$$

α1 ... α9; β1 .... β9 – coefficients which are in Tables 2 and 3;

Table 2

VALUES OF THE COEFFICIENT A FOR SOLAR COLLECTORS OF II AND III TYPES

Type of the solar	Values of coefficient								
	α1	α2	α3	α4	α5	α6	α7	α8	α9
II	607,0	-80,0	-3,0	-1340,0	437,5	22,5	1900,0	-1125,0	25,0
III	298,0	148,5	-61,5	150,0	1112,0	337,5	-700,0	1725,0	-775,0

Table 3

VALUES OF THE COEFFICIENT B FOR SOLAR COLLECTORS OF II AND III TYPES

Type of the solar	Values of coefficient								
	β1	β2	β3	β4	β5	β6	β7	β8	β9
II	1,177	-0,496	0,140	-2,6	3,6	-0,995	3,350	-5,05	1,400
III	1,062	-0,434	0,158	-2,465	2,958	-1,088	3,550	-4,475	1,775

The equation (4) is applied to use the scheme shown in Figure 3.

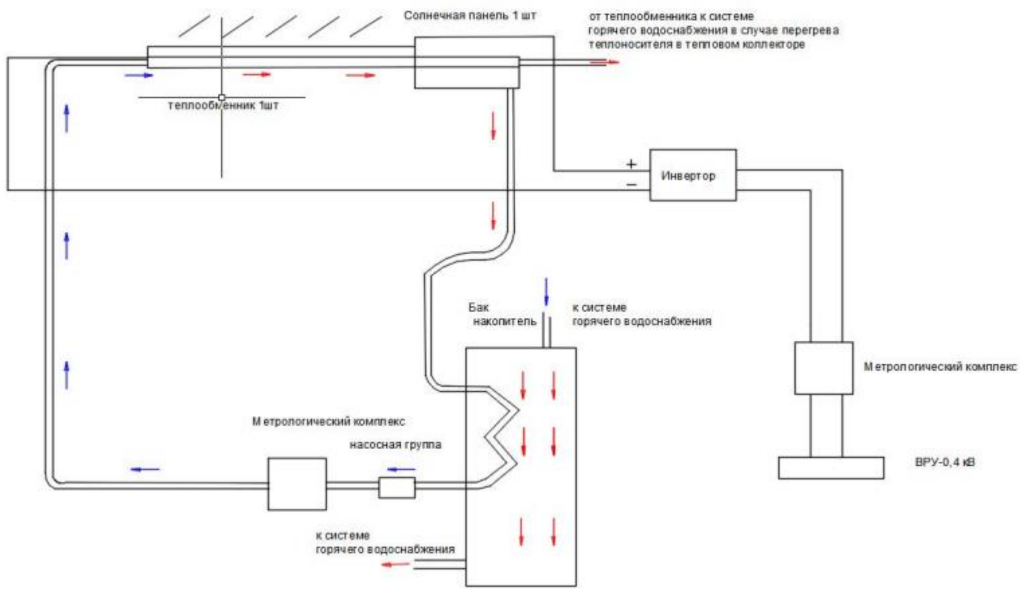

Figure 3. Basic scheme of solar hot water supply system

The equation (4) is applied at values:
$1050 \le I \le 1900$; $1 \le r \le 3$; $0,2 \le f \le 0,4$. The total area of the solar collector surface can be found according to the formula

$$F = Qc/q, \text{ m}^2. \quad (7)$$

Calculation of solar hot water supply system

Specific annual heat capacity (scheme in Figure 3) is defined by the formula

$$q = a + b(Is - 1050), \text{ kW} \cdot \text{h/m}^2 \quad (8)$$

Value of coefficients a and b are in Table 4.

$$q = 355 + 0,8(1365 - 1050)=607 \text{ kW}\cdot\text{h/m}^2$$

Table 4

VALUES OF COEFFICIENTS A AND B IN DEPENDENCE ON THE TYPE OF A SOLAR COLLECTOR

Type of the solar	Values of coefficient	
	a	b
I	235	0,75
II	355	0,80

The equation (8) is true at f = 0,5 and $1050 \le I \le 1900$. We will find specific annual productivity for hot water supply

$$q = a + b\cdot(Is - 1050), \text{ kW} \cdot \text{h/m}^2$$

For other values of the coefficient *f* replacement for studied types of solar collectors I and II, the value of specific annual heat capacity *q* should be increased (reduced) in accordance with the data in Table. 4 and is determined by the formula

$$qi = q\cdot(1 + \Delta q/100) , \text{ kW} \cdot \text{h/m}^2 , \quad (9)$$

where qi – specific annual heat capacity at values *f*, different from 0,5;

Δq – change of annual specific heat capacity of solar collectors, %.

Table 5

CHANGE IN THE VALUE OF SPECIFIC ANNUAL HEAT CAPACITY ΔQ FROM ANNUAL OUTPUT OF SOLAR RADIATION ON THE HORIZONTAL SURFACE H AND COEFFICIENT F

Values H, kW· h/m2	Values Δq, % at			
	f = 0,3	f = 0,4	f = 0,5	f = 0,6
Less than 1500	+17	+9	0	-10
More than 1500	+10	+5	0	-6

The value *f* of larger than 0,6 is obtained at H≥1700.

The solar radiation is recalculated when rays fall on the inclined plane, which is characterized by coefficients of the location of a solar collector for direct Ps and Pg of the inclined radiation [2].

The coefficient of the location of a solar collector for direct radiation Ps is a function of latitude φ=43.59 º for Sochi, the angle of inclination of the collector β, the angle of declination of the Sun δ, which in turn depends on time. The coefficient of the location of a solar collector for scattered radiation is determined by the equation

$$P = cos^2 \frac{\beta}{2} \quad (10)$$

where β – angle of solar collector's inclination to the horizon 45º. So,

$$P_s = cos^2 \frac{45{,}02}{2} = 0{,}75$$

$$P_g = cos^2 \frac{45}{2} = 0{,}76$$

The angle β is recommended to be taken equal to the latitude of the locality, β = φ for year-round systems and β = φ - 15º for systems operating in the summer.

The intensity of falling solar radiation for each light day is determined by the expression

$$g = P_s \cdot I_s + P_g \cdot I_g \quad (11)$$

where (Is) – direct intensity in the upper line; 1365 kW·h/m² ; (Ig). – scattered intensity in the lower line 1099 kW·h/m²

Then,

$$g = 0{,}96 \cdot 1365 + 0{,}76 \cdot 1099 = 1310 + 835{,}24 = 2145{,}24 \ kW \cdot h/m^2 per\ year$$

Calculate the intensity of solar radiation in the coldest month and the warmest one [5]

For January, where Is =37 kW·h/m²; where Ig =65,8 kW·h/m²

$$g_я = 0{,}96 \cdot 37 + 0{,}76 \cdot 65{,}8 = 85{,}53\ kW \cdot h/m^2$$

For July, where Is=206,8 kW·h/m²; Ig=95,78 kW·h/m²

$$g_и = 0{,}96 \cdot 206{,}8 + 0{,}76 \cdot 95{,}78 = 271{,}32\ kW \cdot h/m^2$$

The intensity of solar radiation qi varies throughout the year. Therefore, the efficiency of the installation will also change. The efficiency of the installation is determined by the expression [8]

$$\eta = 0{,}8\left(\theta - \frac{8k\Delta t}{g}\right) \quad (12)$$

where θ – a given optical characteristic of a solar collector are taken for single-glass collectors θ = 0,73 [6], for double-glass ones θ = 0,63 [6]; k – given coefficient of heat capacity of a solar collector, for single-glass ones – k = 8 W/(m² ·K), for double-glass – k = 5 W/(m² ·K) [6] ; Δt – difference between average temperature of boiled water and average temperature of external air. Find the coolant temperature at the inlet and outlet of the collector with regard to ambient temperature;

$$t_1 = t_x + 5;\ t_2 = t_г + 5 \quad (13)$$

where t_x and $t_г$ – water temperature at inlet and outlet of the collector; t_x=10ºC; $t_г$=70ºC, then t^1=15 ºC; t^2=75 ºC; $t_н^{ср}$ = 7,4 ºC

Then the difference between the average temperature of the coolant and the average daily temperature of the outside air will be

$$\Delta t = 0{,}5 \cdot (t_1 - t_2) - t_н^{ср}$$

$$\Delta t = 22{,}6\ {}^oC \quad (14)$$

There was made the calculation of the efficiency of the solar collector in winter (January)

$$\eta = 0{,}8\left(0{,}7 - \frac{8k\Delta t}{g}\right)$$

$$\eta = 0{,}8\left(0{,}7 - \frac{8 \cdot 8 \cdot 22{,}6}{85530}\right) = 0{,}55$$

There was made the calculation of the efficiency of the solar collector in summer (June)

t_x=17ºC; $t_г$=100ºC, then t^1=15 ºC; t^2=75 ºC; $t_н^{ср}$ = 29,8 ºC; Δt =11,7 ºC

$$\eta = 0{,}8\left(0{,}7 - \frac{8 \cdot 8 \cdot 11{,}7}{271320}\right) = 0{,}56$$

The total surface area of solar collectors with hot water is determined by the formula

$$F = \frac{Q_c}{g}$$

$$F = \frac{903{,}81}{27{,}56} = 32{,}79м^2 \quad (15)$$

Economic efficiency

The following formula is used to determine the economic payback of solar collectors with thermal backup:

$$T_{CK} = (K_г - K_т)/(Q \cdot C_T) \quad (16)$$

where Q — annual (seasonal) amount of heat energy produced by the solar collector Qc=0,777 Gcal; $K_г$ and $K_т$ — investments in solar collectors and renewable traditional energy source $K_г$=1014000 rub., C_T— cost of renewable energy 1 Gcal=1820 rub. for Sochi.

Solar installations of the objects which are not demanding the rigid maintenance of temperature of hot water and respectively duplication by the traditional power source (for example, showers or recreation centers), the term of economic payback can be calculated by the formula

$$T_{CK} = \frac{K_{CK}}{Q \cdot C_T} \quad (17)$$

The results of economic calculations of solar installations is reasonable as shown in [7], to supplement in some cases the calculations of terms of energy payback, when compared with the amount of energy produced by the solar installation and spent on the production of materials and its installation. Formulas (15) and (16) are given for the conditions of absence of interest rate for a bank loan, in the presence of which the formula (18) (by the analogy with the method of Doctor of Technical Sciences V. G. Gagarin [6] is taken the form:

$$T = \frac{\ln\left[\frac{1}{1-\left(\frac{K_г}{Q \cdot C_T}\right)\cdot(П/100)}\right]}{\ln(1+П/100)} \quad (18)$$

where П — annual interest rate for loan; 11%. Then,

$$T = \frac{\ln\left[\frac{1}{1-\left(\frac{1014000}{0{,}777 \cdot 10^9 \cdot 1820}\right)\cdot(11/100)}\right]}{\ln(1+11/100)} = 1\ год$$

In energy sector, the optimal payback period is from 5 to 7 years, in our case, the payback meets these indicators. According to the calculations, the efficiency of the installation was η=0.55 for the warm period and η=0.56 for the coldest month in the year, the efficiency can be increased if the calculation takes into account the electric module for electricity production. The payback period was one year. When adjusting the payback can be changed to an increase for another year, the MTS of building in Sochi can be 2 years with regard to the tests of the solar collector. The average payback time in energy sector is 5-7 years.

Hybrid solar collector

The use of hybrid plants for the production of electric and thermal energy has previously been considered in researches of scientists (for example, All-Russian Institute of Agricultural Electrification, Moscow [5]), but structurally solar collectors were developed in separate buildings, which reduced their overall efficiency.

The main features that characterize the developed combined solar collector:

- Single form factor: sandwich panel consisting of solar and solar collector elements to generate electric and thermal energy, respectively. At the same time, the solar collector, in addition to the main function, performs the function of an effective coolant of the solar panel, which increases its reliability and service life, and the solar panel in turn increases the efficiency of the solar collector.
- Due to the single structure and combination of solar collector panels, reduction of occupied area on the roof, reduction of wind loads and, as a consequence, load on the roof itself is achieved.
- The use of solar infrared battery can increase its efficiency by generating electricity not only from the visible part of solar spectrum, but also from the infrared region.
- The application of the solar collector allows you to save energy resources on lighting by up to 50 % and locally to organize hot water supply of the building.
- One panel of the solar collector (Figure 4) with overall dimensions of 1910x1073x55 mm allows to generate electric power to 135 W, heat power up to 700 W.

Figure 4. Appearance of combined solar collector.

It is supposed to install the solar collector on the roof (semicircle, in direction of Sun) in two rows at a distance of 1.9 m between rows, with the angle of panels' inclination to the horizon - 45º. This locality (Figure 5) is optimal for roof area, it does not allow shading the solar collector with its own structures and provides maximum insolation in accordance with recommendations [1,2,4,5].

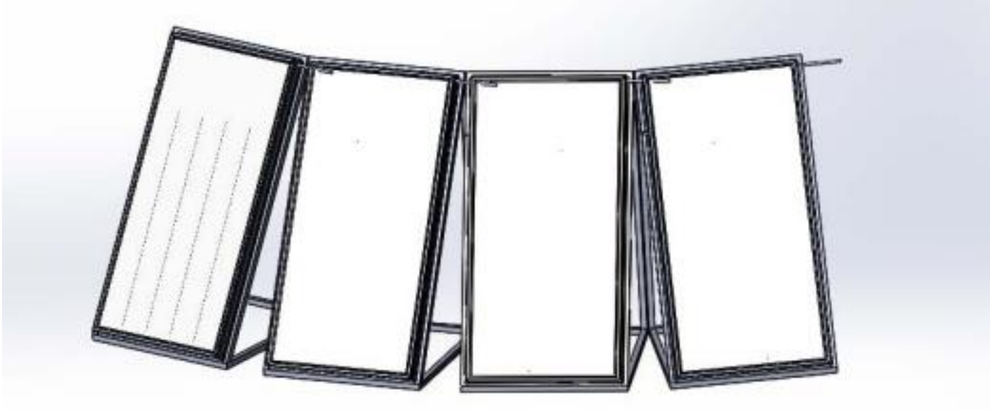

Figure 5. Location of combined solar collector panels while installing on flat roof

Structurally, the system of autonomous electric and thermal power supply with the use of solar collectors consists of: solar collector with a heat exchanger tank in a protective housing with transparent coating and heat insulating layer, inverter, circulation pump, metering and measuring energy parameters, cold water supply pipeline to heat exchange tank, hot water removal pipeline from heat exchange tank to hot water supply system.

Cold water from water supply system enters the coil located in heat exchanger, where it is heated and enters the coil of storage tank of hot water supply system, gives its heat and the process is repeated again. The cavity of heat exchanger is filled with non-freezing liquid to prevent damage during low ambient temperatures. In the period of high temperatures, in the case of coolant's overheating, it is provided a pipeline for removal of hot water from the coil of heat exchanger to hot water supply system.

To select the optimal configuration and parameters of the system of autonomous energy saving of buildings, it is necessary to take into account the following factors affecting its performance: climatic features of the region, intensity of solar irradiation, parameters of existing power supply system of the building. The number and type of solar collectors used as well as the necessary set of metering devices and control parameters of solar collectors are determined on the basis of these data.

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