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PECULIARITIES METHODS OF OPTIMIZATION CALCULATION OF PARAMETERS OF COMBINED SOLAR POWER PLANTS

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Abstract

This paper presents the types of combined devices, their appearance, methods of use, directions of use, and advantages in use. In addition, calculations of the optimization parameters of solar installations were considered.

Keywords: energy, solar flux, power, installation, combined system, photo module, modular type, collectors.

Introduction

The issues of calculation of combined solar power plants were considered by many authors [1-6]. Simple expressions have been proposed to determine the main energy parameters of combined systems. Based on these calculation methods, the parameters of combined solar power plants were calculated, and their efficiency, the amount of specific capital investments and electricity generation were determined. In addition, the tasks of choosing the optimal dimensions of the collectors, the design features of the collectors, the limits of operating temperatures to achieve maximum efficiency, etc., were solved.

Methodology

Let us analyze a simpler and sufficiently accurate method for calculating the main parameters of combined systems proposed in [7-13].

In order to optimize the parameters of the combined solar power plants under consideration, a mathematical model has been developed that makes it possible to carry out variant and optimization calculations for various input data [14-23].

The volume of the report allows only the main used calculated ratios to be given:

The power of the solar radiation flux incident on the station is equal to

$$q_S = S \cdot F \tag{1}$$

where: S - flux density of direct solar radiation,

F is the total aperture area of parabolic trough concentrators.

The electrical power of the photo batteries of the combined station N_O is:

N_E \u003d $q_S \cdot \eta_0 \cdot \varepsilon \cdot \eta_{PV}$ (2)

η_0 - optical efficiency of concentrators,

η_{PV} - efficiency of photo batteries, taking into account the degree of radiation concentration and operating temperature, ε - coefficient of filling the front surface of the radiation receiver with photocells.

The electric power in the steam turbine part of the station is equal to:

$$q_T\ \eta_{TH} = q_{S\_}\ \eta_0\ (\eta_{hl}^{rec} - \eta_{PV})\ \eta_{TH} \qquad (3)$$

η_{TH} is the thermodynamic conversion efficiency taking into account the efficiency of the turbine, generator, pumps and heat transfer losses.

Heat losses in the receiver of solar radiation are the sum of the actual radiation losses and convective heat transfer to the atmosphere

$$q_{hl}^{rec} = F_{fs}\ [\ k\sigma\ T_{fs}^4 - k\sigma\ T_a^4 + \alpha^a{}_{conv}\ (T_{fs} - T_a)] \qquad (4)$$

where F_{fs} is the area of the free (without thermal insulation) surface of the receiver, T_{fs} is the absolute temperature of this surface, T_a is the air temperature, k is the emissivity of the receiver, $\alpha^a{}_{conv}$ - coefficient of convective heat transfer to the atmosphere [24-31].

The calculation of heat transfer in the cooling channel of the receiver of solar radiation, which is also the steam generator of the thermodynamic part of the plant, is determined by the heat balance equation:

$$q_T = G_{wfc\_}\ (h_{1c} - h_{2c}) \qquad (5)$$

Where G_{wfc} is the flow rate of the working fluid (or a special coolant in the case of a two-circuit scheme) in the cooling channel, h_{1c} And h_{2c} - enthalpies of the working fluid at the outlet and inlet of the channel, as well as the heat transfer equation from photocells to the working fluid:

$$qT = \int_0^{\infty} K_{ec}\ (t_c - t_{wf})\ df + \int_{f_{ch}}^{f_{ec}} K_{ev}\ (t_c - t_{wf})\ df \qquad (6)$$

Here K_{ec} and K_{ev} - heat transfer coefficients in the economizer and evaporator sections of the channel, t_c and t_{wf} are the temperatures of the photocells and the working fluid, f_{ec} and f_{ch} are the areas of the washed surface of the economizer section and the channel as a whole [32-37].

In [3], the dependence of the photocell efficiency on the concentration of solar radiation and temperature is discussed in more detail. It is known that the smallest decrease in efficiency with increasing temperature is characteristic of photoconverters based on gallium arsenide. However, literature data on their effectiveness in the temperature range of 100-200 ℃ and concentrations up to 100 are few and largely contradictory.

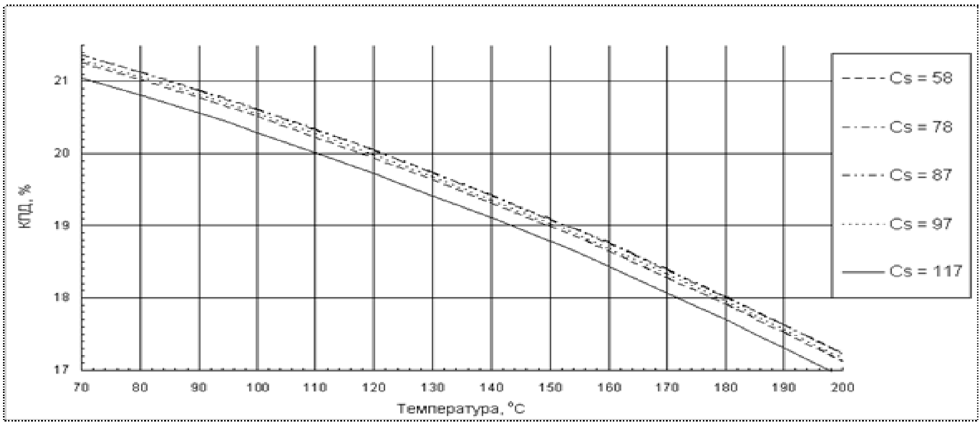

Fig 1. Dependence of efficiency. elements on concentration and temperature with an accuracy of ± 0.5 absolute processes [3]

Optimization calculations were carried out in the temperature range of the working fluid in front of the turbine 150-200 ℃ and solar radiation concentration 80-100. Since the efficiency of the photocell decreases with increasing temperature, while the efficiency of the steam-power cycle, on the contrary, increases, it is natural to expect some optimum that ensures the maximum efficiency of the combined installation. However, the calculated results showed that in the selected temperature range, its increase leads to an increase in the total efficiency of the installation, since the efficiency of the steam-power cycle increases more intensively than the efficiency decreases. photo batteries. Therefore, the desired optimum is at a temperature exceeding 200 ℃, however, for this region there are no experimental data on the efficiency of GaAs elements. Extrapolation to this area would be unreliable.

Total efficiency _ the gross of a single-circuit combined plant in the considered range of temperature and concentration is from 0.276 to 0.295, and the efficiency is net, taking into account the energy consumption for own needs, including the conversion of direct current into alternating current, from 0.256 to 0.277. For a double-circuit installation, efficiency. gross is from 0.256 to 0.274, and efficiency. net from 0.230 to 0.245. As follows from these data, the efficiency of a combined photo thermodynamic solar power plant is 1.5-2 times higher than the efficiency of photovoltaic and steam-powered solar plants used separately.

Results

The results of calculations also show that for a single-loop plant at a temperature before the turbine of 150, 175 and 200 ℃, the share of the steam turbine part of the plant in its total capacity is 0.45, respectively; 0.49 and 0.53, and for a double-circuit 0.42; 0.47 and 0.51.

The higher efficiency of a combined solar power plant cannot in itself unequivocally indicate its advantage without a feasibility study. The assessment of specific capital costs showed that they range from 1700 to 1850 dollars/kW for a single-circuit plant, and from 2050 to 2200 dollars/kW for a double-circuit plant in the considered range of temperature and concentration.

Since many types of equipment necessary for the creation of combined solar installations are not produced by the industry, the estimation of capital costs, of course, is associated with a number of assumptions. For example, we assumed that the cost per unit area of a GaAs photocell is 10 times higher than the cost per unit area of silicon photo batteries, the price of which is known. The cost of the concentrating system consists of the cost of the mirrors, the turntable on which the mirrors are mounted, the electric drive and the automatic control system. The cost of polished glass mirrors, according to the Institute of Technical Glass, if ordered for at least 5,000 m^2 is $100 per 1 m^2. The cost of the slewing bearing (SPU) was estimated based on the preliminary design of the parabolic trough concentrator module, commissioned by ENIN by one of the design institutes in the early 1990s. With a specific metal consumption of the OPU of 43.4 kg per 1 m^2 of the aperture area of the module, its specific cost in modern prices is 86.8 dollars/m^2. Similar assumptions are made for the module rotation control system, for the direct current to alternating current conversion system, etc.

It should be noted that, despite numerous proven and recommended methods for calculating combined systems, the choice of an effective variant seems to be a rather difficult task since the efficiency of the system depends on numerous factors. Simpler and more economical solutions to this issue allow efficient use of solar energy. This requires comparative calculations and analysis of the effectiveness of various schemes, as well as optimization of parameters and modelling of their operating modes. On this basis, it is possible to choose and recommend the most rational, technological and economic system, as well as the method of their calculation.

Combined systems are calculated by combining the calculation methods of individual subsystems into a common model and then optimizing the overall objective function. Below we consider the energy balance and the engineering methodology for calculating the main subsystem - a flat and parabolic trough collector.

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