OPTIMIZATION OF LOAD SCHEDULES OF ENTERPRISES WITH PHOTOVOLTAIC PLANTS
ОПТИМИЗАЦИЯ ГРАФИКОВ НАГРУЗКИ ПРЕДПРИЯТИЙ С ФОТОЭЛЕКТРИЧЕСКИМИ УСТАНОВКАМИ

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Abstract: At present, one of the most important issues at the level of various manufacturing enterprises is the development of ways for building and efficiently using of renewable energy sources, especially solar energy. In this regard, this article proposes a mathematical model of the problem of determining the optimal daily mode of operation of a photovoltaic system in an enterprise with a private photovoltaic system connected to the electrical system.

Ключевые слова: оптимизация, возобновляемый источник энергии, электростанция, график нагрузки, математическая модель, фотоэлектрическая станция..

Аннотация. В настоящее время одним из важнейших вопросов на уровне различных производственных предприятий является разработка путей создания и эффективного использования возобновляемых источников энергии, в частности солнечной энергии. В связи с этим в данной статье предлагается математическая модель задачи определения оптимального суточного режима работы фотоэлектрической системы на предприятии, имеющем собственную фотоэлектрическую систему, подключенную к электросети.

In the world today, consumers with power plants operating on renewable energy sources are using the particle swarm optimization method to optimally control the power, find the best configurations and determine the dimensions of the components. [1-3]. Many scientific publications have considered the issues of determining the optimal size of power plants working on renewable energy sources, and minimization of production and maintenance costs is considered as an objective function. However, optimal scheduling of consumer load schedules has not been considered in these developments [4-6].

The advantages of renewable energy sources, unlike oil and gas reserves, are that they are environmentally friendly and unlimited. Therefore, sooner or later, the energy supply system of all countries is moving to the widespread use of renewable energy sources. [7-8]. Therefore, a number of works are being carried out in the Republic of Uzbekistan on the construction and use of solar and wind power systems from devices operating at the expense of renewable energy sources. In order to effectively build and use such devices, it is necessary to determine their optimal parameters in advance based on the use of suitable mathematical models and algorithms.

In addition to the solar panels that generate electricity, the solar photoelectric power station installed at the enterprise includes additional equipment, such as hybrid inverters, a device that controls the power generated in the photoelectric station and converts direct current into alternating current, and a monitor system that monitors the parameters of the station's operating mode.

Among these equipments, it is possible to include the accumulator battery, which is used for rational use of the generated electricity.

In solving this problem, the electric capacity of the battery W, the load graph of the consumer for the planned day $P_L(t)$, the definition of the purchase of electricity from the electric power system C_t, the power graph of the solar photovoltaic power plant $P_{PV}(t)$, the minimum and maximum limit capacities of the battery battery charging (the discharge capacity is taken with a negative sign) is known data. The unknowns that can be determined as a result of solving the problem are the optimal active power graph $P_{G.PV}(t)$ provided by the solar photovoltaic power plant to the consumer, the optimal active power graph received from the electric power system (optimal load graph of the consumer in relation to the electric power system) $P_{PS}(t)$ and the optimal charging of the accumulator battery/ the discharge power graph is $P_{B.PV}(t)$.

To solve this problem, the following mathematical model of the optimization problem is proposed. According to it, the objective function to be minimized is the function of the total costs associated with the electricity received from the solar photovoltaic power plant and the electric power system during the day [9]:

$$З=\sum_{t=1}^{24}\left[C_t P_{PS}^{(t)}+\beta P_{G.PV}^{(t)}\right]\rightarrow \min$$

here, C_t is the price (tariff) of electricity received from the electric power system at t-th hour of the day; $P_{PS}^{(t)}$ – active power received from the electric power system at t-th hour of the day; $P_{G.PV}^{(t)}$ is the active power provided by the solar photovoltaic power plant at the t-hour of the day; β - the coefficient that includes the costs of production, installation, operation and maintenance of solar modules and equipment serving it is calculated.

Boundary conditions:

active power balance in enterprise for each hour of the day:

$$P_{PS}^{(t)}+P_{G.PV}^{(t)}=P_L^{(t)},\ \ t=1,\,2,\,\ldots,\,24$$

the condition that for each hour of the day the power of photovoltaic plant is equal to the sum of power consumed to charge the battery and power output from the inverter:

$$P_{PV}^{(t)} - P_{B.PV}^{(t)} = P_{G.PV}^{(t)}, \; t = 1, 2, \ldots, 24$$

the limit condition for the maximum possible charge/discharge capacity of the battery (negative sign means the discharge power):

$$-P_{B.PV.\max} \le P_{B.PV} \le P_{B.PV.\max}, \; t = 1, 2, \ldots, 24$$

inequality on minimum and maximum power that can be produced every hour of the day (determined by the power of inverter):

$$0 \le P_{G.PV}^{(t)} \le P_{G.PV.\max}^{(t)}, \; t = 1, 2, \ldots, 24$$

inequality on energy capacity of the battery:

$$W_{bal.PV} + \sum_{k=1}^{t-1} \left[P_{PV}^{(k)} - P_{G.PV}^{(k)} \right] * \Delta t^{(k)} \le W_{PV}, \; t = 2, 3, \ldots, 24$$

where: $P_{PV}^{(t)}$ is the active power of the solar photovoltaic power station at the t-th hour of the day; $P_{L}^{(t)}$ – the total active power load of the consumer at the t-th hour of the day; $P_{B.PV.max}$ is the maximum possible charge or discharge capacity of the battery; $P_{G.PV.max}^{(t)}$ is the maximum power that can be produced for consumption by the solar photovoltaic power plant at the t-th hour of the day; W_{PV} is the electrical capacity of the battery installed in the solar photoelectric plant; $W_{bal.PV}$ is the remaining electric charge of the battery installed in the solar photovoltaic power station from the previous day

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