Study of work efficiency of the energy system at the introduction of small hydropower plants

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Abstract. The paper describes a comprehensive approach to assessing the effectiveness of introducing renewable energy sources by the example of switching on small hydropower plants in a certain section of the energy system. The study combines an algorithm for selecting the composition of the included generating equipment in the case of connecting new consumers, and a developed program for calculating and constructing generation and load schedules. The results of the research are presented on the example of the introduction of mini hydroelectric power plants through joint work, the developed approach and the program.

1. Introduction

Currently, technologies based on renewable energy sources (RES) are developing worldwide. And our country is no exception. According to the state energy strategy of Russia until 2035, the main strategic guidelines include the creation of alternative energy sources based on renewable energy sources, which increase energy and environmental safety in the region and save non-renewable energy resources. The location of such a generation near the consumer will increase the capacity in electric networks, reduce the loss of electricity during transmission, and give autonomy of power supply in hard-to-reach areas. This is a positive trend in the development of renewable energy. Such sources of energy will save natural fuel, fully utilize the potential of natural resources.

2. Materials and methods

To conduct a study of the efficiency of the energy system during the implementation of small hydropower plants, a comprehensive approach was used to apply the proposed algorithm for determining the impact on the regional fuel balance of new generating capacities and the developed program in VBA for calculating and scheduling loads and power flows \cite{1}.

To accomplish this task, an algorithm is presented for choosing the composition of the included generating equipment when a new consumer is connected to the power system (figure 1). When connecting new capacities, the consumer chooses the method of generating electric energy: its own generation or the country's combined energy system.

In the second case, an application for a technological connection to the grid company is submitted. The question of how to acquire electrical energy is being addressed. All electricity generated at hydroelectric power stations, power plants, thermal power plants, nuclear power plants, as well as generation sources operating on renewable energy sources, is sold by generating companies in the capacity market. Depending on the consumer's reliability category (according to the PUE of Chapter...
1.2, paragraphs 1.2.17–1.2.21), the number of independent sources of electricity that will supply the consumer with electricity is selected. Next, modeling is carried out of various options for supplying power to the consumer, taking into account the location of power sources, losses in power lines, fuel consumption for the production of 1 kWh of electric energy, a model with more efficient use of fuel resources is selected.

When calculating the effect of introducing a small generation in the territory under consideration in the proposed algorithm, it is necessary to change the parameters for power sources based on renewable energy sources with a known declared load.

The main actions of the algorithm:
a) selection of power and location of a new source of small generation;
b) determination of the closest consumers of electric energy;
c) creating a scheme of power lines from a source of small generation to a consumer with the calculation of losses in it;
d) the definition of existing lines suitable for the consumer;
e) calculation of losses in power lines from the current source of generation to the consumer with a decrease in power output due to the input of small generation;
f) determination, reduction of losses in electric networks after the introduction of small generation;
g) calculation of the saved fuel at the heat station as a result of a decrease in the power output [2].

![Figure 1. Block diagram of the selection of the composition of the included generating equipment.](image-url)
In the developed program, the algorithm consists of calculating the main parameters of the graphs of electrical loads. The block diagram shown in figure 2 describes an algorithm for calculating the main parameters of the load graph and its construction for analysis and smoothing of peak loads.

Figure 2. The block diagram of the proposed algorithm of the program.

The main actions of the software algorithm:

a) calculation of maximum, minimum and average daily capacities;
b) the calculation of the fill factors of the graph, the unevenness of the graph and the shape of the graph;
c) the calculation of the annual time of use of the maximum load, the annual time of use of the maximum power loss

d) the calculation of reactive and full power loads;
e) daily load schedules of all capacities are built;
f) measures are taken to regulate the loads (recounting) [3].

In the course of the work, the section of the electric network X of the power system was investigated. Three options for connecting the nth consumer from different generation sources were considered. The following conditions and limitations are indicated: the consumer in question is currently powered by a hydroelectric power station. The power supply to the consumer and the possible reduction in the loss of transmitted power are considered when connected to the CHPP located next to the consumer and the introduction of a small generation, more specifically Mini Hydroelectric Power Station on the River R near the consumer. For the selected source, a small river R and sufficient terrain for its construction are located nearby. The pressure for the station will be 4.4 m, the flow rate is 35 m$^3$/s, the utilization rate is 0.55, and the guaranteed rated power is 831 kW. This capacity will be considered sufficient for the power supply to the consumer.

Figure 3 shows the consumer power circuit from three-generation sources.

![Figure 3. Consumer power scheme from three sources of generation.](image)

We calculate the following consumer power options:

a) from three sources of generation: HPPs, TPPs and Mini HPPs;

b) from two sources of generation: hydroelectric power station and Mini hydroelectric power station;

c) from two sources of generation: TPP and Mini HPP.

3. Results of experimental studies

According to the algorithm, power losses in the network sections were calculated (table 1).

Using the power of Mini Hydroelectric Power Station will reduce losses in overhead lines, as well as reduce the cost of purchasing additional capacity to cover these losses. The calculation results showed that the implementation of Mini HPPs with guaranteed power of 831 kW will reduce grid
losses by 17.27 kW, and the power supplied to the HPP will be reduced by 848.3 kW. It was also
revealed that the power supplied to the CHPP can be reduced by 847.8 kW.

**Table 1.** A summary table of the results obtained with the implementation of the Mini HPP.

| Circuit number | Plot                  | Losses, kW | Power generated by the generation source, kW | Power issued by the source, taking into account losses, kW | Amount of fuel saved, t/year | Loss reduction in power lines, thousand kWh/year |
|----------------|-----------------------|------------|---------------------------------------------|-----------------------------------------------------------|-----------------------------|-----------------------------------------------|
| 1              | Mini HPP Consumer     | - 2,6      | 831                                         | 833,6                                                     | -                           | 23                                            |
| 2              | HPP Consumer          | - 17,27    | 848,27                                      | -                                                         | 151                         |
| 3              | CHPP Consumer         | - 16,83    | 847,83                                      | 911                                                       | 147                         |

Using the program, we got the following graphs of consumer loading and generation taking into
account losses (figures 4).

**Figure 4.** Daily load and generation schedule.
Figure 4 shows that the daily load schedule and the generation schedule of Mini HPPs with losses are practically indistinguishable. When powered by hydropower plants and thermal power plants, losses are approximately equal to 2% of the total power output. When modeling processes in the X power system with the introduction of renewable energy sources, the following results were obtained:

When introducing a Mini HPP, two possible scenarios are possible:

a) losses in the electric grid complex will decrease by 151 thousand kWh per year. The released capacity of hydroelectric power stations can be transferred to other parts of the power system, this is possible both during peak hours of the load and in the base.

b) losses in the electric grid complex will decrease by 147 thousand kWh per year, and fuel economy at the TPP will amount to 911 t. t. per year. The use of a comprehensive assessment of the introduction of the new generation made it possible to assess how much the losses in electric networks will decrease and how much fuel costs will be reduced at thermal power plants when new generation sources are connected to the power system [4].

4. Conclusions
The study showed that when the calculation and modeling methods work together, the accuracy of the selection of generating equipment increases, which contributes to an increase in energy efficiency. The load graphs clearly show the overloaded sections of the network, as well as the underload of consumers. This approach contributes to the modeling of various network load options, both from traditional and alternative energy sources, and the selection of the best option. When applying the latter, an increase in energy and economic efficiency was revealed. In the case of the introduction of small hydropower plants in the power system, it is also possible to unload other generating facilities of the studied area.

References
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