Modelling of developing capacity of power systems based on hybrid power complexes by reliability indicators

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Abstract. Currently, short-term power supply failures of consumers are the main cause of failures in the stability of normal operating modes of the system. The result of real power supply failures is emergency modes due to improper load distribution. We propose the joint operation of algorithm and the program for forecasting capacity of power transmission lines in order to ensure reliable uninterrupted operation of power system. The results of the study are presented on the example of hybrid operation of the Thermal Power Plant (TPP) and Mini hydroelectric power plant (HPP).

1. Introduction
With the development of heat installations, the problem of transporting energy to consumers arises. Due to the deterioration of energy equipment, power is not fully delivered in many consumption areas. The use of hybrid energy complexes is the main way to increase the quality of energy output, as well as increase the throughput. The work of hybrid power complexes involves balancing the power in the considered power section, that is, they are a primary cell with distributed generation, distributed storage and distributed controlled energy consumption[1].

2. Materials and methods
To study the efficient and sustainable operation of the energy system when introducing renewable energy sources, an integrated approach is proposed to use the developed algorithm for determining the impact of new generating capacities on the fuel balance of the region and a program for calculating parameters and compiling load schedules.

To perform this task, an algorithm is presented for selecting the composition of the included generating equipment when connecting a new consumer to the power system (Figure 1).
The main actions of the proposed algorithm:

a) selecting of the power and location of the new small generation source;

b) determination of the nearest electric power consumers;

c) creation of a diagram of transmission lines from a small generation source to a consumer with calculation of losses in it;

d) identification of existing lines suitable for the consumer;

e) calculation of losses in power transmission lines from the current generation source to the consumer at reduction of output power due to input of small generation;

f) determination of how much loss in electrical networks decreased after the introduction of small generation;

g) calculation of saved fuel at the heat station as a result of reduction of output power[2].

Program has been developed to calculate parameters and plot energy loads. The flowchart shown in figure 2 describes the algorithm for calculating the basic parameters of a load graph and constructing it for analyzing and smoothing peak loads [3].

Figure 1. Block Diagram of Selection Equipment Composition Source.

The main actions of the proposed algorithm:

- a) selecting of the power and location of the new small generation source;
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- d) identification of existing lines suitable for the consumer;
- e) calculation of losses in power transmission lines from the current generation source to the consumer at reduction of output power due to input of small generation;
- f) determination of how much loss in electrical networks decreased after the introduction of small generation;
- g) calculation of saved fuel at the heat station as a result of reduction of output power[2].

Program has been developed to calculate parameters and plot energy loads. The flowchart shown in figure 2 describes the algorithm for calculating the basic parameters of a load graph and constructing it for analyzing and smoothing peak loads [3].
The main actions of the software algorithm:

a) the calculation of maximum, minimum and average daily capacity;

b) the calculation of graph filling factors, graph unevenness and graph shape;

c) the calculation of annual usage time of maximum load, annual usage time of maximum power losses;

d) the calculation of reactive and full capacity of loads;

e) daily load schedules of all capacities are built;

f) load control measures (recalculation) are performed [4].

As a test of the integrated approach, a simulation of the study of the efficiency and reliability of the energy section was carried out. Figure 3 shows a simplified power supply diagram of the power section, where the power generation source is the HPP. Consider the power supply option from the hybrid power complex: HPP and Mini hydroelectric power station (HPP) (Figure 4).

**Figure 2.** Block Diagram of the program algorithm.
Hydroelectric Power Plant. The consumer during power supply from the HPP are 2% more than during power supply from the Mini HPP-2 MW. It is located next to a small river. Let's denote the output power of a TPP-74 MW, of around 2 MW. It is located next to a small river. Let's denote the output power of a TPP-74 MW, TRDNS-35000/110, TMN-10000/35, TDTN-25000/110, TDC-80000/110

\[ \text{Transformer Parameters} \]

| Name of the transformer | \( U_{1} \) nom, \( kV \) | \( U_{2} \) nom, \( kV \) | \( S_{\text{nom}} \) MW | \( \mu_{k} \) | \( \Delta P_{\text{short}} \) kW | \( \Delta P_{\text{non-load}} \) kW | \( R_{k} \) Ohm | \( X_{k} \) Ohm | \( B_{k} \) \( 10^{5} \) S | \( K_{t} \) |
|------------------------|-----------------|-----------------|-----------------|---------|-----------------|-----------------|--------|--------|-----------------|--------|
| TDC-80000/110          | 6.3             | 110             | 80              | 10.5    | 0.6             | 310             | 70     | 0.71     | 19.2             | 11.34  | 0.057 |
| TMN-2500/110           | 11              | 110             | 25              | 10.5    | 1.5             | 22              | 5.5    | 42.6     | 508.2            | 28.35  | 0.1   |
| TDTN-25000/110         | 10.5            | 110             | 25              | 10.5    | 0.7             | 120             | 27     | 1.5      | 56.9/0/          | 18.9   | 0.318/|
| TMN-10000/35           | 10.5            | 35              | 10              | 7.5     | 0.8             | 65              | 14.5   | 0.88     | 10.1             | 5.923  | 0.286 |
| TRDNS-63000/35         | 10.5            | 36.75           | 63              | 11.5    | 0.3             | 250             | 50     | 0.1      | 2.5              | 42     | 0.28  |

In the initial section of the network under consideration, the consumer is determined to have a load of around 2 MW. It is located next to a small river. Let's denote the output power of a TPP-74 MW, the power of a Mini HPP-2 MW.

3. Results of experimental studies

Having calculated the power flows, we reveal that the losses in the lines to the designated consumer during power supply from the HPP are 2% more than during power supply from the Mini Hydroelectric Power Plant.

Figures 5-6 show power supply diagrams with power overflows.
Figure 5. Section of Power Flow Diagram at Power Supply from HPP.
Section of power flow diagram at power supply from HPP and Mini HPP.

This pattern is due to the fact that the location of the Mini Hydroelectric Power Plant is quite close to the consumer. Using the power of Mini HPP will reduce losses in overhead lines, as well as reduce the cost of buying additional capacity to cover these losses [5]. Table 3 shows the results of calculations at different types of power supply.

**Table 3. Summary table of results obtained**

| Scheme No. | Site | Losses, kW | Power output from generation source, kW | Power output by source including losses, kW | Quantity of saved fuel, t at. r. / year |
|------------|------|------------|----------------------------------------|--------------------------------------------|----------------------------------------|
| 1          | Mini HPP - Consumer | 0.6 | 1.5 | 1.6 | - |
| 2          | TPP - Consumer | 3.4 | 4.9 | 849 |

Mini HPP is a renewable energy source that does not require fuel costs. Thus, when the consumer is supplied with power from the Mini-Hydroelectric Power Station, fuel is saved at the HPP for 849 TPA.

The main indicator of reliability of the line capacity is the static stability factor for power (Kp) and voltage (Ku) [6].

Figure 5 shows the power flow graphs at different circuit nodes created in the program.
Analysis of the circuit units shows that when connecting a new source, it is not allowed to reduce the voltage below the required one, static stability in terms of power and voltage is within the permissible limits. The capacity reserve at power supply from Mini Hydroelectric Power Plant is 1.89% more than at power supply from HPP[7].

4. Conclusion

According to the results of the study, it can be concluded that the proposed joint work of the algorithm and program is reliable and adequate.

The integrated approach will allow to fully simulate the process of power transfer from generating facilities to consumers. It will also make it possible to assess the possibility of energy transfer in certain sections of the power system and to clarify the throughput from the point of view of reliability [8].

In the course of application of the mathematical model of the operational calculation of capacity when introducing new capacities at the HPP the patterns of forecasting capacity can be revealed in order to reduce investment costs for the unreasonable development of power lines, as well as to determine a qualitative approach where it is necessary to improve safety and reliability.

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References

[1] M.M. Sultanov, I.A. Boldyrev, Yu.A, Gorban. (2019). Research of dynamic characteristics of signals for calculation of technical and economic indicators and increase in power efficiency of the equipment of thermal power plant. IOP Conference Series: Materials Science and Engineering. 552. 012007. 10.1088/1757-899X/552/1/012007.

[2] Study of energy efficiency of generating systems in modern conditions of energy consumption: teaching manual/M.M. Sultanov, O.I. Zhelyaskova, I.L. Riga. Volzhsky: Branch of FSBOU VO “NIU” MPEI “in Volzhsky, 2019. 59 pages.
[3] Sultanov M.M., Zhelyaskova O.I., Zhelyaskov S.S. Modeling the process of analyzing the operation of the energy system at peak loads//Twenty-fifth inter-university scientific and practical conference of young scientists and students, Volzhsky, May 22-31, 2019: theses of reports. Volzhsky: Branch of FSBOU VO "NIU" MPEI "in Volzhsky, 2019. 86-88 pages.

[4] Sultanov M.M., Zhelyaskova O.I. Program for calculating parameters and plotting the energy system. Federal Intellectual Property Service. Certificate No. 2019667320 of 23.12.2019.

[5] M.M. Sultanov, I.A. Boldyrev, Yu.A. Gorban. Electrical generation unit technical and economic indexes parameter study. (2019) International Youth Conference on Radio Electronics, Electrical and Power Engineering (REEPE), 14-15 March 2019: – IEEE, Moscow, Russia, ISBN: 978-1-5386-9334-6.

[6] M.S. Ivanitckii, M.M. Sultanov, V.M. Trukhanov. (2020). Analysis of the Influence of Operating Modes of Heat Generating Plants on the Energy and Environmental Safety of Thermal Power Plants. 1-5. 10.1109/REEPE49198.2020.9059205.

[7] Sultanov, M & Truhanov, V & Gorban, Yu. (2019). Parametric model for predicting the reliability of heat power equipment of TPP. IOP Conference Series: Materials Science and Engineering, 552. 012006. 10.1088/1757-899X/552/1/012006.

[8] V.M. Truhanov, M.M. Sultanov, Yu.A. Gorban. Nonparametric model for predicting the reliability of heat power equipment of TPP. (2019) International Youth Conference on Radio Electronics, Electrical and Power Engineering (REEPE), 14-15 March 2019: – IEEE, Moscow, Russia, ISBN: 978-1-5386-9334-6.