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PROSPECTS FOR DEVELOPMENT OF ELECTRIC POWER SYSTEM OF THE REPUBLIC OF SAKHA (YAKUTIA)

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Keywords: electric power system, power district, transmission line, substation, hydroelectric power plant, power flows.
Abstract. This article examines transformation processes in the electric power sector of the Republic of Sakha (Yakutia), specifically the integration of previously isolated power districts and their connection to the unified power system of the East. The processes of power transmission from the western power district of Yakutia to the unified power system of the East are described, static and dynamic stability calculations of the system are performed, and conclusions are drawn based on the calculation results.

ПЕРСПЕКТИВЫ РАЗВИТИЯ ЭЛЕКТРОЭНЕРГЕТИЧЕСКОЙ СИСТЕМЫ РЕСПУБЛИКИ САХА (ЯКУТИЯ)

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Ключевые слова: электроэнергетическая система, энергорайон, линия электропередачи, подстанция, гидроэлектростанция, перетоки мощности.
Аннотация. В статье рассматриваются трансформационные процессы в электроэнергетике Республики Саха (Якутия), а именно объединение ранее изолированных энергорайонов между собой, а также присоединение их к объединенной энергетической системе Востока. Описаны процессы по выдаче мощности из западного энергетического района Якутии в объединенную энергосистему Востока, произведены расчеты статической и динамической устойчивости системы, сделаны выводы по результатам расчетов.

Introduction. The power system of the Republic of Sakha (Yakutia), further in the text Yakutia, includes centralized and decentralized power supply zones. Centralized power supply covers 36% of the republic's territory, home to 85% of the population [1].

The centralized power supply zone consists of three power system regions the Western (WER), Central (CER), and South Yakut (SYER) regions of Yakutia's power system which currently operate as part of the Eastern Unified Power System (EUPS) [2].

Until January 2019, the WER power supply system was isolated from the Yakut and Amur Unified Power Systems. The isolated regions of Yakutia had surplus power generated from hydroelectric power plants (HPPs), thermal power plants (TPPs), and diesel generators (DPPs). In January 2019, by introducing new 220 kV overhead power transmission lines the connection of the energy-surplus WER with the energy-deficient CER through the SYER, as well as with the EUPS, was achieved [3].

In this work, some statistical data is taken from the Decree of the Head of Yakutia (Decree of the Head of the Republic of Sakha (Yakutia) dated April 29, 2022 No. 2424 "On the scheme and program for the development of the electric power industry of the Republic of Sakha (Yakutia) for 2022-2026". – URL: https://docs.cntd.ru/document/406063293).

Power Distribution from WER. The WER power system covers the following territories of Western Yakutia: Mirninsky, Olyokminsky, Lensky, Suntarsky, Nyurbinsky, Vilyuysky, and Verkhnevilyuysky uluses (districts).

WER is connected to:

− SYER via the 220 kV NPS-15 – Olyokminsk No. 1 overhead line with a branch to the NPS-14 substation, and the 220 kV NPS-15 – Olyokminsk No. 2 overhead line with a branch to the NPS-14 substation;

− the Irkutsk Region power grid via the 220 kV Peleduy – NPS-9 No. 1 overhead line, the 220 kV Peleduy – NPS No. 9 No. 2 overhead line, the 220 kV Peleduy – Sukhoi Log No. 1 overhead line, and the 220 kV Peleduy – Sukhoi Log No. 2 overhead line. Under normal conditions, the 220 kV Peleduy substation is supplied by the Irkutsk Region power grid.

A map of the Irkutsk Region power grid showing substations and overhead lines is shown in figure 1.

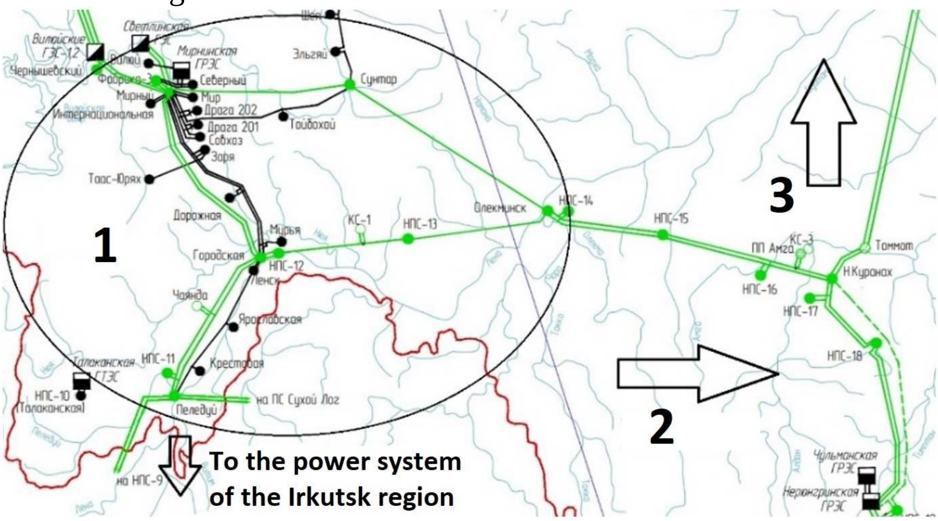

Fig. 1. Map of the WER (220 kV overhead power lines and substations are shown in green, and 110 kV in black), where 1 – WER, 2 – SYER, 3 – CER

The CER is connected to the SYER via the 220 kV Tommot – Maya 1st circuit overhead power line and the 220 kV Tommot – Maya 2nd circuit overhead power line.

The SYER is connected to:

− the Amur Region power grid via the 220 kV Neryungri TPP – Tynda overhead power line with a branch to the NPS-19 substation, the 220 kV Tynda – Nagorny overhead power line with a branch to the NPS-19 substation, the 220 kV Yuktali – Khani overhead power line with a branch to the Olekma substation, the 220 kV Prizeyskaya – Elgaugol No. 1 overhead power line, and the 35 kV Khani – Khani 2 overhead power line.

− the Zabaikalsky Krai power grid via the 220 kV Khani – Chara (BD-75) overhead power line.

Also located in the Yakutia are 35 kV and higher substations, which are connected to adjacent power systems in the Magadan Region and are not connected to the Yakutsk power system.

Power is supplied to the village of Chersky in the far northeast of the Yakutia from the 110 kV Chersky substation via the 224.7 km long 110 kV Vstrechny – Chersky overhead transmission line from the Chaun-Bilibino power hub in the Chukotka Autonomous Okrug and is operated by JSC Chukotenergo.

As of 01.01.2023, the total installed capacity of generating equipment of power plants of the energy system of the Yakutia is 2031.4 MW, including HPP 957.5 MW, TPP 1073.9 MW [4].

Calculations of static and dynamic stability. This study included calculations of the static stability of the electrical grid in controlled sections of the Yakutia power system, determining the potential output of electrical power and energy generated by the WER hydroelectric power plants, and the dynamic stability of the generating equipment of the Vilyui HPPs cascade 1 and 2, and the Svetlinskaya HPP. Dynamic stability calculations were performed to determine the maximum permissible energy flows in the "District-City" and "District-Olyokminsk" controlled sections, which are shown in figure 2.

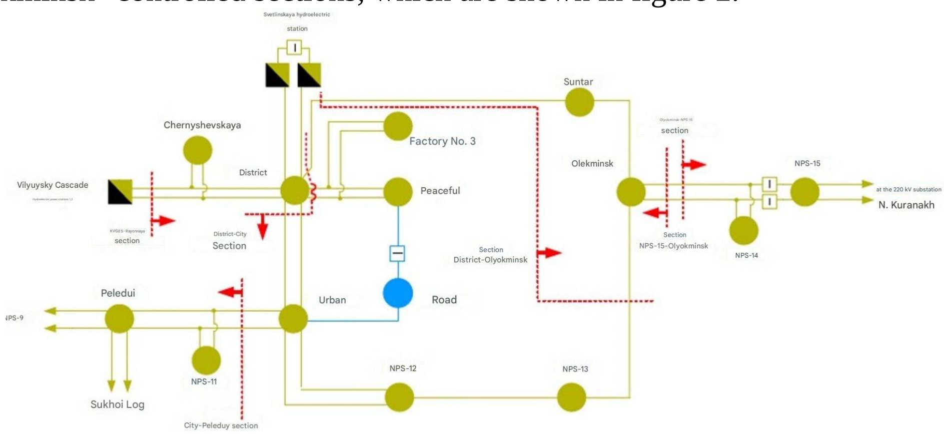

Fig. 2. Controlled cross-sections "District-City" and "City-Peleduy" (marked with red arrows)

Static stability calculations are performed for different coupling types between the station generators and the receiving system busbars. The purpose of the calculation is to formulate an expression for the angular power characteristic and analyze it [5].

Static and dynamic stability calculations for the generating equipment of the Vilyui HPPs cascade 1 and 2, and the Svetlinskaya HPP were performed using verified power system computational models in the macroblock format of the Eurostag software and computing suite.

The available capacity of the Vilyui HPPs cascade 1 and 2, and the Svetlinskaya HPP for the period under review until 2027 is 680 MW and 189 MW, respectively.

Calculation Results. Static and dynamic stability calculations showed that the available capacity of the WER hydroelectric power plants is limited by the existing controlled cross-sections (CCS) "District-Olyokminsk" and "District-City".

In the normal scheme, the criterion determining the maximum permissible energy flow (MPE) in the "District-Olyokminsk" and "District-City" CCS is the dynamic stability of the generating equipment of the Vilyui HPPs cascade 1 and 2, and the Svetlinskaya HPP under a standard disturbance with tripping of the 220 kV "City-District No. 2" overhead line due to a single-phase short circuit (SC) caused by the circuit breaker failure backup device.

Therefore, the capacity of the existing power grid of the considered CCS in the WER does not allow the WER hydroelectric power plants to deliver the available capacity. To increase the capacity of the considered CCS, the following minimum technical solutions were proposed:

− reducing the breaker failure protection time in the 220 kV cell of the 220 kV "City-District No. 2" overhead line at the 220 kV District substation to 0.2 s;

− expanding the 220 kV switchgear (SG) at the 220 kV District substation by two line cells with connection to the existing 220 kV "District-City" overhead lines, circuits I and II;

− incorporating the 110 kV busbar junction switch (BCS) at the 220 kV District substation in the normal circuit.

The implementation of the above technical solutions will increase the minimum operating capacity at the "District-City" and "District-Olyokminsk" CCS by 43 MW. At the same time, the implementation of these measures does not fully meet the regulatory requirements for the power distribution scheme of the Western Yakutia power plants. A subsequent increase in the maximum permissible power (MPP) in these compressor stations will require significant grid construction, including the construction of new, extended 220 kV overhead power lines.

Conclusion. This paper examines and considers development paths for an isolated electric power system operating until 2019 with a significant surplus of generating equipment capacity, and also analyzes vectors for developing the Far East's energy systems.

The problem with the operation of the Western Yakutia power system stems from the inability to quickly respond to power supply restoration during complete blackouts in isolated operation, as there are no systems providing redundancy.

The analysis and calculations show that significant investments from the federal budget will be required for further development of the Western Yakutia energy sector [6]. The development of the electric power complex will spur regional development in local areas, the exploration of new deposits, with a corresponding increase in qualified personnel and the creation of new jobs.

References / Список литературы

1. Kuznetsov N., Morozov I. Energy efficiency of buildings in arctic regions of the Russian Federation // Journal of Physics Conference Series. 2021, vol. 2096, p. 012056.
2. Volotkovskaya N.S., Semenov A.S., Fedorov O.V. Feasibility of Energy Sector Development and Optimization Program of the Republic of Sakha (Yakutia) // IOP Conference Series Materials Science and Engineering. 2020, vol. 753, p. 082033.
3. Semenov A., Volotkovskaya N., Bebikhov Y., Yakushev I., Fedorov O., Gracheva E. Analysis of the efficiency of development scenarios for the energy complex of the North-East of Russia // Lecture Notes in Civil Engineering. 2021, vol. 141, pp. 231-240.
4. Pavlov N.V., Lepov V.V., Zakharov V.E., Prokhorov D.V. On development prospects of the energy industry in the Russian Far North // Energy Systems Research. 2023, vol. 6, is. 1(21), pp. 55-61.
5. Wang H., Zhao Sh., Meng J., Tian Ya., Sun Yu., Wang K. Entropy weight and grey relational analysis based virtual capacitance collaborative control for multiple energy storage units // IET Power Electronics. 2023, vol. 16, is. 3, pp. 375-38.
6. Gulyaev P., Grigoryeva E. Forecast of electricity consumption in Yakutia – strategizing horizon 2032 // E3S Web of Conferences. 2023, vol. 460, p. 07016.

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