Key Defining Features of the Electric Power Industry in Asian Regions of Russia in Light of Decarbonization Efforts

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***Abstract* — The article examines key defining features of the electric power industry of Asian regions of Russia in light of decarbonization efforts and does this through a case study of integrated power systems of Siberia and the East. We analyze the main characteristics of these integrated power systems, including the mix of installed capacity of power plants, of electricity generation and consumption, and of the fuel thermal power plants burn. On the basis of this analysis, we conclude that the mix of generating capacity of the considered electric power systems falls short of being perfect from the standpoint of decarbonization efforts and that there is a need to convert some of the existing thermal power plants to natural gas combustion and prioritize natural gas combustion when designing new ones.**

***Index Terms*: power system, percentage contribution, hydropower plant, thermal power plant, coal, gas, fuel oil.**

I. Introduction

The climate agenda and the decarbonization policy closely related to it are relevant not only abroad [1], but also in this country [2]. This is especially important for integrated power systems (IPSs) of Siberia and the East, which are the largest consumers of coal as their fuel.

II. Subject of Study

The IPS of Siberia is one of the largest integrated systems of the Unified Energy System (UES) of Russia. The IPS of Siberia serves electricity consumers in the Altai, Krasnoyarsk, and Zabaykalsky territories, Irkutsk, Novosibirsk, Omsk, Tomsk, Chita, and Kemerovo regions, as well as the Republics of Altai, Buryatia, Khakassia, and Tyva. The total area covered by the IPS of Siberia is 4 944.3 thousand km^2. More than 19 million people live in the cities and towns there. The electric power complex of the integrated system consists of 118 power plants with a total installed capacity of 52.1 GW. Of these, hydropower plants (HPP) account for 25.3 GW or 48.5%, thermal power plants account for 26.5 GW or 50.9%, and solar power plants account for 0.3 GW or 0.6% (Table 1) [3]. The annual electric power generation by power plants of the IPS of Siberia in 2020 was 207 billion kWh, including: TPPs – 89 billion kWh or 43%, HPPs – 118 billion kWh or 56.9%, SPP – 0.3 billion kWh or 0.1%, and the annual electricity consumption of the integrated power system was 209 billion kWh (Tables 1 and 2) [3].

The main power grid of the IPS of Siberia is formed on the basis of 110, 220, 500 and 1 150 kV power transmission lines with a total length of about 103 thousand km.

The Norilsk power supply system in the north of the Krasnoyarsk territory operates independently of the IPS of Siberia due to its geographical remoteness.

The IPS of the East is a peripheral integrated power system of the country, recently incorporated into the UES of Russia. The IPS of the East is connected to the UES of Siberia and borders the power system of China. The IPS of the East serves electricity consumers located in five federal subjects of the Russian Federation: the Amur region, Primorsky and Khabarovsk territories, the Jewish autonomous region, and the Republic of Sakha (Yakutia). The total area covered by the IPS of the East is 4 457.4 thousand km^2. There are 5 million people living in cities and towns in this area. The integrated power system of the East is formed by 40 power plants with unit capacity of 5 MW and above, 653 110–500 kV power transmission lines with a total length of about 34 000 km. The total installed capacity of power plants of the IPS of the East as of 01.01.2021 was 11.1 GW. TPPs (6.5 GW or 58.5%), which have a limited control range, dominate in the mix of generating capacity. HPPs account for 41.5%, or 4.6 GW (Table 1) [3]. Annual electric power generation by the power plants of IPS of the East in 2020 was 43.9 billion kWh, including: TPPs – 26.9 billion kWh or 61.4%, HPPs – 17 billion kWh or 38.6%, and the annual electricity consumption of the integrated power system was 40.7 billion kWh (Tables 2 and 3) [3].

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http://dx.doi.org/10.25729/esr.2023.01.0003
Received March 06, 2023. Revised April 11, 2023.
Accepted April 18, 2023. Available online April 30, 2023.

Table 1. Installed Capacity Mix of Power Plants as of 01.01.2021

Power system	Total, MW	TPP		HPP		SPP	
		MW	%	MW	%	MW	%
IPS of Siberia	52 139.94	26 537.96	50.90	25 301.78	48.53	300.20	0.57
IPS of the East	11 116.09	6 498.59	58.46	4 617.50	41.54	-	-

Table 2. Power Consumption and Maximum Load

Power system	Million kWh	%	MW
Republic of Altai and Altai territory	10 391.3	4.96	1 756
Republic of Buryatia	5 510.6	2.63	932
Zabaykalsky territory	8 192.5	3.91	1 290
Irkutsk region	55 980.5	26.74	8 326
Kemerovo region	31 293.3	14.95	4 335
Krasnoyarsk territory and the Republic of Tyva	47 490.9	22.68	6 891
Novosibirsk region	15 963.5	7.62	2 887
Omsk region	10 350.4	4.94	1 694
Tomsk region	7 607.8	3.63	1 237
Republic of Khakassia	16 588.0	7.92	2 132
Republic of Altai and Altai territory	10 391.3	4.96	1 756
TOTAL IPS of Siberia	209 368.7	100	30 852*
Amur region	9 124.3	22.43	1 470
Primorsky territory	13 535.8	33.26	2 411
Khabarovsk territory and Jewish autonomous region	10 541.1	25.90	1 816
Republic of Sakha (Yakutia)	7 493.2	18.41	1 318
TOTAL IPS of the East	40 694.5	100	6 701*

* Combined maximum value

Table 3. Power generation in 2020

Metric	IPS of Siberia		IPS of the East	
	million	%	million	%
Power generation,	207 014.2	100	43 899.4	100
of which: TPP	88 997.7	42.99	26 940.0	61.37
HPP	117 739.6	56.88	16 959.4	38.63
SPP	276.9	0.13	-	-

The main generating sources are located in the northwestern part of the IPS of the East, while the main consumption areas are in the southeast. The IPS of the East has one of the highest shares of the public utility load in the UES of Russia – about 25%.

For geographical and technological reasons, the power systems of the four subjects of the Russian Federation that make up the Far Eastern Federal District operate independently of the UES of Russia. These are the power systems of Kamchatka territory, Sakhalin region, Magadan region, and Chukotka autonomous district. In Khabarovsk Krau, the Nikolayevsky power district operates independently of the IPS of the East.

The Siberian and Eastern EPSs have export-oriented interconnections with neighboring countries. The Mongolian power system operates in parallel with the IPS of Siberia through a 220 kV double-circuit transmission line from the power system of Buryatiya. The IPS of the East is connected to the power system of China via 220 and 500 kV transmission lines through a DC link, it also enables AC operation in the «islanded mode» [4].

III. Analysis of Key Defining Features of IPSs of Siberia and the East

The large spatial extent of the IPS of Siberia and IPS of the East and the harsh natural and climatic conditions in the regions they cover result in higher capital intensity and operating costs, as well as long construction periods for power plants and power grid facilities.

The actual power losses in the power grids of PJSC «Rosseti Siberia» by 2020 amounted to 4 264.21 million kWh or 7.28% of the amount supplied to the grid [5], whereas, for example, the actual power losses in power grids of PJSC «Rosseti North-West» by 2020 amounted to 2,066 million kWh or 6.22% of the amount supplied to the grid [6].

The long fall and winter period in these regions leads to large amounts of heat produced at CHPPs, and accordingly, large amounts of fuel burned and large amounts of harmful emissions.

The highest electricity consumption and the highest maximum electricity load in the IPS of Siberia are observed in the Irkutsk region, the Krasnoyarsk territory, and the Republic of Khakassia, which is explained by the presence of major aluminum smelters in these regions. In the IPS of the East, the highest level of electricity consumption and maximum electricity load are observed in Primorsky and

Table 4. The share of the IPS of Siberia and the IPS of the East in the UES of Russia

Power system	Installed capacity of power plants, MW/%	Power generation, billion kWh/%	Power consumption, billion kWh/%	Combined maximum value of load, MW/%
UES of Russia	245 313 / 100	1 047.03 / 100	1 033.72 / 100	151 962 / 100
IPS of Siberia	52 140 / 21.3	20 701 / 19.8	20 937 / 20.3	28 486 / 18.7
IPS of the East	11 116 / 4.5	43.90 / 4.2	40.69 / 3.9	6 520 / 4.3
UES of Russia	245 313 / 100	1 047.03 / 100	1 033.72 / 100	151 962 / 100

Khabarovsk territories as the most industrially developed regions.

The share the IPS of Siberia and the IPS of the East in the UES of Russia as measured by key metrics (installed capacity of power plants, the combined maximum electric load, generation and consumption of electricity), as of 01.01.2021, is summed up in the Table 4, compiled based on the data in [3].

As shown in Table 4, the share of the IPS of Siberia and IPS of the East in the UES of Russia as measured by key metrics is about 20% and 4%, respectively. At the same time, the IPS of the East and the IPS of Siberia are characterized by higher growth rates of demand for electric power than the average for the UES of Russia. The average annual growth rate to 2028 is projected at 4.2% and 1.6%, respectively, and 1.1% – for the UES of Russia [4].

A feature of the IPS of Siberia and IPS of the East that make them stand apart from electric power systems of the European part of the country is the large share of HPPs in the installed capacity mix: 48.5% and 41.5%, respectively.

The largest HPPs of the country operate as part of the IPS of Siberia: Sayano-Shushenskaya HPP (6 721 MW), Krasnoyarskaya HPP (6 000 MW), Bratskaya HPP (4 500 MW), Ust-Ilimskaya HPP (3 840 MW), and Boguchanskaya HPP (2 997 MW). The IPS of the East includes major HPPs as well: Zeiskaya (1 330 MW) and Bureyskaya (2 010 MW).

A large share of HPPs provides carbon-free output, high maneuverability of these IPSs, and together with TPPs, running on cheap local coal, allows maintaining relatively low electricity tariffs in the respective regions (Irkutsk region, Krasnoyarsk territory, Republic of Khakassia).

However, along with a large share of HPPs, the IPS of Siberia and IPS of the East are characterized by a large number of lignite-fired thermal power plants.

The following major coal-fired TPPs operate as part of the IPS of Siberia: Novosibirsk TPP-5 (1 200 MW), Tom'-Usinskaya SDPP [State District Power Plant] (1 345 MW), Belovskaya SDPP (1 260 MW), Berezovskaya SDPP (2 400 MW), Krasnoyarskaya SDPP-2 (1 250 MW), Nazarovskaya SDPP (1 308 MW), Irkutskaya CHPP-10 (1 110 MW), Gusinoozerskaya TPP (1 130 MW), and Kharanorskaya SDPP (665 MW). There are also large coal-fired TPPs in the IPS of Siberia: Neryungrinskaya SDPP (618 MW), Khabarovskaya CHPP-3 (720 MW) In recent years, power generation units at Khabarovsk CHPP-3 have been undergoing conversion to natural gas combustion , and Primorskaya SDPP (1 467 MW).

Analysis of statistical information shows that coal accounts for 85.6% of the mix of the fuel burned by TPPs of the IPS of Siberia, while gas accounts for 14.0%, and fuel oil for the rest. In the mix of fuel burned by TPPs of the IPS of the East, coal accounts for 62.3%, gas for 34.9%, and petroleum fuel for the rest (Fig. 1).

On the one hand, this explains a relatively high average specific fuel consumption by Siberian and Far Eastern TPPs, which in the IPS of Siberia is 350 g c.e./kWh, and in the IPS of the East it is 390 g c.e./kWh (for comparison, in the IPS of the European Russia the value of this metric is 290 g c.e./kWh).

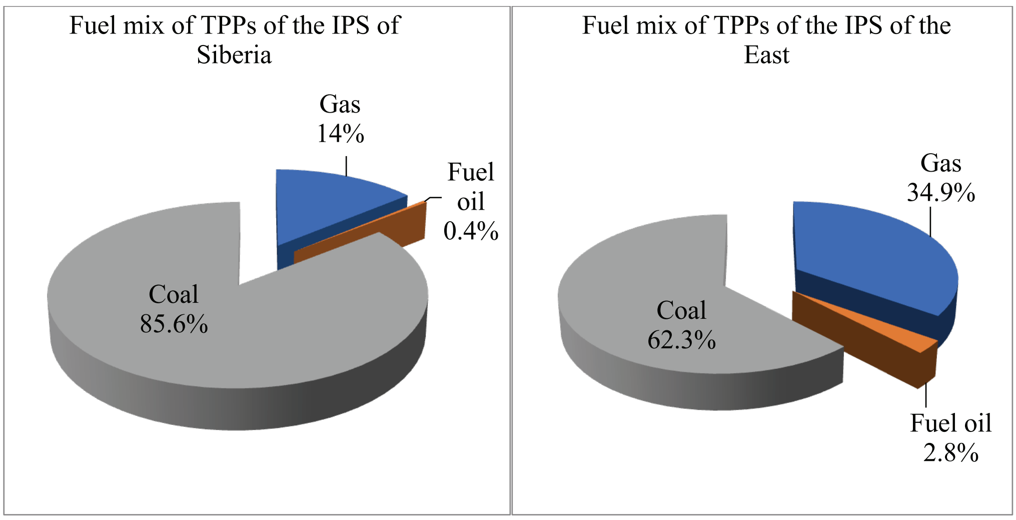

Fig. 1. Mix of fuel burned by TPPs, %.

On the other hand, this puts stress on the natural environment of the adjacent areas due to large amounts of harmful emissions, which increase significantly during low-water periods as a result of a decrease in electricity generation by HPPs and a corresponding increase in generation by TPPs. A striking example of this situation is the «black sky» effect in Krasnoyarsk. Krasnoyarsk is included in the federal project «Clean Air» of the national project «Ecology» along with the cities of Bratsk, Norilsk, Chita, Gusinoozersk, Selenginsk, Ulan-Ude, Kyzyl, Abakan, Petrovsk-Zabaikalsky, Achinsk, Lesosibirsk, Minusinsk, Ussuriisk, Komsomolsk-on-Amur, Chegdomyn, Angarsk, Zima, Irkutsk, Svirsk, Usolye-Sibirskoye, Cheremkhovo, Shelekhov, Yuzhno-Sakhalinsk [7].

IV. Conclusion

The above considerations allow us to arrive at the following conclusions:

- IPSs of Siberia and the East are large and important components of the UES of Russia, with a share of about 20% and 4%, respectively, as measured by key metrics;

- The large spatial extent of the IPS of Siberia and the IPS of the East and the harsh natural and climatic conditions in the regions they cover result in higher capital intensity and operating costs, as well as long construction periods for power plants and power grid facilities;

- the proximity of the integrated power systems of Mongolia and China and the availability of interconnections with these power systems underpin the export prospects of the IPS of Siberia and the IPS of the East, which is of most relevance in the current political and economic environment;

- a large share of HPPs in the generating capacity mix of the IPS of Siberia and the IPS of the East provides carbon-free output, high maneuverability of these IPSs, and along with TPPs that run on cheap local coal, allows one maintaining relatively low electricity tariffs in the respective regions (Irkutsk region, Krasnoyarsk territory, Republic of Khakassia);

- the availability of a large number of coal-fired TPPs in the IPS of Siberia and the IPS of the East, combined with the long heating season, result in large amounts of harmful emissions and a lot of stress put on the natural environment in the regions they cover, especially in cities where coal-fired TPPs are located. Along with the modernization and improvement of the environmental performance of the boiler equipment of these TPPs and the use of renewable energy sources, a radical solution to this problem should be the conversion of existing coal-fired TPPs to natural gas (where technically possible) and prioritizing natural gas combustion when designing new ones.

Acknowledgments

The research was carried out under State Assignment Project (no. FWEU-2022-0001) of the Basic Research Program of the Russian Federation 2021-2030 and made use of the resources of the «High-Temperature Circuit» shared research facilities center (Ministry of Science and Higher Education of the Russian Federation, project no 13.CKP.21.0038).

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