Analysis of the change impact in the share of generation from HPPs in the structure of the unified power system energy balance to residential tariff

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Annotation. The paper analyzes the structure of the energy balance of the Russian Federation for power systems, draws conclusions on the impact of HPPs in the structure of electricity generation on the price of electricity for ultimate customers. The influence of the construction of new hydropower stations on the development of waterways is considered.

1. Introduction
The structure of the energy balance of any country can be viewed both from the point of commercial interests view of specific energy producers, the state, and from the point of view of the final consumers interests [1]. The development of the economy, especially in the part of energy-intensive industries, is directly related to the cost of energy resources [2]. It becomes important to understand the influence of the generation structure on the formation of the electricity price. The strategy of power capacities development should take into account the interests of all groups of consumers, including the population.

2. Assessment of the hydropower share in the energy balance
The structure of the installed capacity of the Unified Power Systems (UPS) power plants and UPS of Russia as of 01.01.2018, as well as the generation of electricity in the UPS of Russia in 2017 are shown in Tables 1 and 2 (information was obtained from an open source [3]).

Table 1. Balance of IPS power plants for installed capacity and for electricity generation (%)

| Power system | Installed capacity, MW | Generation, mln kWh | HEP | CHP | NPS | WPP | SPP |
|--------------|------------------------|---------------------|-----|-----|-----|-----|-----|
| UPS of Russia| 239812,20              | 20,20               | 67,88 | 11,64 | 0,06 | 0,22 |
|              | 1053862,03             | 16,98               | 63,70 | 19,25 | 0,01 | 0,05 |
| IPS of Center| 53077,07               | 3,37                | 71,01 | 25,62 | -    | -    |
|              | 237546,50              | 1,84                | 55,91 | 42,25 | -    | -    |
|              | 27203,76               | 25,60               | 59,23 | 14,97 | 0,13 | 0,07 |
Analysis of the table data shows that the potential for hydro resources of the regions, taking into account the already commissioned capacities, is not fully utilized. The best indicators for the power and generation balance were revealed in the North-West, where 12.03% of the hydroelectric power accounted for 13.03% of the power system. The worst balance ratio in the IPS of the South. And at the same time, there is a shortage of capacities, which can be realized precisely due to the energy of water resources.

Taking into account the different potentials for hydropower generation in the Russia regions and referring to separate integrated power systems, a study was made of the variable component of generation facilities separate groups in the IPS, where hydropower is present.

Table 2 shows data on variable costs in the generation structure for 2017. Variable costs depend on the amount of energy production. They are taken into account when forming a tariff for consumed electricity. Unlike them, fixed costs form a fee for capacity.

Table 2. Variable costs in the generation structure for 2017, RUR / MWh

| Power system        | HEP  | CHP   | NPS  | SDPP  |
|---------------------|------|-------|------|-------|
| IPS of Center       | 21.75| 1008.33| 250.5| 1087.94|
| IPS of Northwestern | 21.10| 938.78| 250.3| 1230.25|
| IPS of Southern     | 18.87| 1020.97| 226.9| 1181.74|
| IPS of mid-Volga Region | 16.56| 1081.19| n/a | 1411.9 |
| IPS of East         | n/a  | n/a   | -    | -     |
| IPS of Siberia      | 21.65| 637.30| -    | 613.01|

The results of the variable cost analysis unambiguously demonstrate the advantage of HPPs and NPPs, in the structure of circulating assets of which there are no (HPPs) or minimal (NPP) costs for fuel resources. An analysis was made of the connection of the share of HPPs in the IPS with the electricity tariff for the population in large settlements provided by electricity in the framework of the IPS considered (Table 3, Figures 1, 2).
Table 3. Dependence of the residential tariff on the HPPs share

| Power system         | HEP, % | Residential tariff for 2017 (averages taking into account changes from 1.07.2017), rubles / kWh |
|----------------------|--------|-----------------------------------------------------------------------------------------------|
| IPS of Center        | 3,37   | from 4,43 to 5,38                                                                             |
| IPS of Ural          | 3,52   | from 3,77 to 4,85                                                                             |
| IPS of Northwestern  | 12,36  | from 3,88 to 4,59                                                                             |
| IPS of Southern      | 27,59  | from 3,66 to 4,28                                                                             |
| IPS of mid-Volga Region | 25,60 | from 3,50 to 3,64                                                                             |
| IPS of East          | 38,52  | from 2,77 to 4,27                                                                             |
| IPS of Siberia       | 48,71  | from 0,99 to 3,07                                                                             |

Figure 1. Dependence of the residential tariff on the HPPs share in the IPS at the installed capacity

Figure 2. Dependence of the residential tariff on the HPPs share in the IPS on the electricity generated in 2017
The method of forecasting changes in tariffs with a change in the share of electricity generation with the use of hydro resources, allows to investigate graphical dependencies. Practically linear dependence is revealed. Although these schedules are somewhat arbitrary, since a number of factors influence the tariff, nevertheless, a clear dependence of the tariff reduction on the population on the share of electricity generation at hydroelectric power plants in the IPS is traced, which justifies the economic and social significance of increasing the generation share at hydroelectric facilities.

The confirmed connection allows making preliminary forecasts for the tariff taking into account possible changes in the HPPs share in the energy balance structure. The revealed parameters and relationships confirm the presence of both social significance of increasing the generation share at hydroelectric facilities and, undoubtedly, have a significant effect on the cost of industrial enterprises production, especially energy-intensive ones [4-5].

An analysis of regional electricity tariffs shows that they are significantly lower in regions with a high proportion of hydroelectric power stations in the structure of generating capacities. For example, in the Siberian regions [8], on the territory of three of which (the Krasnoyarsk Territory, the Irkutsk Region and the Republic of Khakassia) there are large hydroelectric power stations, the one-part tariffs for the population in 2018 are: RUR / kWh: Irkutsk Region - 1,01; The Republic of Khakassia - 1,99; The Krasnoyarsk Territory is 2.37.

In neighboring regions where, practically, there are no HPPs, the tariffs for electricity are much higher, amounting to RUR / kWh: the Republic of Buryatia - 4.24; The Altai Republic - 4.84; Kemerovo region. - 3.15; The Republic of Tuva - 3,3; Tomsk region - 3.25.

Tariffs for electricity in the North Caucasus region: in Dagestan, where HPPs provide their own electricity consumption by 90%, -2.41 rubles / kWh; in North Ossetia, where several small hydropower stations generating about 20% of electricity, -3.86 rubles / kWh; in the Republic of Kabardino-Balkaria, in which hydroelectric power plants produce less than half of the power consumption - 3.58 rubles / kWh.

At the same time, in Kalmykia, where there is no hydroelectric power station, the tariff is one of the highest in the region and is 4.38 rubles / kWh.

Thus, hydropower facilities create the conditions (prerequisites) for a possible reduction of tariffs or containment of their growth while increasing the cost of hydrocarbon fuel for TPPs.

Based on the results of the performed analysis, it can be concluded that the transition to a wider development of fuel-free power is the most rational strategy for the development of the electric power industry in the conditions of the hydrocarbon resources depletion [6] and the predictable increasing redistribution in favor of the chemical industry. In these conditions, the role of hydropower, using renewable water resources, increases [7]. The substitution of thermal generation due to the development of nuclear and hydropower will make it possible to build a balanced highly efficient energy sector, reduce the burden on the environment [9], reduce the final cost of electricity, release hydrocarbon raw materials (for export, chemical industry), provide a comprehensive solution to the water development problems of the country.

3. Complex influence of hydropower engineering

The period 1960-1980. was a period of active hydropower construction, when 36 GW of installed capacity was commissioned in the Russian Federation. Thus, a little less than 2.0 GW was introduced per year. In these years, the creation of a transport-water-energy system in Europe - the Volga-Kama cascade of hydroelectric power stations - was completed.

Today, the Volga-Kama Cascade of HPPs provides the opportunity to operate the largest in Europe water transport system of Russia - the United Deep Sea System of the European part of the Russian Federation that connects the White Sea, the Baltic Sea, the Volga, Moscow, the Caspian Sea and the Azov Sea with the Black Sea [10].

In the regions of the Russian Federation, where there are operated inland waterways, about 90% of the gross domestic product is created and 80% of the population lives.
At the same time, inland waterway transport accounts for less than 2% of the total volume of freight transport and turnover of all types of transport in the Russian Federation, while in Germany 11%, the Netherlands 34%, France 10% trends in river transport growth.

The cost of transporting goods along rivers is 10 times lower compared to road transport and almost 2-fold - with rail. Cascade construction of hydropower facilities on the northern rivers of the Russian Federation, taking into account the need for development of waterways, will ensure transport access to explored and new deposits of natural resources, create conditions for the construction of enterprises for their processing and enrichment, will provide the opportunity to export the products. All this is extremely important for Siberia and the Far East, will contribute to the development and additional loading of the Northern Sea Route.

Thus, the construction of hydroelectric power stations can solve the problems of both electricity supply and transport accessibility of the newly developed regions of Russia.

The construction of hydroelectric and hydraulic structures not only provides an opportunity for the development of water transport, but also solves the problems of technical and drinking water supply, irrigation, irrigation of rivers for sanitary purposes, reduces damages from flooding of territories during the passage of floods. It should be noted that at present the expenses of our state for the liquidation of the consequences of floods, flooding and other natural disasters on water bodies are many times higher than the amounts allocated for the prevention of these phenomena and disasters.

Today, taking into account the need for a breakthrough development of the Russian Federation economy in conditions of limited financial resources, it is advisable to focus on projects that can have a cumulative effect on the entire economy, for the entire industrial development of Russia, and such a project can be modern energy in general and hydropower in particular.

In addition, given the existing redundancy of water resources in some regions of Russia, the creation of integrated use large reservoirs makes it possible to provide for the long-term prospect the possibility of exporting another strategic resource, in the short term, water. Currently, it is difficult to assess the economic effect of the such a resource sale, but this can already be accurately assessed as a possible strategic project of cooperation with neighboring countries that is not inferior to the project of China, the New Silk Road, in political and economic aspects.

Unfortunately, up to now there has not been developed a guideline document that would allow to link the construction of hydropower facilities with the development of electric power engineering, water transport routes, with the decision to reduce the costs of flood control, integrated water supply of territorial conglomerations. And this problem requires an early decision in order to increase the efficiency of each ruble invested in the development of energy.

4. Conclusions

Hydropower should be a key link in the development of energy in Russia. The construction of hydroelectric power stations not only creates the conditions for ensuring the possibility of regulating the tariff component for ultimate customers, but also provides an opportunity for more efficient operation of nuclear and thermal power plants. Unlike other sources of generation, it creates all the conditions for the integrated development of territories, one of the most important - the development of water transport routes, which our North and the Far East are in urgent need. Only this factor, namely the creation of water transport routes and the loading of the Northern Sea Route, can block the resources invested in the construction of hydroelectric power stations. This branch of the electric power industry has a number of advantages - reproducibility of resources, the absence of production waste, low operating costs, the possibility of multi-purpose use of reservoirs.

The revealed tendency of decrease in the price for the electric power at increase in a share of generation from hydroelectric power station in modern conditions of formation of the tariff and earlier at planned economy is the indisputable fact. At present, there is a task to minimize the burden on the regional budget, which is forced to cover the gap between the real cost of energy and the tariff that is set for the population. And the influence of the change in the structure of generating capacities in the direction of increasing the share of HPPs contributes to the solution of this problem.
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