E3S Web of Conferences **77**, 03004 (2019) https://doi.org/10.1051/e3sconf/20197703004
Regional Energy Policy of Asian Russia 2018

A methodological approach to assess the effectiveness of the projects on Russian power export to the North-East Asia countries

Konstantin Smirnov*, Melentiev Energy Systems Institute of Siberian Branch of the Russian Academy of Sciences, Irkutsk, Russia

Abstract. The paper presents a methodological approach to assess the effectiveness of the projects on Russian power export to the North-East Asia countries. The mathematical models are described and the guidelines for selecting the most preferable project on power export are offered.

1 Introduction

Cooperation and interstate integration of Russia with the North-East Asia countries in electric power industry is one of the components of the Eastern energy policy of the country. This cooperation assumes the development of interstate electric ties between Russia's Eastern regions with the adjacent countries: Mongolia, People's Republic of China, Republic of Korea, Japan, and Democratic People's Republic of Korea. The trans-border transmission lines constructed for this purpose can be used both to export power from Russia and to integrate power systems of the above countries for joint operation. In the long term, development of these transmission lines is supposed, first of all, on the basis of the projects on power export from the Eastern regions of the country to the People's Republic of China.

The review of works [1-17] by the author shows that both foreign and domestic researchers pay great attention to forecasting the development of regional power systems and to projects for power export under conditions of initial information ambiguity. At the same time, the problem of assessing the effectiveness of such projects which will concern the regional power systems in the long-term perspective, and selecting the most preferable of them has been studied insufficiently. However, it is very important in methodological and especially applied aspects.

The effectiveness of the projects on power export is assessed using the methodological approach and model tools developed by the author. The developed methodological approach described below involves four investigation stages (Fig. 1):

- analysis of the energy markets in the power importing countries. Determination of a potential niche for the Russian electricity;
- determination of the Russian power industry potentialities for power export;
- assessment of the system effectiveness of export projects using an optimization model for regional power industry development. Multifactor research into

* Corresponding author: k.smirnov@isem.irk.ru

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

regional power industry development applying a risk matrix. Selection of preferable export projects using the game theoretic criteria;

- assessment of the commercial effectiveness of export projects using a simulation production and financial model. Selection of the most effective export project.

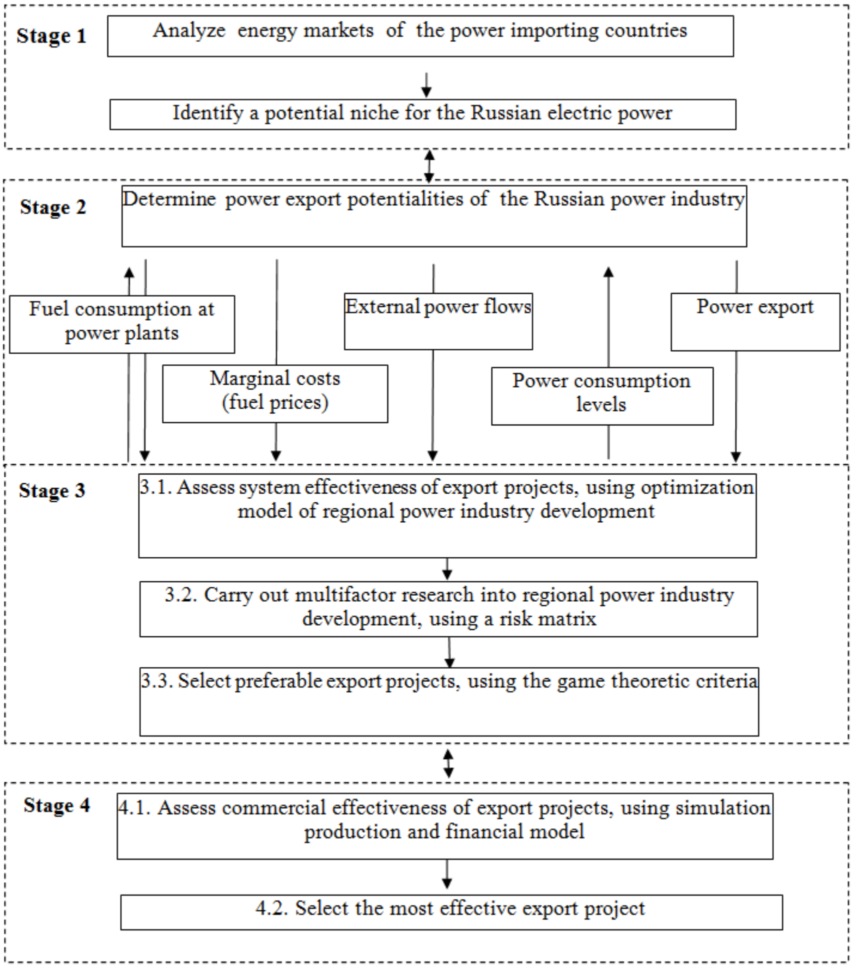

Fig. 1. Basic diagram of the methodological approach to assess the effectiveness of power export projects

A more detailed description of the methodological approach is presented in [18]. The methodological approach involves two mathematical models: the optimization model for the regional power industry development, and the simulation production and financial model for export projects.

2 Optimization model for regional power industry development

To assess the system effectiveness of export projects for a regional power system, the author developed a static optimization multi-nodal model for power industry development in East Siberia.

This model was developed with a more detailed description of power plants in a regional power system. The technological aspect is modeled by individual large existing and future power plants (Fig. 2), with division by type (HPPs, CPPs, CPs) and by type of fuel used (gas, coal, fuel oil, other). The operating CHPs are split into two separate groups by unit capacity: 1) ≥300 MW CPs, and 2) <300 MW CPs.

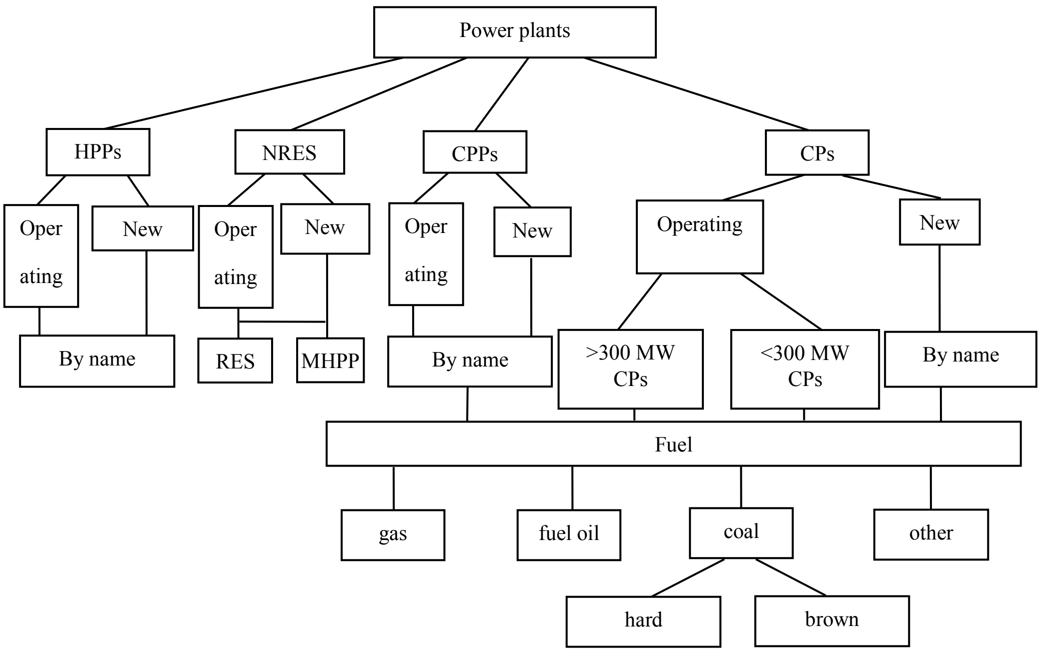

Fig. 2. Technological structure of power plants in the optimization model for regional power system development

Dynamics of capacity retirement is specified for operating power plants and transmission lines with a possibility of capacity restoration and retrofitting.

Generally, a power object (power plant, transmission line) is described in the model by the following indicators: coefficients determining the installed capacity utilization hours; coefficients specifying the heat output; specific fuel consumptions for power generation and heat output; specific investment required for reconstruction and commissioning of new capacities; specific constant costs on production of a unit power; transfer capabilities of transmission lines.

The territorial aspect of the model presents the power industry of East Siberia for 6 regional power systems: Khakassia, Tyva, Krasnoyarsk, Irkutsk, Buryatia, and Chita. In the implemented version of the model, the time aspect covers the period from 2014 to 2030.

Presently, this optimization model is extended by addition of the Far Eastern power system.

The model tools and the methodological approach may be applied to assess the effectiveness of the projects on power export when elaborating the schemes and programs of regional power industry development.

Optimization of the future power industry development in a region assumes solving the following problems:

- selection of a rational combination of power plant capacities (HPPs, CPPs, CPs, including exporting power plants) in the regional power systems (to cover the winter peak load in power systems and power supply for export);
- determination of an optimal structure of power generation (for a year) by type of power plant and fuel;
- determination of rational power and electric energy flows via interconnection tie lines;
- selection of a fuel type and determination of its consumption at power plants and in regional power systems.

The fuel consumption at thermal power plants is optimized in terms of fuel prices and technological capabilities of using different fuels.

When modeling the fuel consumption at power plants using different fuels, the model involves:

- specific fuel consumptions for power production and heat output;
- annual installed capacity utilization hours (describing different operating conditions of power plants);
- technologically feasible combinations of different fuels, if it is possible to use two or more fuels at a power plant; herewith, the sum of shares of different fuels used should be equal to the total fuel consumption for each operating condition of a power plant.

A variable fuel demand by thermal power plants (natural gas, steam coal, fuel oil) forms the consumption part of fuel balances.

The variables limiting fuel consumption by power plants in the considered power system (node) form the production part of fuel balances.

3 Simulation production and financial model for export projects

The commercial effectiveness of the power export projects selected at the third stage, was assessed and the project recommended for implementation was selected by means of the simulation production and financial model developed by the author (Fig. 3).

The model applies the following initial data: design capacity of the export power plants; transfer capabilities of the export transmission lines; number of substations; period of the project implementation; dynamics of commissioning the generating sets and transmission lines; dynamics of investment implementation; dynamics of operating costs; taxation terms.

The export electricity tariffs are determined as a result of calculations on the model (Table). These tariffs should be competitive in a foreign market, on the one hand, and meet the effectiveness criteria of the considered projects, on the other hand.

The Table shows that the project on construction of an export CPP operating on the Kovykta gas (in the Irkutsk Region south) with power transmission via a DC line to the China border is more effective (according to the accepted criterion) as compared with the project on construction of the coal-fired Mugun CPP in the Irkutsk Region. The export tariff at the border is estimated at 8-9 cent/kW·hr for the case of construction of the Kovykta CPP versus the export rate at the border is evaluated as versus 10-11 cent/kW·hr for the Mugun CPP (depending on the fuel cost).

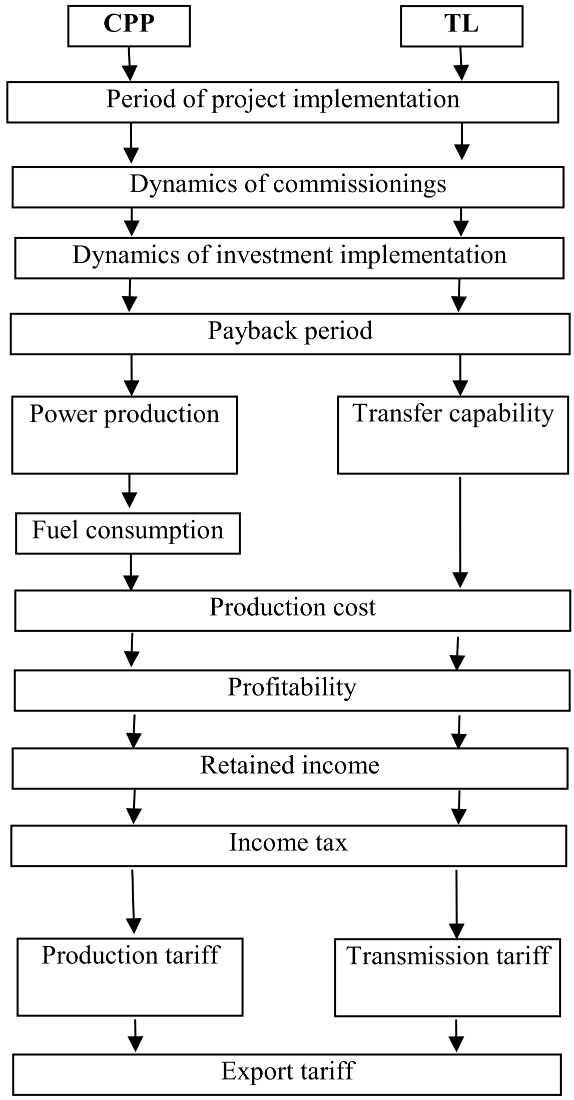

Fig. 3. Basic diagram of the simulation production and financial model to assess the commercial effectiveness of export projects

Table. Electricity tariffs at the China border, cent/kWh

Indicator	CPP	
	Kovykta	Mugun
Tariffs at the receiving end, total	7.9-8.8	10.1-10.6
including:		
for generation	6.5-7.4	8.7-9.2
for transmission	1.4	1.4

4 Conclusions

1. The paper presents a methodological approach to assess the effectiveness of projects on export of Russian power to the countries of North-East Asia.
2. The mathematical models are described in accordance with developed methodological approach.
3. The effectiveness of the projects on Russian power export to the countries of North-East Asia is assessed by means of the mathematical models.
4. The methodological approach and the results of studies provide an additional information to develop cooperation between Russia and the neighboring countries of North-East Asia in power export.

References

1. Y. S. Jang, G.-P. Park, Y. T. Yoon, J.-K. Park, S.-S. Lee. Development of Northeast Asia Interconnected Power Grid and Algorithm Assuring Reliability. Journal of International Council on Electrical Engineering. Vol. 1. No. 1. P. 33-38. (2011)
2. S.-S. Lee, Y.-C. Kim, J.-K. Park, S.-H. Lee, M. Osawa, S.-I. Moon, Y.-T. Yoon. Northeast Asia Interconnection, and Power Flow Analysis Considering Seasonal Load Patterns [online]. Available at: <http://www.jeet.or.kr/ltkpsweb/pub/pubfpfile.aspx>?ppseq=301.
3. Yoon J.Y., Park D.W. Economic Analysis Methodology of Power System Interconnections considering conventional economic benefits and environmental effects [online]. Available at: www.icee-con.org/papers/2002/papers/VolNo.1/1_pso/pso50.pdf.
4. L.S. Belyaev, S.V.Podkovalnikov, V.A. Saveliev, L.Yu.Chudinova. Effectiveness of interstate electric ties. – Novosibirsk: Nauka, 2008. – 239 p.
5. Energy of Russia, outlook (Substantiating materials to the Energy strategy of Russia until 2030). M.: GU IES. – 16 p. (2010)
6. Energy sector of the Baikal region: current state, prospects for development / Ed. by B.G.Saneev; Russian Academy of Sciences, Siberian Branch, Melentiev Energy Systems Institute. - Novosibirsk: Academic press “GEO”, 2015.- 176 p.
7. Fuel and energy complex of the Irkutsk Region: current state and prospects for development / Ed. by B.G.Saneev, P.A. Voronin. - M: Publishing House”Energia”, 2013. - 304 p.
8. Voropai N.I., Podkovalnikov S.V., Saneev B.G. Interstate energy cCooperation in North-East Asia: state, potential projects, energy infrastructure // Energy Policy. – 2014. - No. 2. - P. 55-64.
9. Interstate power interconnection in North-East Asia: prospects and mechanisms of creation, risks and barriers [online]. Available at: <http://www.energosovet.ru/stat487.html>.
10. Belyaev L.S., Kovalev G.F., Podkovalnikov S.V. Efficiency of interstate electric ties in the northern part of the Pacific // Proceedings of the Russian Academy of Sciences. Energetika. -1997 – No.6.
11. Belyaev L.S., Voropai N.I., Podkovalnikov S.V., Shutov G.V. Problems in creating an interstate power interconnection of East Asia // Elektrichestvo. – 1998 - No. 2. - P. 15-21.
12. Integration of electric power industries of Russia's East Regions and the countries of North-East Asia/ L.S.Belyaev, E.D. Volkova, N.I. Voropai, A.Yu. Ognev, S.V. Podkovalnikov, V.A. Saveliev, V.V. Selifanov, V.V. Trufanov. // Region. – 2002. - No. 1. P. 125-135.

13. Podkovalnikov S.V. Power Cooperation between Russia and the countries of Central Asia / S.V Podikalnikov, V.A.Saveliev, L.Yu.Chudinova//Energy: economy, engineering, ecology.- 2010. - No. 11. - P. 15-23.
14. Voropai N.I., Ershevich V.V., Rudenko Yu.N. Development of international power interconnections – a way to creation of the global power system. - Irkutsk, 1955. - 28 p. - (Preprint of SEI SO RAN, 1955; No. 10)
15. Likhachov V.L. Shanghai Cooperation Organization and energy cooperation: current state and prospects for development // Energy Policy. 2010 - Nos. 4-5. - P. 39-46.
16. Volkenau I.M., Zeiliger A.N., Khabachev L.D. Economy of Creating Power Systems. – M.: Energia, 1981. - 320 p.
17. Zeiliger A.N., Malkin P.A., Khabachev L.D.. Issues of substantiating the development of interregional and interstate network ties // Energeticheskoe stoitelstvo. -1994. - No. 3. P. 2-4.
18. Lagerev A., Khanaeva V., Smirnov K. A comprehensive assessment of comparative effectiveness of projects for power export from East Siberia to China: A methodological approach and results of its application // E3S Web of Conferences. Vol.27. ID: 02003. DOI: 10.1051/e3sconf/20182702003. Available at: http://isem.irk.ru/publications/10.1051-e3sconf-20182702003/ (2018)