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## Inside this Issue...



The author reviews the challenges associated with setting energy policies for complex energy systems. Without detailed data on these systems, the chances of unintended consequences is increased. Germany and Canada are compared in terms of what has already occurred and how countries might act to reduce these consequences.



Politics sometimes hinder efficient economic choices. The authors take us through a detailed analysis of electricity inter-connection options as a means to green the Japanese power industry and why these economic options are not likely to be implemented.

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CANADIAN ENERGY RESEARCH INSTITUTE

# *A "Green Option" for the Japanese Power Industry: Sakhalin-Hokkaido Interconnector*

S. Popov and K. Korneev

## Introduction

One of the most discussed power interconnection projects between Russia and Japan is the undersea cable line between Sakhalin and Hokkaido islands. Usually they are considered either as a standalone bilateral infrastructure project, or as an integral part of the proposed East-Asian power grid. The early known feasibility studies of such projects were done in the mid-1990s. RAO UES of Russia and Marubeni industrial group of Japan, with participation of Melentiev Energy Systems Institute of the Siberian branch of the RAS, assessed the prospects for construction of a DC transmission line between Russia and Japan in 1999. The project's final report noted that "establishing such power infrastructure may be economically beneficial to both parties" [1].

Several research projects provide detailed evaluation of the possible power interconnection development in the region. As an example, the publication of S.V. Podkovalnikov *et al* [2] discusses *International Power Grid* development within the northeast Asia region. The article provides a methodology and comprehensive economic efficiency evaluation of such an infrastructure project combining East-Asian economies – Japan, China, Republic of Korea, DPRK, Mongolia, as well as East Siberia and the Far East of Russia.

Feasibility studies of the electricity export projects from Russia to Japan were repeatedly carried out by major electricity companies starting from the year 2000 to mid-2010 – RAO UES in cooperation with the Japanese company Sumimoto in 2003, Inter in 2015, RusHydro in 2016 [3]. Also, the prospects for the construction of the Sakhalin-Hokkaido interconnection (SHIn) were positively evaluated in the research conducted by the Institute of the Global Power Grid (GENI, the USA in 2013), which concentrates on establishing the Asian energy ring. A significant part of the research was devoted to the international power interconnection between Russia and Japan as a component of the East Asian interstate power pool [4].

The interconnection issue has been extensively studied by major scientific and educational centres of Japan, the most significant example is the analytical report of the Institute of Energy Economics in 2015 [5]. In 2015, the Asia-Pacific Energy Research Centre for APEC (APERC) published a special feasibility study report, where the effectiveness of the East-Asian national power grids unification, as well as the single Sakhalin-Hokkaido interconnection, was demonstrated [6].

The essential differences of this study from the above-mentioned approaches are:

- treatment of the undersea HVDC transmission line Is. Sakhalin – Is. Hokkaido as an investment project, without considering the larger market, associated with the joint Hokkaido and Central Honshu Power Grid
- regime flows through the SHIn are accounted as sum for annual import and export, where the utilisation rate for the interconnector's capacity is considered as an endogenous variable.

According to the officially approved July 2015 "Long-Term Energy Supply and Demand Outlook", renewable energy sources should provide no less than 22 percent of total power generation in Japan by 2030, while thermal power plants should supply another 56 percent, with 20 to 22 percent generated by nuclear power plants (NPP). Neither issue of power interconnections, nor electricity imports are considered in official documents. Yet recently the number of SHIn assessments in Japan has increased due to high risks of prohibition for NPP operations and calls for reliable and low-carbon power generation in the Hokkaido region. An additional purpose for the interconnector will be to substitute existing coal generators as a basic electricity supply source, thus reducing future emissions of greenhouse gases (GHG) in Japan.

As of July 2017, despite both sides' belief in the positive impact of the interconnection development, no practical decisions have been made. Therefore, it seems suitable to identify the most significant risk factors affecting the Russian-Japan power interconnector project. Three clusters for such factors are discussed further: economical, institutional, and geopolitical.

| Energy Policy and Institutions |
| --- |
| To pave the way for the import of electric power, many institutions need to be transformed in Japan. The most prominent is power and gas markets liberalisation. Ongoing activity has 2020 as a deadline to complete the transition toward a competitive environment for both wholesale and retail sectors of power and gas markets in Japan. Meanwhile, despite the formal ability to accommodate imported electricity, even under current legislation, the general institutional environment in Japan is not ready for such a radical shift in energy policy. Please refer to the *geopolitical factors*. |

## Economic Factors of the Sakhalin-Hokkaido Power Interconnection Project

Here, the assessments of the economic efficiency of electricity export from Russia through SHIn are made from the Hokkaido Province's Government viewpoint. The Provincial power grid should provide robust electricity supply, where such elements as overall power consumption, rational structure of generators, utilisation of existing interconnectors across Tsugaru Strait are considered. On the other hand, any objects beyond SHIn aren't considered. The SHIn's capacity has been limited to 900 MW.

To provide quantitative assessments of the exported volumes and electricity prices, a non-linear optimisation model for the wholesale market of the Hokkaido Province's power grid has been developed. The use of SHIn as a peak load generation for the Sakhalin power grid was not considered based on its assumed unfeasibility.

Existing and possible new generators within the Hokkaido power grid, as well as the interconnections with the rest of the unified power system of Japan were considered. Technical and economic assumptions in the model for different types of generators, existing and planned for future deployment, corresponds to the Basic Energy Plan of Japan by 2030, and are consistent with Hokkaido power company (HEPCO) reports for fiscal year 2016 [7, 8]. Future fuel prices, the yen to US dollar exchange rate, technical and economic indicators for new generating capacities are the same as has been utilised for year 2020 timeline of the Basic Energy Plan of Japan. Scenario for low energy prices involves actual fuel prices as of April 2016. Optimality criteria for the model is the minimum of the total sum for purchasing electricity at a wholesale market for Hokkaido consumers.

Model constraints for different types of power generators include: upper and lower bounds of installed capacity; capacity factors (annual utilisation rate of installed capacity); redundant (mothballed) power generators to secure supply in case of the interconnector's failure due to non-technological and/or non-economic reasons.

Two interconnectors for the Hokkaido Power Grid are considered: one is to the Is. Sakhalin (international undersea HVDC cable to Russia) and the other is to Is. Honshu, the largest unified power grid in Japan. The latter will support the surplus power outflows from Is. Hokkaido in case of Tomari NPP operations and additional renewable generation (presumably onshore wind). Otherwise, in the case of a permanent nuclear shutdown in Japan, it will serve as a reverse flow of electricity from Is. Honshu. The model considers existing generators and planned commissioning for various types of new generators, including capacity expansion of the Hokkaido-Honshu interconnector before 2020. Future demand (which includes distribution losses) at Is. Hokkaido's power system has been considered as two tiers – 33 TWh and 29 TWh. Historically, from 2001 to 2016, electricity demand at the Hokkaido power grid varied within the 29.6-32.5 TWh range, with a maximum load of 5.9 GW recorded on January 12, 2011 [8].

An assumption was made for electricity imports from Russia – in such a case the total purchase at the Hokkaido wholesale power market should be reduced by 10% in comparison to the purchases exclusively from domestic (Japan) generators.

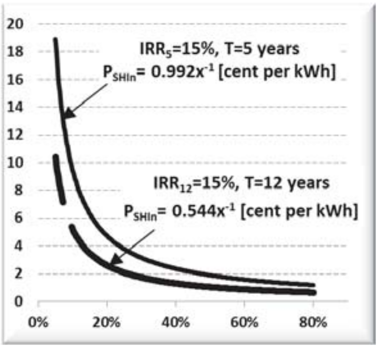
The maintenance cost of mothballed power generators on Is. Hokkaido (700 MW of coal and 200 MW of gas -fired power plants) is considered a substitute interconnector failure for political reasons.

To assess SHIn's financial and economic feasibility, the following assumptions have been made:

- maximum power flow – 900 MW
- capacity factor range – 5% to 65%
- overnight investment cost – $900 million
- lead time – 2 years
- annual fixed O&M cost – $70 million
- discount rate – 7%
- exchange rate, yen per dollar—105.24
- target IRR—15%

To formalise the relationship between wheeling price and capacity factor a series of SHIn financial model runs was made. Approximation for this relationship is based on an exponential function and is shown in Figure 1 for two cases, which refer to the project's payback period of 5 and 12 years. These functions are then used in the optimisation model as the variable cost for SHIn operations. The cost of electricity imported from Sakhalin is defined as the sum of the export price at the SHIn's sending end plus SHIn's wheeling price.

**Figure 1: Relationship between Wheeling Price and SHIn's Capacity Factor**




The export price estimations for the Russian end of the SHIn were derived through a four-stage process. For each stage, solutions of a non-linear optimisation model under different assumptions and scenarios for consumers supplied within the Hokkaido power grid are considered. The first stage is to evaluate the cost of power in the Hokkaido domestic wholesale market without imports and electricity inflows from Is. Honshu. Three Scenarios are considered regarding the operation of Tomari NPP:

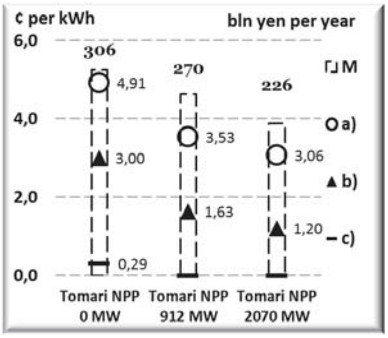
I. permanent shutdown of all generation units (including the newest PWR with installed capacity of 912 MW gross (first grid connected in 2009),
II. permanent shutdown of the two oldest reactors (PWR, 579 MW gross, first grid connected in 1988 and 1990, respectively),
III. grid reconnection for all three reactors and operation license extension for a period of 60 years.

The minimum cost of power supply (i.e., wholesale market volume) is equal to the minimum cost of generation at expected fuel prices in 2020 assuming net zero annual balance for power exchange with the Is. Honshu's power grid. Expected fuel prices in 2020 correspond to the assumptions, utilised by the Working Group for Power Generation Cost Verification within the Japanese government in 2015 under the process of the Basic Energy Plan amendments.

The second stage is to introduce the SHIn project and estimate export prices at Is. Sakhalin which is enough to keep the assumed IRR for the project, while reducing the cost of purchase at the Hokkaido domestic wholesale power market by 10 percent for each of Scenarios I-III. In the third stage, additional reserve capacity (mothballed for political reasons) is accounted, while realisation of the SHIn project should still secure a 10 percent decline of the wholesale power market purchases. In the fourth stage, the analysis for all three previous stages are repeated with only one distinction: instead of future fuel prices (assumptions under the Basic Energy Plan), actual fuel prices for April 2016 are used. In this case, wholesale power market purchases are reduced by 47 percent, which is 4.7 cents per kWh in comparison to 8.81 cents per kWh in Scenario I. For Scenario I, electricity purchases from the Is. Honshu's power grid at 6.0 yen per kWh, purchases are reduced by 2.7 percent to 262 billion yen (which is equal to the wholesale electricity price 7.94 yen per kWh).

The essential outcomes are presented in Figure 2. First, in the case of Scenario II or Scenario III, the total purchases at the Hokkaido wholesale power market plunges 12 percent (to 270 billion yen per year) and 26 percent (to 226 billion yen per year), respectively, compared to Scenario I.

**Figure 2: Competitive Export Prices from Sakhalin (cents per kWh)**




Notes:
M) cost of purchase at the Hokkaido wholesale power market, billion yen per year (stage 1)
a) interconnector and 10 percent decline for the cost of the wholesale power market (stage 2)
b) same as a) plus maintenance of the additional capacity reserves (stage 3)
c) same as a) but for actual April 2016 fuel prices (stage 4)

To compare efficiency of domestic generation versus electricity imports, according to the Kuhn-Tucker theorem, the solution of the dual problem to the model shows slightly more effective incremental generation by Tomari NPP in comparison to imports – 1.1 yen per kWh and 0.95 yen per kWh for each kW of additional capacity, respectively. It is worth mentioning that efficiency estimations were made without considering the cost of greenhouse gas emissions.

In comparison to Scenario I, competitive prices of electricity imports from Russia for Scenarios II and III are reduced by 28 percent and 37 percent respectively, or from 4.9 cents per kWh to 3.5 cents per kWh and 3.1 cents per kWh. However, in the case of the mothballed thermal generators, competitive export prices from Sakhalin plunge to 3.0, 1.6 and 1.2 yen per kWh, respectively for Scenarios I, II and III.

The low-price environment currently dominating the world's energy markets is one of the obstacles facing SHIn project development. In the case of actual April 2016 prices, electricity purchased on the SHIn's Russian side should be less than 0.3 yen per kWh for Scenario I, and negative for Scenarios II and III. Thus, in a low energy price environment, the Russia-Japan power interconnector with its target market within Hokkaido prefecture can't be justified commercially or economically.

Additionally, it should be noted that the analysis implicitly considers competition among export options for Russian energy resources. For example, electricity imports from Russia is competing with the Japanese thermal power generators fuelled by natural gas, which reduces gas consumption by more than 0.75 billion cubic meters, or $400 million, based on projected prices in 2020.

Commercial and economic effectiveness of the SHIn project is affected by risk management assumptions, power flows for regime purposes (hourly, daily, seasonal, etc.) and their respective pricing mechanisms. Yet several important factors are still awaiting thorough study, including the scale of renewable energy development and the pace for smart-grid diffusion in both Japan and Russia.

## Institutional Factors

Japan's Basic Energy Plan to 2030 does not expect electricity exports from Russia or another foreign country and postulates the development of the country's energy sector only considering the internal (domestic) tendencies, conditions and tasks.

By 2020 the Japanese government plans to complete electricity market liberalisation with the implementation of a competitive market where independent generation, transmission and distribution companies will operate. However, price-making mechanisms for generation capacity and additional services within grids haven't been determined yet [9]. The power industry could be partially opened to foreign investors. However, these investors currently face strong institutional obstacles, limiting their participation in large thermal power plant construction. The only thing available now is the new and renewable energy generation business.

Electricity consumption in Japan has remained stable for the last 15 years, showing no significant growth or decline, and, according to the Basic Energy Plan, it will stay almost unchanged until 2030 [7]. Furthermore, the investment strategy within the Basic Energy Plan proclaims a set of actions for low-efficiency and outdated thermal power plants to be substituted by new generators with no foreign investment involvement.

**Geopolitical Factors**

At the end of World War II, Japan fell under economic and political influence of the United States and became an agent of US policy in the East-Asian region. Now Japan is a leader in direct foreign investment in the US economy and the biggest holder of US treasury bonds (as of May 2017, Japan holds 1,107 trillion US dollars) [10]. Several core treaties between Japan and the United States on economic and political issues were signed, starting from the fundamental Treaty for Mutual Cooperation and Security (1960). American officials used to consider Japan as a major ally in the East-Asian region.

On the other hand, geopolitical rapprochement of China and the Russian Federation is occurring. These two countries now have coordinated approaches on many geopolitical issues in East Asia and outside the region. The major goal of the Shanghai Cooperation Organisation, established in 2001, was the formation of a common space for integration and free-trade zone [11]. Some rhetoric has appeared lately about the Organisation's consideration for joint security system implementation.

Unfortunately, today Japan and Russia are involved in different spheres of geopolitical interests in the East-Asian region. But there is hope that economic matters and political misunderstandings will be breached through the development of a good neighbour relationship. If that happens, there is possibility for construction of the interstate energy infrastructure, such as power interconnectors and pipelines.

**Implications**

Russia is a major energy exporter and is the closest neighbour to Japan, one of the world's major energy importers. Power interconnection is a good option for strengthening energy cooperation between them, and can provide positive environmental effects besides diversification of energy supply. However, the long-term balance of three components – Economic, Institutional, and Geopolitical should be positive for each actor to materialise such long-awaited projects, such as the Russian-Japan Interconnector.

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