Institutional Issues of International Power Grid Development in Northeast Asia

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Abstract. With regard to the initiative of "International power interconnections in northeast Asia" here examines the challenges which may hinder the establishment of a common energy system in region. The analysis is based on the APERC methodology for international energy cooperation in the APEC region, and on historical approach to the development of pricing mechanisms and policy in the European common market of electricity trade and system services. Mechanisms for the prevention and overcoming of the revealed problems of regional cooperation in the power sector are proposed.

1 Introduction

Prospects and problems of creating power interconnections are discussed in Northeast Asia region (NEA) for more than a quarter of a century. Currently there are international electric power connections between the four states: Russia and China, China and Mongolia, Russia and Mongolia, China and the Democratic People's Republic of Korea (DPRK). Table 1 shows consumption of electricity in 2015, the share of imports and exports for each NEA country. Despite of availability of the power interconnector infrastructure within region, Mongolia is the only state where international power trade shows significant role in national electricity balance.

Table 1. Import share in final electricity consumption of the Northeast Asia economies in 2015, percent.

Country	Electricity consumption	Import share	Export share
	TWh	*Percent*	*Percent*
China	4877	0.1 (0.1)[1]	0.3 (negl.)
Japan	949	-	-
Russia	726	0.9 (-)	2.5 (0.4)
ROC	495	-	-
DPRK	10	0.4 (0.4)	1.2 (1.2)
Mongolia	5.3	26.9 (26.9)	1.0 (1.0)

[1] In parenthesis – trade between NEA economies
Source: [1].

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The largest electricity flows within NEA are exports from Russia to China, and from China to Mongolia. The main electricity flows in 2009-2016 and the priority of the proposed projects are presented in Fig. 1.

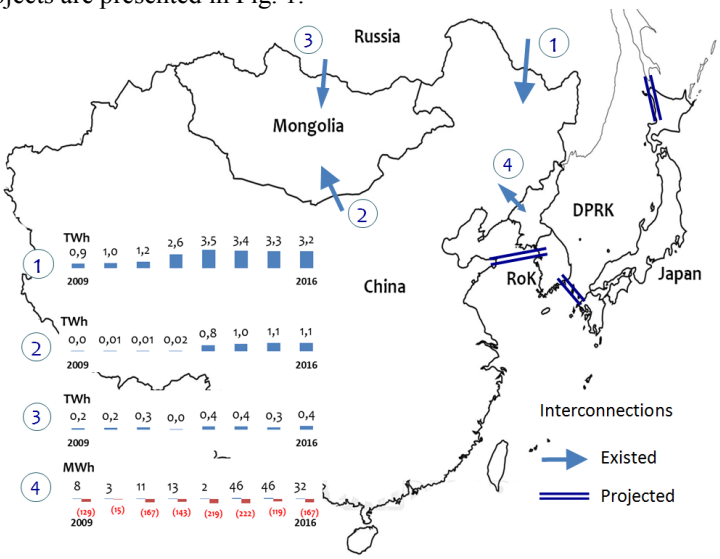

Fig. 1. International power interconnections in Northeast Asia in 2009-2016. Source*:* [2]

Electricity trade (also hereinafter referred as power trade to emphasize its power system particularities) within region is regulated by contracts. This institution requires systematic engagement of the bilateral institutions to the level of intergovernmental commission's competence, at least. Thus, development of new power interconnection project require legislative amendments, and gravity centre shifts from technical and economic issues to financial and political interstate relations.

Despite the fact that Japan and the Republic of Korea (ROK) do not participate in international power trade, the discussion for creation of a regional power network infrastructure is a novelty not only for them. The task to create a developed system of power interconnections change paradigm of energy supply for all countries in the region. For the energy business this means the need to develop (or establish in case of their absence) institutions for international power trade and relevant services within the region. States will need in adjustment of institutions shaping their energy policy, which in turn may affect social, economic and foreign policy frameworks of these states.

This paper deals with critical issues of creating international cooperation institutions imminent for the development of electricity infrastructure in northeast Asia in the long term. The methodological approach to the topic is based upon studies on the practice of multilateral energy cooperation in APEC [3, 4].

2 Purposes and characteristics of initiatives for develop power interconnections in Northeast Asia

It should be noted that there are a lot of projects related to the development of international energy infrastructure in Northeast Asia. All these initiatives differ in time frames, participants list, power infrastructure features, scope of the expected cooperation between national and sub-national power grids, *etc*. For the purpose of this study, the tasks that need to be addressed arose from an initiative of Northeast Asia Regional Power Interconnection

and Cooperation Forum, initiated at the organisational conference held in October 2016 in Beijing [5].

The co-organisers of this international conference were China Electricity Council (CEC) jointly with Global Energy Interconnection Development and Cooperation Organisation (GEIDCO) and Energy Charters Secretariat (ECS). The conference participants included: representatives of governments, energy companies, industry and research organisations, as well as international organisations, notably – the Asian Infrastructure Investment Bank and the United Nations Economic and Social Commission for Asia and the Pacific. The goal of the new initiative was defined as the development of mutual understanding between the participants to facilitate the conclusion of agreements between regional governments to develop international power infrastructure within the Northeast Asia region.

An informal definition of this initiative's goal is the creation of united power system in the region, which will foster the most efficient use of generating and accumulating capacities in the participating countries to meet the needs of domestic electricity consumers. Thus the advantages of remote generation sources will be available to all consumers by means of transit through other member countries.

Steps to achieve this target will require the realisation of the following conditions:

- the rules, agreed by all parties of an interstate power grid, that regulate access to the transmission systems;
- peer participation of stakeholders in the development of transmission systems
- pricing mechanisms availability along the routes of power transmission between generators and consumers.

The latter is required to reflect the technical limitations set by for power generation and transmission system in order to meet the supply and demand balance. In addition, and most important for the coming decades, such pricing mechanisms (determined for short time frames) work effectively in power systems with a high rate of intermittent renewable energy generators.

2.1. The issue of multilateral cooperation

Connecting two hubs in different countries throughout transmission lines demonstrates the bilateral kind of power interconnections in a natural way. Multilateral aspects are possible only in the case of multiple connections between several countries, *i.e*. in case of the establishment of international power grid qua systematic progress of bilateral power interconnections. In this view, multilateral approach will allow to utilise the transit (and storage) potential of the power infrastructure to produce positive effects for all participants of international power grid. Numerous studies show the presence of synergy for such associations established in the region of East Asia. In particular, the salient economic effect appears for the case of increasing share of power, generated from intermittent renewables, and due to the operation mode of the hydropower to provide system services for maintaining power consumption. The most recent publications should be named are by Podkovalnikov et al. [6], Otsuki et al. [7], Otsuki [8].

Within the framework of the *Northeast Asia Regional Power Interconnection* International Energy Initiative (IEI *NEARPIC*), a major source of generation based on wind and solar energy is assumed to be arid and semi-arid areas of the Gobi and Western China, areas of the seas adjacent to Japan, the Korean Peninsula, and coastal provinces of China. The development of European united energy system, which brings together almost all the continent, except Russia and some countries of the former USSR, might be used as an analogy for IEI *NEARPIC*. The major issue for the governments at various levels in East Asia will be the determination of acceptable extent for national markets integration into a regional power grid in North-East Asia (Asian Super Grid).

Regardless of the dominant character of bilateral projects, the participation of several other organisations in the IEI *NEARPIC*, for example, international development banks and research organisations, can have a significant impact on accelerating the achievement of given initiative goals and increase the likelihood of transition to the stage of energy infrastructure's actual development. Such actors' contribution will be most needed for the development of power market regulation institutions: codes for buyers and sellers access to generation and transmission infrastructure; rules of capacity reservation and system regulation; pricing mechanisms; overall market regulation.

2.2 Contradictions between actors

The APERC study says there are three main groups of actors: businesses, governments (which includes international government-based organisations), civil society. For national and international business participation in the IEI *NEARPIC* provides additional opportunities in such areas like R&D, energy infrastructure construction, and operation. Gradual development of energy infrastructure will lead to international power interconnections, and furthermore – to a regional (international unified) power grid. It is important to note that mutual agreement and adaptation of national and international power market institutions are required for creating these opportunities and attracting businesses to such a project. These institutions include the mechanisms of financial, technical, environmental regulation that provide different types of grants, subsidies and guaranties for energy business. The process of reaching agreement on national and international markets institutions is comprehensive, iterative and bilateral. Besides, positive results for businesses may be non-obvious. The examples of the institutions that require agreement between national and international level are government guarantees, tax benefits, fid-in-tariffs, compulsory share of renewable energy in power generation, etc.

National and international government structures play a crucial part because they have an authority to influence on the rest of the IEA *NEARPIC* actors. National governments and international government-based organisations take all the issues related to achievement of positive balance for each actor's contribution and those social, economic, political gains he receives from international energy cooperation.

Imprudent government decisions can lead to contradictions between businesses and the other actors on national (or sub-national) level. The examples of such decisions are shown in the boxes "Economic consequences of power generation infrastructure reduction in import countries" and "Social and economic consequences of providing power maintenance services in export countries". In order to prevent negative consequences of the premature decisions, special mechanism should be implemented within the IEI *NEARPIC*. Such mechanism will assist any actor to examine different models of the international power markets institutions and assess they efficiency. These models can include different levels of informational openness and playground in the areas related to national energy infrastructure operation, regulation of infrastructure development, security criteria. The mechanism, based on different types of models with approved methodology, will be used to explain and validate reasoning along the policy making process, as well as provide opportunities for common language communication within stockholders [3, 4].

Economic consequences of power generation infrastructure reduction in import countries

Electricity import cuts off business activities in importing country, such as fuel production, transportation, conversion, power generation, from sources of profit. For example, through reduction of reserve capacities, the business associated to such generators should fade away. In this case cash flows and value added, related to the business, are withdrawn from the

economy, and total volume of employment rate decreases. At the same time, the opportunity to import electricity can lead to discounted price for consumers that raise competitiveness of domestic production and the total level of economic welfare. Besides, the transfer of environment pollution sources to export countries decreases environmental impact of importers, thus transferring externalities and total cost of environmental abuse.

Social and economic expenses of providing power system services in export countries

The engagement in the system's capacity control raises pressure on the environment. For example, the use of hydro power plant reservoir as an accumulator within integrated power system requires mechanisms for adequate assessment of externalities cost. It might lead to contradictions between businesses and different levels of national authorities, and even rise to acute international issues of joint water systems regulation in exceptional cases. In order to compensate for negative economic and social effects, there should be robust mechanism for redistribution of the income derived at international power markets. This mechanism should ensure both overall positive effects for each affected stakeholder and sustained interest of all actors in cooperation at international level.

2.3 Reforming the national markets

Currently, there are no countries with a truly competitive power market in the East Asia region. The reform of power industry in Japan is still in a stage of testing recently introduced competition rules. While Japan and the Republic of Korea have achieved significant success in introducing market institutions in the electricity sector, they requires time to adapt. The indicator of a mature competitive market is a relatively low threshold for entry of foreign business, such as power generator, electricity trader or network services provider. Although Russia is one of the first and the most advanced economies in introducing competitive mechanisms within power industry in the Northeast Asia, the Russian power wholesale market is not introduced at the territories, related to the IEI *NEARPIC*. The one exception is the Baikal region, representing the most eastern part of the power and system services market in Russia. Yet creation of national competitive and liberalised markets in China and Mongolia are under discussion, there is no real advancement so far. Not participating in the IEI *NEARPIC* process, the DPRK appears to be far from discussion on the rules of cross-border power connections. The existing bilateral trade relations between Russia, China and Mongolia are based on long-term contracts, where the price mechanisms do not reflect the balance on fast evolving national markets for power and network services.

Great efforts in the creation and development of international power and system services trading institutions will be required from all the participants in order to integrate several countries and transform bilateral power interconnections into the international power grid of the Northeast Asia region. Let us assume there are submarine cables between the Shandong province in China and the city of Incheon in the Republic of Korea, between the Republic of Korea and Japan through the Strait of Tsushima. The grid infrastructure is technically able to transfer the power, generated by wind turbines at the south of Mongolia to the Western Prefectures of Japan through China and The Republic of Korea. It is obvious that there should be institutions to regulate the procedure of signing standardised sales/purchase contracts for a unit of capacity between participants from at least two participating countries with minimal transaction costs. Capacity purchase is a deal where the seller guarantees capacity at certain voltage level, by certain discretion of capacity for certain discretion of time, e.g. "*5MW at 500kV voltage for 15 minutes from 11:30 to 11:45*

at X node of the X-Z transmission line". Currently the following binding instruments for the implementation of this transaction are missing:

1. mechanisms for setting a "day ahead" price of a unit of power capacity (UPC) at the Mongolia's wholesale market
2. tariff for the transmission of UPC by the national transmission lines of Mongolia (hereinafter power transmission takes losses into account)
3. custom tariffs on the UPC exported from Mongolia
4. custom tariffs on the UPC imported to China
5. charges, related to injection of UPC into the Chinese power grid
6. transit tariff for the transmission of UPC by the national transmission lines in China from the point of import (from Mongolia) to the point of export (to the Republic of Korea)
7. similar to points 3-6 for UPC imported from the Republic of Korea to the power grid of Japan
8. mechanisms for setting a "day ahead" price of UPC on the wholesale market of Japan.
9. real-time wholesale market to balance consumption and generation for all national power grids in the countries involved
10. post-factum clearing mechanisms to settle forward and balancing deals

In case of significant purchases and sales of renewable power, or in case of utilising large energy accumulators in the system (e.g., pumped storage and/or hydropower plant), or in case of providing critical service to maintaining power quality within the system, the institutions to ensure such transactions are necessary.

The examples of essentiality for the regulation of system services are the mechanisms for incorporating the "externalities cost" into the price of electricity supplied by hydropower plants. There are different operational modes for hydro plants. The first mode is standard, corresponding to the power generation from the controlled source of renewable energy. The second mode refers to the participation in the process of energy accumulation within power grid. An issue of seeking "a fair price" is crucial for creating common rules to determine commercial and economic efficiency for each actor.

The differences in national regulatory framework for power industry will have the most significant impact on the development of pricing mechanisms, which in turn represent a key issue for international power interconnections. Harmonisation of the market regulation institutions for all economies involved in the IEI *NEARPIC* will provide a key to the very success of the international cooperation. Building a joint system for regulation of international trade of power and power system services requires enormous amount of work to bring the legislation of all participating countries to common denominator. Since international power trade has significant impact on social and economic development of the participating countries, it is necessary to ensure working mechanisms of energy strategies coordination for each country, among other types of the common power market institutions. The latter circumstance requires special attention from all of the IEI *NEARPIC* participants, since it may result in a radical revision of the current energy security paradigm.

2.4. The issue of insufficient awareness of the participants

Currently there is no coherent plan to create a system of international power interconnections in Northeast Asia. The lack of tools that would allow a wide range of participants to assess the effectiveness of their participation in IEI *NEARPIC* based on shared vision can complicate and slow down the process of achieving the goals of this international initiative. Moreover, such a major infrastructure project like the construction of the interstate power connections in Northeast Asia has significant multiplicative effects.

Namely, there is an impact on the development of important industries, like mechanical engineering, metallurgy, chemistry, construction. Using the definition of goals set for the IEI *NEARPIC*, this international initiative is expected to solve following tasks in the informational context:

a) to create a platform for constructive discussions and stimulate the search for alternative approaches for issues arising from the international institutions' implementation process, and thus ensure the effective development of interstate power interconnections in Northeast Asia;
b) to spread knowledge on the nature and benefits of cooperation between participating countries, adapted to various segments of the audience.

Creation and development of a mechanism that allows solving these issues on a basis of mutual trust can form bold foundation for this initiative. As it follows from empirical studies described in the second APERC report on international energy initiatives [4], the trust between actors arise on awareness, underpinned by a commitment to achieve common goals (with their adequacy to the circumstances external to the initiative's framework). That postulates the basic prerequisite for the successful implementation of any international energy cooperation.

One kind of inter-actors communication mechanisms can be designed upon modern network resource, with graphic content and gaming component, in order to enhance awareness and intensive considerations of new power interconnection projects. In the form of business game it will provide an opportunity for each participant to consider his own project evaluations at different levels of aggregation relying on proven methodology – from subcontractors to local generators, to regional (or national) government. Another purpose for such a mechanism will be a background preparation for discussions at the working group level.

2.5 The issue of technological scope

To a certain extent the goal, established within the IEI *NEARPIC*, is due to the political requirement to reduce nation's dependence on fossil fuels. One of the most viable approaches to deal with this issue is to accelerate development for renewable power generation. Taking into account technological progress, that means a growth of wind and solar energy share in total electricity production. Additionally, due to intermittent nature of wind and solar energy, the needs to ensure sufficient capacity and topography for transmission lines, and electricity accumulation capacities within power grid, should be taken into account.

In the case of bilateral power connections establishment, even more in case of the Northeast Asia international power grid development, there will be a need for an organisation that holds confidence of all participants to provide guaranties and reduce risks. In such a case, the national energy management systems should be harmonised at the institutional level of multilateral international cooperation.

While at the initial stage the IEI *NEARPIC* is seeking for its ultimate goal and patterns to reach them, it seems appropriate to implement the experience of similar initiatives being undertaken in this region. Established in 1996, the IEI *NAGPF* set its goal as "*to develop the concept of creating a network of international gas trunk pipelines in the Northeast Asia*". Since gas trunk pipelines relates to the technologies of continuous energy transportation, it can be considered as some analogue for power systems. From the very beginning the IEI *NAGPF* principally distanced itself from the liquefied natural gas (LNG) infrastructure, which is based on discrete transportation technologies. The opportunities were missed to consider different but complementary segments of a single market. Two decades later, we have to admit that this approach had significantly reduce importance of

the whole initiative for all participating countries to deal with issues of energy security and domestic market reforms.

Insufficient accounting of technological features could lead to incomplete evaluation of the market segments. For example, the expected commercialisation of the power-to-gas, power-to-liquid technologies will create new markets. Such technologies will became competitive to established technologies for power transmission through wires in terms of energy security, reliability and economic efficiency. Consequences of such technological factors impact inevitably will lead to important transformation of the energy markets institutional structure.

The discrete alternatives for electricity transmission have several advantages, related to security and robustness of energy infrastructure:

1. It allows eliminate the gap between generation and consumption due to accumulating abilities of the discreet energy transportation subsystem.
2. It allows escape the monopsony situation by exploiting ability to diversify transition routes in absence of fixed routes infrastructure.
3. It has no extremely high requirements for robustness of long-distance transportation system to keep power supply security.
4. Domestic consumers of energy services can benefit from enhanced competition between different types of energy carriers at national energy markets and from increased level of energy supply security in general.

The existence of cost-effective alternative technical systems to provide energy services (mechanical movement, lighting, air conditioning, *etc*.) does not mean that the development of power interconnections in the Northeast Asia does not require complex multilateral agreements as precondition. However, considering alternatives can help in evaluation of their (multilateral agreements) structure, scale and sequence of evolution [9].

2.6 The DPRK Issue

Weak representation, or lack of participation of the DPRK in the *NEARPIC* initiative reduces the effectiveness of the entire project, since it excludes the use of its hydropower facilities as regulators (and/or accumulators), and the territory for the construction of power interconnections. Yet, provided the positive economic experience from power interconnections is obtained, and the openness of the IEI *NEARPIC* for the accession of other participants is gained, both would establish a powerful factor to involve the DPRK to the regional energy cooperation activity. In addition to positive impact on the socio-economic development of participating countries, the involvement of the DPRK into the process of negotiating and discussing the institutions of power interconnections development undoubtedly will lead to a much healthier political climate within the region.

The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) is representative of the highest level of international intergovernmental actors in IEI *NEARPIC*. The role of this organisation by definition is to act as a mediator between governments to assist in solving common social and economic issues, and it is especially important due to the significance of political factor in the East Asia region. Currently, ESCAP is one of the most influential and trusting actor within the IEI *NEARPIC* process, and by its status has the opportunity to engage the DPRK into the process. The format of the initiative allows actors to discuss technical, economic, social and financial regulation emerging during the implementation of joint projects, and assess the participants' economic and social effectiveness, while leaving political factors behind the scene, or reducing them to technical parameters.

When considering the issue of the DPRK involvement, one should take into account the negative experience of similar initiative on energy cooperation at the Korean Peninsula,

which was doomed to failure from the very beginning because of an incorrect goal setting (see "The KEDO Initiative" box).

KEDO Initiative

The negative environmental assessment was the official reason for termination of the project to build a nuclear power plant in the DPRK – the project, proposed by the United States, the ROK and Japan in March 1995. The KEDO project (Korean Energy Development Organisation) initiative was offered in exchange to the DPRK's refusal from constructing a nuclear power plant, based either on the Soviet, or domestic technologies. The main argument for the negative environmental assessment was aroused from discrepancy between the capacity of proposed power plant (two 1GW reactors) and existing status of the DPRK power grid. In this country a single generator capacities do not exceed 200-300 MW, and the country's backbone transmission lines does not guarantee safe operation of nuclear reactors due to overall grid inefficiency.

Experts had foreseen such results long before, after abandonment of the first nuclear power plant project north to DMZ. On a wave of consequences after USSR dissolution, project for several 400 MW reactors of the USSR design had been substituted by another project on the same site. That new project implements US-based technologies for two 1000 MW units, which actually could not fit to the DPRK power system. Petroleum deliveries to the DPRK dried up in 2003, following negative conclusion of the project's environmental impact assessment. Overall, the process lead to the second withdrew of the DPRK from the Nuclear Non-Proliferation Treaty. The first time the DPRK leave the Nuclear Non-Proliferation Treaty in year 1993, after failure of the comprehensive safeguards regime implementation under agreement with the IAEA (came into force in April 1992).

The Directorate of the KEDO program on May 31, 2006 decided to stop any activity for the reactor construction. As a consequence the existed minimal level of confidence in both nuclear non-proliferation and energy cooperation between the DPRK and the KEDO member countries was eliminated [10].

Implications

The strengthening of integration processes in the Northeast Asia region and the concept of a single electricity market development are behind the elaboration of options to create regional power grid. The Northeast Asia economies have favourable economic and geographical conditions, appropriate technologies, but lack of experience in energy cooperation is a significant barrier for such a project. Dramatic transformation for power market institutions, as well as rethinking of principles of the national energy policy will be required for each participant in such a complex integration project.

International energy initiatives can become an effective mechanism for energy cooperation within the region. The project of such an initiative - *NEARPIC* - is intended to provide the platform to facilitate the development of power interconnections in the region through the preparation of favourable framework for multilateral cooperation. The main task at the current stage is to organise the search for proper international cooperation mechanisms, which will ensure the effectiveness of such cooperation for each actor. The need to create a methodology for assessing the effectiveness, and tools for practical use derives from the main task. On the basis of such mechanisms, it will be possible to carry out comprehensive assessments of the Northeast Asia power industries synergy, seek a balance of interests among various actor groups within multilateral framework, like energy business, governments and intergovernmental organisations, and civil society.

The authors consider major factors impeding effective Northeast Asian countries cooperation on the path to unified regional electric power infrastructure:

- Contradicting interests of participants, qualitative heterogeneity and quantitative incommensurability of benefits and costs for each actor.
- Unequal status of the national power market institutions within Northeast Asia countries is leading to inconsistency of national financial, technical and environmental regulation.
- Complicated political stage within the Asia-Pacific region (and Northeast Asia in particular), supplemented by weak mutual understanding in long-term energy policy.
- Lack of coordinated information support for international projects in power industry, leading to a lack of understanding of already announced initiatives for participants, non-commercial organisations and population.

Nevertheless, successful overcoming of the above-described problems is quite possible, which is proved by the example of power market development in Europe. A clear understanding by all participants of issues and priorities for the creation of Northeast Asian joint power grid will positively affect the development of such complex forms of cooperation as power interconnections within the region.

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