Comparative analysis of renewable energy integration in Germany and Russia

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Abstract. The problems and prospects of renewable energy penetration to the Russian regional energy systems are discussed. The comparative analysis of renewable technologies development was done considering Russian and Germany power systems as ones with quite similar initial conditions before the energy transition has been started. Implementation a considerable renewable generation share into a “traditional” power system seems to be perfectly technically feasible still with the state-of-the-art technologies. Substantial organizational, financial and economical efforts seem to be unavoidable. Careful preliminary planing of renewables implementation is crucial to ensure viability of the volatile renewable generation working as a part of the Russian power system.

1. Introduction
The current changes in the global energy balance and the structural shifts which have begun in energy systems around the world during the last twenty years allow for a statement that the "energy transition" from a theoretical concept has become a reality. One of the main features of this transformation process is a substantial increase of a renewable energy share in the national energy balances. This fact unavoidably leads to a change of approaches towards control of energy systems operation which now should be designed to provide an opportunity for integration of volatile renewable generation. A number of such approaches has been still tested in the real applications under different operating conditions. Analysis of the accumulated experience is a valuable tool to intensify energy transition processes around the world.

2. Study focus and motivation
Russia being one of the few countries decreased their greenhouse gases emissions during last thirty years remains among the world leading emitters. Decarbonization of the national energy sector may play a significant role both in promoting development of the national economics and in contributing to the global climate policy targets. Implementation of the renewable energy should be considered as one of the key factors in this transformation process.

Nowadays, a new stage of renewable energy development in Russia is about to began. The power supply contracts, which were one of the main financial tools to attract investment for renovation of the fossil-fueled generation during last ten years and proved to be quite effective, are planned to be used for supporting development of renewable generation during the next decade. Similar financial mechanisms are planned to be utilized to increase Renewable energy commissioning dramatically.
Implementation of renewable technologies into the existing power systems of Russia means a wide range of tasks, ranging from the issues of technological and infrastructural integration to regulatory and market support. Emergence of fundamentally new problems linked with an increase in the share of renewable energy may be expected due to dramatical differences between the stochastically nature of renewable generation and perfectly controllable thermal, nuclear and large hydropower plants, which form the basis of the Russian power industry nowadays. It seems reasonable to look for possible ways to resolve emerging problems in the experience still accumulated around the world.

The renewable generation technologies has attracted quite active research interest in Russia during last decades. However, system level works focused on implementation of renewable power into the national power system are almost entirely limited by considering economic and financial aspects of this development [1]-[6]. The technical aspects of renewable power integration considering the existing practices of highly centralized Russian power system were mainly ignored until a few recent works [7]-[8].

The aim of the presented work is to fulfill a comparative analysis of the renewable generation development taking into account issues resulting from a contradictions between the nature of renewable sources and the implications of the traditional centralized power systems.

As a benchmark for our analysis we have chosen Germany, where up to the beginning of 2000s coal-fired thermal power plants and nuclear power plants were the basis of the national energy system, have been providing about 80% of electricity production. Integration measures implemented during last twenty years have allowed to drop coal and nuclear generation to about 50% substituting it by renewable power.

3. Renewable policy in Russia

3.1. Financial and economical supporting measures

Renewable energy were identified as one of the national energy policy priorities as early as almost twenty years ago by the Federal Law "On Electric Power Industry" in 2003. Today commissioning and operation of renewable energy power plants in Russia are regulated and supported by a number of regulatory financial and economic measures. They define the procedure for qualification of as a renewable energy power object, the rules for determining the capacity price, the capacity selling mechanism relating the qualified renewable generation and so forth.

The existing electric energy market structure determines which mechanisms are applicable for stimulating renewable generation development both at wholesale and retail markets. The main tool of economic support towards renewable generation at the wholesale power market has become the so called power supply contract. This support mechanism guarantees return on invested capital with a fixed revenue and compensation of the profit and property tax as well as operating costs at some fixed costs level. The necessary requirements for commissioning under this contract are localization of the equipment production, ensuring the normative value of capacity utilization factor and compliance with the requirement for equipment availability.

Implementation of the first projects under the power supply contracts started in 2013. In 2015 the Order of the Government of the Russian Federation has defined the current target for renewable energy generation in the country. Production and consumption of electricity generated using renewable power should be as high as 4.5% by 2024 which means more than five-times increase as compared with the actual renewable share.

It should be noted that to the date, almost the entire amount of the renewable power has been commissioned on the wholesale electricity market. Lagging of renewable generation development on the retail markets was resulted from the following conditions:

- lack of a formalized mechanisms for selecting projects intended to operate on the retail markets and for long-term contracting based on the results of such a project selection;
- financial support conditions differ from mechanisms ones utilized on the wholesale electricity market. Namely, capital cost levels are lower, the tariff is calculated on the basis of actual costs rather than to the project costs;
- the tariff in the stand-alone systems is set only for purely renewable generation not for the power complex as a whole which makes it impossible to take into account substitution generation by the project selection and in the tariff application.
The reasons listed above determine currently much higher attractivity of wholesale markets for renewable power implementation as compared with retail ones.

3.2. Integration policy
Volatile nature of the renewable energy is in quite contrast with predictability of the nuclear, fossil-fueled and regulated hydropower plants that are still almost exclusively contributing to power supply in Russia. Integration of the renewable generation into such kind of power systems naturally requires for some measures which account both demand patterns, specific of co-operating technologies and topology of the power grids.

One of the typical features of the regional power systems in Russia is an excessive amount of installed capacity operating in the base-load mode. Quite in contrast, a certain deficit of peak capacity reserves is another serious issue in the national power grid. This situation has initially resulted from changes in the structure of electricity consumption and generation combined with rapid changes of financial and economic circumstances. The power system problems was aggravated by prevalence of a balance calculation approach by planning of the power systems development during recent decades. Besides, generation facilities commissioned under power supply contracts were located to optimize financial efficiency metrics which didn’t accounted for the system efficiency in the optimal way [8].

The mentioned constrains are a lot of serious challenges to ensure reliability of the electricity supply and make testing and implementing of the new control approaches quite cumbersome. The modern approaches like energy storage solutions or an "active consumers" concepts under such circumstances belong rather to purely academic research than to development programs. Moreover, even electricity flows between regional energy systems should be considered as an undesirable phenomenon [8]. As a result, only the regional power systems of the Urals and Siberia, where the share of industrial power consumers is high, meet the balanced supply criterium in the sense of ability to satisfy the diurnal power demand in a technological sensible and economically effective way. Integration of renewable energy into the existing Russian regional power systems seems to be anything but trivial.

The technical side of renewable energy power plants development has still less support as compared with economical aspects. A few technical regulations were approved recently to facilitate renewables integration into the national power system.

A national standard [9] determines technical requirements for wind power plants considering their participation in the primary frequency regulation. Control of active and reactive power of the wind power plant is addressed. However, the document does not contain any methods or recommendations aimed at integrating the production of wind turbines in the existing power systems.

The new national standard [10] came into effect in the begin of 2019 and relates to the general requirements for planning the development both centralized and stand-alone power systems. However, this document does not provide any technical solutions aimed at integrating of renewable power into the existing power systems. The thermal, nuclear and hydro power plants are considered as solely power system participants. The only mention of wind and solar power plants is a requirement to provide a commissioned renewable-energy power plant with a 100% capacity reserve. In fact, this means that today each wind turbine or photovoltaic generator in Russia should be duplicated by simultaneous commissioning of equal electric capacity or transfer to the reserve of existing capacities with the appropriate payment.
Thus, despite the fact that the renewable generation belongs to the priorities of the Russian power industry development, the existing technical policy does not take into consideration system aspects. That may lead to a decrease in system efficiency when introducing renewable generation technologies on a large scale to existing highly centralized Russian power systems. The recent data on capacity factors of the newly commissioned wind and photovoltaic power plants are to a certain degree confirming that there were some issues with commissioning renewable generation. Increase of the renewable penetration may easily lead to intensifying of the possible negative effects linked to mismatch between the existing power operation practices and intrinsic characteristics of renewable
energy. The development of alternative approaches to the operation of regional power systems in Russia with a considerable renewable amount seems to be urgently required the most intensive research.

4. Germany: price of success

Five years ago the concerns related to the large-scale introduction of the renewable power in Germany included a potential negative impact of a high share of RES on the reliability of energy systems [12]. Such a consideration was in many respects close to the today discussions about the renewable energy future in Russia. Surprisingly, the experience of the past years has shown that the increase in the share of wind power generation has even led to a certain improvement in the reliability of the German power system. Today, the stable operation of German regional power systems is ensured for a quite high share of renewable energy in power balance – up to a record high of 75% achieved in February 2020, when wind farms located the northern regions of Germany were particularly favoured by the weather conditions [13].

4.1 Economic support concept

The Renewable Energy Act (EEG) with its several editions is the main instrument for supporting renewable energy in Germany. This law prioritizes the production and consumption of energy produced using renewable generation. The first version of the EEG established fixed tariffs for renewable electricity as well as the period of validity of these tariffs, and obligated energy companies to buy this renewable energy. At the same time, the additional costs incurred were not subsidized, but were in fact paid by the end users. The 2009 and 2012 editions of the EEG-law essentially determined the adjustments to the fixed tariffs for various types of renewable power in order to achieve a given structure of renewable power operating as a part of the German power system. The significant burden on end users should be decreased according to the 2017 EEG-version that prescribes a step-by-step shift from the fixed tariff system to direct competitive sales of renewable electricity. Such a progress was indeed made possible due to quite successful technological integration of renewable power into German energy system.

4.2 Technological measures

One of the prerequisites of the renewables integration success were definitely optimization and expansion of the transition and distribution power grid which included backup networks constructed keeping in mind planned changes in the structure of the national energy system. Implementation of these measures was facilitated by the fact that the system operators in Germany are owners of the power grids in the areas where they operate. The main challenges nowadays are related to the need for different network operators to interact with each other smoothly to ensure fulfilment of the tasks that are relevant to the whole national territory (e.g., replacing nuclear power plants located in the south with wind farms operating in the north of the country) [13].

Another renewable energy integration approach included introduction of quite strict requirements thermal and nuclear power plants. The large-scale power plants traditionally operated as base-load plants now operate balancing the renewable generation variations to ensuring frequency regulation for the power system. Utilization of this measure means the need to reimburse the expenditures arising from a variable operation mode of the nuclear and thermal power plants, which leads to an additional costs of renewable generation for consumers.

The third integration concept to be mentioned is utilization of the power flows between the regional power system and the adjacent ones in order to balance volatile renewable generation. This measure is the most used for the regimes of energy systems with high share of renewable generation. In addition, the flows between the energy systems of Germany and neighbouring countries (Poland, Czech Republic, Denmark) are also used.

These measures was proved to be very effective to establish integration of an increasing renewable generation share into a centralized German power grid that relied initially on inertial large-scale coal and nuclear power plants. However, the policy implemented implied a positive social perception towards the energy transition and associated increase of a financial burden for consumers. Nowadays
the electricity price in Germany in one of the highest in Europe, but the renewable share in the brutto power generation of 30-40% is already today securely ensured [14].

5. Discussion and conclusions
The German experience demonstrates that the guaranteed capacity payment mechanism is not the only effective tool to stimulate development of the renewable generation. It is also important to create market mechanisms to stimulate economical viability of the renewable power. Keeping in mind the quite low costs of fossil fuels in Russia, the grid parity of renewable energy sources may achieved under constraints of the Russian power system at a lower cost of "green" energy.

The main lesson may be learned from the German “Energiewende” is that implementation a considerable renewable generation share into a “traditional” power system is perfectly feasible from a purely technical point of view. There is no any major technical obstacles to ensure integration of 1-5% renewable share which corresponds to the Russian plans for the next few years. However, substantial organizational, financial and economical efforts seem to be unavoidable if the natural conditions for renewables development are not exceptionally favourable like it is the case in Norway, Denmark or Island.

New technological concepts like large-scale power accumulation solutions or smart-grid solutions could contribute to facilitation of the renewable power implementation. However, these measures seem still to belong to the future power systems rather to actual ones. Nowadays integration of the renewable power is ensured by the proper power grid expansion, increase of the regulation range of the existing power plants and use of the power flows between different power systems. Consistent technical policy is essential to make these measures work.

Another key aspect of the renewable integration is the social perception of the technology itself and associated additional cost. The renewable energy still remains quite expensive in terms of direct costs. However, account for indirect consequences like improvement of the life quality or driving of economical development may reverse this conclusion. A holistic approach combining energy systems modeling with social and ecological aspects is crucial to ensure viability of the renewable generation in the power system.

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