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The Problem of Electricity Demand and Supply Balancing in Germany as a Side Effect of the Renewable Energy Sources Development

Abstract. *The major goal of German energy policy is becoming independent of external fuel supplies and preventing climate changes. Therefore, German government has been consistently replacing fossil fuel energy sources with renewables. As the power generation from renewable sources is highly dependent upon the weather conditions, and due to the fact that dispatchable sources have been pushed out of the market maintaining balance between the energy supply and demand is becoming more and more difficult. The state intervention such as system support by conventional reserve power plants has become inevitable.*

Keywords: *available power, renewable energy sources, reserve power plants*

Introduction

For several years, Germany has been trying to become independent of importing energy resources. The process of power sector transformation has been named *Energiewende* and it means implementing renewable energy sources and moving away from those based on fossil fuels. However, a number of problems have been encountered in the process.

From the technological point of view, operating any power system is connected with the challenge of maintaining the balance between the supply and demand of electrical energy in any given moment. For years, these systems have been

operated on the assumption that it is the demand that changes and the supply is supposed to comply with that change. This has changed together with the integration of the renewable energy sources, as their supply is strongly dependent upon the weather conditions. Nowadays, both supply and demand are changeable and the balance between the two is much more difficult to accomplish. Facing the lack of energy storage technology on a large scale, the only solution to the problem of maintaining the mentioned above balance seems to be using dispatchable energy sources, such as the sources based on fossil fuels. These, unfortunately, are being pushed out of the market by subsidized non-dispatchable (renewable) energy sources. This phenomenon can be observed in a number of countries due to the fact that the most common form of energy market in Europe is Energy Only Market which comprises only electrical energy turnover.

However, the power system cannot function without another crucial product which is available capacity. In the past, energy was generated almost solely in conventional power plants. In case of this type of energy sources available power is a natural product obtained together with electrical energy. Therefore, Energy Only Market was efficient and no attention was devoted to available power as a product. However, one must bear in mind that there has been a huge change in the structure of energy production in recent years. A gradual decrease in conventional power plants capacity has been observed together with a huge rise in the capacity of renewable installations. The loss of service of available power has become a side effect of renewable energy sources development. Due to the fact that Germany is a leader in renewable energy sources integration, it is this country that suffered first from pushing out available power and encountered difficulties in balancing energy supply and demand. This situation has led to the regulator's and state's reaction and the implementation of a number of new solutions.

The purpose of the following paper is to present the most significant problems connected with the ongoing transformation of German energy industry which is based on systematically increasing share of renewable energy sources and the solutions undertaken by the German government.

1. Dispatchable power capacity deficiency in German power system

The goal of German energy policy is to cover 80% demand for electricity with renewable energy sources and to reduce the greenhouse gas emissions by 80% by the end of 2050. Both the progress in development of renewable energy sources and the amount of financial resources allocated for that purpose in Germany are unprecedented in Europe. The subsidies have been systematically increasing in the past years, reaching 23.7 billion euro in 2015, and the predicted amount in

2016 is to be 25.5 billion euro [BDEW 2016b: 70]. The total amount that has been paid to the producers since 2000 is estimated at 190 billion euro.

German energy policy besides positive effects, including the renewable energy sources share of 32.6%, has brought about some negative consequences as well. One should realize that the energy production with the use of wind power and photovoltaic energy sources is dependent on the weather conditions, which is why these energy sources are called non-dispatchable. Due to the fact that conventional energy sources can be activated on demand and the production volume can be regulated they are called dispatchable energy sources. The share of dispatchable sources in German power system has been systematically declining in the past few years, which makes maintaining the safety of its operation and balancing the supply and demand more and more difficult.

The renewable energy sources act [Erneuerbare-Energien-Gesetz – EEG 2014] guarantees that they are granted the priority in the power grid access. This means that the energy from these sources needs to be collected from the producer regardless of the current market price. In the periods of favourable weather conditions, renewable sources supply large volumes of electricity, what results in a fall in the wholesale price. Nowadays, energy prices are on the lowest level in history. The wholesale prices are more and more often negative, which means that the seller needs to pay for collecting his or her product (for example, on 8.05.2016 between 14.00 and 15.00 o'clock it was possible to receive energy together with the payment 130.09 euro/MWh) [EPEX SPOT 2016]. The volume of energy produced from wind and photovoltaic sources had doubled in the years 2011-2015, reaching the level of 126.4 TWh in 2015. At the same time, the average energy price had fallen by almost 50% to 30.97 euro/MWh. Details are presented in Table 1.

Table 1. Supply of non-dispatchable energy sources and average energy price

Year	2011	2012	2013	2014	2015
Amount of energy produced from wind and solar radiation (TWh)	68.5	77.1	82.7	93.4	126.4
Average energy price (product baseload) (euro/MWh)	56.07	49.30	39.08	35.09	30.97

Source: own on the basis of BDEW 2016a: 40; 2016b: 13.

However, the low wholesale energy price is not a problem for the owners of renewable energy sources as they receive compensation calculated as the difference between the selling price and the contract price. This compensation is financed by households and added to their electricity bills as a special charge for renewable sources (German EEG-Umlage), which, for the year 2016, was established at the level of 6.354 cent/kWh.

That is different for conventional energy sources whose income has been constantly decreasing due to falling wholesale prices. Low energy prices have led to the situation in which conventional power plants exploitation has ceased to be profitable. Two units of Irsching gas power plant, built in 2010 and 2011, can be referred to as an example. Their efficiency factor of 59.7% and 60.4% makes them the most modern units in the world, yet, according to the owner – E.ON – the power plant has not worked for a single hour supplying the energy to the market since 2014 [E.ON 2015]. This resulted in the owner's decision to put forward a motion to the regulatory authority for the facilities to be closed down. The situation of Irsching power plant reflects the phenomenon, which is now being observed throughout Germany, of moving conventional energy sources to the right on the merit order list and replacing them by subsidized renewable energy sources. The biggest energy producers have already restructured their companies by isolating unprofitable sectors of conventional energy production (as a risk optimization). Energy market does not stimulate investors to build new conventional facilities. On the contrary, producers put forward motions to the regulatory authority to close down many conventional units. According to the German regulator, 69 power plants with the joint capacity of 14367 MW, which is more than half of Poland's energy demand, had requested permission to turn off their facilities between the end of 2012 and November 2015 [Bundesnetzagentur 2015: 67]. The mentioned above report does not specify the reasons why the producers want to close down their facilities (rate of decapitalization or loss of profitability).

Another reason for decrease in available capacity has been the German government's decision to decommission nuclear power plants. This was mostly due to the accident at the Fukushima nuclear power plant in 2011. At that time the German government decided to phase out nuclear power. Prior to that, nuclear power plants were considered as transitional energy sources until they could be entirely replaced by renewable energy sources as soon as the electricity grid is properly strengthened. After the accident in Fukushima, 9 nuclear power units were closed down in Germany, the joint capacity of which was of over 10 GW. The 8 remaining nuclear power units with the capacity of over 11 GW will have been closed down by the end of 2022. The overall costs of dismantling all the German nuclear power plants were estimated at 47.5 billion euro in 2015. One needs to bear in mind that although nuclear power plants are expensive in terms of investment costs, which have already been incurred, they are relative cheap in terms of variable costs. Therefore, they are much less susceptible to low prices on the wholesale market when compared to other conventional power plants. As the result of that, there was no risk of ceasing production due to low profitability as it happens in the case of gas and coal based power plants. The German government's decision resulted in the loss of 17 units with the power capacity of over 20 GW from the

power grid. Moreover, most of the closed down plants were situated in the south of the country which is the region characterized by the highest power demand.

The German government has pledged reductions of greenhouse gas emissions by 40% until 2020 (with reference to 1990) as part of the European Union climate policy. As achieving this goal might be at risk the Germany has decided to close down several brown coal plants with a total capacity of 2.7 GW, which is 13% of the overall capacity of all lignite-based power plants, which is another reason for the decrease in the share of dispatchable power in the system. The units ought to be decommissioned gradually starting from 2016. They will be, however, maintained ready for use to secure the grid's safety for the period of 4 years. Then, they will be closed down permanently. Their owners will be compensated for the decommissioning with 230 million euro a year for the period of 7 years. These costs will result in the price rise of 0.05 cent/kWh that will be borne by the customers.

Another problem that German electrical system needs to face is the geographical distribution of energy sources. The regulatory authority states in the annual report [Bundesnetzagentur 2015] that there is energy oversupply in the north of the country, while the demand in the south cannot be satisfied by the existing power plants. Moreover, the electrical grid is not developed enough for the excess energy to be transported to the south, which very often results in the power grid overload. This phenomenon intensifies annually between October and April. Some of the energy produced in the north is transported south with the use of neighbouring countries systems, mainly those of Poland and the Czech Republic.

The Main River is considered to be the border line between the north (energy oversupply) and the south (energy deficit) in the public debate. Although the energy balance of the plants under construction and those which are planned to be decommissioned by 2019 is positive, it is still considered as unfavourable due to the investments location. To the north of the Main River the capacity of the units under construction is expected to exceed the capacity of those which are going to be decommissioned (those based on gas and coal), while to the south of the Main River the capacity balance is short (missing 2323 MW). Therefore, the problems with energy transmission from the north to the south are expected to increase. One should take into consideration the fact that the decisions on new investments were taken several years ago. There has been a significant fall in the wholesale prices since then, and that is why the units under construction are not expected to be profitable.

2. Actions undertaken to maintain energy balance and security of the system operation

In a time of Energiewende, maintaining the energy supply and demand balance together with the operational system security is getting more and more dif-

ficult and it requires that the German government and the regulatory authority should introduce supporting mechanisms and take proper actions.

According to the Regulation on Network Reserve issued in 2013 [Netzreserveverordnung 2013], so-called network reserve was introduced. The objective of this service is to maintain the energy supply in the south of the country at those times when transmission of energy (generated in wind power plants) from the north is not possible. This service is provided by those power plants whose operation within the energy market is no longer profitable, but whose motion to the regulator for decommissioning was rejected on the basis of their significance in maintaining the system safety. These units are at the grid operator's disposal who can activate them especially between October and April (that is why this reserve is commonly referred to as "winter reserve") when problems with satisfying the energy demand in the south are expected. German system is also supported by reserve power plants located abroad, i.e. in Austria, Italy, France and Switzerland. Indispensable reserve for the period between October 2014 and April 2015 was established at 3636 MW. At that time German grid operators had to use the reserve for seven days and sometimes this potential was almost fully exploited. The analysis conducted by the grid operators and confirmed by the regulatory authority exhibited the necessity of increasing the reserve to 7515 MW for the period between October 2015 and April 2016. It needs to be stated that less than the half of the reserve (2995 MW) comes from German power plants and the rest (4520 MW) is provided from power plants located abroad. During this period of time the reserve had been activated for 93 days in total. The reserve for the winter of 2016/2017 was established at 5400 MW. The costs of the mentioned above service tend to rise systematically and amounted to 56.3 million euro in 2013, 66.8 million euro in 2014 and 168 million euro in 2015 [Bundesnetzagentur 2016: 18]. Whether the service in question will be needed in the future and to what extent is dependent upon the advancement in the power grid development and its capacity in terms of transferring energy from the north to the south.

The Act on Energy Market introduces another mechanism [Strommarktgesetz 2016]. It states that a new type of power reserve will be established starting from the winter 2018/2019. The service will be provided by those power plants which will win the tender and will sign a contract with the grid operator. The obligation of tendering these contracts will be incumbent upon the transmission network operators. Producers are forbidden to trade produced energy freely – their facilities are going to be at the sole disposal of the grid operator (they must not be market participants). After the contract expires the units are obliged to cease their operations. The main goal of this service is to create a safety buffer in case the volume of energy available on the market is not sufficient to satisfy the existing demand. This might happen when the energy production based on renewable energy sources is not sufficient. First tender procedures will be initiated in 2017 and their aim is to

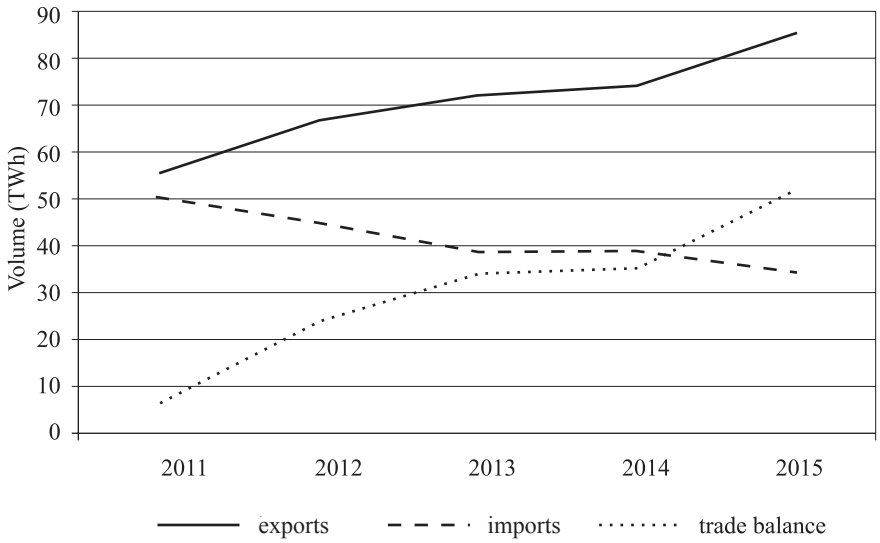
contract the capacity of 2 GW of reserve power for the winter of 2018/2019. Then, starting from 2020/2021 the reserve should constitute 5% of maximum annual demand. After that, the ministry (Bundesministerium für Wirtschaft und Energie) is supposed to verify the volume of the reserve every two years. Power plants will be granted an annual payment to cover fixed costs and variable costs. The latter are costs of producing energy when the facilities are activated on the operator's demand. The exact costs of this new service will be known after the tenders are closed, however, according to the ministry's estimation, they will be in the range of 130 and 260 million euro a year. The costs of maintaining the facilities ready to use are to be transferred to the end users (between 0.028 and 0.055 cent/kWh). The activation costs, however, will be incurred by balancing groups which are responsible for causing imbalance in the system (these users who did not desist from consumption despite there was not enough energy for them on the market).

According to the same act, it will be possible to build new power plants if it is necessary for maintaining the safety of the system operation. These units will be used as both the network reserve and the capacity reserve, depending on the need. The total capacity of such facilities throughout the country cannot exceed 2 GW. The operators of transmission networks are supposed to carry out the analysis by the end of January 2017 and decide whether the construction of the new facilities is really necessary. Taking into consideration the energy deficit in the south of Germany, it might be assumed that the decision will be positive. The volume of demand for new capacities will be verified in the following years. The proposal of the Regulation on Capacity Reserve [Kapazitätsreserveverordnung 2015] imposes the requirement on the new reserve power plants according to which they need to supply their full power within 45 minutes after receiving the signal from the network operator. Such short start-up period can only be provided by gas power plants. Therefore, it is essential for the tenderer to make sure whether the gas infrastructure is sufficiently developed and to provide gas fuel by signing proper contract with the gas network operator. There are also other arguments in favour of gas technology, such as lower fixed costs and capital expenditures when compared to coal based power plants. High variable costs (fuel price) do not influence the profitability of the investment as the reserve power plants are supposed to operate for a limited number of hours a year and the product they offer is, above all, availability.

Apart from the actions undertaken within the country, Germany is highly interested in the development of the common energy market in Europe. Removing barriers in the free international energy trading would result in finding more clients interested in buying German energy during the periods of oversupply and in satisfying German electricity demand thanks to import during the periods of deficit (e.g. days without wind). The markets of Germany and Austria are already put together, which is profitable for both countries. Austrian pumped-storage power plants buy cheap German energy in order to store and resell it when prices rise.

This exchange is also profitable for Germany because makes it possible to sell the energy for which customers are hard to find. Austria is the biggest trading partner for Germany in terms of electricity exchange. The total volume of exports and imports and the balance of exchange for Germany are presented in Figure 1. It can be noticed that the exports have been rising systematically for a few years and in 2015 the balance of exchange (exports less imports) reached the record value of 51.8 TWh (this is as much as one third of Polish demand for electricity) and it is connected with the increasing production from renewable energy sources.

Figure 1. Balance of international exchange of German system



Source: own on the basis of BDEW 2016b: 13.

Interesting conclusions can be drawn from the comparison of the average prices Germany used in international exchange. The data from the regulator indicate [Bundesnetzagentur 2015: 145] that electricity was sold abroad at the average price of 36.98 euro/MWh in 2013, and bought for 39.7 euro/MWh. The following year the average exports price was 32.12 euro/MWh, and imports price – 34.05 euro/MWh. The difference of about 2 euro/MWh is an apparent loss for German economy. In reality the trade with other countries is for the German power system the cheapest form of energy storage. That is why the construction of additional connections with Denmark, Sweden and Norway is being planned in order to take advantage of favourable hydrological conditions of Scandinavian countries (energy storage possibilities) in order to export oversupply and support the system during the supply deficit.

Conclusion

The example of Germany shows that the transition to renewable energy sources is a complex process. Rapid development of subsidized renewable sources has resulted in the decrease in the wholesale price of energy. This, in turn, has led to the loss of profitability of numerous conventional power plants which either have already withdrawn from the market or are going to withdraw in the nearest future. This is how conventional units have been pushed out of the market by the renewable energy sources.

The loss of dispatchable energy sources is also directly connected with political decisions, the first of which was the one made in 2011 on closing down all the existing nuclear power plants. The second one concerned decommissioning some of the lignite power plants. The development of renewable energy sources together with the decommissioning of conventional power plants results in the constantly diminishing share of dispatchable units in the system. The fact that the supply of energy from renewable sources is highly dependent on the weather conditions and is obtained in the periods in which it does not suit to the demand makes it even more complicated. Thus, ensuring the power balance and safe network operation is becoming more and more difficult.

Energy Only Market, on which the service of availability of energy sources for work is not provided, cannot solve the arising problem. Therefore, the intervention of the government and the regulatory authority, which is to ensure enough power that can be generated on the operator's demand, has become indispensable. The service of network reserve has been introduced recently in order to provide supply in the south of the country. Another service, that is the capacity reserve is supposed to satisfy the demand when the supply available on the market is not sufficient. Also the measures that have been undertaken in Europe in order to remove the barriers in the free energy trade will result in stabilizing the German system. As a result of the energy exchange the periodic surplus is exported from the German system. When the demand is high and supply low, Germany can reduce the deficit with imports. The cheapest form of energy storage is using the systems of other countries. Therefore, Germany is planning to build more transmission lines with Scandinavian countries in order to use their, favourable for energy storage, hydrological conditions.

The introduction of the new reserve system together with the actions undertaken in order to enhance international energy trade will make it possible to increase the share of renewable sources in the energy mix. This will also provide the time necessary to develop the network and the technology necessary for energy storage.

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Problem bilansowania popytu i podaży energii elektrycznej w Niemczech jako skutek uboczny wprowadzenia odnawialnych źródeł energii

Streszczenie. *Celem polityki energetycznej Niemiec jest uniezależnienie od zewnętrznych dostaw paliw oraz zapobieganie zmianom klimatu. Dlatego niemiecki rząd konsekwentnie przeprowadza proces zastępowania źródeł energii opartych o paliwa kopalne, źródłami odnawialnymi. Ponieważ produkcja źródeł odnawialnych zależna jest od warunków pogodowych a źródła sterowalne zostały wyparte z rynku, zapewnienie równowagi popytu i podaży w niemieckim systemie elektroenergetycznym staje się coraz trudniejsze. Koniecznym okazało się podjęcie działań rządu takich jak np. wsparcie pracy systemu przez konwencjonalne elektrownie rezerwowe.*

Słowa kluczowe: *moc dyspozycyjna, odnawialne źródła energii, elektrownie rezerwowe*