STUDY OF POSSIBLE PROVISION OF CONTROL POWER WITH RENEWABLE ENERGY FACILITIES, WITH RESPECT TO RESTRICTIONS IN DISTRIBUTION SYSTEMS

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ABSTRACT

The following work represents the first significant contribution towards the topics such as operational management and network security as well as frequency stability, which can be used to value and estimate the potential for the supply of the ancillary services of generating units from the distribution grid. The further objective of this work is the identification of the factors that are taken into account in the integration of the new control power suppliers into an overall concept. In addition to technical basics, the organization and coordination tasks between the participants should be also considered.

INTRODUCTION

At present, the structure of power supply in Germany is going through a period of basic change due to the energy transition. The still consistent extension of the decentralized generating units with renewable energy sources involves a gradual technical as well as market-oriented marginalization of the power from conventional energy sources. The question is: how far the current system of consumption, power generation and network meet these new requirements?
The current developments are not only connected with an enormous remodeling or extension of the network but also with the supply of certain ancillary services.
In East Germany, the distribution system operators (DSO) and transmission system operator (TSO) 50Hertz Transmission have come to an agreement about a common approach of dealing with topics related to the future supply of ancillary services [1].

CONTROL POWER AND NETWORK SECURITY IN GERMANY

Basics of the control power supply

The active power is adapted by means of various methods and regulation strategies at any time in order to ensure a balance between the generated and consumed electric power. In Germany the frequency is essentially stabilized by three types of control power: primary, secondary and tertiary control power. These three control power types take turns in steps and thereby they serve different purposes. When the primary control power holds the frequency change back, the secondary and tertiary control power lead the frequency to their intended value back through direct activation in the control zone and they balance the power generation between the control zones [2].

In Germany the control power products are tendered through the common platform from TSO www.regelleistung.net. The generating units and providers of control power must be prequalified in advance.

Nowadays, there are only a small number of providers in the control power market in comparison to the Energy-Only market. But the provider structure in Germany has changed from very few providers with great generation capacities to more providers with a pool of many distributed generating units. The change can be particularly seen through the increased expansion of smaller decentralized generating units and also through the adjustments of market conditions over the last few years [3].
The current discussions concentrates on further changes of tendering periods, product lengths, lead times and on bid and pool sizes, with the objective of further control power market opening for certain generating units based on renewable energies [2]. Current studies focus on the development of forecasting and detection procedures for control power from generating units based on wind energy [4] [5].

The guarantee of network security

Most of the generating units based on renewable energies are connected to the distribution system. This affects mainly regions with small population and low industrial density, where the wind energy power has substantially increased particularly in recent years. This leads to the circumstance, that the generated power is not fully needed at lower network levels. Wide network extension is required when it comes to the transportation of the generated power. Recently, the required network development could not follow the rapid extension of renewable energies. Therefore measures to ensure the network security had to be established.

The system ensuring the network security of the investigated DSO for 110-kV network is based on preventive reduction of generated power. As a result the highest possible line current is calculated for the respective examined congested operating sources by means of measured line currents and in consideration of the current switching state in the network in the contingency analysis (n-1). If, in consideration of reserves, this current will exceed the limit value of the examined operating sources, accordingly after the priorization of the generating units and depending on the primary energy sources and the effectiveness for the bottleneck, the power which is to be reduced has to be determined per generating units. Then the generating units receive the appropriate signal through the network control system for the necessary power to be reduced. A continuous calculation of the system guarantees that the availabilities of the network, the generation, as well as the weather conditions and the resulting power changes are taken into consideration, that only so much power is lowered as actually needed.

The guarantee of network security in the transmission system is carried out through the grid and market related to operational measures according to §13(1) German Energy Act. So for example in the context of redispatch measures the generating units output will be adapted to relieve the power related bottlenecks [6]. If these operational measures will be exhausted, the TSO has the opportunity of direct adapting of the generated power according to §13(2) German Energy Act. Therefore, the renewable generating units are significantly lowered due to the connection with the network system. This requires a coordinating cooperation between TSO and DSO.

ANALYSIS OF THE FEED-IN CHARACTERISTICS

The examined network area of a Middle German regional DSO is presently shaped especially by the high number of wind and solar parks. Around half of the installed wind energy power of the DSO is directly connected in the 110-kV network. When it comes to the installed photovoltaic (PV) power, this will be applied for about one third. Most generating units connected to the high-voltage grid are in the so called direct marketing. Because of the size of the whole generation plant at the network connection point they have a great potential for possible supply of ancillary services in the future.

In the following analysis the main emphasis is put on the evaluation of all 110-kV-network connected wind- and PV-parks, on selected biogas plants and other conventional power plants in the considered network area. In order to be able to involve a further large part of the power produced in the network, the selected generating units has to be also taken into consideration as they are connected to the medium voltage (MV) bus bar of the 110-kV supply transformer station.

The database for the following analysis is formed by the 15-minute mean values of the real measured power values for the year 2013 of generating units in the considered network area as shown in Table **1**.
To examine especially the network situation in the distribution system, the further evaluation is based on the reduction of the generated power within the framework of operational measures to ensure the network security. The distinction is made between the measures of TSO in the context of the cascade conversion, with the reduction of the generation plants in the distribution system, and the measures to ensure the network security of DSO directly in the distribution system.

	conventional plants	wind	PV	biogas
110-kV	12 pcs.	55 pcs.	23 pcs.	2 pcs.
	523 MW	1870 MW	777 MW	40 MW
MV		52 pcs.	3 pcs.	
		775 MW	43 MW	

Table 1: The overview of the number and installed power of the examined generating units of the considered network area

By means of these data, the annual load curves or the load duration curves are created at first. There is a selection of single energy sources, some of the spatial distributions or single generation plants. In a further step the power connection data are combined with data needed for the secondary and tertiary control power launch in the control area of 50Hertz Transmission and for the implemented network security measures of DSO. By the order of the annual duration curve, the allocation of further data added to the current value of the generated power remains, so the connections and dependences can be analyzed.

POTENTIAL ANALYSIS FOR THE CONTROL POWER SUPPLY

<u>The analysis of the feed-in characteristic in relation to the current control power launch</u>

In a first step, the potential of control power supply is investigated by combining the feed-in of renewables, secondary control power and tertiary control power.

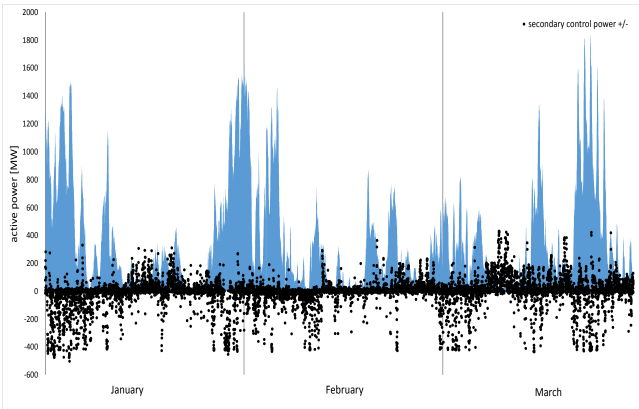

Figure **1**: The load curve of wind and PV feed-in and the secondary control power 50Hertz Transmission of Jan to Mar 2013

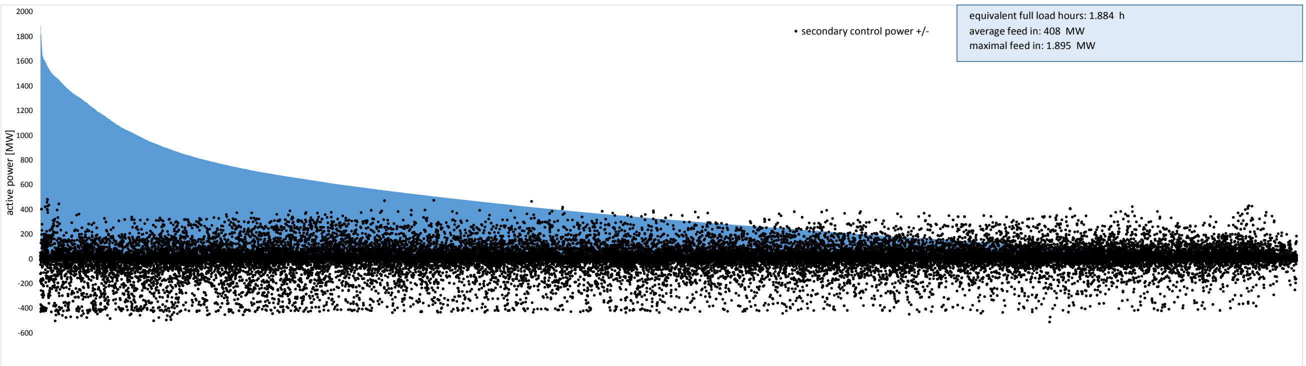

Figure **2**: The load duration curve of wind and PV feed-in and the secondary control power 50Hertz Transmission

Figure **1** shows the load curve for the wind and PV feed-in of all 110-kV generation plants (blue line) and the secondary control power (black points) for the period of January to March 2013. Especially in situations with high feed-in the demand of negative secondary control power increases.

With the presentation of the load duration curve in Figure **2** for the high feed-in power a slight accumulation of the launches of the negative control power can be seen. Generally the launches on the whole duration curve are evenly distributed.

In particular for less launches, which are used primarily to balance the load noise, it can be noticed in an exact analysis of data that within 15 min negative as well as positive launches can exist there. Since the secondary control power must be completely activated within 5 min, this action is comprehensible.

For the balancing of the forecast deviations and also due to renewable power generation, higher outputs for the secondary control power are considerably needed. In order to show when the secondary control power for this balancing is not sufficient, it is necessary to analyze the tertiary control power which, temporally and from technical point of view, removes the secondary control power.

Figure **3** shows the load curve with the tertiary control power for the same period of January to March 2013. Especially in early January the launches of tertiary control power are particularly high.

According to the load duration curve in Figure **4** in certain situations with a high feed-in the launch of the negative tertiary control power is increasing. Since the tertiary control power temporally removes the secondary control power, it can be concluded that in situations with higher feed-in the range of performance of the negative secondary control power is already exploited.

Due to the presented connection between feed-in and negative tertiary control power it can be deduced that there is a future potential for the supply of the negative control power from the renewable generating units. The supply of the positive control power is generally always connected with a reduced mode of operation of the plants.

In the case of the renewable generating units, it is connected with the reduction of paid energy volumes. The prices for the control power would have to rise well above the current values, so that a decreased mode of operation would be economically interesting [7].

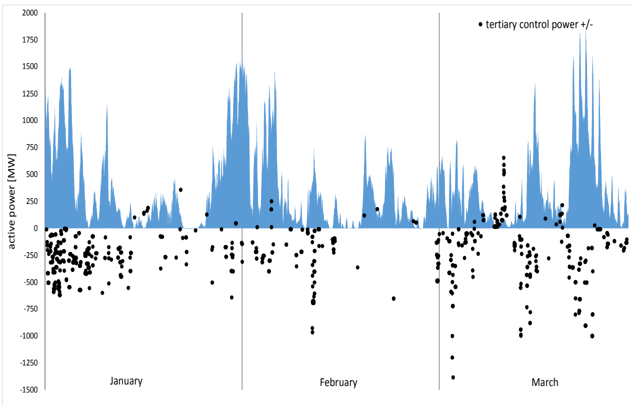

Figure **3**: The load curve of wind and PV feed-in and the tertiary control power 50Hertz Transmission of Jan to Mar 2013

Therefore the right thing for the renewable generating units would mainly depend on the weather conditions, the supply of the negative control power and on the specific curtailment of the plants, which is necessary.
Particularly in situations where the generating units have a high potential for the negative control power due to their current feed-in, the need of negative control power is also increasing. In the future, this need could be consequently covered by the renewable generating units.

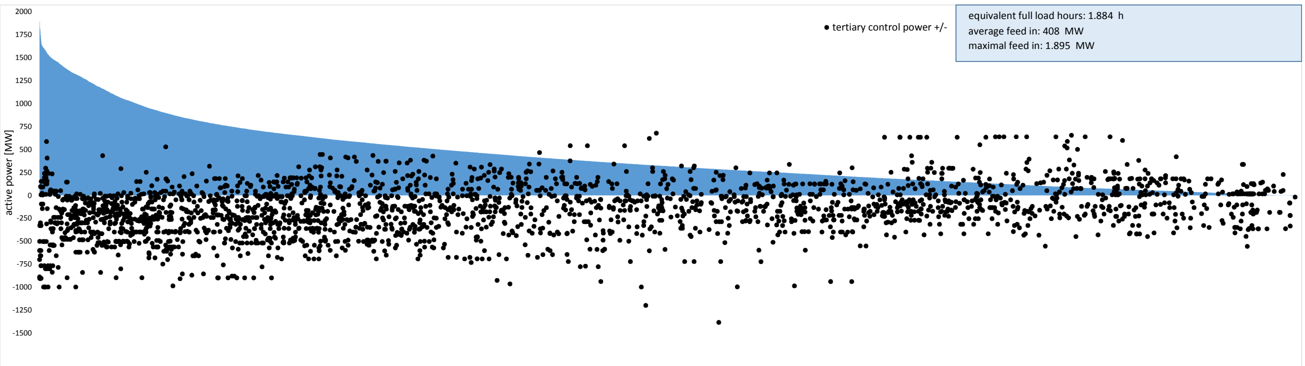

Figure **4**: The load duration curve of wind and PV feed-in and the tertiary control power 50Hertz Transmission

The analysis of feed-in characteristic in consideration of the network security

For the potential analysis of the supply of the control power in the following investigation the main emphasis is put on the network situation in the distribution system in a respective part of the grid or in the whole system. A criterion for the network situation is made up by the measures taken for ensuring the network security, where the generating units with their active power have to be reduced.

Figure **5** and Figure **6** show the specific measures for the whole wind and photovoltaic feed-in in the considered 110-kV network for the year 2013 with the value of the restricted power. For the measures of the TSO the outputs, which must be realized in the considered network area, can be seen here.

Figure **6** presents a clear connection between a high feed-in and the related curtailment of the generated power. Especially the situations with the achieved measures of the TSO seem to be remarkable because of the high limited power of up to 500 MW.
The presentation of the points where the measures end (Figure **6**Figure) shows a clear relocation in the feed-in characteristics. This gives a conclusion about the used required safety-related hysteresis concerning the implemented measures.

The evaluation of the network security and the contribution of the single generating units is a challenge especially when it comes to the meshed 110-kV grid. While in easy stub and ring structures the load flow direction is easy to judge, in the meshed grid structures the current network situation plays a crucial role.

According to the impedance ratio on specific network nodes the currents split up into various strands and they have various effect on the potential grid bottlenecks. That is why the assessment of the cause and the effect is possible only by doing an extensive network calculation. The additional planned decommissioning of the network parts e.g. due to the construction works or unplanned downtimes constantly change the specific network situation.

It can be said that in relation to the supply of the ancillary services, the use of the network security measures and the potential for the supply of the negative tertiary control power correlate with each other provided that the feed-in is particularly high.

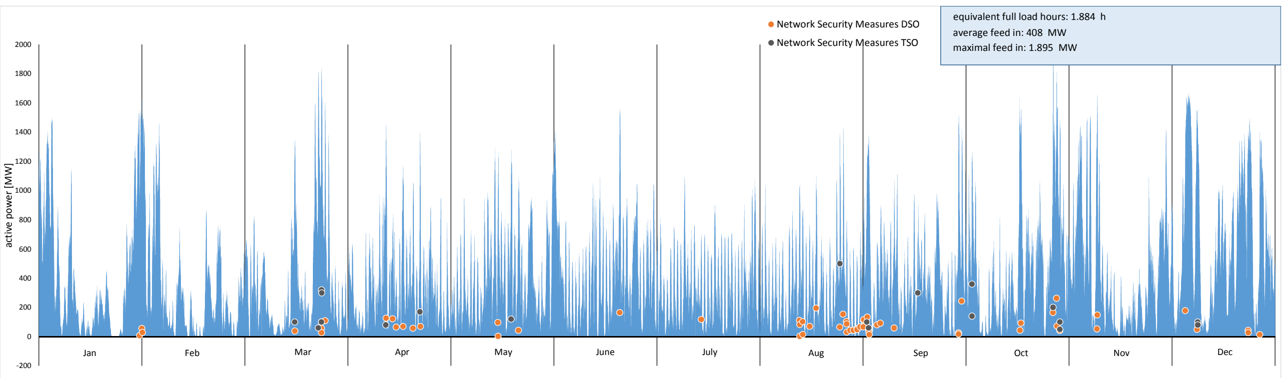

Figure 5: The annual load curve of wind and PV feed-in and the measures to ensure the security network

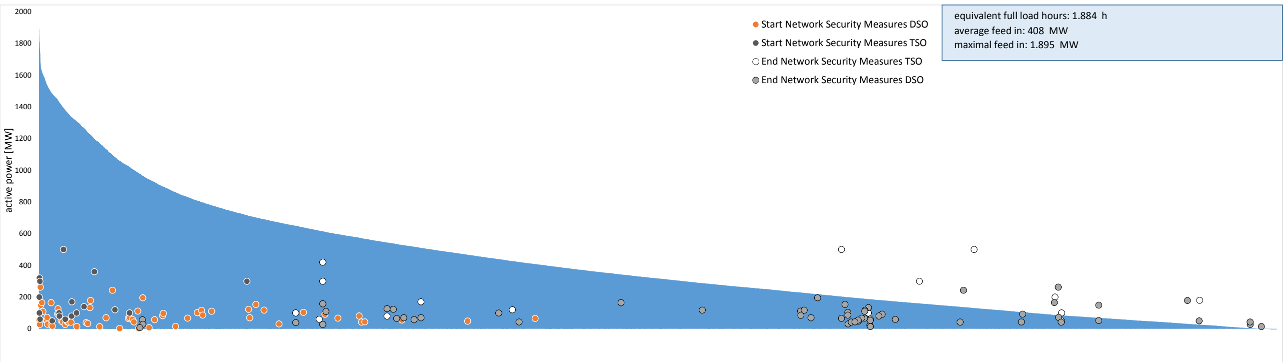

Figure 6: The load duration curve of wind and PV feed-in and the measures to ensure the security network

While considering the single network parts or generating units it can be noticed that not all of the generating units can feed unrestricted at any time and consequently they are not available for the supply of ancillary services. The assessment, which generating units are suitable for certain ancillary services is possible only in close cooperation with the DSO.

THE RESULT AND DEDUCTION OF THE REQUIREMENTS

The performed analysis shows potentials as well as obstacles for the supply of the control power by renewable generating units connected to the distribution network in situations with high feed-in. However, in general the supply of control power from the distribution network cannot be considered independently of the network situation. The basic requirement in the future is to involve the DSO in the coordination tasks with the evaluation of generating units with regard to the control power and network security. So the DSO is responsible for the assessment and the evaluation of the respective network situation for the concrete generating units. In the future the DSO will have to receive more relevance in the prequalification process and in the direct process of the control power supply, so that the appropriate safety in the whole system will be continued.

Furthermore, it is necessary in the evaluation to ensure that the network security in the distribution grid has a higher priority than the control power supply. If the marketed control power is not already launched due to this priority, the DSO could be acting in a coordinated way with possible protection concepts. The communication between the marketers, DSO and TSO is necessary. In detail the DSO could for example select the possible prequalified generating units in the network area, which are not directly affected by network security measures. The advantage of big regional DSO's with a modern network control system is the review of the whole system and also the possibility to intervene in the network operation in an extensive and coordinated way.
By further handling of this topic the main emphasis is put on more specific observation of the network situation. An additional objective is not only the preparation of market-based as well as technical concepts to retain the network and system security but also the coordination of the partners involved.

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