PROVISION OF TERTIARY CONTROL BY A REGENERATIVE VIRTUAL POWER PLANT

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Summary

In the future renewable energy sources have to take over the provision of ancillary services which are now mainly provided by conventional power plants. For this reason we investigated how much negative tertiary control can maximally be provided by a regenerative virtual power plant consisting of a pump storage plant, biogas plants and a wind park. Economic aspects were not considered. In order to evaluate the influence of different markets (Day-Ahead and Intraday market), the composition of the virtual power plant, different reliabilities of the schedule and a new method to provide tertiary control with wind parks we defined and simulated seven scenarios. It has been shown that the provision of tertiary control with a virtual power plant including a big wind park does not make sense under current conditions. Therefore we proposed a new method for the proof of the provision of tertiary control considering the characteristics of intermittent power producers like wind parks.

1. Introduction

Today ancillary services are mainly provided by conventional power plants. Since the share of renewable energies of the electricity production increases every year renewable power plants will have to take over the provision of ancillary services. This is emphasized by the fact that the share of renewables in certain times of the year (strong wind, low load) is much higher than the average share over the year. Because of the extension of the wind energy it can be expected that in the near future wind energy will provide 100% of the energy needed at times. For this reason wind energy will have to provide ancillary services sooner or later.

There are a number of investigations dealing with the technical feasibility of wind power plants to deliver ancillary services. For example in [4] and [5] where methods are presented how wind power plants can provide control energy.

There are also papers considering the profitability [3] of providing control energy with wind power plants. In spite of these studies until now no wind power plant has provided control energy in Germany.

In this work we focus on the regulation framework and the question whether this framework is suited for wind power plants.

Thus, we analyzed how much negative tertiary control can maximally be provided by a wind park, a pump storage plant (PSP) and biogas plants combined in a regenerative virtual power plant (RVPP). The investigation focuses on the technical capabilities. Economic aspects were not taken into account. We focused on the market for tertiary control, since auctions are held each working day for the next day on this market, except for weekends and holidays. It is not possible to get reliable forecasts for the hourly wind power production of one month which makes it impossible for wind parks to participate at the market for secondary or primary control.

2. The virtual power plant and the markets

The RVPP consist of a wind park (62 MW installed capacity) a PSP (80 MW generator capacity, 616 MWh storage content) and biogas plants (overall 10 MW installed capacity). The biogas plants have a constant gas production which corresponds with an electric energy production of 7 MW. Moreover the biogas plants can store gas for an electric energy production of 60 MWh. The energy production respectively energy consumption of the components of the RVPP are controlled by an energy management system. In our scenarios the PSP and the biogas plants are used to balance the forecast errors of the wind park.

Three different markets are considered in this work. The first one is the market for tertiary control. The minimum offer is 15 MW and six blocks of four hours beginning at midnight are traded as negative and positive tertiary control. The offer for the next day has to be made before 10 a.m. except for weekends and holidays where the offer has to be made at the last working day before the whole weekend respectively holiday plus one day.

The biggest challenge for the wind park operator at this market is to proof the provision of tertiary control. According to the current regulations in Germany the proof is done by a comparison of the schedule and the real energy production. Normally this schedule is sent to the transmission system operator at 2:30 p.m. for the following day. The difference between the schedule and the real energy production has to match the provided tertiary control otherwise the provider didn’t supply tertiary control. In order to be able to prove the delivery of the tertiary control in the RVPP the biogas plants and the PSP have to balance the forecast errors of the wind park in order to keep the schedule.

The other two markets are the EPEX Spot markets. At the EPEX Day-Ahead market and at the EPEX Intraday market the minimum offer is 0.1 MW. At the EPEX Day-Ahead market the offers for every hour of the next day have to be made until 12 a.m. at every day of the week. At the Intraday market the latest offer for an hour can be made 75 minutes before the beginning of this hour. This market is very interesting for wind park operators, since they can use short term forecasts, which are more exact than day-ahead forecasts.

3. Scenarios

We defined seven scenarios in order to investigate the influence of the following aspects on the maximal negative tertiary control offer:

- participation at different Spot markets
- composition of the RVPP
- a new method to proof the provision of tertiary control

Moreover in every scenario containing a wind park the influence of different reliabilities on the schedule was investigated. Fig.1 shows an overview over the seven scenarios.

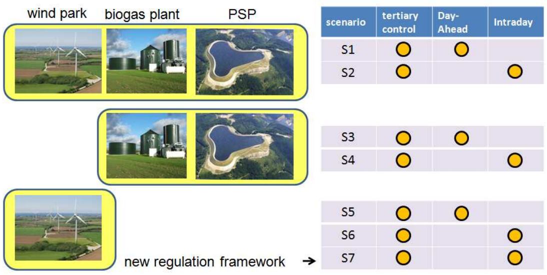

Fig. 1 The seven investigated scenarios

In scenario one (S1) and two (S2) the composition of the RVPP is the same. The only difference is that in scenario two the energy produced by the RVPP is sold at the Intraday market and not at the Day-Ahead market. It can be expected that this has a positive effect on the amount of tertiary control that can be provided, because the PSP and the biogas storages can be loaded respectively unloaded faster. Moreover for selling the energy of the wind park at the Intraday market and for the schedule of the wind park respectively RVPP the short term forecast can be used, which is more exact than the day-ahead forecast. The same is the case for scenario three (S3) and four (S4).
There are three different layouts of the RVPP. In S1 and S2 the RVPP consists of all energy units, in S3 and S4 the RVPP only consists of the biogas plants and the PSP and in S5, S6 and S7 the RVPP consist of the wind park only. With the comparison of these scenarios it can be investigated whether the contribution of the wind park to the RVPP has a positive effect on the amount of tertiary control that can be provided.
In all scenarios with a wind park different reliabilities of the schedule of the RVPP were considered (80%, 90% and 95%), since a reliability of 100% cannot be realized (s. chapter 4) and the effect of different reliabilities on the amount of tertiary control are to be investigated. A reliability of 90% means that the reserved energy of the PSP for balancing the forecast error is big enough at 90% of the year and that the reserved power of the PSP for balancing the forecast error is big enough at 90% of the year.

In scenario S7 a new method for the proof of the provision of tertiary control suitable for wind parks is introduced. With this method the real energy production is not compared with the planned energy production but with the energy production without control of the wind power production. The method to calculate the energy production without control is not examined in this work. When this proof method is applied the wind park doesn’t have to keep the schedule which is only possible with the help of storage plants like PSP. Moreover the wind park does not have to make an offer at the previous day. The transmission system operator has the possibility to control the whole energy production of the wind park without the need for an offer by the wind park at the day before. For this reason the transmission system operator only has to pay an energy price. It can be expected that the new method has a positive effect on the amount of tertiary control which can be provided by the RVPP respectively by the wind park.

4. Model

The maximum amount of tertiary control that can be offered by the RVPP was calculated in all scenarios with an optimization technique called Simplex method [2]. The most difficult part was to handle the forecast error of the wind power forecast. The approach was to reserve power and energy storage capacities of the PSP for balancing the forecast error.
The energy reserve was calculated by analyzing the error of the wind power forecast. For every 15 minutes interval we calculated how big the storage capacity of a PSP has to be to balance the error. With these values we constructed a distribution function. The result was that it is not possible to provide tertiary control with a wind park with a reliability of 100% (s. Fig 2) when the RVPP trades at the Day-Ahead market. For this reason the calculations have been done considering different reliabilities (80%, 90% and 95%).
A reliability of 100% would have been possible by trading at the Intraday market. But to keep the scenarios comparable we chose the same reliabilities for the scenarios with the Intraday market.

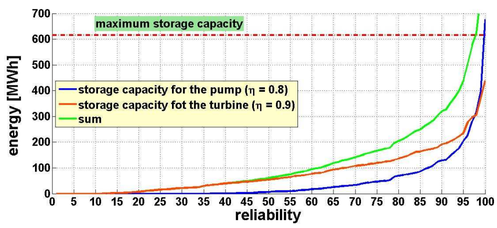

Fig. 2 Energy reserve for balancing the forecast error of the wind power production for different reliabilities

The power reserve was calculated with a similar method. For every 15 minutes interval of the year we calculated how much power is needed from the turbine or pump of the PSP to compensate the error of the forecast. With these values we constructed a distribution function and identified the power reserve for different reliabilities (also 80%, 90% and 95%) (s.Fig.3).

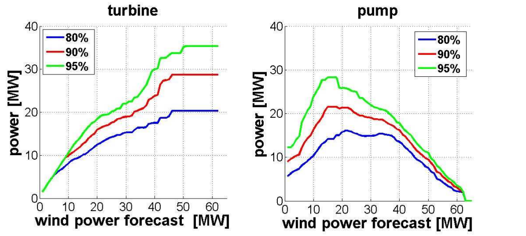

Fig. 3 Power reserve of the PSP pump and turbine for different reliabilities (80%, 90% and 95%)

The aim was to calculate the maximum amount of negative tertiary control which can be provided by the RVPP. The negative tertiary control offer is the sum of the wind power production and the possible energy consumption of the PSP considering the storage capacity of the PSP and the energy and power reserve for balancing the forecast error. Moreover the biogas plants also contribute to the tertiary control offer because they can stop their electricity production for a defined time limited by the storage capacity.

At every 15 minute interval the sum of the purchase at the EPEX, the provision of tertiary control and the positive balancing power must be as big as the sum of the sale at the EPEX and the negative balancing power (Fig. 4). The offer for the tertiary control market has been calculated at 10 a.m., the offer for the EPEX Day-Ahead market at noon and in the scenarios with the Intraday market an offer has been calculated at every hour. It was assumed that the offers were accepted.

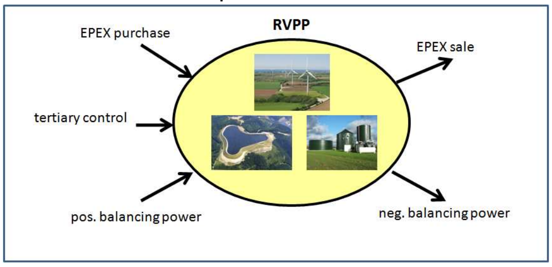

Fig. 4 Illustration of the balance condition of the RVPP

Fig. 5 shows the energy management of the RVPP for every 15 minutes interval. At first it is checked if there is a call for tertiary control. Next the balance of the RVPP is calculated considering the sales and purchases at the EPEX and the energy production of the wind park. If the RVPP does not produce enough energy to cover the offered amount of energy (RVPP deficit) there are three possibilities. The biogas plants are started, the PSP turbine produces energy and positive balancing power is used. Positive balancing power should only be used when the other two possibilities are exhausted because the RVPP will be disqualified if there is a call for tertiary control at the same time. When the RVPP produces too much energy (RVPP surplus) there are also three possibilities. The pumps of the PSP are started, the energy production of the wind park is reduced and negative balancing power is consumed. As it is for positive balancing power, negative balancing power should only be used in extreme cases.

At a RVPP surplus the biogas plants don't produce electric energy unless the biogas storages are full.

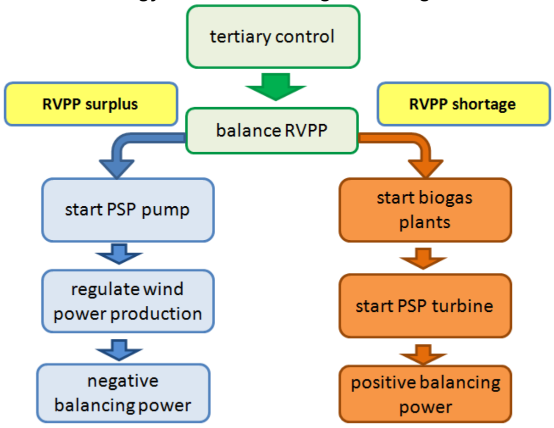

Fig. 5 Energy management of the RVPP

5. Results

The two diagrams in Fig. 6 show the simulation results for S1. The upper diagram shows the negative tertiary control offer subdivided into the different components of the RVPP.

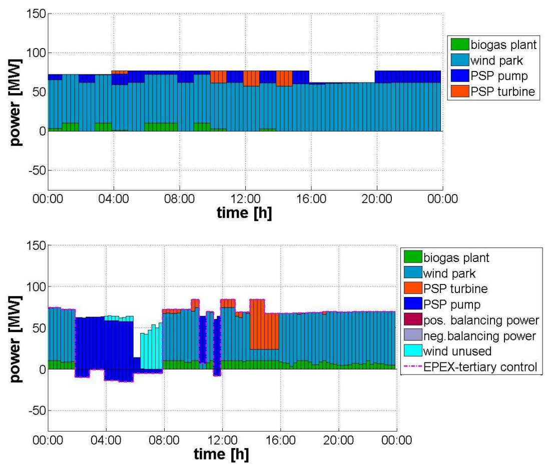

Fig. 6 Simulations results of S1 – tertiary control offer (upper diagram) and real energy production (lower diagram)

The lower diagram shows the real energy production of the RVPP. The pink dashed line corresponds to the planned schedule of the RVPP plus the provision of tertiary control. If the pink line is beneath or close to zero the RVPP provides tertiary control, for example between 2 a.m. and 8 a.m. On the day shown in the diagram the energy production of the wind park has to be regulated to provide enough tertiary control but no balancing power has to be used to keep the schedule.

Tab. 1 shows the results of the seven scenarios for a reliability of the schedule of 90%. In the upper row the average amount of tertiary control and on the lower row the number of disqualifications. A disqualification occurs when the RVPP is not able to provide the called amount of tertiary control because the wind power production is already reduced to zero and the PSP and the biogas storages are full

Tab.1 Simulation results for the different scenarios

	S1	S2	S3	S4	S5	S6	S7
average tertiary control (MW)	25.6	72.2	22.6	78.3	0.4	0.4	13.7
disqualification	32	11	0	0	2	2	0

By the comparison of S1 and S2 and accordingly S3 and S4 it can be seen that trading on the Intraday market has a positive effect on the amount of tertiary control. This is mainly caused by the effect that the PSP and the biogas plants are able to load and unload faster. For example if the PSP has to load because there is a call for negative tertiary control it is able to unload 75 to 135 minutes later if it sells its energy at the Intraday market whereas at the Day-Ahead market it can unload 12 to 32 hours later. In S5 and S6 the contribution to different markets has no effect on the amount of tertiary control that can be provided. This is obvious since the offer of tertiary control of a wind park only depends on the day-ahead forecast because the offer has to be made at 10 a.m. the previous day.
It can be seen that the contribution at the Intraday market has a positive effect on the number of disqualifications. Moreover in S3 and S4 there have been no disqualifications since no wind park fluctuations have to be handled.
Another interesting point is the influence of the composition of the RVPP. When comparing S1 with S3 and S2 with S4 it can be seen that the contribution of the wind park has almost no effect on the amount of tertiary control that can be provided but increases the number of disqualifications considerably. This is caused by the fact that the power and energy reserve by the PSP to balance the wind variability is bigger than the possible provision of tertiary control by the wind park.
The reliability of the schedule has almost no effect on the amount of tertiary control in S1. The amount of tertiary control only increases from 24.5 MW at a reliability of 95% to 27.7 MW at a reliability of 80% but the amount of disqualifications decreases from 42 (80%) to 21 (95%). In S2 the effect is considerably bigger: The amount of tertiary control rises from 64.3 MW (95%) to 78.4 MW (80%) but the amount of disqualifications decreases from 16 (80%) to 9 (95%).
The comparison of S7 with S6 and S5 shows that the new method has got a strong positive effect on the amount of tertiary control. 13.7 MW corresponds to the average power production of the wind park since the transmission system operator has always the possibility to regulate the whole power production of the wind park. There have also been no disqualifications since the RVPP operator respectively the wind park operator doesn't have to make an offer which he has to keep.

6. Conclusion

In this work we calculated how much negative tertiary control can maximally be provided by a RVPP without considering economic aspects. In order to investigate the influence of different markets, different RVPP compositions, different reliabilities of the schedule and a new method to proof the provision of tertiary control by wind parks we defined seven scenarios.
It has been shown that under current market conditions the provision of tertiary control with RVPP with a considerable amount of wind energy does not make sense even combined with a PSP and biogas plants balancing the fluctuations of the wind power production. This is caused by the fact, that the power and energy reserve by the PSP to balance the wind variability is bigger than the possible provision of tertiary control by the wind park. Therefore it is necessary to develop a new regulation framework considering the particular characteristics of fluctuating power feed-in by wind turbines. A first approach is the new method which we defined and investigated in scenario seven.
Moreover it has been demonstrated that the contribution at the Intraday market has a positive effect on the amount of tertiary control compared to the Day-Ahead market. This effect is bigger than the variation of the reliability of the schedule between 80% and 95%.

7. Acknowledgement

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8. References

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