View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Ghent University Academic Bibliography

Positive balancing service by solar Virtual Power Plants

Brecht Zwaenepoel*, Tine L. Vandoorn*, Greet Van Eetvelde‡ and Lieven Vandevelde*
*Electrical Energy Laboratory, Ghent University, Ghent, Belgium
Email: Brecht.zwaenepoel@ugent.be
†UGent Power-Link, Ghent University, Ghent, Belgium
Email: lieven.vandevelde@ugent.be
‡Center for Mobility and Spatial Planning, Ghent University, Ghent, Belgium
Email: greet.vaneetvelde@ugent.be

***Abstract*—During the past years, a large amount of photovoltaic (PV) capacity has been installed in Belgium. The main driver for this was the abundant government support (GreenPower Certicates). However, during the last few years, the support for new installations has been withdrawn and new PV capacity ceased. In previous research, it has been proven that selling PV energy of existing plants directly on the wholesale market is not feasible due to the large share of green power certicates awarded to these plants. However, the price of green power certicates has dropped signicantly and hence the balance between certicate and commodity revenue is restored. This paper investigates the possibility of providing positive balancing services to the transmission system operator by aggregating solar power in a technical Virtual Power Plant.**

The paper concludes that it seems not interesting, neither economically nor energetically, to keep solar plants solely for positive balancing purposes. Combination of solar power with other sources or consumers can however be profitable, as solar power is quickly switched in case it is needed to react fast.

I. Introduction

The last few years, photovoltaic solar (PV) power was seen as an attractive technology to produce environmental friendly electricity [1]. The government offered an abundant financial support scheme to investors, which resulted in a large expansion of the installed capacity. Due to the green and clean label of PV power, the government awarded this (and other renewable energy sources) a privileged status. Renewable energy sources are largely excluded from balancing obligation and market participation. This resulted in a situation where most of the revenue of PV installations came from governmental subsidies (green power certificates) and not from the selling of energy. As investigated in [2], in the former subsidy scheme in Flanders (Belgium) the balance between commodity value and subsidy income makes it not feasible for PV owners to participate in wholesale market operation. The potential extra revenue is not up to the added risk of a volatile and uncertain market. However, due to the quick decline of the GPC price, for new installations it can become economically profitable to act in the wholesale market as average day ahead market price is generally higher than the fixed price offered by suppliers. However, the variability and the unpredictability of PV power makes it very hard to determine the available power to trade. As the best way to trade is the day ahead market, production should be predicted. As mismatch between prediction and effective production is penalised, trading the entire PV production is not without risk. In previous research [3], it has been proved that often the imbalance market can be more profitable than the day ahead market. In this paper, it is investigated if it could be profitable to omit the day ahead market entirely and provide only positive balancing services. This is verified by real data of 2013, provided by the Belgian transmission system operator Elia.

II. Need for new trading strategies

During recent years, abundant financial support was provided for renewable energy sources. In Flanders (Belgium) for example, abundant green power certificates were awarded to e.g. wind and solar installations. However, today, new PV installations do not receive these high subsidies any more. They are however still offered a protected market position, but for how long? To make the financial model of these technologies future proof, they need to be incorporated in the existing energy market and compete with traditional power plants.

As has been shown in [2], PV energy alone is hard to aggregate and sell on wholesale markets due to prediction errors [4]. Wind power is better predictable, but also suffers from weather dependence. Thermal plants may lack the dynamic capabilities of power electronic interfaced units like PV and wind, but are more predictable and stable. Dynamic loads may have a large impact on user comfort and storage is expensive. However, by combining the benefits of different sources within a single VPP, the drawbacks of a single source VPP might be (partially) mitigated.

Keeping solar power from direct market access enables this source to provide positive reserve capacity. As solar power has no moving parts, if sun is available, the power can be instantaneously available without any start-up delay. Hence, PV power could be an attractive source for balancing services. In this paper, the economic viability of providing positive balancing services with an aggregated PV park is investigated.

III. Providing balancing power

Balancing services have a crucial role in the stability of the electrical system. As Balance Responsible Parties (ARPs) should predict their production and consumption, their will always be some real time imbalance. As a consequence, the demand for balancing services is very volatile. As a result, the price of balancing energy can vary from just a few euro

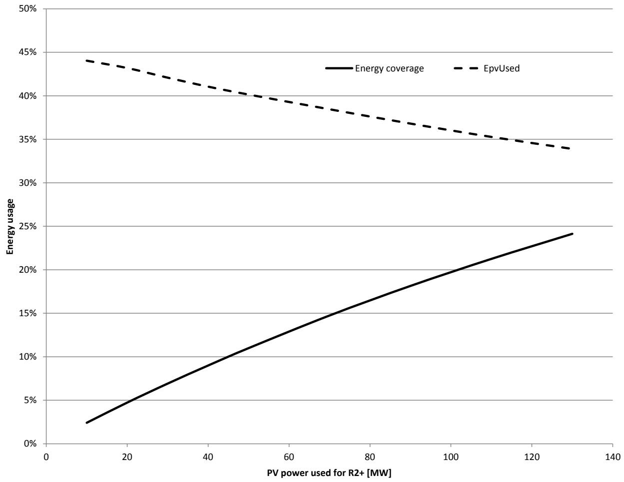

Fig. 1. Coverage of R2+ energy by solar power in function of reserved solar capacity

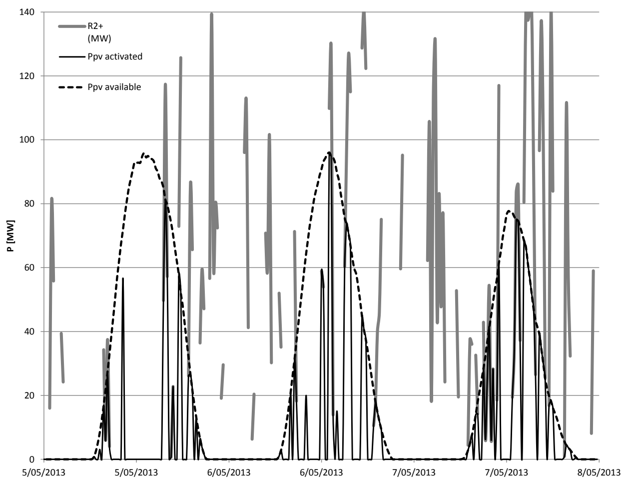

Fig. 2. Requested R2+ power, Available PV power and activated PV power

per MWh to several hundreds euro per MWh in just a couple of minutes (Fig. 4. In [3], the relation between the price obtained on the day ahead market and the balancing services is examined. It was concluded that often the monthly average of the balancing prices is often higher than the average price of the day ahead market. This could open an opportunity for solar power. As a solar plant has very high dynamics, it could be a very interesting provider of balancing services. However, as one can never be sure of solar power for a certain time in advance, negative balancing services are somewhat difficult.

In this paper, the authors investigate if it could be profitable not to sell solar energy on the day ahead market, but keep it as quick deployable positive balancing power. As such, solar plants can cover some of the balancing services covered formerly by gas turbines. However, this is only valid as long as there is enough solar power available. Also, a producer should nominate the available reserve power a day before possible activation. This further increases the difficulty of providing positive balancing power with a single renewable source.

As a result of keeping reserve power, a lot of energy will be curtailed. This will result in waste of renewable energy, but can save on natural gas or other primary sources as the must run time of gas fired plants can be reduced. However, due to the intermittency, solar power will never be able to replace controllable sources like gas turbines. As is shown in Fig. 1, even in a sunny month like June, only 40 % of the R2+ energy can be delivered by solar power.

As Fig. 2 shows, requested upwards regulation power is a discontinuous function (grey line). The dashed line shows the available power of three consecutive days in May 2013. It can be clearly seen that many requests of R2+ power are larger or fall completely outside the available PV power. The reserved solar power consisted of an aggregated PV park of 130 MWp spread all over Belgium. This spread minimised the short term variability typically seen on PV power curves. It should also be noted that although 130 MWp solar power was installed, this peak power was never reached.

IV. Price of positive balancing power

As has been presented in [3], Fig. 3 depicts the average price of the day ahead market, positive balancing service and negative balancing cervice. However, this are only average values. It is more important the price is high at the times much solar power is available and positive balancing power is requested for.

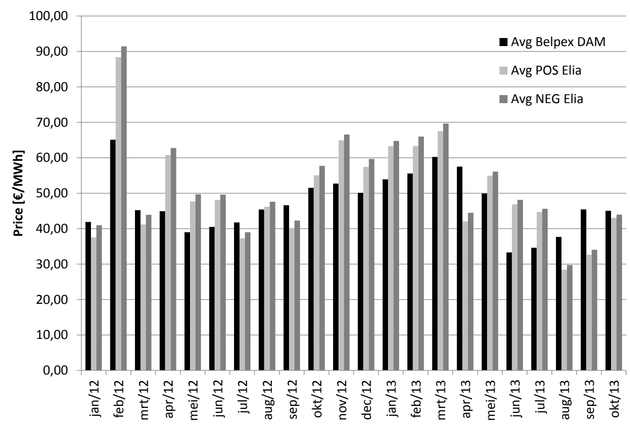

Fig. 3. Monthly average DAM, POS and NEG prices in Belgium

According to the market rules, the price for reserve power is determined by merit order [5]. The supplier is paid (or need to pay) the bid price. However, in the data published by the TSO, only the price of the largest selected order is shown. As a result, only the supplier with the highest selected bid will receive the reported price. The other selected suppliers will receive a lower price according to their bid. As a remark, the BRPs who need to buy balancing services to compensate for their imbalance pay all the highest bid with an added premium.

Figure 3 shows an excerpt of prices offered for energy. The double black line shows the Belpex DAM price. This is the price of the day ahead wholesale market. The grey line is the price the BRPs get for having a positive imbalance. The thick black line shows the price offered by the grid operator for R2+ (positive frequency restoration reserve). As not for every fifteen minutes positive regulation power is requested, there is not always a price fixed, hence this is not a continuous line. This graph shows the price of R2+ is

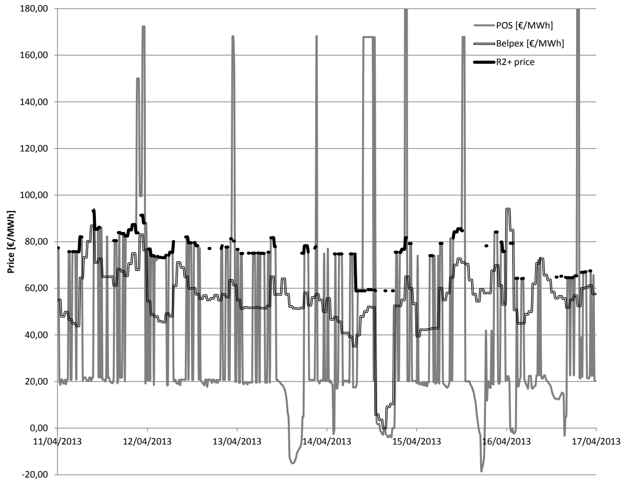

Fig. 4. Price of R2+, Positive imbalance and Belpex DAM

almost always above the DAM price by a considerable margin. This should encourage suppliers to keep some headroom and provide upward regulation if the system requests for it (large suppliers are obliged to keep headroom and need to provide this service in order to get grid access).

The most flexible price is the price of the positive imbalance settlement. It fluctuates considerably between very low values (20 €/MWh and quite high values (80 €/MWh). This price sometimes even gets negative or sky-rockets to extreme prices of 180 €/MWh and more.

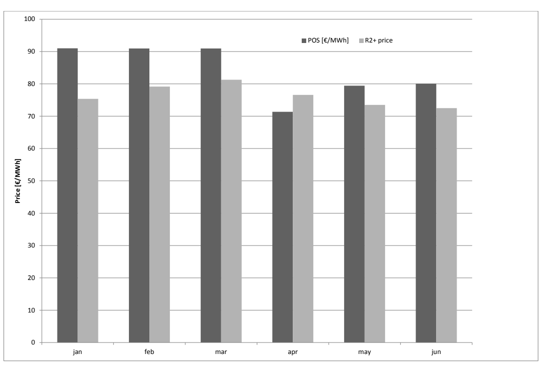

Fig. 5. Average price of R2+ compared to positve imbalance price per month (2013)

Figure 5 shows the average price of both positive imbalance power and R2+ for the quarters R2+ is requested. It can be seen the positive imbalance settlement price is higher than the R2+ price. If compared to Fig. 4, this could be attributed to the high price spikes paid for positive imbalances.

V. CASE STUDY

In this section, it is investigated how much financial gain or loss a cluster of PV power would have if used solely for upward balancing. This means no power is sold to the market and all the power from the VPP is sold as upward regulation

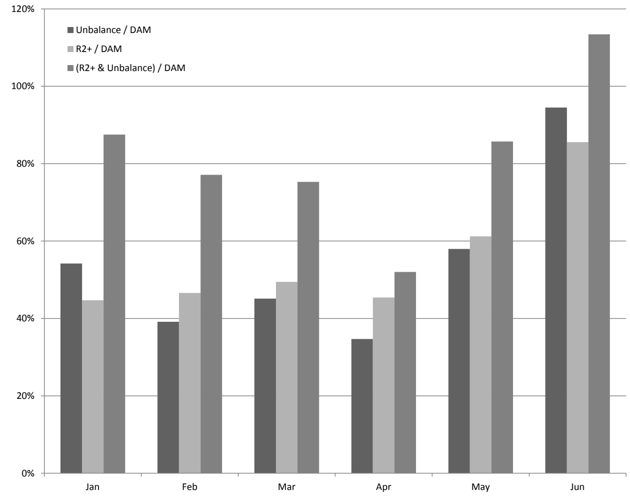

Fig. 6. The relative margin of upwards power to wholesale (day ahead) trading

power. The VPP used for this case study consists of many smaller PV plants spread all over Belgium to reduce short therm variability (cloud cover). The total installed power is set to 10 MWp and is solely used for upward regulation.

Figure 6 shows the relative financial result of trading solar energy as upward regulation power. The reference used is the revenue obtained if the power was perfectly predicted and sold to the day ahead prices.

Each left bar (dark grey) shows the relative result if the solar power was not taken into account by predicting the market position. All produced power is so sold at the positive imbalance price. Although the price is often significant higher than the day ahead price, large portions of the time an upwards imbalance is offered only a very low price. This results in a significant loss in all months investigated.

The second bar (light grey) shows the relative result of selling the PV power as frequency restoration reserve (R2+). The results are somewhat mixed, but on average about the same result of positive imbalance is obtained. Generally, a significant loss is obtained compared to selling to the day ahead market.

The third bar (middle grey) of Fig. 6 shows the relative result if first power is sold to the TSO as R2+. The remainder of the energy is sold as positive imbalance. For the first months, this still results in a loss compared to DAM trading. However, in June a positive result is obtained using this method. It should be noted however that according to Fig. 3, the average day ahead price was quite low compared to the earlier months of 2013. This could indicate it it is only interesting to sell PV power as reserve power if the average DAM price is quite low.

The second aspect studied is the energetic efficiency. As stated above, keeping PV power in reserve to provide balancing services will result in a net energy loss. As positive balancing power is not always needed, the PV power should be curtailed if not sold as positive balancing power. Fig. 7 represents the effective produced energy per month relative to unrestricted production. It can be seen only about 40 % of the available energy is actually produced to deliver R2+ power. This is a loss of 60 % of energy compared to normal operation of the

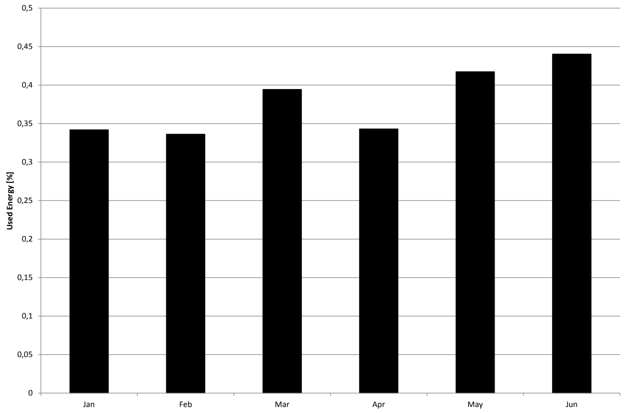

Fig. 7. Part of PV power used to deliver R2+ relative to potential available PV energy per month

same PV park. If R2+ service is provided, the remainder can be curtailed or can be sold as positive imbalance. As indicated above, it is financially less negative to sell the remainder as positive imbalance instead of curtailing it. Also, this will result in less or no curtailed energy.

VI. Conclusion

Trading solar power in the existing wholesale markets is not straight forward. Even if a VPP can aggregate enough power to meet the minimum requirements to participate in the markets or to deliver ancillary services, it should be decided how to trade the power. However, it seems to be preferable to combine solar power with other technologies to mitigate the uncertainties.

The case study performed suggest keeping PV power in reserve to deliver positive frequency restoration reserves is nor economically nor energetically profitable. Although previous research suggested that due to the on average higher price of positive imbalance compared to day ahead trading, it could be viable to keep PV power in reserve, this study shows this is not always true. Further research should indicate if combining this methodology with switchable loads would be more interesting.

Acknowledgment

The research was carried out in the frame of the Interuniversity Attraction Poles program IAP-VII-02, funded by the Belgian Government. The research of T. Vandoorn is funded by the Special Research Fund (BOF) of Ghent University (Belgium).

References

[1] VREG, “Evolutie van het aantal zonnepanelen en hun vermogen,” VREG, Tech. Rep., 2013.

[2] B. Zwaenepoel, J. Laveyne, L. Vandevelde, T. Vandoorn, B. Meersman, and G. Van Eetvelde, “Solar commercial virtual power plant,” in *2013 IEEE Power and Energy Society General Meeting*. Vancouver, BC, Canada: IEEE, Jul 2013.

[3] B. Zwaenepoel, T. Vandoorn, J. Laveyne, G. Van Eetvelde, and L. Vandevelde, “Solar commercial virtual power plant day ahead trading,” in *2014 IEEE Power and Energy Society General Meeting*. Washington DC, USA: IEEE, Jul 2014.

[4] M. Diagne, M. David, P. Lauret, J. Boland, and N. Schmutz, “Review of solar irradiance forecasting methods and a proposition for small-scale insular grids,” *Renewable and Sustainable Energy Reviews*, vol. 27, pp. 65 – 76, Nov 2013.

[5] Elia, “Marktwerkingsregels voor de compensatie van de kwartuuronevenwichten (quarterly imbalance compensation market rules),” Elia System Operator, Tech. Rep., 2014.