Producers and Virtual Power Producers

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Abstract: - Nowadays, in the whole world, we can see a large increase of the use of renewable energy sources and Distributed Generation (DG) of electricity. This increase makes these units importance higher. The aggregation of DG plants gives place to a new concept: the Virtual Power Producer (VPP). VPPs can reinforce the importance of these generation technologies making them valuable in electricity markets. However VPPs introduce new problems, namely the one of reserve management. This paper presents some results obtained with a simulation tool (ViProd) developed to support VPPs in the analysis of their operation and management methods and of their strategy effects.

Key-Words: - Distributed Generation (DG) , Electricity Market, Price Forecast, Reserve Management, Virtual Power Producer (VPP)

1 Introduction

All over the world Distributed Generation (DG) is seen as a valuable help to get cleaner and more efficient electricity. With DG, electricity is produced near to consumers and not transmitted over long distances. Thus, it is possible to get lower losses. Moreover, new generation technologies, mainly based on renewable resources, with environmental advantages are a key issue for sustainable development.

Investments in this field are encouraged by a favorable regulatory framework and the equipment costs are more attractive every day. At this stage, the main technologies used are micro and hydro turbines, fuel cells, wind generation, and solar cells.

The developments of new low emission generation technologies impose us to rethink the location of a significant part of the generation: Distributed generators owned by decentralized players can provide a significant amount of the electricity generation. To get more negotiation power in the market and to get advantages of scale economy, these players can be aggregated giving place to a new concept: the Virtual Power Producer (VPP). VPPs are multi-technology and multi-site heterogeneous entities.

Current electricity markets have effectively implemented real-time and day-ahead markets. VPPs should adopt organization and management methodologies so that they can make DG a really profitable activity able to participate in these markets. VPPs operate in the market according to the market rules, which can differ from market to market.

2 Virtual Power Producers (VPP) - Producers

So that the virtual power producer is an entity capable to coexist with the other market agents, it is necessary that it gets profits and that has credibility. However the virtual power producer depends on the producers associated to it. There are several advantages in being aggregated to a VPP, of which we refer the following ones:

- Market participation costs - to negotiate the generated energy in the market, it is necessary an adequate staff. When being associated to the virtual power producer, the producers leave to the VPP these issues. This strategy can also be applied to the carbon markets. It is still possible to define common strategies of actuation in the market;
- Penalty Management - when virtual power producer determines a reserve value, this enables a reduction of the penalties to be charged to the producers. The goal will be to assure that the value of reserve costs does not exceed the value to pay for the penalties. On the other hand, when producers are associated, it is possible to have producers with surplus generation and others in

shortage generation, balancing the general production of the virtual power producer;

- Maintenance costs - the maintenance costs can be reduced. If some of the producers have similar technologies, it is possible to create stocks, as well as a single maintenance group for all producers;
- Project - the experience acquired for the virtual power producer will facilitate the new producing plants licensing process. The advantages can be reflected on the bureaucratic level or obtaining credit facilities;
- Marketing - the marketing shares will be developed by the virtual power producer and must include all the activities that are associated to the producers;
- Business - When being associated to a virtual power producer the producers have more expression in the energy context, what will allow them to have some influence in decision making;
- Generation Management - the generation management of the generating units will be undertaken by the virtual power producer what will ease the actuation of the producers. Currently, this problem does not exist because all the generated energy is injected in the grid, however, in a market environment this context could be modified.

Besides all enumerated advantages, the price paid for the energy must be advantageous for the producers. If the paid price to the VPP is lower than the market price, probably the producers prefer to negotiate directly in the market. The remuneration of the producers will therefore be one of the complicated tasks of the VPP, since it has to deal with opposite interests.

Another important aspect is generation management. As already referred, one of the main advantages that the VPP provides to the producers is the existence of production reserve. However, this reserve can be guaranteed in several ways, namely through the aggregated producers, when these can assure the required capacity, or through contracts with thermal or large hydroelectric plants. The problem is that the existence of reserves raises the energy price, what can imply that the energy is not sold.

In this context the reserve/generation management, the elaboration of the prices to negotiate in the market and the remuneration of the producers are three important aspects for the good functioning of the VPP.

3 Virtual Power Producers (VPP) – Generation Management

One of the functions of the VPP is to determine the amount of energy to be negotiated in the market. This is a complex task namely due to the uncertainty of the generation forecasts.

VPPs must identify the characteristics of each of their associates and try to optimize the selling activity so that each associate delivers the biggest possible amount of energy. The ideal situation would be to sell all the energy that its associates are able to produce at each instant. The problem is that this is not possible due to the uncertainty of generation of the technologies that depend from natural resources as the wind, sun, waves or water flows.

The method used by the markets to penalize the violation of the established contracts is not uniform, which implies different forms for the VPPs action.

In markets where penalty mechanisms exist, such as the French, the Italian, the Finnish, the Swedish or the British, the VPPs have to conveniently manage the generation capacity of the associated producers to assure enough reserves, to compensate generation oscillations.

The energy reserves will have to be assured, in first place, by producers using technologies that allow them to control the net injected power, such as co-generation, fuel cells, or gas turbines. These producers may establish contracts with the VPP, for supplying the imbalance settlement energy, below of their nominal capacities.

Another possibility for the VPP to assure some level of reserve will be to have specific plants to accomplish this goal. These plants can be managed by the VPP or by another entity.

It is also possible to establish contracts with large power plants. These contracts may be bilateral for large periods of time, for example 6 or 12 months, with a fixed power contract, or daily in the spot market, in function of the necessities forecast. If the energy is bought in the market the purchase price will be equal to the selling price, resulting in profits due to the inexistence of penalties. If the energy is acquired by bilateral contracts, it will have a fixed value every day and it can be used for reserve or as a part of the production after checking that it is not necessary to use all power for reserve.

The VPP can also adopt a hybrid solution, combing more than one option of reserve, in order to minimize the costs and to diversify options.

4 Virtual Power Producers (VPP) – Market Price Formulation

The strategy adopted for the generation calculation influences directly the energy price proposal for the VPP. If the VPP has high values of reserve, the energy price rises. On the other hand, if the reserve is too low, the VPP will have penalties.

An important factor in the elaboration of the prices for a VPP, is the governmental benefits given to the producers that make use of DG. Currently the regulating entities impose values of remuneration for each technology, based on the amount of production. Given the importance that the government gives to this type of technologies, it is natural that the subsidies are kept even with the liberalization of the markets. The price that the VPP offers to the market can be calculated through an expression that considers the values presented by each associated producer.

The price considered for each producer must be agreed with the VPP so that competitive prices can be obtained, to allow the producers to have revenues from their investments in reasonable periods of time.

If subsidies exist, these will have to be included in the calculation of the prices considered for the producers. The price of the reserve will also have to be previously agreed between the VPP and the producers.

This way of working implies a great complicity between the VPP and the associated producers in order to prevent speculations. The profit edge is variable, but the minimum value is given by the value of sell percentage.

In markets where price variations are frequent, the VPP will be able to define different strategies, as for example, the prices elaboration depending on the generating technologies, to obtain prices that can be easily adapted to the market.

In this scenario the technologies can be divided in 4 groups. The first group will include the technologies for which the primary energy cannot be stored, as for example wind, solar, and co-generation.

The second group includes the technologies for which it is possible to store the primary resource and for strategically interests it could be convenient to use the resources in the periods when the price of energy is higher. The technologies that belong to this group are the hydroelectric with dam, the biomass and biogas.

The third group includes the VPP reserve, either the production part that the VPP has contracted for reserve with the producers or with thermal central offices.

The fourth group includes the technologies for which the primary resources are storable, but expensive, as for example, gas turbines and fuel cells.

5 Virtual Power Producers (VPP) – Energy Price Formulation

After the closing of the market, the VPP will have to forward the production scheduling to the associated producers, as well as determining the value to be paid to them for the energy.

Despite the prices presented in the market being calculated on the basis of the prices presented by the producers, the producers' remuneration strategy must take into account the market price for which the energy has been sold.

<u>Proportionality method</u> - As a first approach, we can consider that each producer remuneration should be proportional to value of the produced energy relative to the total produced energy by associated producers.

$$p_t = \left(p_m \times E_p \pm I_{VPP}\right) \times \left(1 - L\right) - p_r \tag{1}$$

Where :

p_t – *Total payment to the producers*

p_m – *Energy market Price*

E_p – *Energy Delivered*

I_{VPP} – *Penalties of VPP*

L – *Profit VPP*

p_r – *Reserve cost*

$$p_i = \frac{p_t}{\sum_{i=1}^{n} E_i} \times E_i + p_r \times \frac{E_{ri}}{E_r} \tag{2}$$

Where :

p_i – *Payment to the producer i*

E_i – *Energy delivered by the producer i*

E_{ri} – *Reserve of the producer i*

E_r – *VPP reserve*

This method consists in paying to the producers a value which is directly proportional to the produced energy, considering a previously defined value to pay for the reserve.

This method is somehow unfair because it is mainly advantageous for the producers that cannot guarantee the production, because they usually sell all the produced energy. On the other hand, the producers that accept to adapt their production to the general necessities of the VPP are impaired because their contribution to the producer aggregation is not recognized.

Equal percentage method - Another form of remuneration of the produced energy consists in providing equal percentages of the profits to the producers, the same that they would have in case of no association with VPP.

$$p_t = \left(p_m \times E_p \pm I_{VPP}\right) \times (1 - L) - p_{re} \qquad (3)$$

Where :
p_{re} – *External reserve cost*

$$p_i = \frac{p_t}{\sum_{i=1}^{n}\left(p_m \times \left(E_i + E_{di}\right) \pm I_i\right)} \times \left(p_m \times \left(E_i + E_{di}\right) \pm I_i\right) \quad (4)$$

Where :
E_{di} – *Energy that could be delivered by producer i*
I_i – *Penalties that the producer i could have*

Factor "G" Method – In this method the price to pay to the producers will be divided in 3 parts: the relative value of energy, the reserve capacity, and the use of the reserve.
The value to pay for the produced energy (foreseen) is given by the following expression:

$$p_{i1} = p_m \times E_{pi} \times (1 - L) \qquad (5)$$

Where :
p_{i1} – *Payment to the producer i (part 1)*
E_{pi} – *Foreseen Delivered Energy by the producer i*

The second part is related with the existing reserves:

$$p_{i2} = p_m \times G \times \left(E_{ri} - E_r \times \frac{E_{pi}}{E_p}\right) \qquad (6)$$

Where :
p_{i2} – *Payment to the producer i (part 2)*
G – *Factor G*

In this expression all the producers pay for the reserve, but the producers that make use of technologies with controllable production can be relieved from reserve payment, since they have a strong probability of not using it. If the VPP opts for this type of management, we will have that:

$$\begin{cases} p_{i2d} = p_m \times G \times E_{ri} \\ p_{i2u} = -p_m \times G \times E_r \times \dfrac{E_{pi}}{E_{pu}} \end{cases} \qquad (7)$$

Where :
p_{i2d} – *Payment to the producer i (part 2)*
With dispatchable technology
p_{i2u} – *Payment to the producer i (part 2)*
With non – dispatchable technology
E_{pu} – *Sold Energy by non – dispatchable technology*

The third part deals with the use of the reserve in function of the production technologies. For production technologies for which it is not possible to control the production, the use of reserves can be significantly different from the foreseen. If the used reserve is larger than foreseen the use is negative, if the used reserve is smaller than foreseen the use is positive.
The expressions of calculation of this part are different for the two situations. If the production is larger than foreseen, the expressions are the following ones:

$$\begin{cases} p_{i3e} = p_m(\Delta E) * (1 - G) + \\ \quad + (\Delta P) * Epi / Ep_1 * (1 - L) * G \\ p_{i3f} = p_m[(-\Delta E) * (G + L - 1)] + \\ \quad + (\Delta P) * Epi / Ep_2 * (1 - L) * (1 - G) \end{cases} \qquad (8)$$

Where:
p_{i3e} – *Payment to the producer i (part 3)*
With surplus generation
p_{i2f} – *Payment to the producer i (part 3)*
With shortage generation

If the production is smaller than foreseen, the expressions are as follows:

$$\begin{cases} p_{i3e} = p_m(\Delta E) * (1 - G) + \\ \quad + (\Delta P) * Epi / Ep_1 * (1 - L) * (1 - G) \\ p_{i3f} = p_m[(-\Delta E) * (G + L - 1)] + \\ \quad + (\Delta P) * Epi / Ep_2 * (1 - L) * G \end{cases} \qquad (9)$$

6 Case Study

A simulation tool, ViProd, has been developed to simulate the operation of a VPP and its interaction with the market. This tool takes into account the characteristics of the technologies used by the power producers and can be used to provide decision support to VPPs.
With the developed simulation tool, several studies were done, using different levels of reserve. The goal was to verify which is the most advantageous strategy to pay the energy to the producers. On the other hand,

this tool will be very useful for the producers because it can verify, in different conditions, how much it receives when aggregated to the VPP.
In this case study, the simulation considers three wind power producers association. Each one of these producers has a co-generation unit with a nominal power of about 10% of the wind farm capacity.

Table 1 – Producers

Producer	Technology	P (kW)	P_T (kW)
1	Wind farm	30.000	33.030
	Co-generation	3.030	
2	Wind farm	20.000	22.100
	Co-generation	2.100	
3	Wind farm	13.000	14.250
	Co-generation	1.250	

Co-generation will serve as support of the wind farms, to compensate the generation variations of this type of generating units.
In this case study, all the required reserve is assured by the VPP own means. The energy price considered is relative to 28 of November, in the France market. In this case, we simulated 5 scenarios. In the first one, all co-generation capacity is reserve, in the second, third and fourth scenarios 15%, 10% and 5% of reserve are assured, respectively. In the fifth scenario, reserve does not exist.
For each scenario, 3 strategies, described in Section 5, have been studied. The undertaken simulations considered several situations concerning the wind farm generation, changing between 50% and 150% of the foreseen generation. The presented value is the average of the 3 wind farm and 3 co-generation producers.
In the next figures it's possible to see the evolution of the price paid for the energy to the producers for the VPP. The values are in percentage because were considered as reference the price that the producers would receive if they actuate directly in the market.

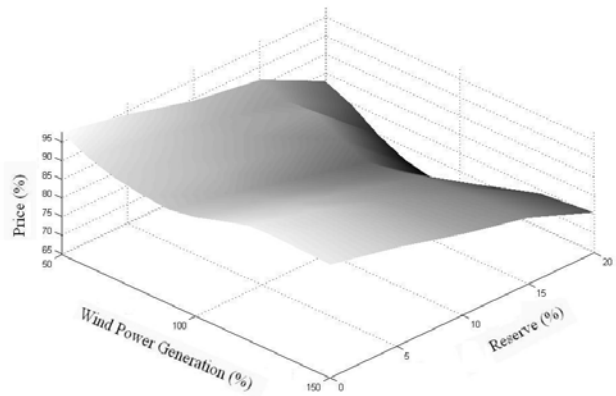

Fig. 1 – Price Variation for Wind Farm considering the Strategy 1

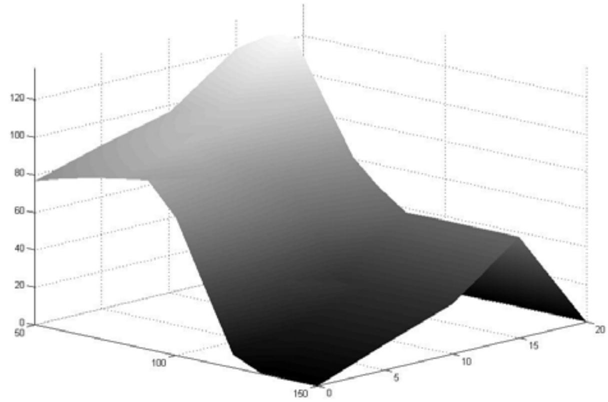

Fig. 2 – Price Variation for Co-generation considering the Strategy 1

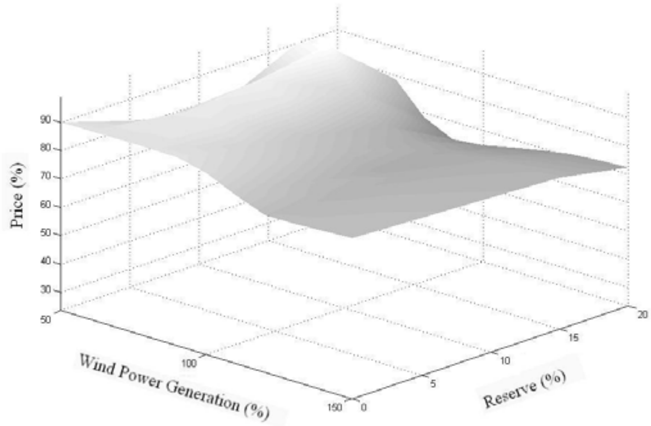

Fig. 3 – Price Variation for all producers considering the Strategy 2

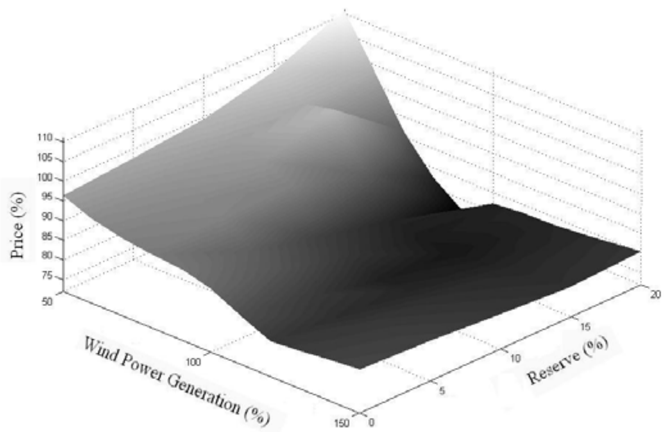

Fig. 4 – Price Variation for Wind farm considering the Strategy 3

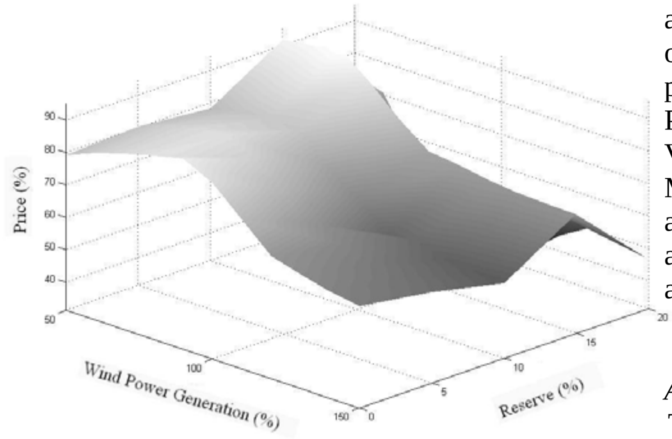

Fig. 5 – Price Variation for Co-generation considering the Strategy 3

Analyzing figures 1 to 5, it is possible to see that strategy 1 is very sorrowful for the co-generation, since when they are not to produce their income is null when the wind producers are with surplus generation.

In strategy 2 the graph is common because the receipts are proportionally equal. The obtained values are acceptable, varying between 70% and 105% of the value that the producers would receive if they actuate directly in the market. The problem of this strategy it is that who does not fulfil with the stipulated generation is not penalized.

The third strategy showed more favourable to the Wind producers, since they obtain, in certain cases, to receive more than when they are isolated. However the co-generation has more advantages in the market actuation, due to its small dimension.

7 Conclusions and Future Work

In this paper we presented a simulation tool (ViProd) for studying Virtual Power Producers (VPP) operation. This tool allows creating several producers using different generation technologies and simulates the internal generation scheduling as well the interaction between the VPP and the electricity market.

Some VPP producers' payment strategies have been presented and analysed. The main goal is to decide what is the best VPP management strategy for paying the delivered energy to the aggregated producers.

The remuneration of the producers is in fact a complex issue of VPP operation, since there are opposite interests in game.

This paper includes a case study to demonstrate the results of all considered producers payment strategies. The results have been obtained using Viprod and considering France market characteristics and real prices. With Viprod a VPP can analyse its own data and decide the most adjusted producers' payment strategies to each situation.

Presently, we are working on the integration of ViProd with an electricity market simulator – MASCEM [4] that has been developed in GECAD as a multi-agent system. This integration will allow analyzing the results of several VPP strategies when acting in the market.

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