

IMPORTANCE OF TECHNOLOGIES CHARACTERISTICS FOR VPPs

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The large increase of renewable energy sources and Distributed Generation (DG) of electricity gives place to the Virtual Power Producer (VPP) concept. VPPs can reinforce the importance of these generation technologies making them valuable in electricity markets. One of the most important tasks of a VPP is the conjugation of technologies to obtain a consistent set of associated producers and allow them to operate in the electric market.

This paper presents some characteristics regarding already existent technologies and relevant aspects for producers and for VPP.

***Keywords:* Distributed Generation, Virtual Power Producer, Technologies, Electricity Markets**

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 consumers and not transmitted over long distances. Thus, it is possible to get lower losses [1]. 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 favourable regulatory framework and the equipment costs are more attractive every day. At this stage, the main technologies used are mini and micro gas turbines 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 have more importance in the market and 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 [13].

Current electricity markets have effectively implemented real-time and day-ahead markets [7]. VPPs should adopt organization and management methodologies so that they can make DG a really profitable activity able to participate in these markets.

In order to operate in an efficient way, VPPs should have detailed knowledge about the aggregated producers in order to coordinate the several generation technologies towards a common goal. This knowledge includes characteristics such as:

- technology ripeness;
- profitability;
- availability and reliability;
- dispatchability;
- greenhouse effect gases;
- relation with external factors;
- lifetime.

As these characteristics can be more or less important for the evaluation to be undertaken, weighting factors can be considered. These factors are assigned taking into account economic and market criteria [6]. This allows producing an evaluation matrix for the considered technologies, according to all the relevant criteria.

With this matrix the VPP can identify, in presence with specific situation, which type of producer is more interesting for its own strategy.

2. Characteristics of technologies

For each enunciated technology, was proposing a ponderation to classify all the DG technologies. Each characteristic was divided in five different levels, for characterize the DG technologies in a convenient way [2].

The ponderation is the following:

Technology ripeness – The ripeness of with technology depends, essentially, of the experience and know-how that exists to use it and of the well done implementation of production units.

The levels are the following:

- 1 - Technology in study stage;
- 2 - Technology in development stage;
- 3 - Technology in prototype phase with strong probability of success;
- 4 - Technology in initial commercial phases or applied in specific situations;
- 5 - Technology in large commercial scale and with manufactures competition.

Profitability - The profit that comes from technologies can be evaluated using its payback. The profit technology evaluation is always uncertain because of the primary resources variability regarding the geographic localization. In cases of technologies dependent of fossil resources, the price of this resource can be very different in short time slices.

The levels are the following:

- 1 - Payback > 16 years;
- 2 - 12 years < Payback 16 years;
- 3 - 8 years < Payback 12 years;
- 4 - 4 years < Payback 8 years;
- 5 - Payback 4 years.

Availability and Reliability- The technology availability and reliability are defined according to the number of hours that it provides energy to the system all through the year.

The interruption in the delivery can occur when the production units are being repaired, in maintenance or because of internal or external problems relative to the generation installation.

Other factor that must be considered is the annual use of the installed power, considering the functioning characteristics.

The levels corresponds to steps of twenty percent time and are the following:

- 1 - Utilization factor < 1.752 h/year;
- 2 - 1.752 h/year Utilization factor < 3.504 h/year;
- 3 - 3.504 h/year Utilization factor < 5.256 h/year;
- 4 - 5.256 h/year Utilization factor < 7.008 h/year;
- 5 - Utilization factor 7.008 h/year.

Dispatchability - If the technology in use is considered more or less dispatchable, is possible to estimate its electricity generation in a specific period of time.

The levels are the following:

- 1 - No possibility of generation forecast;
- 2 - Foreseen production with lower degree of assurance;
- 3 - Foreseen production with higher degree of assurance;
- 4 - Supervised production relative to energy needs but variable because of the year seasons or because of the primary resource energy reserve.
- 5 - Supervised production regarding energy needs.

Greenhouse effect gases - The technology pollution is classified by the rate of emission to the atmosphere of CO₂ and other gases that contributes for greenhouse effect.

In certain cases the level of gases emission can be negative because some technologies emit CO₂ but prevent deliverance of other type of gases that are substantially harmless for greenhouse effect.

It's essential to consider the gas emission during the equipment transport, setting and improvement, but in this particular case it was only considered the emissions relative to lifetime technology because this value is dependent of the project conditions.

The levels are the following:

- 1 - GHG > 1 t_{CO2}/ MWh;
- 2 - 0,50 < GHG 1 t_{CO2}/ MWh;
- 3 - 0 < GHG 0,50 t_{CO2}/ MWh ;
- 4 - GHG = 0 t_{CO2}/ MWh;
- 5 - GHG < 0 t_{CO2}/ MWh.

Lifetime- The lifetime is the period of time that the system carries out normal action in the most suitable way, considering specified conditions:

The levels are the following:

- 1 - Lifetime < 10 years;
- 2 - 10 Lifetime < 15 years;
- 3 - 15 Lifetime < 20 years;
- 4 - 20 Lifetime < 25 years;
- 5 - Lifetime 25 years.

Relation with external factors- Some energy advantage is directly related with external factors, like natural gas and crude oil prices, or primary energy resources.

Regarding the relation with external factors it's going to be distinguish by positive or negative dependencies.

Table 1- Classification of DG Technologies

	Wind farm	Small Hydroelectric	Photovoltaic	Biomass/ Biogas	Cogeneration	Fuel Cell	Geothermal	Tidal	Waves	Mini-Turbines
Technology ripeness	5	5	4	5	5	4	5	2	3	5
Profitability	4-5	4	2	3	4	3	4	?	?	4
Availability and reliability	2	2	1	4	5	5	4	?	?	5
Dispatchability	2	3/4	2	4	5	5	4	2/3	3	5
Greenhouse effect gases	4	4	4	5	Var.	Var.	4	4	4	Var.
Lifetime	4	5	4	5	4	4	5	?	?	4
Relation with external factors	3	4	3	5	Var.	2	3	3	3	1

“Var.” – The technologies are several technical solutions with different performances

“?” – The technologies are in development and don’t have final results

The negative dependencies are directly related to external producer factors and are not controllable. The positive dependencies are related to internal factors, optimizing necessary or already existent processes for energy generation to complement the technologies already existent.

The levels are the following:

- 1- Extremely dependent of external factors;
- 2- Dependent of external factors;
- 3- Independent of external factors;
- 4- Dependent of internal factors;
- 5- Dependent of internal factors and originating in existent technologies

3. Classification of technologies

The table I present studied technologies classification used by producers in distributed generation:

- Wind farm;
- Small Hydroelectric;
- Photovoltaic;
- Biomass/ Biogas;
- Cogeneration (CHP);
- Fuel Cell;
- Geothermal;
- Tidal;
- Waves;
- Mini-Turbines.

The tidal and waves technologies are in development, because of this, have factors witch quantification is very difficult or impossible because don’t have significant technical and experimental results.

Dispatchability – The technologies that are more easily dispatchable are the ones that depend of fossil resources or either, the cogeneration, the mini-turbines and fuel-cell that work with natural gas.

The small hydroelectric, biomass, biogas and the geothermal can be considered dispatchable because it’s possible foreseen the generation in 30 or 60 minutes periods to commercialize in the electricity market in the following day.

In the specific case of the small hydroelectric, if it’s water wire and without water reservoir, the generation forecast have a higher risk. The risk depends on the experience and the knowledge of the river flow. If exist an upstream hydroelectric that controls the river flow, this reduces the forecast uncertainty.

The wind farm and photovoltaic cannot be dispatchable because exist a higher generation uncertainty. However, there are several studies with some results and models such as HIRLAM or SKIRON [4]. With this models it’s possible improve the knowledge of the wind speed, sun radiation and temperature. With this information it’s possible to increase the forecast results.

Profitability – The technologies profitability calculation is particularly critical, therefore depends of several factors, many of then variable in time and in a unexpected form.

The factors that more condition this type of analysis are the following:

Financing - Governments of the different countries, mainly the most rich and developed, finance the projects of these technologies to stimulate its development. The problem is for how much time and in what forms will the financing have in next years;

Tariffs - Another rule imposed for the administration is the DG technologies tariffs differentiation. The goal is to turn them in profit technologies. The problem is the commercialisation in electricity market. With the technologies subsidies the generation costs are too lower for sell in open market. The solution is the attribution of subsidies for kWh supplied and technology in function of the dimension of plant and the market historic price.

However, this situation will raise, certainly, doubts to other market agents, who have one strong expression in the electricity market context;

Renewable resources - The production of some of the exploitations depends on natural power resources, as the wind, sun and water.

The forecasts for long time periods become each time less warrantable. For example, in the 2005, the generation of the large hydroelectric plants in Portugal was 51% below in comparatively with the 2004 [8], with more 200 MW installed power;

Other resources - Oil and natural gas prices instability is an important analysis factor concerning the investments profitability. Between 2003 and 2005 the price of one barrel of oil "jumped" from 35\$USD for 60\$USD. Concerning to hydrogen, the price will tend to lower given that it is the most abundant element of the planet and because there are many ways to obtain it, even so, the ideal form of getting it is yet unknown;

Carbon Market - Another factor that can modify the plants profitability is the operation in the carbon markets. Effectively, the companies will have to pay for their pollution, being this value imputed directly in the energy price. The difficulty is to define the date of entrance in service of this market, the taxes and its way of functioning;

Parallel markets - There are technologies, as the cogeneration and fuel cells that release energy under the heat form. This heat can be sold, increasing its profitability;

Marketing Strategies - the incorporation of one specific technology in a producer mix may have consequences regarding its exterior image, increasing its profits in an indirect form.

With all these changeable conditions, the evaluation of the profitability is only possible considering the moment when it is carried through, given that the inherent risks to one project of this nature are each time more difficult to be evaluated. For example, if the financings and subsidies disappear, this will be a sufficiently compromising factor for the profitability of the investment on a wind farm.

However, the increasing of oil prices and the valuation of the emissions of the GHG, makes wind farms more competitive face to the traditional ones.

To know the consequences of these variations, sensitivity analyses were made using different values of costs. Knowing what is the limit of investment to optimize profit is seen as a advantage.

Availability and reliability- The availability of the technologies is one more value for the cogeneration and for the mini-turbines, since they do not depend of renewed resources and the maintenance shares are of simple execution and causes relatively short times of non-availability.

The Biomass, Biogas and geothermal technology presents good levels of reliability.

However, the resources don't depend continually from the reserves that can exist.

The levels of availability in wind power, small hydroelectric, tidal, waves and photovoltaic are changeable because of the places where they are installed, the season of the year, hour of the day and from year to year.

GHG emission - The GHG emission is null in wind and photovoltaic exploitations and negligible in the small hydroelectric, existing inevitable emissions during the development, construction, transport, assembly and recycling of the equipment.

In biomass and biogas case the inherent emissions to its functioning are "favourable" for the environment.

Power plants that use biogas as fuel emit carbon dioxide (CO₂) to the atmosphere, but they prevent the methane emission (CH₄), that is, for the same weight, 21 times more harmful for the green house effect.

On the other hand, this process destroys the

pathologic agents and eliminates the risk of soil contamination and water courses, superficial and underground, that the residues could provoke if they weren't treated.

In the cogeneration and mini-turbines the emissions are changeable according to the type of fuel used. According to Hatzigaryiou [4], a system that uses diesel emits in average 650 g/kWh of CO₂ and 10 g/kWh of NO_x (nitric oxides). A system that uses natural gas emits in average 550g/kWh of CO₂ and 0,5 g/kWh of NO_x.

However, it can be found different values. The software of RETScreen International, suggests 980 g/kWh of CO₂ for diesel and 490 g/kWh of CO₂ for the natural gas. The emissions of NO_x are not considered in this software.

In the specific case of the cogeneration is more complicated to report a value, given that it can function, using biomass or biogas, and the produced thermal power has to be considered[9].

The fuel cells present different technologies and different primary power resources consequentially the GHG emission values are very variable.

The variations of the emission levels of the fuel cells are associated not to the generation energy process, in which the emissions are null, but to the form of obtaining the hydrogen that could be obtained by different methods (for example: electrolyse or thermolysis).

Lifetime - The lifetime is raised in any of the technologies, placing itself between 20 and 30 years, with exception for the technologies associates to the sea energy that are still in development.

Technology ripeness - All the considered technologies, except tidal and waves that is in experimental phase, presents a raised state of maturity. The manufacturer great challenge, is finding forms to reduce the production costs and assembly, to achieve a more profitable and competitive technology.

This is one of the aspects that influence a bigger development of photovoltaic plants.

The fuel cells are in an initial phase of commercialization, but with great expectations to its development, mainly, because they use hydrogen as primary resource. Being pointed by many specialists as a technology that will be able to substitute the actual fossil fuel based generation technologies.

One of the great barriers of this technology is the acquisition, transport and storage of the hydrogen because it is a highly explosive substance.

Relation with external factors - the electricity generation prices of micro and mini-turbines are strongly dependent on oil and natural gas prices, besides they are also dependent on the resource supply, that doesn't exclusively depends of controllable factors.

In the cogeneration, the situation is similar having, however, other factors that are important to consider, like the exploitation of the generated heat. This double exploitation makes cogeneration one of the technologies with bigger income.

The cogeneration can still work using biogas or biomass, increasing the interest of the investors in this technology.

The fuel cells also depend of primary resources. However, if the primary source is hydrogen, it is possible to obtain it in any place of the planet by using several processes.

The wind power, geothermal, tidal, waves and photovoltaic technologies do not depend of external factors and don't have any type of direct benefit in other areas of activity.

The small hydroelectric can bring advantages in the regularization of rivers flows, although in a small scale and specific situations. The water storage will be available to the adjacent irrigation of fields and to potable water to the cities.

The biomass and biogas are the technologies that are more related with factors that benefit, directly the society in general.

Between the main exploitations we have:

- Exploitation of the resultant excrement of the farming and cattle raising industry;
- Exploitation of the resultant residues of the cleanness of the forests;
- Exploitation of biogas resultant of the sanitary embankments;
- Exploitation of the excesses of the wood industry;
- Exploitation of the agriculture spares.

4. Important Factors for VPP

Not hindering the described classifications for the different characteristics, not all assume the same importance for the VPP.

The factor that will be more determinative for the Virtual Power Producer will be the price to which the producer will be able to supply the energy to it (the generation cost).

The energy price is extremely important to the VPP because the principal law that prevails in liberalized markets is the energy price.

To perform pricing the producer will need to consider several aspects as the profitability, reliability, maintenance costs, equipment acquisition costs and primary resource costs.

The GHG costs emissions could also be included in the price of the energy when the VPP does not accumulate this function.

The Dispatchability of the production technologies is also of great importance to the VPP, therefore it will have to make generation and reserve management, according to the uncertainty of the forecasts given by the producers.

The importance of the production guarantee is different in all markets because the penalty methods for contract breach are also different. In some markets the unfulfilling of contracts can lead to the exclusion of the producers.

The probability of the equipment to function according with the foreseen reliability, is a determinant factor in the risk analysis, what directly influences the spinning and static reserves, that are necessary in each instant, as well as the profit edges associates to this risk. In this point, the inherent risk to the maturity of the technology will have to be considered.

The VPP will have to consider external factors to the technologies, such as, the impact of the use of "green" energies, partnerships with companies associated to the productive process (as example, the exploitation of the heat in the cogeneration or heat and cool in tri-generation), agreements with cellulose companies (when it is regarding biomass) or agreements with farmers (in the case of the small hydroelectric).

There is some technologies used in the distributed generation, where the energy price is related with the non renewable primary energy resources. In these cases the VPP must have forecasts of resources prices and needs to diversify them to avoid being subject to critical price changes.

The VPP must have a clear notion of the technology lifetime to plan renovation strategies and future investments.

The knowledge of the lifetime of technologies will allow the development of a renewal strategy for them (in an ideal moment) to optimize the global performance of the Virtual Power Producer and serve as element of regulation on the contracts length.

A factor that could be determinative for the VPP will be the relative localization of the producers. Given the existing restrictions to the level of the nets, if there are two producers connected in the same substation it will be possible to exist a coordination between them with the aim to optimize their generations, mainly if exists extra equipment, in the generating units.

The classification of the most important characteristics is in the following order:

Generation costs	10
Dispatchability	7
Reliability	5
Relation with external factors	4
Geographic localization	2
Lifetime	2

With these values it's possible to classify all the technologies and determine the interaction between them, considering the benefit that it could imply for VPP.

5. Conclusion

In this paper we presented principal characteristics of DG technologies. These characteristics are very important in the VPPs activity, namely for planning the technologies group structure associated to him.

Another important task of the VPP is the management of the generation and reserves. The knowledge of technologies characteristics allows optimization on the electricity bids in the market by the VPP and decreases the penalties risk.

Also in the establishment of contracts the information about technologies is important for negotiating the best prices of energy and the length of the contracts.

The most important factor for VPP is the price who producer can generate the electricity. The energy price for VPP is extremely important because the principal law that prevails in the liberalized markets is the energy price.

The reliability and the dispatchability determine the risk that the VPP takes in assuring the contracts. Because of these factors and the market rules, the VPP needs power in spinning reserve. The reserve cost is a part of the price to bid in the market. If the risk is higher, this will lead to a subsequent increase on reserve and in the energy price.

The external factors, localization and life time are important factors for the establishment of new contracts with producers.

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