Feasibility study of virtual power plants

Hugo Filipe Ferreira Patrício
Departamento de Engenharia e Gestão Industrial
Instituto Superior Técnico
Lisboa, Portugal
hugofili@gmail.com

Abstract

The energy sector has been undergoing significant changes over the last decades. There is a growing trend to incorporate generation of electricity from Renewable Energy Sources (RES-E).

This study focuses on the daily Iberian electricity market and its aim is to assess the economic and financial feasibility for a company to operate as an intermediary between the market and a set of clients who own photovoltaic systems. To this effect, a financial model and a market simulator were built in which the financial model is capable of evaluating the capacity of the company to generate income based on data generated from the market simulator.

The main goal of the simulator is to provide the set of sales data to use in the financial model. Both the simulator and the financial are dependent on a set of parameters that aim to simulate the real scenario as much as possible. After defining an average scenario, the most relevant data was collected and analysed. Finally, a sensitivity analysis was performed on the critical parameters.

Having in mind that the simulator represents a very simplified model of the real electricity market dynamic, it was possible to conclude that it is feasible to implement a business model idea such as defined previously and taking into consideration the assumptions made and the values fixated for the parameters.…

Keywords— electric energy; virtual power plants; photovoltaic systems; market simulator; financial model

I. INTRODUCTION

One of the key issues that humanity faces nowadays is related with the growing scarcity of fossil fuel based energy resources coupled with a higher awareness towards themes as global warming and climate change. Therefore, the alternatives to the use of these fossil fuels are becoming more relevant in the world of energy consumption.

Throughout the years there have been significant technological progresses relative to RES-E. Not only about their diversity but also about their efficiency.

In this context there are now micro producers of renewable energy sources, especially photovoltaic and wind generation systems who aim at getting their infrastructures self-sufficient regarding the energy consumption. As technology progresses, the efficiency of this type of energy production allows for net surplus in terms of production vs. consumption that can be traded in energy markets. However, the isolated production of these micro producers is not relevant when the scale is the energetic daily consumption of a country and therefore they have little to no strength when compared to the big market players. The distribution grid has also developed considerably with special focus for smart grids that allow for real time energy management and data transmission regarding the energy traffic.

At a political level, the liberalization, legislation and regulation of the energy sector is also evolving in a way that facilitates the dynamic and implementation of new ideas.

Having this scenario in mind, the proposed concept of study is the aggregation of RES-E producers in a virtual network that operates in the Iberian electricity market with the objective to generate income to both the company and the producers with the assumption that the feed-in-tariffs are not in play anymore (which should happen in years to come).

II. LITERATURE REVIEW

In this section we overview some of the key concepts like virtual power plants (VPP), smart grids and also a brief description of the technical tools used for analysis in this study.

Smart Grid – There is no globally accepted definition of the concept of smart grid, though it has become a household name in the context of electricity grid development. The European Technology Platform Smart Grid defines it as an " electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies" *(European Technology Platform SmartGrids, 2013)*. Another definition describes it as an “electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable.” *(Gharavi & Ghafurian, 2011)*

VPP – A virtual power plant can be defined as an energy management decentralized system with the core competence of aggregating the production capacity of distributed generators with the objective of selling it in the energy market (Peik-Herfeh, Seifi, & Sheikh-El-Eslami, 2012). Others present it as a flexible representation of distributed energy resources (DER) portfolio (Pudjianto, Ramsay, & Strbac, 2007).

Net Present Value (NPV) – First it is convenient to introduce the concept of present value (PV) in which NPV is built. According to (Brealey & Myers, 1998) the first basic financial principle is that a euro today is more valuable than a euro available tomorrow, because it is possible to invest that euro and immediately start to collect interest. Having this in consideration, the PV of a future income can be obtained by multiplying it with a positive factor that should be inferior to 1 in order to be coherent with the principle enunciated before. Therefore it can be formulated as:

$$PV = R_x \times \frac{1}{1+i} \tag{1}$$

Where:

$$R_x - future\ income$$
$$factor\ = \frac{1}{1+i}$$
$$i - discount\ rate$$

The interest rate i represents the rate of return that one would obtain from an alternative investment e.g. treasure bonds with a certain maturity. The PV therefore represents the gross value of a hypothetical investment in the present date. If we discount the initial investment we get the liquid value which can be positive or negative a reference that is going to be used as acceptance or rejection criteria of the investment and also an investment measure of attractiveness. From this discount operation with get the NPV. Hence and according to the nomenclature used in (Soares, Fernandes, Março, & Marques, 2007), the NPV is formulated as:

$$NPV = \sum_{k=0}^{n} \frac{CF_k}{(1+i)^k} \tag{2}$$

Where:

$$CF_k - investment\ and\ exploration\ cash\ flows$$
$$k - period\ number$$

Internal rate of return (IRR) – According to (Soares, Fernandes, Março, & Marques, 2007) IRR is the discount rate for which the NPV value is 0. As a project criteria it is used by comparing the IRR with the discount rate previously defined. If IRR>discount rate, then the project is within the acceptance zone. This implies directly that the NPV>0. IRR can be formulated as:

$$NPV = \sum_{k=0}^{n} \frac{CF_k}{(1+i)^k} = 0$$

Where:

$$IRR = i$$

Discount rate and Capital Asset Pricing Model – As we defined previously, the definition of discount rate is crucial for the calculation of NPV, serving also as a term of comparison with IRR. The discount rate should reflect the cost of opportunity of an alternative investment. In this study in order to estimate the discount rate it was used the Capital Asset Pricing model. This method is used more commonly to assed the appropriate return of a financial asset. However it is also common to find it associated to the estimation of the discount rate. It is formulated as:

$$E(R_k) = R_f + \beta_k \times (E(R_m) - R_f) \tag{3}$$

Where:

$$E(R_k) - \ expected\ return\ on\ the\ capital\ asset\ k$$
$$R_f - risk\ free\ rate\ of\ interest\ for\ asset\ f$$
$$\text{typically}\ government\ bonds$$
$$\beta_k - Beta\ of\ asset\ k$$
$$E(R_m) - \ \text{expected return of the market}$$

III. ELECTRICITY MARKET ANALYSIS

The macroscopic environment that surrounds this project is critical for its success and as such it is prudent to take a look at the major indicators of the electricity market starting in the European Union (EU) and then zooming in to Portugal and the market where the company is going to operate, MIBEL.

EU – In figure 1 we can observe that the EU registers an accentuated development regarding photovoltaic energy production.

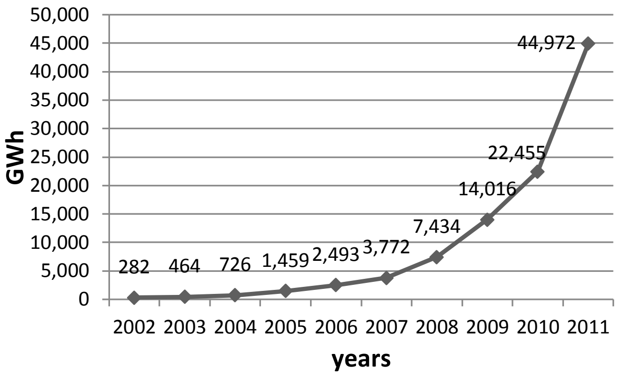

Figure 1– Evolution of photovoltaic energy production in EU (27). Source: Eurostat

Portugal – Figure 2 shows that before 2006 there was residual investment in photovoltaic energy production and then in the following years the growth is comparable to that of the EU.

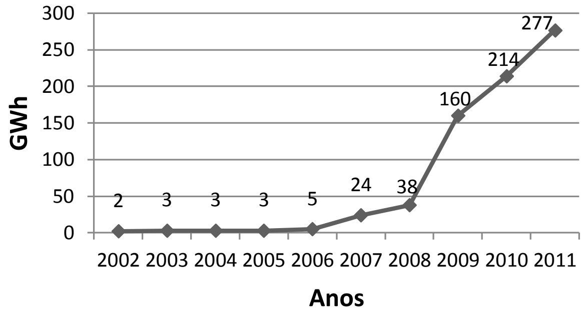

Figure 2 – Evolution of photovoltaic energy production in Portugal . Source: eurostat

MIBEL – Figure 3 shows the evolution of the spot market average price in 2012 that according to (ERSE, 2013) was 48,07€, 5% lower than in 2011. In terms of market splitting time, there has been a consistent drop which indicates market maturity and also a development in the connection grid between Portugal and Spain.

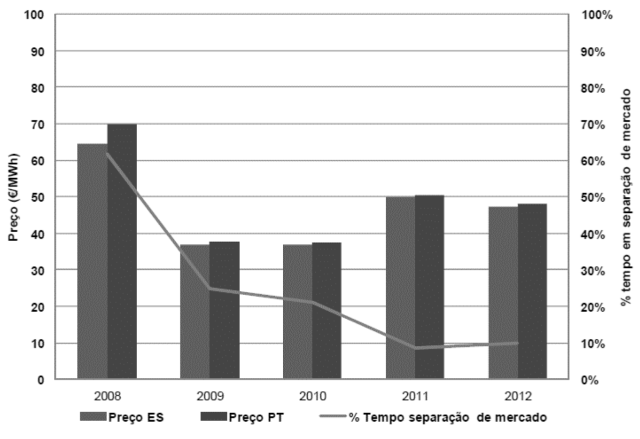

Figure 3- Evolution of MIBEL spot market average price and market splitting time

IV. FINANCIAL MODEL AND ENTERPRISE

Throughout this study a series of assumptions will be made that affect the activity of the company and its performance. The most important one, and a *sine qua non* condition is that the feed-in-tariffs that nowadays reward micro generation in Portugal no longer exist. Current legislation (Decreto-Lei n.º 118-A/2010, 2010) determines that the energy produced in micro generation terms will be rewarded at 400€/Mwh during the first 8 years, 240€/Mwh in the next 7 years and finally a discount of 20€/Mwh will be applied in the following years. As previously stated, in 2012 the average spot market price in MIBEL was 48,07€Mwh, a very distant value to that imposed by law which invalidates any attempt to compete with such price environment .

Business Model

At an operational level it is considered that the enterprise acts as a wholesaler in the electric energy market. An intermediary between the producers and MIBEL spot market which aggregates the energy produced by the clients and sells it later on the market.

Regarding the legal relationship with the clients, two contracting models will be considered: Production/Consumption balance sale and total production sale.

Production/Consumption balance sale – In this model the aggregate value to take in the market represents solely the client's excess in production (photovoltaic system)

Total production sale – In this option it is considered that the total production of a photovoltaic system is taken to the market.

Financial Model

With the objective of evaluating the project from a financial point of view an Excel model was built that allows the automated definition of critical parameters that will provide the values to be discussed in chapter VI.

The construction of this model was structurally inspired on chapter 9 of the book "Investment Projects Evaluation on a business optic" (Soares, Fernandes, Março, & Marques, 2007) with the adequate adaptations taking into consideration that at the time the book was written there was a different national accounting norm in play. The IAPMEI business model excel template was also a guide taken in consideration. (IAPMEI)

It was considered that year 0 was for investment only, having the commercial activity beginning in year 1. The total period in analysis was 8 years taking into consideration the standard for the nature of investment.

Technical, economic and financial assumptions – A set of parameters were defined that affect the organization of the model.

V. Market simulator

The main goal when building the market simulator was to provide a liquid sales value to be used in the financial model. At the same time this will inspire some conclusions about the business model e.g. the study of the possibility of selling the total production of each photovoltaic system.

To this effect, an excel model was built that allows getting a sales estimative from a set of initial parameters.

Assumptions

Taking into consideration that this simulator is a very simplified model of a real market it is important to discuss the main assumptions taken:

All energy placed on the market is sold – this assumption is partially a simplification but also a direct consequence of the company nature. A simplification because we do not know beforehand which price is going to be set for a specific date and time and therefore the only biding strategy that guarantees that the energy is completely sold is setting the price at the minimum value (0€). According to the single clearing pricing model that is in play the only way that the energy is not sold (when placed at 0€) it's when the demand is null. On the other hand this represents a consequence of the company's nature taking into consideration that it is a wholesaler with no variable costs. Meaning that given this model and not having the necessary market strength to be a price maker, setting the price at x or x+dx is the same provided that the energy to be sold is set below the market price.

Each client as only one photovoltaic system – It is considered that in which concerns the present study, each client represents only one photovoltaic system, so their meanings are interchangeable.

Data – all data (production, consumption, market prices) is organized in tables that contain information for each hour of each day during a full year.

Production – the production data used is referent to the photovoltaic system model xxx given by company xxx.

Consumption – the data represents the electric consumption of two households with different profiles. One with 2 people in permanence during the day (profile A) and another with the household empty during labor hours (profile B).

Market prices – The data used was obtained from OMIP´s website (OMIP, 2013). It represents the price for each hour of each day of 2012 in the sport market of MIBEL. This is also the base point since it was the last year with full available data.

Parameters

Number of clients – This parameter represents the total number of clients (photovoltaic systems) of each profile. It can be edited with the objective of varying the sales and it is pivotal in finding the Critical point of sales.

Business growth rate – This parameter allows to define the rate at which the business will grow. A percentage is defined to the amount of clients gained every year.

Gross sales percentage – In the business model chosen, a part of the income generated in the market is distributed to the clients.

Sales calculation – It is the central part of this model taking into consideration that it is the connection with the financial model.

Electric consumption bill of clients – One of the business models of clients aims to compare the total production of a photovoltaic system with the electric bill of a client. To this effect it was built a segment that allows to calculate for each profile the electric consumption bill. The tariff used was EDP BTN (<=20,7 kVA e >2,3 kVA).

VI. Results and Sensitivity analysis

In this chapter the data collected from the financial model and the market simulator defined previously will be analysed.

Scenario setting

In a study that involves a big number of parameters with direct influence in business feasibility it is important to define an average scenario in which all the parameters are as close as possible to real conditions. The values presented are only for the parameters which are lately going to be the object of a sensitivity analysis.

Standard scenario

Discount rate – Using the CAPM this parameter was calculated, and the computed value was **7.64%**.

Personnel remuneration rate (PRR) – this parameter is initially set a 0% and it affects the payment due to the collaborators in a uniform fashion.

Number of clients – It was defined that the initial number of clients (Profile A + Profile B) was 4200 reflecting partially the number obtained when studying the break even sales needs.

Business growth rate – The chosen value was 4%, where this number represents about 100 new clients every year, a value deemed feasible for the commercial structure of the company to obtain.

Safety margin – Taking into consideration that the energy being sold is going to be produced in the day after it is negotiated a set of risks are associated with this operations model. E.g. the fact that RES-E such as photovoltaic systems are extremely sensible to meteorological conditions and the fact that the quantity definition is based on production historical data. Thus, this parameter is set a **5%,** which means that every production entry will be subtracted 5% of its value.

Sales commission – For both business models under study it is assumed that part of the sales is delivered to the customers. Having this in mind, the company sales commission is set at a constant value of 20% during the whole period of exploration.

Breakeven point

According to the standard scenario defined, the breakeven point in terms of sales outputted by the financial model is **177.102€**.

Considering the value obtained above and using the goal seek function in the simulator it was calculated that the breakeven point in terms of clients was the following:

	Balance Sales		Total Sales	
	Profile A	Profile B	Profile A	Profile B
Number of clients	4,565	3,751	3,084	3,084

NPV, IRR and Pay-back period

These set of results are the most critical considering the financial performance of the company, and the results computed by the financial model taking in consideration the standard scenario were:

NPV	€ 70,057
IRR	19%
Pay-back	5 years and 39 days

Sensitivity Analysis

A set of sensitivity analysis were performed in order to better understand how the parameters affect one of the projects acceptance criteria (NPV).

Discount rate – Figure 4 shows the evolution of NPV caused by the variation of the discount rate. We can observe that NPV is always positive for the selected interval. From this we can conclude that the discount rate is very solid, and it presents strong resistance to upper variations of the average scenario discount rate. Regarding this parameter it is considered that the results validate the project acceptance.

Figure 4 – Sensitivity analysis on discount rate

PRR – The results obtained for the variation of personnel remuneration rate are as shown in figure 5. Incremental steps of 2% were chosen.

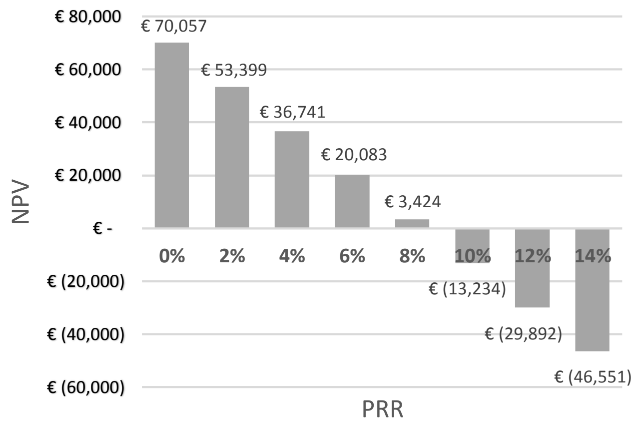

Figure 5 – Sensitivity analysis on personnel remuneration rate

As it is possible to observe, from 10% the NPV is negative. Using the goal seek function in the financial model it was computed the value for which NPV is 0, which is **8,41%**, and its considered as the maximum ceiling allowed for the PRR in order to accept the project.

Number of clients – Figure 6 shows the results obtained for the sensitivity analysis on the number of clients. Every value presented in this figure represents the variation of the number of clients of a profile having the same parameter fixed for the other profile at 2100 clients.

For both profiles, values under 1900 clients implicate a negative NPV. This minimum value is extremely high and it represents it strongly affects in a negative way the valuation of the business model.

Comparing both profiles against each other, we can observe that Profile B is dominant, both in terms of loss and gaining of clients. Meaning that in negative variation it is more detrimental for NPV and in positive variation is more rewarding for NPV.

Figure 6 – Sensitivity analysis on number of clients

Business growth rate – Figure 7 shows the sensitivity analysis on business growth rate. The values calculates are consistent with the ones obtained in the previous point considering that there is a dependency relation between the two parameters.

Looking at the absolute value obtained for the minimum growth that does bring the NPV to negative values, around 2%, it is considered an acceptable value under normal circumstances. However, putting in perspective with the initial set of parameters, it is considered very demanding in terms of needed client. Therefore, regarding the acceptance of the project, it is considered that this result affects it in a moderate negative way.

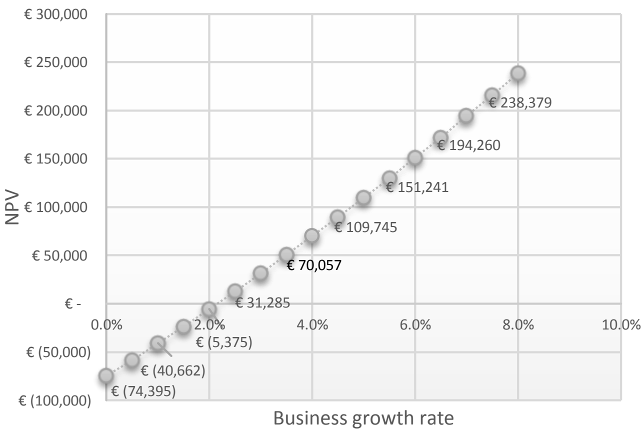

Figure 7 – Sensitivity analysis on business growth rate

Safety margin – Figure 8 shows the sensitivity analysis on safety margin. NPV value is only negative for value around 10%. Considering the risk of electric energy non-delivery due to bad weather conditions or unforeseen consumption variations, the minimum value of 10% is deemed very demanding although acceptable in order model the uncertainty associated with non-delivery risks.

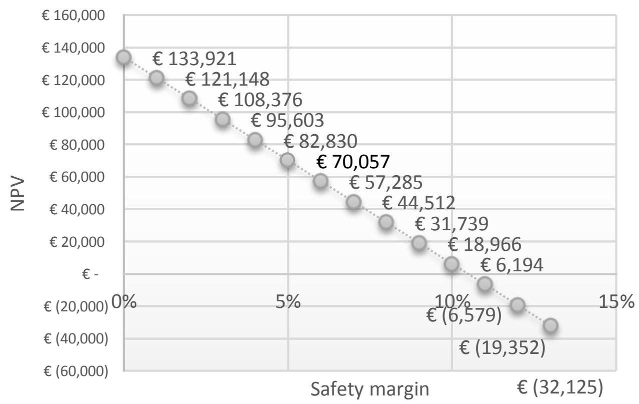

Figure 8 – Sensitivity analysis on safety margin

Sales commission – Figure 9 shows the sensitivity analysis on sales commission. In the absence of a comparison term with similar companies, the values obtained in this variation are deemed positive for the acceptance of the business model, observing that the minimum value is set around 12,5% of sales commission in order to obtain a positive NPV.

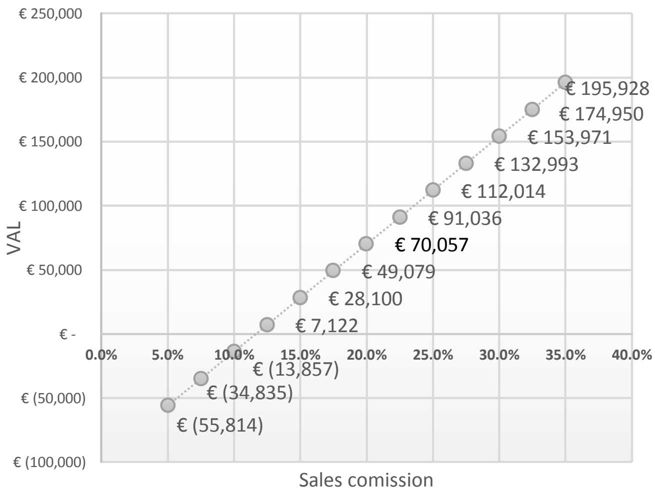

Figure 9 – Sensitivity analysis on sales commission

VIII. CONCLUSIONS

The main goal of this study was to assess the financial and economic feasibility of a company operating in the daily market of the Iberian electricity market acting as a wholesaler, bridging micro-producers and the electricity market.

This business model assumes that feed-in tariffs are not in play due to the fact that their established price is way above the average price for the daily market, thus making it impossible to compete. Hence, this a study with a future horizon and scope.

Regarding the social and political environment it is considered that the ideal conditions are set for the development of the business model. At European Union level, there is an enormous pressure towards the development of RES-E projects due to the commitments made in order to address environmental concerns. Focusing in Portugal, it is observed a favorable environment regarding the objectives set at government level.

Looking at the acceptance by potential clients, it is considered that there is a collective awareness and openness towards investment in RES-E. The validation of this notion is out of the scope of this study but it is acknowledged as a point of interest regarding future studies.

On a technological level, the future environment will become more competitive taking into consideration the development of electric vehicles capable of storing electric production, which constitutes a substitute product to the business model in study.

At the present time, the electricity produced from photovoltaic systems is considered a non-dispatchable source of energy. Therefore the electricity markets appear as an easy expedition source.

Technological development can also work in favor of the business model, considering the fact that the distribution grid is always being upgrades and that the photovoltaic systems have been consistently improving in terms of efficiency.

The concept chosen for the business model consist in negotiating the net balance of the production vs. consumption relationship of a costumer household. The option of working with balances has upsides and downsides. On one hand, the company is exposed to client variability consumption habits and on other hand it makes the product more marketable, given it is easier to convince a client to provide an energetic balance in comparison with the total production of his photovoltaic system.

The data used to model the individual consumption of both profiles was based on two differently characterized households which aim to represent the average consumption trend of national consumers. However, it would be interesting to introduce a level of variability in this data or even to use a bigger database in order to generate some uncertainty.

Also, on a market price level, there is a mutual issue to what was discussed in the previous paragraph. The evolution of market prices was associated with a constant market growth rate and therefore it does not accurately describes the volatile nature of an electricity market.

In developing this study it was necessary to incorporate a set of assumptions. Amongst the most important is the fact that all energy is presumed sold, failing to account for the situations in which defaulting the delivery is a possibility, such occasions as weather conditions or unpredictable consumption peeks. The introduction of the safety margin parameter appears as a compensation for the exposed limitation.

The financial model acts as a data generator provider and it needs the sales input provided by the simulator. The construction of the model follow standard rules concerning project evaluation and aims at acting as a support tool for the hypothesis analysis.

From the simulator, financial model and sensitivity analysis set of results the most important ones are going to be discussed.

70.057€ was the value obtained for the NPV from the setting of an average scenario. Looking at this value from a macroscopic point of view it is considered that the value validates the feasibility of the business model. Also, the IRR, which value was 19% indicates the same conclusion as to accept the project.

The breakeven point, located at 5 years and 39 days, presents some issues regarding business attractivity. The same situation occurs with value calculated for the critical point of sales in terms of clients (4.565 for profile A and 3.751 for profile B).

Looking at the results obtained from the sensitivity analysis, it is observed that the test associated with the depreciation rate and sales commission, confirms the validation of the project. While the other parameters sensitivity analysis, raise some issues related with the elevated need of clients and with the personnel structure deemed very sensible to variations.

IX. References

Brealey, R. A., & Myers, S. C. (1998). *Princípios de Finanças Empresariais* (5ª Edição ed.). McGraw-Hill.

ERSE. (2013). *Relatório anual para a Comissão Europeia.*

European Technology Platform SmartGrids. (10 de 10 de 2013). *FAQ*. Obtido de Smart Grids: http://www.smartgrids.eu/FAQ

Gharavi, H., & Ghafurian, R. (Junho de 2011). Smart Grid: The Electric Energy System of the Future. *Proceedings of the IEEE*, 918.

IAPMEI. (s.d.). *Guias práticos de suporte à gestão - Modelo de Plano de Negócios.* Obtido em 12 de 06 de 2013, de IAPMEI: http://www.iapmei.pt/resources/download/Finicia_pn_v12_062012.xls

OMIP. (25 de 08 de 2013). *Downloads*. Obtido de http://www.omip.pt/Downloads/tabid/104/language/en-GB/Default.aspx

Peik-Herfeh, M., Seifi, H., & Sheikh-El-Eslami, M. (2012). Decision making of a virtual power plant under uncertainties for bidding. *Electrical Power and Energy Systems*.

Pudjianto, D., Ramsay, C., & Strbac, G. (2007). Virtual Power Plant and system integration of DER. *IET Renewable Power Generation*.

Soares, J. O., Fernandes, A. V., Março, A. A., & Marques, J. P. (2007). *Avaliação de Projectos de Investimento na Óptica Empresarial* (2ª ed.). Edições Sílabo.