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Abstract. After liberalization of the electric sector and due to the expansion of distributed generation with the appearing of new kinds of producers and consumers, a new power player emerged taking an major role in the commercialization of electricity - the commercial agent or aggregator. The aggregator thus enables small and medium clients to access to market prices that were impossible to obtain by themselves, since scale is an important factor in the electric energy market. This paper is focused on analyzing how the variation of prices in the energy market affects the aggregator's customer portfolio energy sold and its total profits. The weekly market prices considered showed different levels of volatility. The effect of market price variation, both in terms of average value and variance, was analysed for a typical clients' portfolio in terms of profitability and risk. As it was expected the highest levels of profitability were attained in the weeks of lowest average prices that also correspond to the highest price volatilities increasing also the risk of the aggregator.

Keywords: Aggregation, Portfolio optimization, Load diagrams, Energy prices, Risk and profitability

1   Introduction

The electricity system is facing new challenges with respect to its development and future shape [1]. These challenges are the result of the growing emergence of an increasingly large number of small and average energy producers, they are already today a very reasonable size group for which it is necessary to develop new forms of participation and integration into the power grid and consequently the energy market, to achieve these goals it is necessary to develop new inclusion strategies [2].

This new type of electricity producers based on renewable sources has different characteristics from those traditionally found in the electric power system, such as, for

example, the intermittency of production and, sometimes reduced volume due to these constraints, so an association that aggregates and represents them will bring benefits to both [3].

1.1   Purpose of the Paper

Nowadays after the liberalization of the electric sector and due to the expansion of distributed generation with the appearing of new kinds of producers and consumers, a new entity emerged ''aggregator''.

In order to develop this study one simulator specially built for this purpose was used: the "Commercial Agents in the Electricity Market (CAEM)" and the optimization module (PA). This simulator will analyze each aggregator costumer's portfolio, showing both risks and profitability associated [2].

The Pareto frontier establishes the relationship between profitability and risk expected relating to a diversified portfolio of assets, in which each asset has a nominal weight. Graphically draws a curve of optimum places on risk profitability plan. The best portfolios are located on the Pareto curve, i.e. those that offer either the highest rentability for a given risk level or the lowest risk for a given rentability

The Pareto frontier allows the aggregator to characterize the optimal directions in the profitability/risk plan that it should follow when introducing new customers in the portfolio according to its risk aversion [4].

1.2   Outline of the Paper

This study is divided into six sections, in the first section an introduction to the development of power systems is done stressing the importance of the inclusion of small consumers and producers in the Electricity Market. The second section presents the aggregation phenomenon contribution to the electrical market for the "cyber-physical systems. In the third section the study of investment portfolios and how to aggregate to the electric market is done, particularly in regard to the grouping of different types of energy assets and the advantages of grouping. The fourth section illustrates the adaptation of the economic theory of Harry Markowitz to portfolios of the electricity market, all the necessary equations for the preparation of simulations are presented and in the fifth section, the simulations are performed. The variation in profitability and risk of a portfolio of electricity market assets, given the different electricity price profiles observed in the electricity market is studied. The work ends with the conclusions over the results of prepared simulations.

2   Contribution to Cyber-Physical Systems

Nowadays it is not possible for small producers and consumers to reach the global market, therefore it should exist an entity that interacts and establishes the needed contracts. This entity, called Aggregator, will settle a contract with producers and consumers allowing them to establish connections in the global market [5]. Ultimately

this will lead to the creation of a Network since there's real interaction between producers/consumers and aggregators, the outcome gives them access to the global market (Fig.1).

There are some methods that helps the aggregator obtain a better efficiency such as smart grids. Smarts grids have the ability to enable an active participation in Demand Dispatch (DD), which ultimately represents more penetration in Distributed Energy Resources (DER), new storage capacity, assets optimization and new and better market opportunities [1]. A smart grid combined with smart meters is a synonym of knowledge and allows the aggregator to have real time feed-back regarding consumption levels.

There are two words in this theme, related to our Cyber-Physical System that must be emphasized; these words are accuracy and efficiency. Accuracy is directly related with smart meters, allowing a better control and supervision of energy consumption. This enables the aggregator to be more precise in contracts decisions with consumers and producers. With this in mind, there will be a better efficiency in energy and contractual terms optimizing the relation between producers and consumers allowing them to reduce energy consumption on full peak hours and increase it in the valley periods.
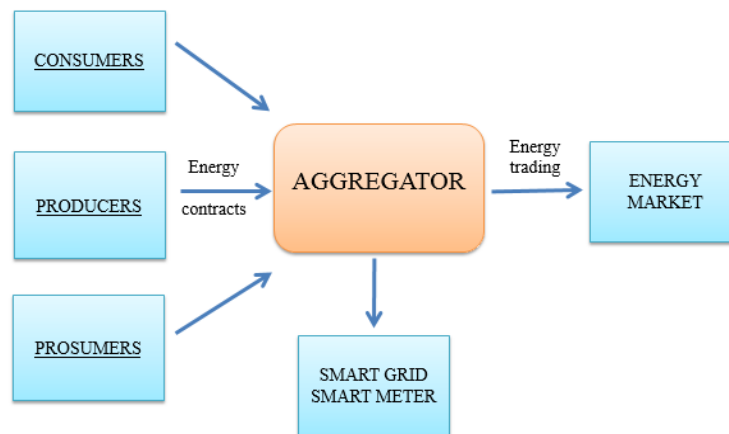

Fig. 1. Cyber-Physical System Aggregator Network.

3 Related Literature

3.1 Economic theory overview

The Portfolio Theory has its origins on the scientific article ''Portfolio Selection of Nobel Economy'' by Harry Markowitz. In this article he addresses the choice of

financial assets portfolios of uncertain future value by following completely new criteria at the time: the expected return criteria variance [6].

Harry Markowitz sensed that different investor's choices and diversification (Fig.2) were based on two distinct issues: the trade-off between risk and rentability of investments and the correlation between the returns of different assets [6].

The risk suggested was measured by Harry Markowitz as dispersion return. Thus, Harry Markowitz provided an analytical foundation for the portfolios diversification on financial markets and established the optimal and most rational composition methodology for assets portfolios whose future value is uncertain [7] [8].
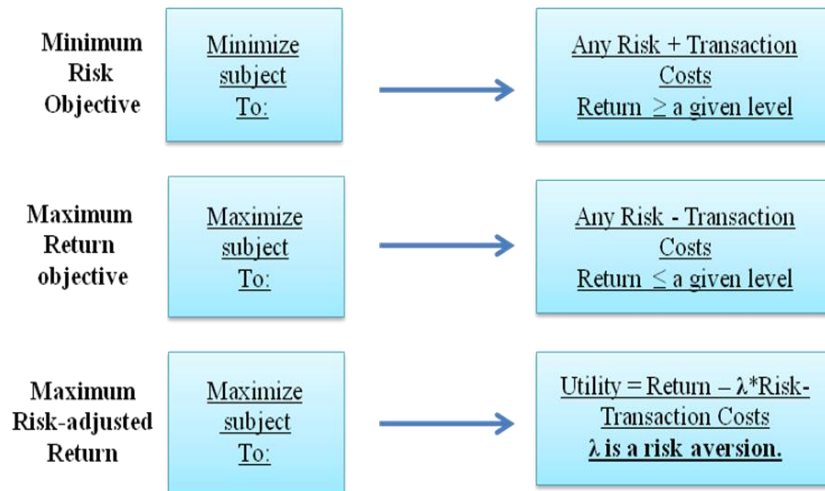

Fig.2. Harry Markowitz, portfolio theory cases.

3.2   Aggregators

The aggregator is an entity that eases the access of its customers to the electricity market, establishes the electricity purchase or sale to its customers, with great versatility in the kind of contractual clauses offered [9].

Based on knowledge of the load diagram of their clients through the use of smart-meters, the aggregating agent may establish a pricing policy contracted with their customers, promoting the relocation of some consumption from the peak hours to the valley hours or other more favorable to the system operator's point of view [9] [10].

This kind of aggregating agent is intended to combine the economic interests of a large and diverse number of small and medium customers in terms of volume of traded energy, thus providing critical mass to enable them to trade on the energy market [11].

4   Methodology

The economic behavior analysis, considering the risk and profitability of the customers aggregator portfolio from the electricity company, is based on the market traded energy, as well as the client's loads forecast, and was conducted with the help of the tool developed in MATLAB (Fig.3):
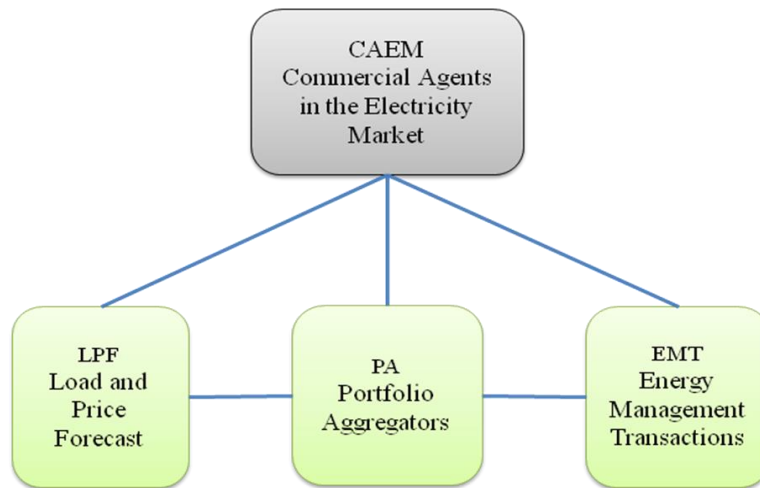

Fig.3. Simulator CAEM and the computation modules.

It shows the main inputs and outputs and how the simulators integration is to be used in the case studies, for a client's portfolio, with several consumers, producers and "prosumers", with aggregator contract for the supply and energy purchase. The first main inputs are the historical data series of the customers.

Also the contracted prices for sale and/or energy purchase predefined in the contract terms are indispensable: all this information available (input) allows, with appropriate treatment, the simulators to obtain the desirable output [2], [4].

The profitability and risk of the portfolio for one entire week, 168 periods (hours), are computed, according to equation 1, and for its calculation a set of different scenarios of energy and prices are considered.

$$E(R_P) = \sum_{i=1}^{n} E(R_i) \times w_i \tag{1}$$

Where *E(Rp)* profitability of portfolio *P*, *E(Ri)* profitability of client *i*, in the set of scenarios, and w_i the weight of client in portfolio *P*, n is the number of clients in portfolio *P*, finally, *i* is the type of clients in portfolio.

$$\sigma_P = \sqrt{\sigma_P^2} \tag{2}$$

Where σ_P is the risk the portfolio *P*.

$$\sigma_P^2 = \sum_{i=1}^{n} w_i^2 \ \sigma_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} w_i \ w_j \ \sigma_{i,j} \tag{3}$$

Where σ_P^2 is the variance of the portfolio P, σ_i^2 is the variance of client i, w_i and w_j are the weights of the clients in the portfolio and $\sigma_{i,j}$ the covariance between the clients i and j, and n the total number of different type of clients. The Pareto curve of the portfolio is computed according to the equations 4 and 5.

$$\min \quad \sigma_P^2 = \sum_{i=1}^{n} w_i^2 \ \sigma_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} w_i \ w_j \ \sigma_{i,j}$$

$$s.a \quad \sum_{i=1}^{n} E(R_i) \ w_i \ \geq E(R_c)$$

$$\sum_{i=1}^{n} w_i \ = 1 \tag{4}$$

$$0 \leq \ w_i \ \leq 1 \qquad i = 1, 2, 3, \ldots., n$$

$$\max \quad E(Rp) = \sum_{i=1}^{n} E(R_i) \ w_i$$

$$s.a \quad \sum_{i=1}^{n} w_i^2 \ \sigma_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} w_i \ w_j \ \sigma_{i,j} \ \leq \sigma_v^2$$

$$\sum_{i=1}^{n} w_i \ = 1 \tag{5}$$

$$0 \leq \ w_i \ \leq 1 \qquad i = 1, 2, 3, \ldots., n$$

5   Case Study

The simulations and results performed in this study were based on a clients group, composed by consumers, producers and "prosumers" as shown on Table 1. The time horizon of this study requires one specific week of energy consumption/production levels, and applying to compute the profit and risk of the portfolio, twenty weeks of different energy market prices, between 10/03/2014 until 21/07/2014.

In Fig.4, the profiles of clients B, L, O and Q, are shown, all the profiles are presented in a 168 hours time period.

For the computation of rentability and risk variation of the portfolio composition, several weeks of energy market prices are considered, four of them are displayed in Fig. 4.

The simulations are done on the same portfolio composition considering to all of them, the same consumption profiles and production levels. The results up to four weeks simulations are showed on Table 2.

Computation of profitability and risk are made with the PA simulator, Fig. 5, presents an example of the simulation, and the results for the week 10/03/2014 (P1).

Table 1. Customers' portfolio characterization

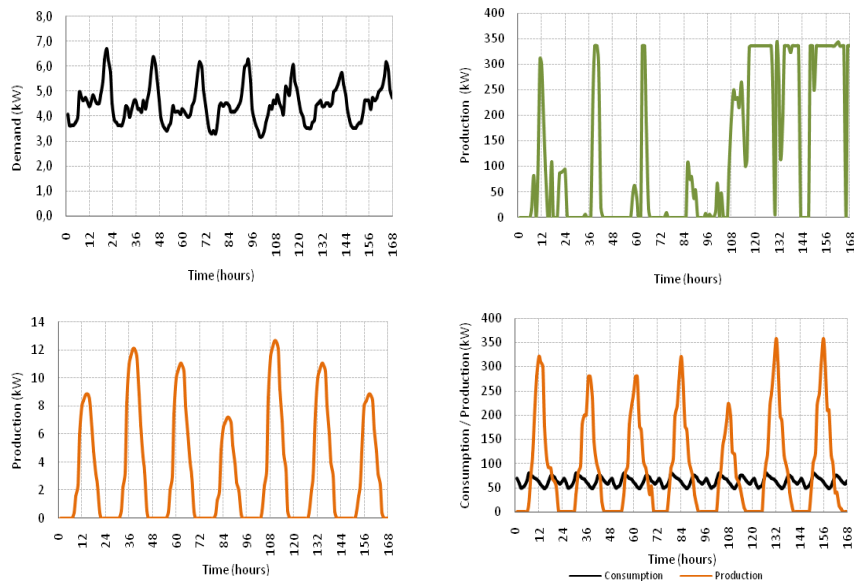| Type Profile	Nature	Type Source	Power (kVA)	Nº	Energy (kVA/week)	Weight (%)	Risk, P1 (σ_i)
A	Consumer	--------	3,45	6000	203	9,24	0,84
B	Consumer	--------	6,90	4000	755	22,93	0,88
C	Consumer	--------	13,80	2500	1234	23,45	0,93
L	Producer	Wind	350,0	200	20665	31,4	8,19
M	Producer	Photovoltaic	4,00	600	195	0,89	7,26
O	Producer	Photovoltaic	12,00	600	569	2,59	6,43
Q	Prosumer	Photovoltaic	90/350	40	25683	7,81	4,84
R	Prosumer	Cogeneration	130/160	10	22234	1,69	1,02

Fig.3. Load profiles: a) B - Residential consumer; b) L - Wind producer; c) O - Photovoltaic producer; d) Q - Consumer and Photovoltaic producer, prosumer.

Figure 6 shows the values of R_P, σ_P of the portfolio, P, with the considered composition, according to Table 1, along with the set of price market scenarios in the study, with specific reference of some chosen weeks. Finally on Table 2 the results of the simulations for the week prices mentioned on Fig.4.
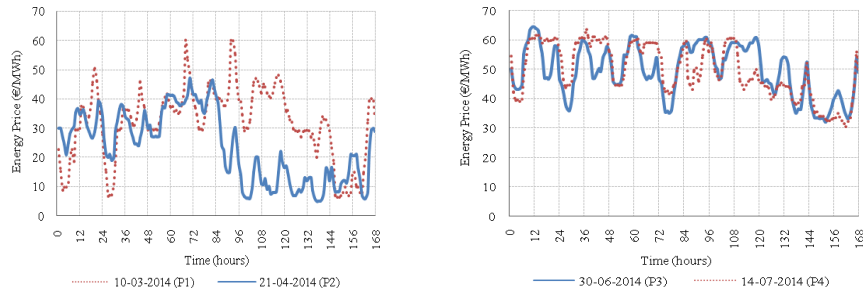
Fig.4. Energy market load profiles: a) Weeks 10/03/2014 (P1) and 21/04/2014 (P2); b) Weeks 30/06/2014 (P3) and 14/07/2014 (P4).
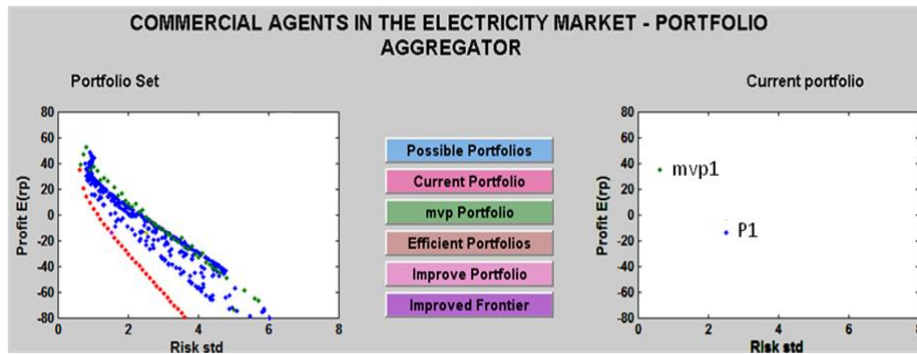

Fig.5. Efficient frontier design, location of the R_P, σ_P to the current portfolio and minimum variance point. Results of PA simulator using energy week market prices 10/03/2014 (P1).

6 Conclusions

The profitability and risk computation of a portfolio aggregator under a certain composition was possible by using the developed simulator. In this case study, a composition portfolio with a significant percentage of energy producers with higher risk, namely the wind and photovoltaic, promotes a higher risk level on the portfolio. The simulation results show the high dependence of the energy price vector, such is noticeable through the analysis of his standard deviation.

The combination of the high risk level of some customers portfolio with the price vector, leads to high risk values in the portfolio. It is also possible to verify that the profitability of the portfolio depends on the energy price contracts established between aggregator and customers, but another decisive influence is the average value of the energy market price vector.

Table 2. Profitability and risk for portfolio, *P*, considering different energy price market

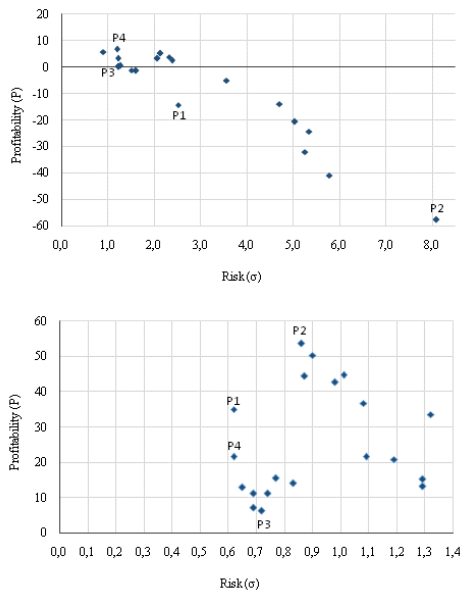| Week	13-01-2014 (P1)	10-02-2014 (P2)	21-04-2014 (P3)	12-05-2014 (P4)
Profitability	-14,22	-57,63	0,38	6,7
Risk (σ_P)	2,52	8,09	1,22	1,2
E. price	31,9	23,7	49,5	49,6
E. price (Std)	12,3	12,0	8,7	9,1

Fig.6. Evaluation of profitability, R_P and risk, σ_P: a) Portfolio P; b) Minimum variance point, mvp.

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