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Demand response approaches for real-time renewable energy integration
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Economic Survey on a Community of Prosumers and Distributed Generations

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Abstract

The use of demand response programs and distributed renewable energy resources play an important role in nowadays electricity markets. Most of the demand response programs are performed for large-scale resources. This is a barrier for the small and medium scale consumers, producers, and prosumers in order to participate in the electricity market negotiations. To overcome this barrier, a third-party entity, such as community or an aggregator, should play a role an intermediate player between the end-users and network operators. However, before the implementation of the business models, they should be well surveyed in term of economic and financial profits in order to prevent future problems. This paper proposes an economic survey on a community of the consumers and distributed generations, considering different pricing schemes. The community consists of residential, commercial, and industrial consumers as well as photovoltaic and wind turbines. In this survey, the annual costs of this community are investigated considering the current pricing schemes in two countries of Portugal and Germany.

Keywords: aggregator, community, demand response, distributed generation

1. Introduction

The appearance of Demand Response (DR) programs in nowadays power system, create an opportunity for the research society to focus on this topic. DR programs can be defined as altering the consumption profiles of the end-users in order to react to the price variations due to the economic or technical issues [1]. Two main categories are considered for DR programs, which electricity customers can participate in the programs considered on those categories [2]: price-based and incentive based. In fact, DR programs bring flexibility to the electricity markets by controlling the consumption patterns [3].

Furthermore, the use of Distributed Renewable Energy Resources (DRERs), especially wind turbines and Photovoltaic (PV), enables power distribution network to reduce the congestion of network on the peak hours as well as full benefits from them while participating in the market negotiations [4].

The main issue in these new concepts is the minimum capacity rate that the resources should contain, in order to be able to participate in the market negotiations. Based on [5]–[7], the minimum reduction capacity of DR resources is 100 kW in different electricity markets. Therefore, the small and medium resources would not be capable to individually participate in those markets [8]. For solving such problems, a third-party entity, such as a community or an aggregator should be placed between the demand side and the grid side in order to aggregate the small and medium scale resources and participate them as one resource in the electricity market [9][10]. However, all the models and scenarios should be well investigated in term of economic and financial profits in order to prevent the future problem.

This paper presents an economic survey on a community of consumers, producers, and prosumers by considering different electricity pricing rates. The consumers participated in this community consist of residential buildings, commercial centers, and industrial units. Also, the DRERs of the community include PV pilots in two scale of small and large, PV arrays in the residential buildings considered as prosumers, and several wind turbines. The consumption and generation profiles utilized in this paper are real data provided by a smart metering company in Germany (www.discovergy.com). Several pricing schemes would be applied to this community in order to survey the annual costs considering DRERs.

After this first introductory section, the community model will be presented in Section 2. Section 3 will present the economic survey of the community and the annual costs will be provided. Finally, Section 4 will present the main conclusions of this work.

2. Community Model

A local community grid is related to a group of consumers, producers, and prosumers that some of them may have a contract with a central controller unit called Community Manager (CM), in order to be controlled and organized by this unit. The differences between a community and an aggregator are that a community has a smaller number of grid players, however, an aggregator has a significant number of players. Also, the community is interest based, however, the aggregator is profit based.

Fig. 1 illustrates an overall view of the proposed community grid. In this model, there are 100 consumers and 100 producers. The consumers of the community consist of 79 residential houses, 16 commercial shops, 3 commercial centers, and 2 industrial units. The producers include 22 small-scale PV pilots, 13 large-scale PV pilots, 18 wind turbines, and 47 PV arrays in residential houses considered as 47 prosumers. These classifications are performed based on the average daily consumption/generation rates of the resources.

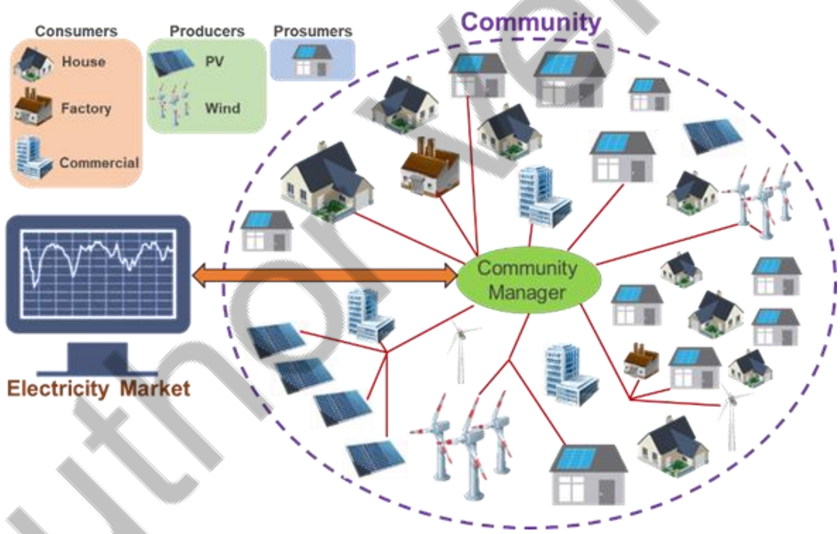

Fig. 36: Overall perspective of the community model.

In this network, the CM is not owning any resources of the grid and it is responsible to balance the rate of consumption and generation in the community members, by providing some strategic plans, namely DR programs or resource scheduling, to the players. The main interest of CM is firstly to feed the demand of the players by its local energy resources available in the community as well as the surplus of production of the prosumers. By this way, the CM would be able to stop purchasing energy from an external supplier. Also, if the generation rate of the community is less than the electricity consumption, it is affordable for the CM to pay incentives to its members to reduce their consumption instead of buying energy from the market. For this purpose, the CM is able to perform DR programs in order to be applied by the consumers and prosumers.

Fig. 2 shows the total consumption and generation profiles considered for the community network. The data shown on Fig. 2 are the real consumption and generation data for an entire year with three minutes time interval, which have been adapted from the smart metering company in Germany (Discovergy GmbH).

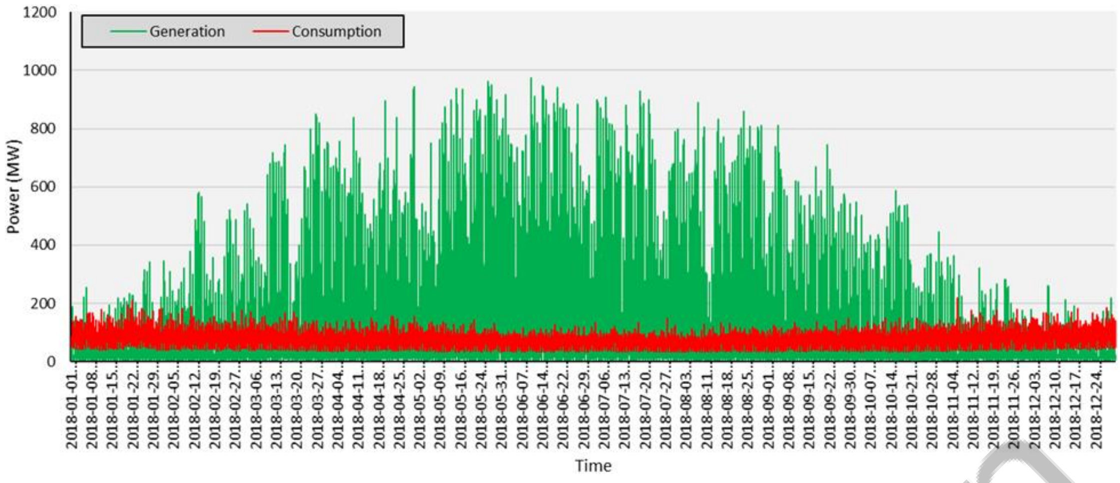

Fig. 2: Total consumption and generation profiles considered for the community.

As can be seen in Fig. 2, the generation rate in summer is much higher than in the winter, which is due to the high generation rate of PV pilots. Since the rate of consumption is almost equal during the year, the CM not only is able to supply the community demand via the local resources but also, it can export energy to the external supplier during the summer. Detailed consumption profiles of the community are shown by Fig. 3, which are related to residential houses, commercial shops. Commercial centers, and industrial units.

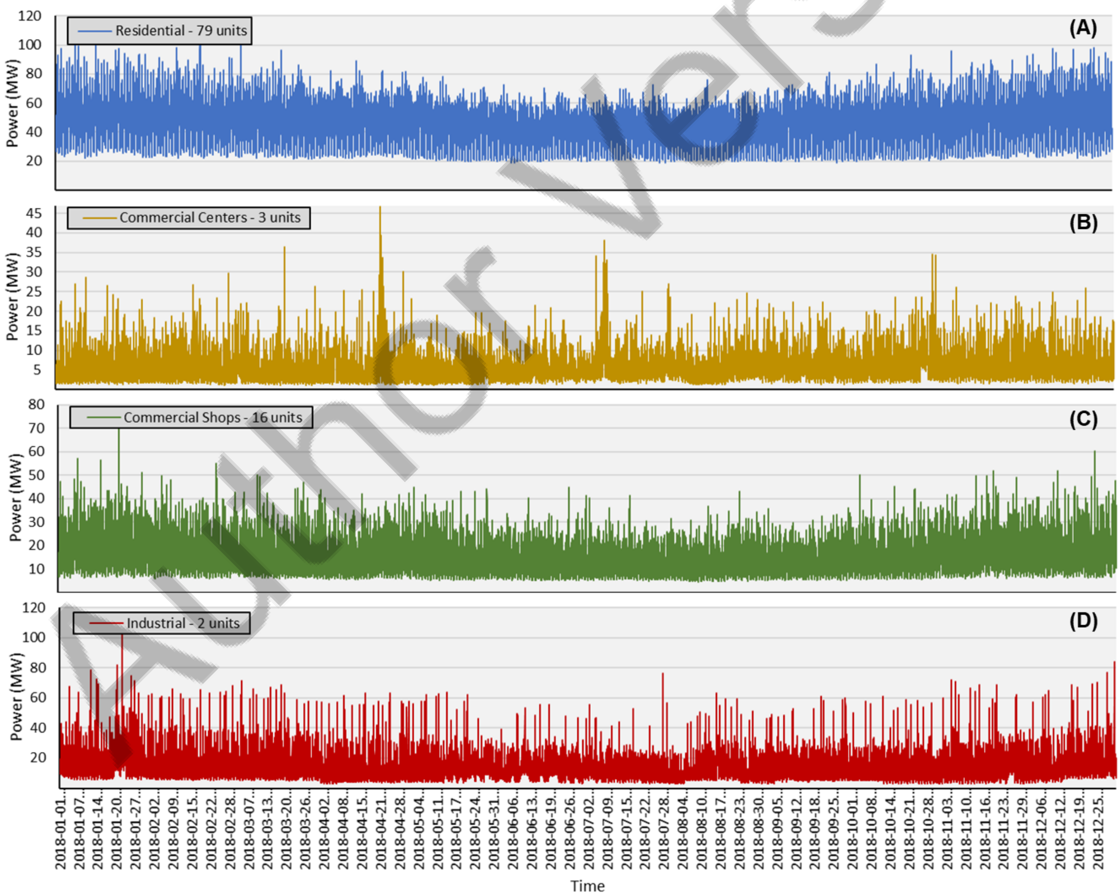

Fig. 3: Consumption profile of the community players: (A) 79 residential houses, (B) 3 commercial centers, (C) 16 commercial shops, (D) 2 industrial units.

As it is clear in Fig. 3, the consumption profile of residential houses is a bit lower in summer comparing to the winter. This is due to the geographical areas and weather conditions. Also, in the same figure, the profile of commercial buildings in the working hours is higher than the nights. These points would be useful for the CM in order to perform DR programs or loads scheduling. The profiles shown in Fig. 2 and 3, will be used in the next section in order to compare and analyze the annual costs of the community.

3. Economic Analysis

In this section, it is considered that the community is in two countries in Europe: Portugal and Germany. Therefore, the electricity prices and regulation of these two countries would be applied in the community and the results will be compared.

The first analysis is given to the annual costs of the community with the Portuguese electricity prices. Therefore, the electricity price for consumption has been adapted from [11], which is 0.15 EUR/kWh. Also, the price of electricity generation has been adapted from [12], which stands as 0.09 EUR/kWh. Fig. 4 shows the calculated annual costs for Portugal.

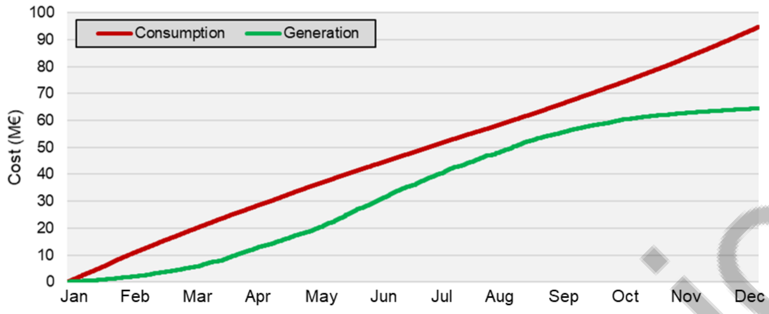

Fig. 4: Accumulated costs of the community for one year with Portuguese prices.

Furthermore, Table 1 demonstrates the detailed accumulated consumption costs for the different sectors of the community while it operates with Portuguese prices.

Table 12: Accumulated consumption costs of community with Portuguese electricity prices.

	Consumers				**Producers**
	Residential Houses	**Commercial Centres**	**Commercial Shops**	**Industrial Units**	**PV and wind turbines**
Cost (M€)	54.6	24.2	9.6	5.4	64.5
	Total: 93.8				**Total: 64.5**

Regarding the community costs with Germany electricity prices, Fig. 5 and Table 2 demonstrate the economic analysis. In those results, the electricity price for consumption has been adapted from [13], which stands for 0.25 EUR/kWh, and the generation costs adapted from [14] stands for 0.09 EUR/kWh.

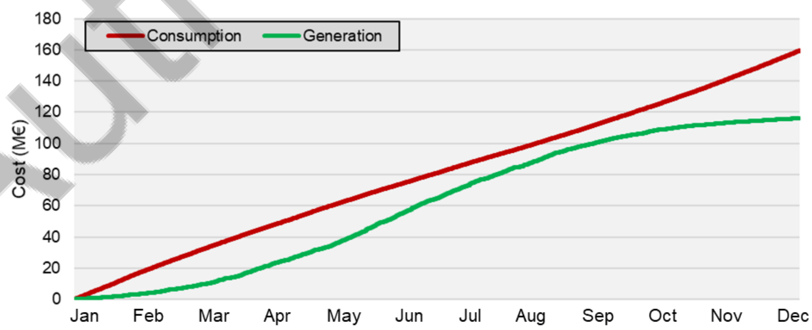

Fig. 5: Accumulated costs of the community for one year with prices in Germany.

Table 2: Accumulated consumption costs of community with German electricity prices.

	Consumers				**Producers**
	Residential Houses	**Commercial Centres**	**Commercial Shops**	**Industrial Units**	**PV and wind turbines**
Cost (M€)	97.7	10.1	28.1	23.5	116.1
	Total: 159.4				**Total: 116.1**

4. Conclusions

This paper provides a community model of the consumers and producers considering several players. The community players consist of residential houses, commercial buildings, and industrial units. Moreover, an economic survey on the annual costs of the community was performed. The consumption and generation data were the real data adapted from a smart metering company in Germany.

The results of the paper illustrate a comparison between the consumption and generation costs for an entire year while the pricing schemes of the two countries in Europe are applied. These kinds of analysis are very useful for network operators and community managers in order to identify the best and optimal situations for performing demand response programs and loads scheduling.

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References

[1] A. Srivastava, S. Van Passel, and E. Laes, “Assessing the success of electricity demand response programs: A meta-analysis,” Energy Res. Soc. Sci., vol. 40, pp. 110–117, Jun. 2018.

[2] J. Wang, H. Zhong, Z. Ma, Q. Xia, and C. Kang, “Review and prospect of integrated demand response in the multi-energy system,” Appl. Energy, vol. 202, pp. 772–782, Sep. 2017.

[3] X. Zhang, G. Hug, J. Z. Kolter, and I. Harjunkoski, “Demand Response of Ancillary Service From Industrial Loads Coordinated With Energy Storage,” IEEE Trans. Power Syst., vol. 33, no. 1, pp. 951–961, Jan. 2018.

[4] O. Abrishambaf, P. Faria, L. Gomes, J. Spínola, Z. Vale, and J. Corchado, “Implementation of a Real-Time Microgrid Simulation Platform Based on Centralized and Distributed Management,” Energies, vol. 10, no. 6, p. 806, Jun. 2017.

[5] S. Bakr and S. Cranefield, “Using the Shapley Value for Fair Consumer Compensation in Energy Demand Response Programs: Comparing Algorithms,” in 2015 IEEE International Conference on Data Science and Data Intensive Systems, 2015, pp. 440–447.

[6] K. Khezeli, W. Lin, and E. Bitar, “Learning to Buy (and Sell) Demand Response * *This work was supported in part by NSF grant ECCS-1351621, NSF grant CNS-1239178, NSF grant IIP- 1632124, US DoE under the CERTS initiative, and the Simons Institute for the Theory of Computing.,” IFAC-PapersOnLine, vol. 50, no. 1, pp. 6761–6767, Jul. 2017.

[7] N. G. Paterakis, O. Erdinç, and J. P. S. Catalão, “An overview of Demand Response: Key-elements and international experience,” Renew. Sustain. Energy Rev., vol. 69, pp. 871–891, Mar. 2017.

[8] L. Gkatzikis, I. Koutsopoulos, and T. Salonidis, “The Role of Aggregators in Smart Grid Demand Response Markets,” IEEE J. Sel. Areas Commun., vol. 31, no. 7, pp. 1247–1257, Jul. 2013.

[9] P. Siano, “Demand response and smart grids—A survey,” Renew. Sustain. Energy Rev., vol. 30, pp. 461–478, Feb. 2014.

[10] S. S. Reddy, “Optimizing energy and demand response programs using multi-objective optimization,” Electr. Eng., vol. 99, no. 1, pp. 397–406, Mar. 2017.

[11] “EDP Tarifarios.” [Online]. Available: https://www.edp.pt/particulares/energia/tarifarios/. [Accessed: 10-Jan-2019].

[12] “Portugal FIT Prices.” [Online]. Available: https://www.pv-magazine.com/2018/01/24/portugal-announces-fit-distributed-solar-generation-fit-of-e95-mwh-for-2018/. [Accessed: 10-Jan-2019].

[13] “heidelberg STROM basis.” [Online]. Available: https://www.swhd.de/de/Energie-und-Wasser/Strom/heidelberg-STROM-basis-/Preise/. [Accessed: 10-Jan-2019].

[14] “German Feed-in tariff.” [Online]. Available: http://www.res-legal.eu/search-by-country/germany/single/s/res-e/t/promotion/aid/feed-in-tariff-eeg-feed-in-tariff/lastp/135/. [Accessed: 10-Jan-2019].