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Microgrids, a new business model for the energy market

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Abstract. Microgrids and distributed generation technologies are proposed, from diverse sources, as one of the most promising solutions for the current problems of electric systems in developed countries and as a way of improving the situation of developing ones. In this line, through E+ Project, a tool to manage microgrids in urban environments is being developed, as well as the business model needed for its implementation. This document describes the E+ business model, based on two main agents: the prosumer and the APM (Aggregated Prosumers' Manager). The model will suppose a revolution of the current scenario because of the modification of the agents involved and the consideration of the optimization of the distribution grid and the reduction of the final costumer bill as the highest goals. Since the implementation process is not easy due to regulatory barriers, an implementation roadmap is proposed presenting different steps or phases.

Key words

Microgrid, business model, prosumer, regulation, distributed generation,

1. Introduction

Currently, the electric system is organized around generation and consumption points connected with long transport lines. This configuration may suppose certain problems, like: losses in distribution and transport of electricity (usually over 8%, [1]), overloads in some electric lines, a great temporal variability in energy demand, the difficult balance between energy generation and demand and, finally, the problematic and expensive extension of those grids.

One of the most promising solutions to solve these problems associated with the current electric system is the use of microgrids and distributed generation (DG) systems [2]. A microgrid is the electric system composed of a coordinated group of generation and energy storage devices feeding several loads, in such a way that grid connected and islanded operation are possible [3]. The operation is based on the adaptation of these electric generators and energy storage devices integrated in low voltage to cover a certain electric demand according to a certain strategy [4], [5]. The use of these technologies reduces losses in transport and distribution grids and decreases the dependence of consumers on energy from the electric grid. Besides the sale of excess of energy production, the use of microgrids is expected to lead to a market of secondary services [6], as improvements of power quality or grid support services.

2. New business model: E+ concept

The final goal of E+ project is to develop, execute and demonstrate new energy management and operation methods based on ICT (Information and Communication Technologies) and the associated business model, able to increase both electric and thermal energy efficiency at district level and reach zero or even positive neighbourhoods. In relation to the existing ICT based management tools, mainly focused on controlling units such as a house or a building, the new control system (E+ tool) will be able to manage and control energy at neighbourhood level, integrating basic elements (e.g. generation sources, storage devices, street lighting), more complex units (e.g. buildings, malls…) and the whole distribution grid.

A. Current situation

Nowadays, in both thermal and electrical business models, consumers do not have a relevant role, in such a way that they are limited to energy consumption and the interaction and influence in the energy market is almost inexistent. Only large consumers have certain relevance in the electric system, being able to negotiate energy prices and other conditions in the electric supply with commercial aggregators or even the energy market. As a consequence, consumers tend to act as passive agents not taking advantage of possible savings from the current energy market liberalization. Specifically, up to €13

billion could have been saved for EU consumers if they had contracted the cheapest available electricity tariff [7].
The current business model is shown in Fig. 1. The structure is based on a strict separation of activities associated with each agent. The TSO (Transmission System Operator) owns and manages the transport grid. Generators sell energy to the EMO (Energy Market Operator) and ancillary services to the TSO. The DSO (Distribution System Operator) owns and manages the distribution grid and the CA (Commercial Aggregator) is an intermediate agent selling energy to final consumers.

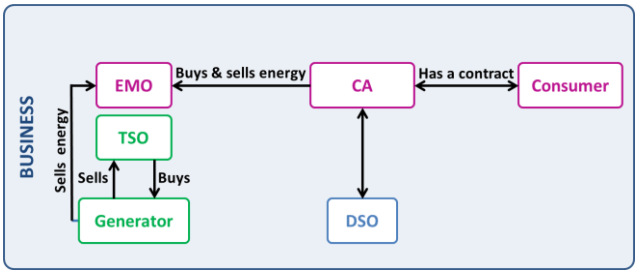

Fig. 1. Current business model

B. New actors: prosumer and APM

Two main new actors are introduced by E+ business model (in addition to those considered currently according to EC Task Force for Smart Grids EG 3) to achieve the optimization objectives of the project: prosumer and APM (Aggregated Prosumer's Manager). The prosumer consumes and generates energy and is able to sell surplus energy. Using storage devices, they can choose the most appropriate moment for consumption or delivery of energy, influencing the electric market. Really, prosumers are natural or legal entities able to establish different contractual relations with APM, DSO or CA. On the other hand, the APM is a natural or legal entity that represents one or several prosumers and manages their installations and electric energy supply to optimize the distribution grid and reduce final energy bills of its customers. The APM can interact with the remaining agents in the electric system and collaborates closely with the DSO to manage and optimize the operation of the distribution grid, offering ancillary services related to grid quality or reactive power compensation.

A new business model has been developed once eight existing models have been analysed, which do not fit with the optimization goals of E+. These models are:

- Commercial.
- Regulated.
- Simple.
- Hybrid.
- Prosumer.
- Island.
- Semi-region.
- Prosumer as a balance responsible party.

C. E+ business model

The E+ business model is represented in Fig. 2 by business and management layers based on the Smart Grid Architecture Model (SGAM) for smart grids, including the new actors mentioned before. Here, the CA disappears since the APM is the intermediary agent between prosumers and the remaining agents. The APM will use E+ tool to optimize the operation of the distribution grid and establish communications with the DSO. The DSO will consider this information to achieve the best operation of the grid in terms of reduction of demand peaks, losses…

Besides, the presence of the APM has another effect: reduction and simplification of certain tasks of the DSO. Since the APM will have a contractual relation with several prosumers, the DSO only has to take information from the meter of the APM, who will share costs between prosumers, as Fig. 3 represents. Another secondary benefit is that the APM will buy large energy volumes at lower prices than one only prosumer. This implies a reduction in final energy bills for prosumers.

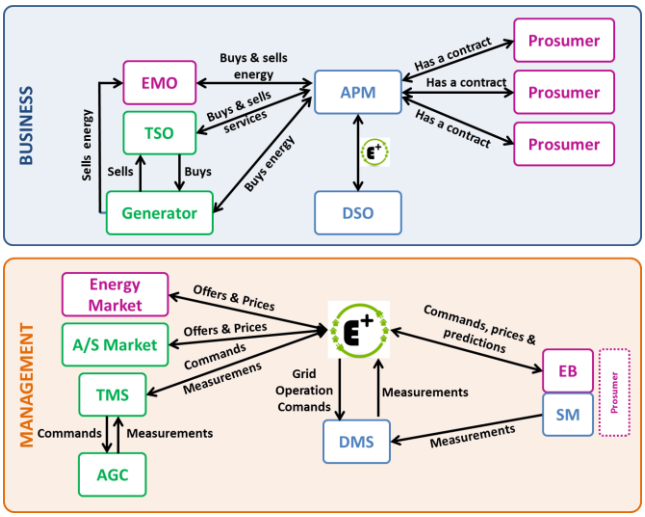

Fig. 2. E+ business model

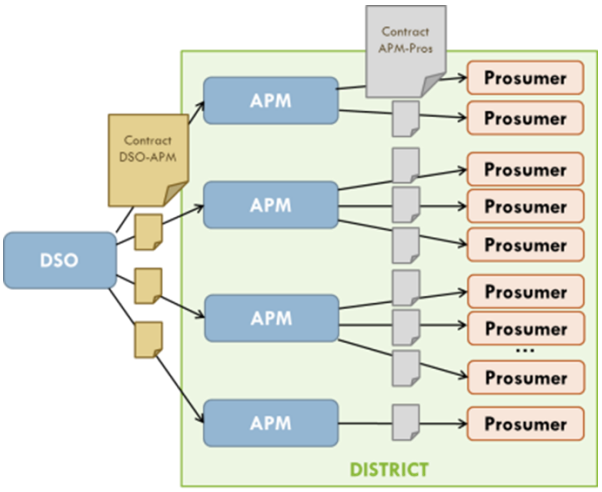

Fig. 3. Contractual relationship between DSO, APM and prosumers

Then, through this contractual relationship, APMs supply energy to one or several prosumers and manage their excess of generation (sending it to other prosumers or selling it to the EMO), in such a way that the prosumer, through the APM, is not only able to sell and buy energy to the market, but also offers ancillary services to grid operators as TSO and DSO.

Fig. 4. shows an extended version of business model already represented in Fig. 3. Here, it is important to consider the fact that a grid managed by one DSO can include several APM. Then, a conflictive situation may appear since the indications of several APM can be contradictory. Then, the DSO in the area will choose the most energy efficient and technically viable solution guaranteeing that all APM have the same rights of access to the grid, in such a way that abusive or monopolistic practices of one or several APM against other ones are avoided.

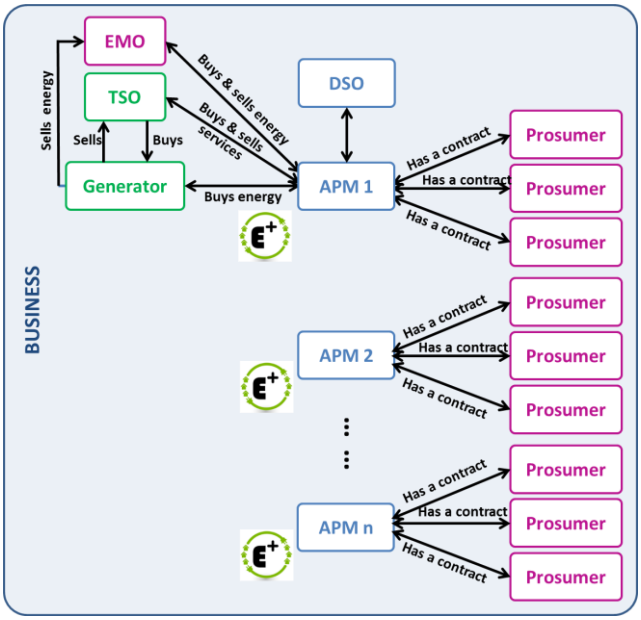

Fig. 4. Relationship between several APM associated with the same grid and DSO

D. New E+ business model for thermal microgrids

The business model presented for electric microgrids can be applied to the thermal situation but, in this case, it is not so developed currently because: there are few thermal microgrids at district level; the concept of transport grid has no sense since thermal systems have a local extension; and there are not regulations imposing the separation between production, distribution and commercialization businesses as in the electric case. This simplicity can be inferred from an analysis of the current thermal business model, represented in Fig. 5.

E+ proposes the simplification of the electric business represented in Fig. 2. Again (see Fig. 6), prosumer and APM are the core of the model and, since a local thermal grid is operated, only a "distribution grid" is implemented, managed by the distributor and the APM with the final goal of energy optimization. In comparison with the current business model, there are several heat producers offering heat at different prices, creating a thermal generation market in competition. Similarly to the electric case, the APM optimizes the operation of the distribution grid (e.g. reducing losses) and minimizes final thermal bills of prosumers, buying thermal energy at the lowest price offered by heat producers or providing recommendations about the use of their own installations (boilers, heat pumps, solar thermal systems…).

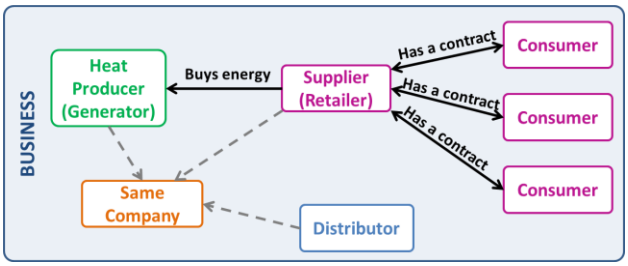

Fig. 5. Current thermal model

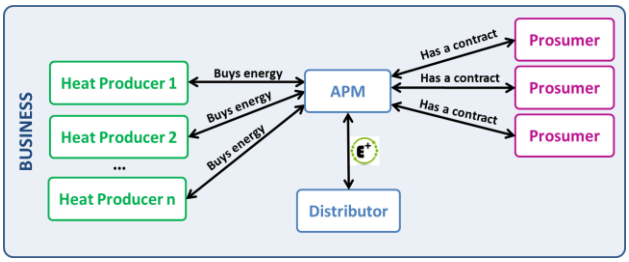

Fig. 6. E+ business model for thermal microgrids

3. Implementation roadmap and limitations

Due to the great quantity of involved agents and the regulations applying to the different electric installations affected, this section shows a logical sequence for the implementation of the definitive E+ business model presented in section 2. Besides, this complexity of the environment related to the E+ business model generates important limitations to be considered, which will be also mentioned in this section. The thermal case is not included in this roadmap, since it is easy to achieve from the current situation and, in several EU member states, there are not specific regulations for that field.

A. Implementation roadmap

1) Phase 1. DSO and CA work together

This initial step proposes a new entity composed of two separate bodies: DSO and CA, for both commercializing energy between final consumers and optimizing the use of the distribution grid avoiding losses, inefficiencies and excesses of generation. Then, commercial and regulated business models are shared, aiming at achieving a more efficient market than the current scheme, reducing energy losses and generating savings in final consumers bills. Fig. 7 represents the business layer in this phase of the roadmap:

The joint operation of DSO and CA implies the following aspects:

- The benefits of the CA, coming from the optimization of grid operation, are shared with the DSO, which generates incentives for continuous improvements towards a better grid operation.
- The energy bill is reduced for final consumers, through achieved economic savings linked to improvements in grid management.
- Optimization of distribution grid operation and information exchange between DSO and CA using the E+ application.

It is important to note that this operation of DSO and CA working together could suppose monopolistic behaviours, so the different CA should have the same possibilities for grid access. The remaining actors operate in the same way as in the current scenario.

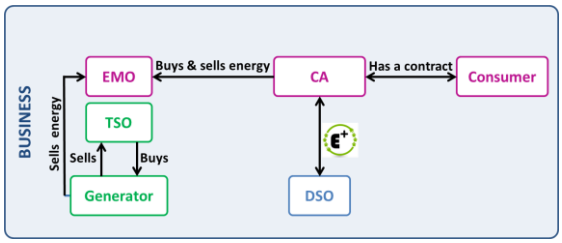

Fig. 7. Business model in phase 1 of roadmap

2) Phase 2. DSO and CA work together with the prosumer

This phase is a fundamental step towards the E+ final goal of energy positive neighbourhoods since the prosumer appears, being a natural or legal person able to consume but also generate energy for self-consumption or deliver surplus energy. Fig. 8 presents the CA as an entity that communicates the prosumer with the remaining agents, since a direct relationship with them (e.g. EMO, TSO) appears as too complex for the most of prosumers.

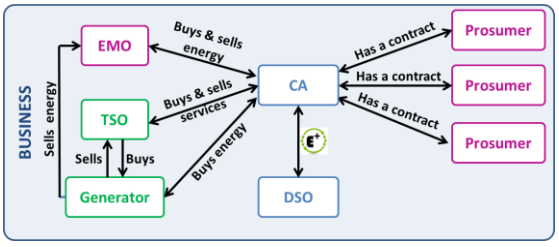

Fig. 8. Business model in phase 2 of roadmap

This phase implies the following facts:

- The consumption of prosumers is already adapted to energy prices and generation patterns to optimize their electric consumption.
- Distributed generation appears as the key to achieve the introduction of prosumers.
- Surplus energy from prosumers is sold to the grid through the entity CA/DSO.
- CA and DSO operate in the same way as phase 1 and again, monopolistic behaviours must be prevented.

This phase is close to the definitive E+ business model but the APM has not appeared, since its role makes sense when the quantity and entity of prosumers are important.

B. Limitations

Besides the economical limitations, expected to be solved once the proposed roadmap is implemented, other barriers will appear, as certain regulations or a lack of policies, mainly at technical field, limiting the use of electric microgrids in districts and, as a consequence, the definitive application of E+ business model. Since the regulatory spectrum in the EU is wide, varied and complex, the limitations applying to the Spanish case are mentioned here:

- There are not specific self-consumption regulations. Only Royal Decree 1699/2011 regulates the connection of low power generation installations. This document established a certain period of time to legislate technically and economically self-consumption in Spain. However, once that time expired, regulations going towards self-consumption in Spain have not been created.
- Renewable generation installations will be only based on one technology, which prevents hybridization. Hybridization concept is an interesting solution to face the uncertainty and uncontrollable character of renewable sources as wind or solar through the integration of them as a whole.
- The use of storage devices is not allowed in renewable generation installations. The use of storage technologies is another solution for that uncertain and uncontrollable character of renewable sources, since surplus energy can be stored in low consumption periods and used if necessary.
- The power of generation installations is limited and the goal of zero energy neighbourhoods appears as a difficult task.
- Islanded operation is not allowed, which prevents the exchange of energy between microgrids in case of fault upstream of the connection point to the grid or the consumption supply to a grid inside the same installation.
- Lack of regulations in connection to public distribution grid of electric energy storage installations due to technical, property and final use reasons.
- There are not unified regulations for the distribution grid since each DSO sets different conditions. This fact can suppose a barrier about the relation between APM and DSO. Nevertheless, Procedures of Operation for the Distribution grid (POD) are being developed, in the same direction of the unification done in the transport grid.
- Lack of regulation for the EV charging infrastructures or the operation of V2G points connected to the distribution grid. A draft has been partially developed, being the key for the implementation of the electric vehicle in the electric system and the microgrids.

4. Impact of the implementation of the new business model

A. Impact on the current electricity market agents

The expected implementation of the E+ business model is strongly associated with the development of new neighbourhoods where E+ tool is able to operate. For this reason, taking into account that for the European Union the evolution of urbanization is expected to grow from 73% in 2010 to 80% by 2030 [8], an average population of 6,000 neighbours per neighbourhood [9] and there are around 500 million inhabitants in the EU-27 [10] with a 70% in urban areas [11], it can be assumed that about 5,700 new neighbourhoods will be built by 2033. If a linear growth from 0% in 2013 to 10% in 2033 is supposed for the number of new neighbourhoods following E+ recommendations (neighbourhoods suitable for E+) and a non-linear regression from 0% in 2014 to 7% in 2033 for E+ neighbourhoods using E+ tool, Table I provides an estimation of the possible evolution for the penetration of E+ tool in the EU for the following two decades:

Table I. Expected evolution for the implementation of E+ tool in EU.

Year	New neighbourhoods in EU (accumulated)	Total neighbourhoods suitable for E+ use in EU	New neighbourhoods using E+ recommendations	Neighbourhoods using E+ control system	Neighbours using E+ control system
2014	900	60,833	0	1	6,000
2015	1,199	60,839	6	2	12,000
2020	2,693	61,169	126	458	2,750,498
2025	4,188	62,545	395	993	5,955,323
2030	5,682	65,716	814	2,878	17,268,185
2033	6,579	68,791	1,136	4,734	28,403,596

Considering the fact that each APM manages a neighbourhood using E+ tool, up to 4,734 APM could appear in 2033 managing energy costs and consumptions from about 28 million neighbours. Besides, if a prosumer can represent an individual neighbour or several of them (a building as a whole can be managed by an APM and be considered as a prosumer), several million of E+ prosumers are expected to appear in 2033.

The APM role can be assumed by existing and new actors of the current energy market. Because of their similarities with the APM, the current agents that can evolve into Aggregated Prosumers Managers are:

- Retailer.
- Energy Services Companies (ESCOs).
- Property managers

B. Costs and benefits involved in the new business model

The implementation and use of microgrids implies several costs and benefits to be considered. Table II [16], [17] summarizes the main benefits and costs associated with microgrids:

Table II. Costs and benefits of the implementation of microgrids and implication of E+ business model agents.

Benefits	Costs
- Sale of surplus energy - Reduction of losses - Reduction of emissions costs - Generation and consumption adequacy - Increased reliability - Grid investment deferral	- Microgrid development - Distribution costs - Microgrid maintenance - Management

Mainly, these benefits and costs involve DSO and APM. The DSO will manage and implement the necessary microgrid infrastructures to achieve the most energy efficient operation reducing losses. The role of the DSO in E+ business model is related to operate the microgrid to enable the best actuation of the APM. For this reason, the costs mentioned in Table II are directly associated with the DSO. This entity will pay for both fixed costs (microgrid development) and variable costs (distribution cost, microgrid maintenance and management) of the microgrid. It is important to consider that the APM will be also able to implement and own a microgrid assuming, in this case, these costs. On the other hand, certain benefits as reduction of losses or increased reliability are related to the microgrid infrastructures investments assumed by the DSO.

On the other hand, the APM will be focused on the energy costs and losses reduction for the prosumers in a neighbourhood. Then, an APM will be that agent able to achieve every benefit included in Table II through the optimizations achieved using E+ tool. The APM will be paid by prosumers to increase these benefits and obtain the maximum energy and cost savings for them.

As a consequence of the implementation of microgrids, important improvements can be obtained for prosumers [18]:

- Energy cost reduction ranging from 10.4% (island operation) to 22.2% (energy exchange operation) in relation to the current case taking energy from the distribution grid.
- Energy losses reduction of 82% with the use of microgrids.

5. Conclusions

The application of microgrids to urban environments appears as a solution or mitigation of the problems of the current electric system. In this way, E+ presents an ICT based tool able to reach energy and cost savings at neighbourhood level but, for its implementation, a new business model is necessary. This paper presents this new business model based on the introduction of two new actors: the APM and the prosumer, allowing that microgrids acquire certain importance in urban ambiences.

Despite the benefits derived from the use of microgrids in European cities and the proposed business model, the implementation roadmap is not evident and easy. For this reason, an implementation roadmap divided into two phases is proposed to enable this transition. The complexity of the implementation of this business model is mainly associated with the regulatory framework, which has been analysed in depth, being determined the regulations or lack of policies that are supposing a clear barrier.

Nevertheless, some positive aspects have been observed. The analysis of expected penetration of E+ tool and the evolution of some agents in the current energy market, such as the retailer or the ESCO, provide the idea that the new business model described here could be a reality in a long term scenario. This fact is also reinforced by the important energy and cost savings to be achieved if microgrids are widely used.

Acknowledgements

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