E-balance business proposal: How to find benefits from active demand response

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Abstract. This paper presents the basis of an energy exchange system for the energy flexibility supply, and a specific proposition for the e-balance platform. It also demonstrates how such a system could operate on the European market (Poland). The pricing model’s results are shortly described as an efficient method used to incentivise prosumers. The e-balance system/platform itself is a result of the European (FP7) collaborative project: e-balance (2013-2017): Balancing the energy production and consumption in energy efficient smart neighbourhoods.

1. Introduction

A large number of renewable energy sources (RES) and new technologies on the demand/active side response (DSR) are becoming increasingly integrated with the current energy market in many countries. It has created quite a number of new possibilities to produce, use, store and balance energy locally with active users, called prosumers, and with aggregators. It has also provided new opportunities to operate with energy flexibility.

These changes also challenge operations of electrical power systems as they increase the uncertainty throughout the whole energy supply chain. As a result, new products are developed (e.g. energy flexibility products) as well as a need for new system services. Control of the power flows in real-time becomes more complex. It creates difficulties for grid operators (reliable supply, the risk of network instability and the possibility of congestions) as well as for market participants (since the energy price may significantly increase).

Facing these challenges, many researches, coalitions, thematic work groups of the European Commission and market organisations (SEDC [15], USEF [16], and others) and numerous European projects (Besos [6], Increase [7], e-balance [1], ePlus [5], Sustainable place [8], others) have been developed to solve these issues. The problems mainly revolve around several questions, i.e.: how to redesign the energy market model, how to introduce an aggregator’s role, how to describe and clearly prepare new business models for the energy exchange management for active demand response, and how to introduce new services and products such as energy flexibility into day-ahead, intra-day and balancing markets (DAM/IDM). The main idea is that energy and grid management can no longer be based on the traditional top-down approach. Instead, a bottom-up approach is required with a larger involvement of the regional grid operators and prosumers. The e-balance platform prepared in the e-balance project can meet most of these expectations [9-10, 12-13].
The aforementioned system is a smart grid platform that supports current and new services in the field of energy balancing, customer data acquisition, customer interaction, energy exchange flexibility and grid resilience. More precisely, in the area of energy balancing, this system will balance energy production and consumption within the local area. Balancing will be performed based on aggregations of a locally constructed planning using fixed time slots. Furthermore, balancing can be scaled up from the local to the city level, regional or national level via an iterative approach. Both geographic and virtual aggregation of users and producers are supported by the concept. In this sense, the system is designed in a fractal-like way [1-4].

The application of such a balancing paradigm requires more active participation of the users/prosumers and aggregators who will aggregate the energy flexibility and offer it on the DAM/IDM as flexibility products. This system also needs an appropriate business model clearly designed and explained, and these aspects are also addressed under the e-balance project [1,11].

**Table 1. USEF versus e-balance propositions – a comparison (table for section 2.1).**

| Energy flexibility – USEF proposition [16] | Energy Exchange Management e-balance proposition |
|-----------------------------------------------|-----------------------------------------------|
| **The aim of the USEF project:** the flexibility comes from prosumers and the smart devices are controlled automatically by a smart energy system. Flexibility is valuable if it is deployed in the flexibility market. The aggregator can aggregate all small portions of flexibility and takes it through BRP to the market. For the DSO, the flexibility is valuable in reducing pick in the grid (and congestions). The BRP uses the flexibility to manage balance between the electricity supply and demand on the wholesale market. The calculation of how much flexibility is actually delivered to the market is done afterwards using a smart meter. There is a high risk of flexibility being sold but not delivered. The core competences for the aggregator are load forecasting and flex forecasting. | **The aim of the e-balance project:** the flexibility comes from prosumers using the e-balance system. This system advises and provides the potential prosumer’s reaction to an aggregator’s request to reduce or increase the energy consumption or production. The decision of being active with it is made only by the prosumer. The aggregator can aggregate all small portions of each reduction. The aggregation is provided from the bottom to upper level in the whole network in every 15 min or less. All flexibility is prepared and offered on the flexibility market/balancing market (depending on a given model). The calculation of how much flexibility is actually delivered to the market is done afterwards using smart meters and e-balance means. Load forecasting in detail is prepared as a complementary to the e-balance system for other market players. |
| **Models:** 7 models of implementing the aggregator’s role to the market have been proposed [16] | **Models:** Three, basic models for the aggregator’s role has been proposed[1]. Two of them are coherent with USEF models. |
| **Price mechanism:** dynamic prices for the flexibility market have been proposed, a supply-demand mechanism, a dynamic process for flexibility product and aggregator’s fee – income margin. | **Price mechanism:** For only integrated model of the aggregator’s market integration, the similar prices mechanism has been proposed. The indirect revenue (hidden incentives) through tariffs has been suggested as well. The aggregator earns the agreed margin from the income. There are no open income mechanisms for retailer and the BRP as a result of the flexibility management. |
| **Contracts:** Depending on the model, different types of contracts have been proposed based on the dynamic market prices. A detailed risk analysis has been performed for the particular types of business models. | **Contracts:** Contracts with prosumers have been proposed for a certain range of flexibility provided during the course of the year with stable prices for the specific amount of provided flexibility, in order to reduce the risk of not fulfilling aggregator’s contracts in the DAM/IDM and balancing (under flexibility) market. |
The most problematic matter is how to organise the aggregator’s role and define all contracts existing between market actors (a win-win strategy is desirable for all sides) in order to reach the e-balance goal which is the maximisation of energy flexibility and incomes (for prosumers mainly) given locally and delivered on the DAM/IDM markets. This issue is considered and prepared in business case project’s documentation.

This paper is a result of the continuation of the research work [11], and presents the next stage of the business model/business case study followed by the explanation of the next steps and simulation of the results.

The USEF proposition is presented and compared shortly to the business case assumptions from the e-balance project in section 2.1 and 2.2. Section 2.3 contains business case essentials and discussion of their financial results obtained from profitability simulations, with some important conclusions concerning the role of prosumers. Final remarks are described in the summary section.

2. Problem formulation and explanation

2.1. The USEF approach versus e-balance business model approach

The USEF Foundation (USEF – refers to the Universal Smart Energy Framework) is a Dutch multi-partner collaboration, developing a new market model, smart energy technologies and new services in the Netherlands. They have prepared a smart grid market model and flexibility market design together with new processes, aggregator’s and prosumers’ roles, standards propositions and a possible impact analysis for the future.

Their proposition answers basic questions: how the flexibility market should operate in general, where the benefits and serious risks of such approach are, and whom they concern [16].

During the e-balance project, the proposition of the business model concept concerning the product flexibility has been worked out, along with the mechanisms of how the prosumer and the aggregator can act and earn (incentives), which benefits and risks they can meet while using the e-balance platform [1,11]. These two approaches have been explained and compared briefly in Table 1. The similarities and differences are highlighted giving picture of the e-balance platform/model in short way. In the main idea the e-balance results are similar to the USEF’s concept and such system could be rolled out on this market.

2.2. Business case assumptions

Considering the specific business case for the particular implementation of the e-balance platform, some technical, market and economic assumptions have been undertaken and described (in Table 2 - framework definition). Based on the developed business model and the assumptions, only one of the possible model scenarios has been chosen for further deliberations.

Similar scenarios were analysed and considered by both the USEF, [16] and the e-balance project. An integrated model for aggregator’s integration to the market was chosen for the further analysis as the one being the most probable and least risky. Then, the analysis of the account model for prosumer’s flex product was done. All our theoretical propositions are explained in detail in[17].

In such a defined case, a specific solution was proposed regarding the manner of concluding a contract and price policy oriented on prosumers’ benefits (incentives) is given in the next section.

2.3. Pricing and the role of prosumer’s behaviour

Prosumers behaviour is of a key importance in the e-balance platform and to its business model success. We have prepared pricing methods for the key participants involved in development of energy flexibility using the e-balance system (energy supplier, aggregator, and customer). They are essentially based on hierarchical optimization models, maximizing profits from demand response product for all parties involved in the system, for a given specific business actions. They are described in more detail in [17]. This section only addresses some conclusions that have resulted from performed
simulation studies of using flexible energy product in specific business cases on the Polish energy market.

Table 2. Framework definition for further simulation and calculation, the Polish case (for section 2.2).

| Considered assumptions | Existing assumption for the Polish business case | Change or simulations |
|------------------------|-----------------------------------------------|----------------------|
| **Technical**          | The grid, which meets the technical conditions to implement the e-balance system, is available. This means that there is a sufficient number of prosumers, the grid is appropriately modernised and measured (existing AMI and DR). There are smart devices at users’ homes: PVs and e-balance system tools. | It is assumed that 5000 prosumers have a PV installation of 3-10 kW minimum power. The pricing method was based on a calculation using a sample of only 1000 and then 5000 prosumers. |
| **Market**             | Reserve market participation rules operate but they are not suitable for placing the energy flexibility as a product on the DAM/IDM | We can assess new reserve market participation rules. There is a need for the market to operate according to a new schedule. The bid structure on the market (minimum bid, increments, bidding periods). Remuneration: power/energy, pay as bid. Penalties for non-delivery of tendered products. |
| **Economic**           | For the new business model – currently there are no rules. Currently there are no other competitors, however what will happen if a new market player offering a cheaper solution comes? | Which payment mechanism is the best strategy to be introduced? How will prosumers earn? How will aggregator earn? Is this the most effective system for prosumer/aggregator? The proposition of pricing method. |
| **Regulatory**         | The current rules are not sufficiently flexible to regulate the flexibility market and new operations. Reserve market is not prepared for DR participation. Only the DSO has responsibility. | A new regulation is needed for the aggregator role, procurement method for flexibility delivery: mandatory/free take as you pay/open market. Measurement responsibility: DSO/aggregator using e-balance tools. |
| **Numeric Parameters** | Actual average electricity price: 72 EUR/MWh (in Dec 2016) Specific region in Poland: Northern Poland Yearly PV production is 12.8 GWh. Yearly consumption is 7 GWh (2171 prosumers). Fixed proposition for flexibility contract: 750 zł/NWh, 174 euro/MWh. Potential demand for the energy flexibility in the Polish grid - around 500 - 800 MW yearly (the TSO’s report). | With only a daily flexibility at the level of 0.5 kWh, a single prosumer can obtain an amount of about 220 PLN (51.16 EUR) per year (assumption: fixed price for the flexibility on the market, for simulation n=5000 prosumers) An average, minimum amount of energy flexibility 0.4 – 0.5 kWh daily, potentially gives 1.5 MW of power yearly in this region (minimum value). The proposed mechanism regarding the pricing and contracts for flexibility is described in the following section. |

Source: Based on the work performed under the e-balance project

In this paper two possible areas of business activities and achieving revenues with the e-balance platform are presented:

- Flexible product creation for energy markets in form of load reduction.
- Local balancing of the small prosumers with micro-generation
The first discussed area of business activity, is generally connected with using e-balance platform functionality in creation of the active demand response actions for cooperating users-prosumers. As a specific business case analysis from this domain, we have performed a simulation study of the potential revenues from using demand reductions to correction of the position on the Polish Balancing Market.

The imbalances between the contracted and the actual delivery are settled on the balancing market using a uniform market clearing price, regardless whether the balancing entity buys or sells energy on that market. In case of establishing high clearing prices, exceeding (sometimes many times) energy prices on the retail market, energy suppliers may decide to correct their actual position, using demand reduction instead of buying balancing energy. E-balance platform allows very fast creation at request of users load reductions, with leading time dropping even to 15 minutes.

After analysis the data from the Polish balancing market from the year 2016, approximately 230 hours (originating from approximately 30 days) were selected, when the balancing price exceeded the assumed retail price \( p_s \) (we have assumed the value of flat retail price of energy \( p_s \) equal 0.3 PLN/kWh). Then we simulated the effects performing the reduction of customer demand at request, in the aforementioned cases.

### Table 3. Profits for different levels of users elasticity \( v_i \) (5000 users pool) Polish Balancing Market.

|                            | Supplier profit (PLN) | User profit (PLN) | Aggregator profit (PLN) |
|---------------------------|-----------------------|-------------------|-------------------------|
| High level of users elasticity \( (v_i = 0.025) \) | 537 526               | 162               | 275 856                 |
| Normal level of users elasticity \( (v_i = 0.05) \) | 277 105               | 83                | 138 552                 |
| Medium level of users elasticity \( (v_i = 0.1) \) | 138 552               | 42                | 69 276                  |
| Low level of users elasticity \( (v_i = 0.2) \)  | 69 276                | 21                | 34 638                  |

The description of the full methodology, used for having presented results, is presented in the correlated paper [17] with all details and also in documentation of the e-balance project [1]. The main obtained results of our studies are presented here, in Table 3. follows from them, that DR's actions in discussed business case are profitable for all parties involved. However, the level of profits is highly dependent on the elasticity (determined in the simulations by the parameter \( v_i \) in the user model) of the users, their tendency to adjust their load in response to proposed incentives. With the high flexibility of the recipients, the potential profit of the supplier would exceed half a million zlotys, the user’s would be at the level of over one hundred and fifty zlotys, and the aggregator would be close to three hundred thousand zlotys. Also in this case, with the low response of the recipients, the benefits of all the participants may be several times lower.

For the purpose of the simulations, the size of the pool of users cooperating with the aggregator (5000) was selected on arbitrary basis, however it is easy to recalculate the gains of aggregator and supplier for a different number of users as they are linear on this parameter.

The second area of business activity discussed in this paper, concerns local balancing of the small prosumers with micro-generation. The e-balance platform provides services allowing aggregation of the small prosumers producing electricity for the needs of their own households. In general, prosumers can achieve revenues by using their capacity to increase the flexibility of active-demand products discussed above. In certain circumstances, however, the aggregation can allow prosumers to generate
additional revenues compared to individual energy sales to the network. They result from the potential benefits of the local load balancing in the neighbourhood.

The business case from this area, discussed here, concerns the analysis of possible revenues from participation in local balancing in e-balance platform of Polish prosumers with photovoltaic sources.

In Poland, the conditions of operation of prosumers producing energy from photovoltaic sources up to 40 kW, for their own needs, is regulated by the law introduced in July 2016. Essentially, it makes it difficult for prosumers to benefit from the sale of energy, with the emphasis on using it for own consumption. The most important financial terms on which settlements are based can be summarized as follows:

- Energy surplus produced by the prosumer is introduced into the grid without receiving any direct financial compensation. Instead, within net-metering settlements during the half-year period, prosumer in return can receive free energy from the grid, according to the ratio:
  - For PV sources up to 10 kW installed capacity, for every 1 kWh entered into grid prosumer can receive 0.8 kWh.
  - For PV sources from 10 to 40 kW installed capacity, for every 1 kWh entered into the grid prosumer can receive 0.7 kWh.

- The energy price considered in the settlements contains the price of the energy itself and the distribution charges for delivering. In Poland, the retail price of electricity is about 0.3 PLN/kWh, and the distribution fee is about 0.24 PLN/kWh.

- Net energy not collected in the half-year metering period is not subject to settlements. It means that, if the prosumer during this period have surplus energy entered into grid, he will not receive any payment.

The above settlement system does not always give the prosumers prospect of the opportunity to obtain full compensation for the energy produced even for he’s own purposes. For instance, in a case of the prosumer using a 5 kW PV installation, with an annual personal demand of 4500 kWh, the energy produced may not be enough to cover that demand. Although (under assumption an average energy production of 920 kWh per year, from 1 kW of installed capacity, which corresponds to the operational parameters of PV installations and the conditions of sunlight for Central Poland) the prosumer should produce about 4600 kWh per year, which even slightly exceeds its annual demand. However, on average, it is estimated that about 30% of the produced energy is immediately used directly by the prosumer. The rest is entered into the grid and can only be recovered by the prosumer in a ratio of 0.8 to the original volume. Under current conditions of net-metering in Poland to cover its demand the prosumer will have to buy in addition about 550 kWh annually.

Aggregation and local balancing in a dedicated area/neighbourhood can provide an increase in the direct use ratio of the energy produced by prosumer, allowing to avoid the negative effects of storing the surpluses in the grid. Not all prosumers participating in aggregation have the same load patterns, some aggregated users can only provide active demand services. Thus, the surplus energy of some users can serve to cover the immediate needs of others.

Also for prosumer sources with a slightly higher capacity, whose PV production exceeds the demand in the net-metering period, the obtained surplus can be used, in the in local balancing process, to cover the needs of other neighborhood partners cooperating in the e-balance system.

We performed simulations of revenues resulting from the local balancing using e-balance platform for a typical household prosumer using PV cells in Poland. More detailed in the analysis we adopt the following assumptions:

- The retail price of energy (energy + distribution) from the network is 0.54 PLN/kWh.
- From the 1 kW installed capacity, PV cell generates on average of 920 kWh of energy per year.
- Prosumer directly uses 30% of the energy produced.
- Prosumer to cover its demand can recover all the energy transferred to the aggregator for local balancing purposes.
• In case of a surplus of energy transferred by prosumer to the aggregator, it is settled at a retail price of 0.54 PLN/kWh.
• The level of annual energy demand of the prosumer as 4 500 kWh, as typical value for a residential home.

In the simulations we did not take into account the costs associated with PV installation itself, assuming they are the same in both cases: individual prosumer and aggregated one. If, for instance, an aggregator as a larger entity can get better purchasing prices for equipment or making wholesale purchases, it can further increase revenues in aggregated prosumer case.

Figure 1. Annual revenues from local balancing for PV sources of various capacity, with small (30%), medium (50%) and large (80%) prosumer’s energy utilization by the aggregator.

Results of the simulation are shown in the Figure 1. As we can see, prosumers aggregation and local balancing within a dedicated neighborhood have in principle generated substantial revenue in each case. Its size depends primarily on the power of the photovoltaic cell, which of course determines the scale of production. For small 3 kW PV installations, aggregation profits vary from about 75 PLN per year, with an average of 50% of the energy utilization by aggregator, to about 120 PLN at high level (80%). With a 5 kW PV capacity, analogous profits are approximately 175 and 280 PLN per year, respectively. With the higher power of the cells, when the savings on the global surplus of energy are also involved, the gains from aggregation are increasing rapidly. For example, at a capacity of 7 kW their estimated value is approximately of about 770 PLN to 940 PLN per year.

3. Summary
In conclusion, the analysed methods of pricing business activities in the field of flexible demand management have yielded the correct results, allowing the proper pricing of the undertaken actions. The prices obtained were fair, and provided benefits generated by the e-balance platform to all the players involved. The simulation studies have also shown that the presented pricing methods also enable the creation of a flexible demand product used in the bidding processes on the ancillary services markets. They allow to set reasonable prices for demand reduction bids that are optimal for its volume.

The results of the simulation studies in section 2.3 showed, however, strong dependence of the profits of business demand response actions on the flexibility of the users, i.e. their willingness to respond to incentives used by the aggregator, and change their load.
For this reason, it is quite obvious that the aggregator’s operating costs should also include a series of marketing and promotional activities in two directions:

- Acquiring more users involved in active demand on the e-balance platform.
- Activating users, encouraging them to be more flexible in response to the DR

That activity may include promotional and educational actions among users, indicating the impact of the platform, and the benefits of increased elasticity, reduced fees for platform hardware and software, higher incentives for users, reduced operator or supplier gains relative to optimal ones, but increasing user elasticity or attracting new users.

Such system like the e-balance platform proposition could fit well to conditions of the USEF market.

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