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Demand response approaches for real-time renewable energy integration
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# Demand Response Approach for the Coordination Between Aggregators and Providers

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**Abstract**

**Nowadays electricity system is looking for innovation in its role. New approaches are being able to discuss because of several issues as environmental, costs, quality and reliability of the electric energy production. In this paper one more aggregation's scheme for demand response will be proposed. Based on National Grid's programs that already exist in the market which will be shown on the current paper. This paper will be a support for a master thesis in electrical engineering based on the same topic.**

Keywords: aggregation models, demand response, market.

## 1. Introduction

Market liberalization isn't a new approach in Europe anymore, even looking for a retailer or wholesale market. The meaning of this paper is an approach on demand response models regarding to UK's programs.

To improve system's reliability, quality and reduce price for the end consumer, according with, [1]–[9], renewables energies has been installed. Managing this production is not an easy task due to renewable production hasn't an accurate forecast during short term. In fact, within one timescale day solar and wind productions can quickly change, due to weather conditions.

The meaning of flexibility, according with [2], is how consumers can change their profile's consumptions without including or removing elements of the manufacturing process (in factories' cases), so flexibility means the ability of changing consumption regarding to outside system's inputs to adapt itself to a better profile.

In renewable production's cases is necessary a more accurate balancing system. To balance the system, loads most be more flexible to shift consumption for demand response instructions, according with [2] and [3]. Both describes how a consumer can be more flexible in a manufacturing enterprise and its importance for the system and factory's sustainability improvement.

In [7], it shows how a provider can be flexible in a microgrid regarding to renewables productions. Providers most adapt consumption or production according with energy price (electric and natural gas), renewable production, demand requirements and storage. Regarding for the optimum point between energy purchase, production and consumption during one year of analyses.

According with [10], there are three types of aggregators. First, production aggregator, responsible to group small generators to access the market; Demand Aggregator, intermediate retailers or distribution companies and consumers with production and/or storage capability; and Commercial Aggregator, response to balance energy supply and buy locally generation electricity. Those aggregations types are important to handle with system's balance and economics issues.

In UK during 2001 the New Electricity Trading Arrangements (NETA) were installed. The big difference between old system and NETA is that while in first one the cost of system's balance was divided by everyone who were connected in electricity system, in NETA the cost of balancing is within the market, making providers get paid to improve system's balance. (Now the) system is not like an electricity pool anymore where market used to change energy and money ignoring technical requirements of balance and operations.

Demand response in this new system can improve, technically, quality, reducing costs and open a new market with providers, aggregators and retailers.

To provide demand response is necessary to be in a pretty regulated market because there are several technical details that system must obey and financial requirements that are important for system's operations reliability. Thus, many entities are studying models to improve demand response. Firstly, models were just for the biggest loads on grid, in order to provide large scale. As consequence, most consumers couldn't be able to provide demand response. In order to solve this problem of provider's constrains, aggregation models in all parts of the world were getting importance to be implemented in the electric system.

The most important thing in this aggregation approach is to improve response reliability and increase power response in different sites of the distribution grid (and not just transmission system). with an aggregator providing DR's management smaller consumer can start to enter in the market of balance and production of energy in distributed energy resources cases.

## 2. UK programs

Table 8 Shows four demand response programs found in UK [11]–[13]. Those programs have some differences between each other in terms of response time, quantity, reduction or increase load and main meaning for the system.

Fast Reserve provides rapid and reliable energy delivery when it's needed by the system, in this case it improves system's reliability for a short timescale.

Table 8: National Grid's DR programs.

| **Fast Reserve** | **STOR** | **DTU** | **FFR** |
|---|---|---|---|
| **Requirements:** | **Requirements:** | **Requirements** | **Requirements** |
| Delivery in 2 minutes after ordering. | Deliver at least 3 MW over a period of 20 minutes. | Minimum power of 1 MW. | Operational meter that switches loads. |
| Delivery rate greater than 25 MW / minute. | Provide for 240 minutes (continuously 2h). | Aggregates equal to or greater than 0.1 MW each. | At least 1 MW of response. |
| At least 15 minutes of cutting or production. | Instruction recovery in 1200 min. | Energy counter with by minute-by-minute or half-hourly. | Aggregation, communicate by only one site with the OS. |
| Deliver at least 50 MW. | availability three times a week. | Only e-mail access for instruction. | Communication with an automatic control device. |
| **Fees:** | **Fees:** | **Fees:** | **Fees:** |
| **Availability [Pounds / hour]** Remuneration for being ready to provide the service. | **Availability [Pounds / hour]** Remuneration for being ready to provide the service. | **Availability [Pounds / hour]** Fixed drive demand. | **Availability [Pounds / hour]** Provision for delivery. |
| **Nominal [Pounds / hour]** Reserve utilization in the available window. | **Utilization [Pounds / hour]** By capped energy in the available window. | **Utilization [Pounds / hour]** Fixed and optional demand. | **Initialization of window [pounds / window]** Payment for the windows in which they are requested. |
| **Utilization [Pounds / MWh]** By capped energy in the available window. | **Optional [Pounds / hour]** By limiting power outside the available window. | - - | **Utilization [Pounds / hour]** Use when requested. |
| - - | **Services** Committed and flexible | - - | **Window Review [Pounds / hour]** For calls outside the contracted window. |
| - - | - - | - - | **Energy response [Pounds / MWh].** Energy provider delivered. |

The meaning of STOR is to provide extra power to help manage actual demand on the system being greater than forecast or unforeseen generation unavailability.

Demand Turn Up (DTU) is used to manage renewables energy resources. When the renewable production's level is high, and the consumption is low is necessary to use this energy in a useful way to hold system's balance. Then DTU is used for this type of balance situations.

Firm Frequency Response (FFR) gives for the provider and SO (System Operator) an alternative route to the market, necessary for the price uncertainty. In this program providers can be in available in the same time in another kind of DR's program and system's frequency is improved.

A simple brief of those programs is presented on Table 8 with some technical requirements and types of payments to provide each program.

## 3. New proposed model

Is proposed a new model of remuneration and penalties regarding for an aggregation communication between provider and aggregator. This new model has been implemented in a computational simulation with twenty providers managed by one aggregator.

Firstly, is necessary to contract providers in a tender process. In this part, each provider agrees with an aggregator the response information, on which most contain all data of available response. Including: Contract Power (CM), normally in MW for large-scale providers; Response Time, is the time that each provider can maintain continuously the contracted power; availability and utilization's fee; maximum permissible error, it's maximum error in delivered power that the provider can fail. If provider deliver less than maximum error, it's considered as deliver failure and it won't be remunerated in the current settlement period. Else it's considered success but by this percentage will reduce availability and utilization payments.

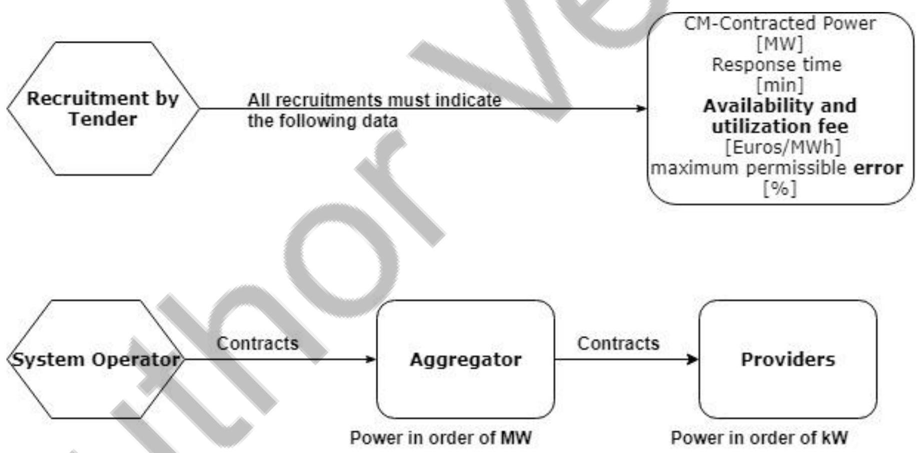


Fig. 25: Contract flowchart.

Fig. 26 presents how providers are dispatched. To provide is proposed a time before the event's beginning to do a communication between provider and aggregator to improve response's reliability and to bring more flexibility to providers in different event's situations.

Firstly, in Fig. 26**Error! Reference source not found.** the aggregator consults all providers about how much they can provide in the next event. "Treply" is the reply time to providers send an answer to aggregator about how much they accept to provider (provider's reply variance is set in the initial contract); "Tanalyze" is the aggregator's time to analyze all possibilities between providers to reduce load, in that time he calculates the optimum dispatch looking to utilization fee, power available and power needed to reduce; Notification is the moment that the aggregator sends a signal to each provider be dispatched, in that moment they will receive the information about how much power they have to provide, how long and the exactly time.

Ramp up and down can be done however providers prefer due to the only requirement is that after event time and before event end the delivered power most be the instructed power by aggregator.

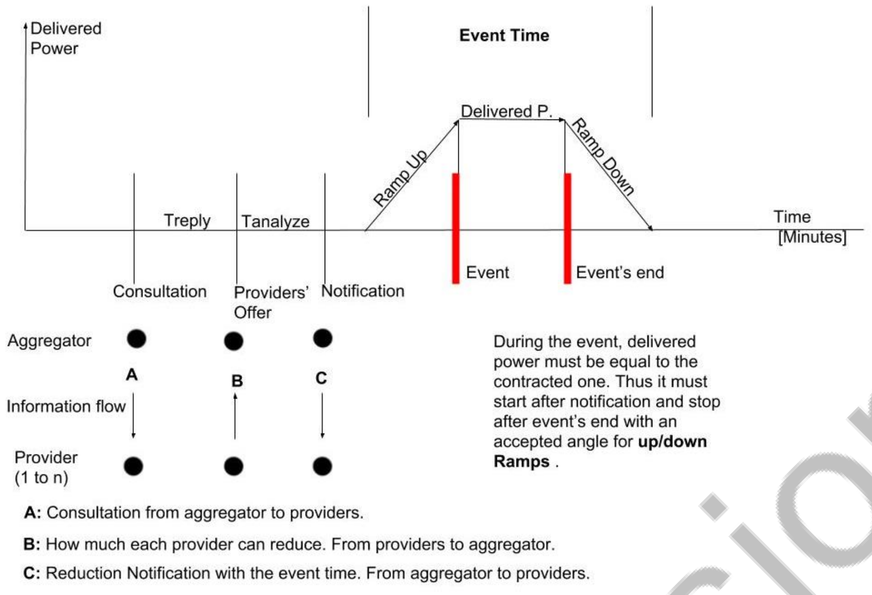


Fig. 26: Event Timeline.

Fig. 27 shows a flowchart describing how aggregator's communication works between all providers and acceptance conditions. In the first part aggregator send the first signal, which has response time data with reduction time, event date and power required. All providers have it as input and they analyze according with their respectively issues. After this period, fixed by contract within any settlement periods times, providers reply to aggregator an output with the valuer of power and time that they accept to provide.

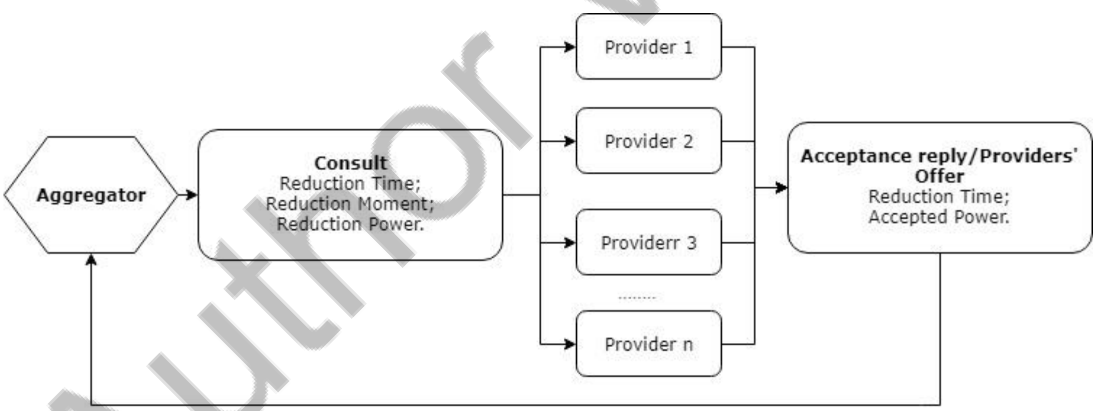


Fig. 27: Aggregation's consultation and providers' offer.

### 4. Payments

To calculate providers' remuneration this model presents two simple types, called: Availability and utilization payment. Both were inspired in STOR.

First payment scheme is shown in Fig. 28 as availability payment, this flowchart demonstrates all possible situations for each settlement period.

Where, in Fig. 4, the first stage is a failure ask, if in the current settlement period it have failed. If it has the current won't be remunerated. Weather not, it sums all previous failures and increase MP in 1% for each failure (the maximum MP can be negotiated between them). After calculate MP, Rb (Base remuneration, called availability) is done according with contracted data presented in Fig. 1.

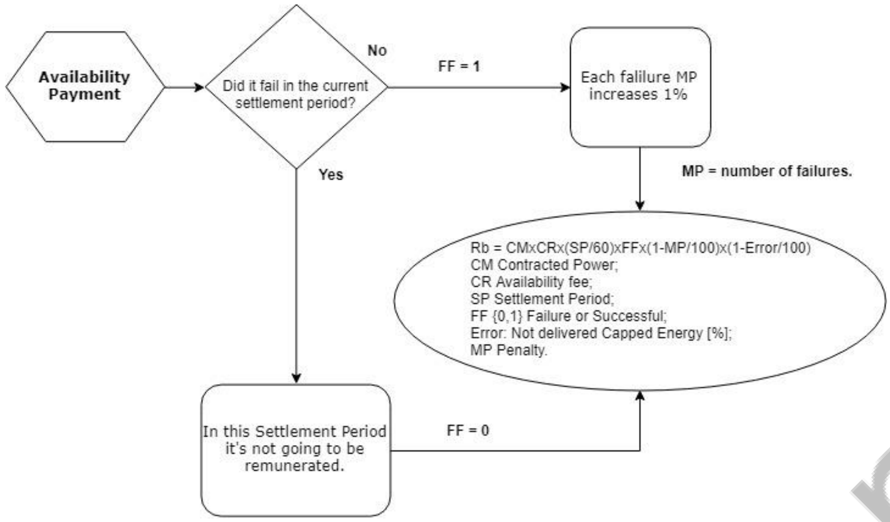


Fig. 28: Availability payment scheme.

Secondly, proper utilization remuneration is shown in the flowchart (Fig. 29).

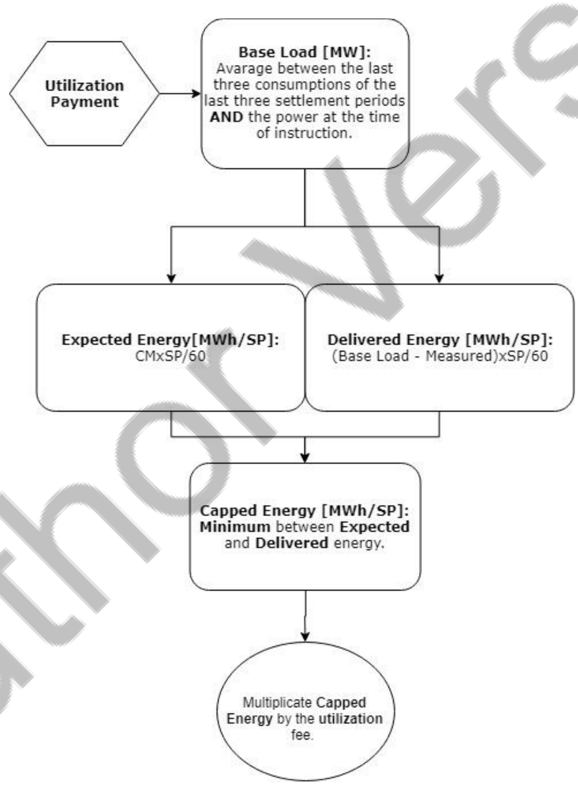


Fig. 29: Utilization payment scheme.

For Fig. 29 its calculations will be done in the event time (red colour in Fig. 26) and stops in the event ends (second red color).

Base load means how much power it was consuming moments before the event. The average between the current time of the notification (instruction) and three last consumptions values, one for each settlement period. Those four values are used as base load to the next steps.

Expected energy is how much it should be providing in the current event and delivered energy is how much it's really providing for the system. Calculated by base load less measured in the current SP. Showing how much it's reduction of power comparing with the previous load (Base Load).

Finally, capped energy is the minimum between expected and delivered energies. Weather it's providing more than expected it will be remunerated by the expected. Otherwise it will be remunerated by how much it is really providing.

According with capped energy is applied utilization fee to calculate how much money it will receive for the current SP.

Total remuneration is the sum of availability and utilization's payment.

## 5. Case Study

To validate the proposed model a simulation has been done. Using a university campus as one group of providers, where each building represents one provider with its own consumption's profile.

During one consumption year, all providers are considered able for demand response in the high load periods of the day, according with [14], it's shown in Table 9.

Table 9: Peak of electric system's load.

| **Winter (29/out – 26/mar)** | **Summer (26/mar – 29/out)** | **Time (Peak/Not peak)** |
|---|---|---|
| 9am – 10:30am | 10:30am – 1pm | Peak |
| 6pm – 8:30pm | 7:30pm – 9pm | Peak |

Those times are used to instruct providers along one year for demand response analyses. Is chosen these periods of event because they represent the biggest consumption period in Portugal, according with [14].

Table 10: Maximum interruptible power of each provider.

| **Provider** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| Power [kW] | 0.391 | 0.35 | 0.436 | 1.98 | 1.724 | 0.562 | 0.196 | 1.236 | 3.564 | 1.493 |
| **Provider** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| Power [kW] | 2.156 | 0.715 | 3.65 | 1.119 | 0.929 | 0.424 | 1.383 | 1.283 | 0.629 | 1.02E-02 |

Table 10 shows how much power providers can dispatch within a reduction event as related in Table 9. This level of power comes from each providers average between the higher hours of their consumption. Due to reliable measurement and uncertain about consumers reducible profile is taken as maximum reducible load 90% of the average between 12:30pm and 3pm consumption of each one.

Table 11: Aggregator's notification.

| **Provider** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Power [kW]** | 0,704 | 0,630 | 0,914 | 5,352 | 3,103 | 1,011 | 0,353 | 2,810 | 6,414 | 2,687 |
| **Provider** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| **Power [kW]** | 3,881 | 1,287 | 6,569 | 2,504 | 2,029 | 0,888 | 3,220 | 2,938 | 1,132 | 0,031 |
| | | **Required by SO [KW]:** | | 48,457 | | | | | | |

Table 11 shows how much power each provider is dispatched after aggregator's optimization, regarding to minimizes costs and provide required power by SO. In this case the optimum is found using Dual-Simplex as a deterministic exact optimization approach, which isn't useful for a bigger case study, due to its low converge velocity comparing with other optimizations approaches as found in [2], [5]–[7] and [9].

Simulated one year of demand response with those twenty providers, one aggregator and the System Operator to produce profit with demand response.

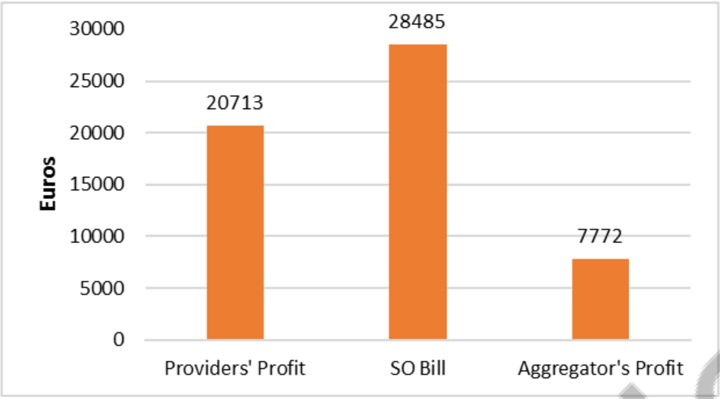


Fig. 30: Aggregation's result.

Fig. 30 shows how much SO most to pay for the system balancing after one year reducing loads in the high energy consumption's moments.

All providers will be remunerated by €20713.00 as showed before but in this valuer isn't includes costs of implementation of any device or other possible cost that can be made by adhering the program. Aggregator will be remunerated as the difference between SO's Bill and Providers' profit, due to SO pays to the aggregator and aggregator pays to providers.

## 6. Conclusion

This model is a new approach to manage demand response with aggregation. It's an important role to improve links between small providers of renewable energies and/or demand response with the electricity market, where is needed more purchase power to deal with that environment.

Its validation has been done in a simple way so the second step for future works is simulate with real time load to measure power reduction with real devices to control the system's response. Loads most have a real reducible power with a useful machine (for example, heating, cooling, elevators, light controlling, etc…) can be changeable examples for demand response applied in real terms.

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