The conception of the aggregator in demand side management for domestic consumers

Muhammad Babar[*], Talha A. Taj, T. P. Imthias Ahamed, Essam A. Al-Ammar

Saudi Aramco Chair in Electrical Power, Department of Electrical Engineering, King Saud University, Riyadh, Saudi Arabia

Abstract

In the demand side management (DSM) the aggregator is appearing as a key player in managing the demand during the peak hours by acting as an energy manager between the utility and the consumer. In this work, an emerging concept of the energy service provider as a business entity for domestic consumers is discussed and focuses on the interactional issues between the utility, the aggregator and the consumers. The paper also discusses the role of communication in the interaction among the three players.

Keywords: Aggregator, demand side management, smart grid

1. Introduction

The increase in consumption of energy resources have highlighted the importance of energy saving across the globe. In past, the main source of energy has been fossil fuel. Therefore, now sustainable energy technologies are poised to become an integral part of the energy supply chain in order to cope the skyrocketing energy demand. Various countries are planning and developing strategies and giving incentives to public for the promotion and development of sustainable energy projects [1]. It has been recognized that investments in Peak Power Demand Management such as load curtailment programs could be significantly more cost effective than building new power plants to supply the peak demand load [2], [3].

Researchers have identified significance of demand response in demand-side management program and consequently have presented many scheduling algorithms and formulated policies and strategies for demand-side management [4], [5]. However, in the emerging electric power market structures, there are opportunities for third-party aggregators to provide demand-side services to multiple consumers. The aggregated response of these can have a significant effect on the power demand if the consumers are willing and committed to load reduction programs [6].

Till today, the implementation of aggregated demand response across the distribution and transmission network has not been addressed in the details. The paper discusses the emerging concept of aggregator in the context of domestic consumers and the paper also focusses on the main implementation issues including the interaction of the aggregator with the consumers and the utility and the strategy for the communication/control network. Thus, the key players in this framework are the consumers, the aggregator and the utility. In the following sections, the role and responsibilities of all three players are discussed along with their nature of interaction and possible communication strategy among each other. Section 2 of the paper discusses the interaction between the utility and the aggregator and Section 3 discusses the interaction between the aggregator and the consumers. Section 4 presents the communication strategy for the framework. Finally, section 5 concludes the paper.

2. Utility and Aggregator

Till today, there is no precise definition for the aggregator. But, in general, aggregator is an energy service provider between the utility and the consumers. The aggregator has an objective to shave the peak demand as well as support the utility in supplying uninterrupted and high quality power to commercial, industrial, institutional and domestic as well as electric vehicles during peak hours with ancillary services [7].

Since, it is challenging for the utility to directly communicate and control thousands of consumers. Therefore, the utility sees the aggregator as a large consumer and an important factor in the smart distribution network. There can be two types of interaction between the utility and the aggregators which are discussed below:

2.1. Mutual interaction

Aggregator can act as a retailer that buys electrical energy at the day-a-head energy market and the utility also makes an ex-ant validation regarding the price bid by the aggregator. On the other hand, the utility provides information and expected demand curve in advance for a particular peak period to the aggregator.

2.2. Directed interaction

In other case, utility directs the aggregator that it has to curtail certain bulk of power whenever it requires. For this service, it would be rewarded by the utility. So, one of the issue in this kind of agreement is that what would be the rewarding mechanism? Because the utility may pay a fixed reward to aggregator against its services or this reward could be based on any dynamic pricing model like time-of-use, critical peak pricing etc. Nevertheless, most of the business models either proposed by the researchers or implemented by the utilities stand on bilateral contract with dynamic pricing model based on critical peak pricing [8], [9].

2.3. Contractual matters

Contracts between the utility and the aggregator may be bilateral or unilateral. If the contract is bilateral, then it is an agreement in which the utility promises to pay the aggregator and in exchange the aggregator promises to curtail the identified power. It means both parties, i.e., utility and aggregator are contractual bound to obey the terms and conditions of the agreement. However, if it is a unilateral contract, then only utility might promise to pay the aggregator if it curtails the identified power. It means that aggregator is not under any obligation to curtail the identified power, but utility is under an obligation to pay a reward to aggregator if it does the job.

For reference, PG&E has started non-tariff program named "aggregator managed portfolio program" according to which it signs bilateral contracts with aggregators by which it may call power curtailment events during high-price periods, emergencies and tests with price-responsive pricing mechanism [10].

3. Aggregator and Consumer

After the advent of Domotics, the controlling of home appliances becomes easier and cost effective [11], [12]. Therefore, nowadays the aggregator and the consumers can easily interact with each other. On the other side, aggregator has to control the load of the consumers by developing systematic control strategy such that it achieve the win-win condition i.e. maximize its own revenue, minimize utility's operational cost and provide incentives to the consumers. Since long it has been an issue for the aggregator to attract the consumers for demand side management (DSM) and retain them. Therefore, lot of effort has been made by the aggregators in order to attract and motivate the consumers such that they allow aggregator to directly control their dispatchable loads during the peak hours. Thus, the interaction between the aggregator and consumer can be classified into the following three types:

3.1. Direct load control (DLC)

DLC is a conventional demand side management technique according to which the load is controlled by the aggregator at any time but in exchange consumer is not rewarded at all [13], [14]. Because of this DLC was not considered as a successful DSM technique and was not appreciated by the consumer.

3.2. Price based control

Currently, many aggregators are providing price-based manual or automated DLC programs to their consumers. By this strategy, consumer may be rewarded in many different ways, among these the most common reward is that consumer would gain fixed price against the load reduction. On the other hand, most of the aggregators are offering dynamic pricing mechanism and thus the consumer would be rewarded with the price based on real time electricity market [15], [16].

3.3. Incentive based control

However, very few researches considered incentive-based program for the aggregator such as energy bidding pricing model [17], [18]. Indeed it could be an opportunity for developing nations that are currently either planning for or implementing the smart network, to consider incentive-based DLC model for commercial and domestic level. Because, incentive-based pricing mechanism effectively caters the social issues like consumer satisfaction and privacy than price-based methods and it also enables consumers to directly interact with energy market by bidding against their power curtailment. The implementation of aggregated demand response with these new features will attract a large number of consumers to perform demand response and gain full benefit from it without altering their life style and personal space.

3.4. Contractual matters

Similarly, contracts between consumers and aggregator may be bilateral or unilateral. If it is a bilateral contract, then it is an agreement in which the aggregator promises to pay the incentive to the consumer and in exchange the consumer promises to switch off or regulate the specific loads to reduce the required consumption. However, if it is a unilateral contract, then only aggregator promises to pay the incentive to the consumer if it switches off or regulates its load. It means that the consumer is not under an obligation to control the load, but the aggregator is under an obligation to pay a reward to the consumer if it shuts the loads.

Most of the contracts implemented by the aggregators or proposed by the researchers for either European, Scandinavia or North America consumers are bilateral contracts because unilateral contracts mainly support the indirect load management strategy which may result in uncertainty and severance during the time of contingency. However, bilateral contracts provide provisions for a variety of load management strategies i.e. indirect, automatic and direct load control.

It can be inferred that most of the literature developed the business model of aggregator with price-responsive mechanism and thus it is easier to implement it for those nations who have already implemented smart network at their domestic level [19], [20].

4. Communication Strategy for Interaction between the Players

The bi-directional communication networking of the smart grid infrastructure enables many demand response (DR) technologies, which control hundreds or thousands of distributed energy resources over vast geographic areas [21]-[24]. There are a number of communication access methods that can be used for the data transfer between the distributed consumers, aggregator and the utility. Wireless communication networking is a capable option because it has a wide-coverage area and low installation and maintenance cost but the consistency and dependability of wireless communication is to be understood. As, the demand response requires continuous exchange of data among the end devices and the aggregator. Therefore, the quality of the wireless communication is one of the major factors, which

also needs to be taken care of.

Now, how to design, implement, and practically integrate efficient communication infrastructures with power systems towards an operable, cost-efficient, and backward-compatible communication solution, such a fundamental question should be elaborated in all critical aspects, including detailed communication requirements, system reliability as well as satisfactory system performance [25]. The major issue while deploying a communication network is to select the network design topology on the basis of which a wireless network infrastructure is constructed using a single or a multi-hop architecture design technique. The optimal routing topology can be selected by running simulations on a hypothetical DLC model using different routing algorithms.

ZigBee Technology offers cost effective solution to communicate up to 65,000 devices present in the same network. So, the ZigBee technology can also be used for communication between the dispatchable loads and the central controller of each consumer. Moreover, communications between the consumers and the aggregator can also use secure Internet link or EDGE technology.

5. Conclusion

The integration of domestic and industrial consumers demand side management via aggregator will help the grid in coping the demand peak during peak hours. Moreover, the utilities and energy regulatory bodies have a new player to do business with i.e. the Aggregator. So, by an appropriate contract between the utility and the consumers, the aggregator can benefit the other two players and can also make revenue from this service.

Future works include the design of consumer selection techniques to optimize the proposed functions of the aggregator. The major obstacles in the implementation of this program are initial investment, consumer awareness and willingness and government policies and strategies. Thus, the key players which include Government, Regulators and Appliance Manufactures should take measures to materialize this concept of aggregation.

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