Services that enhance the Demand Response Capability

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Abstract:

Electrical power system has unbundled in many countries of the world, thus encouraging the energy suppliers to implement demand response programs. Recently, the energy service providers have been looking for a DR program that is driven by the retail market environment. Thus, this paper summarizes the evolution of market-based demand response (mDR). This paper also proposes the key phases required for the successful implementation of mDR for every energy service provider. Lastly, this paper discusses the existing technologies and researches that could be arranged together by using the proposed rule of success in order to make the mDR a reality in near future.

Keywords:

Demand Response, Market-based Control.

1. Introduction

In energy crisis of 1970s, power system faced high spikes in energy costs, thus stimulating power system economists to find a sustainable solution in order to avoid energy crisis in coming future. Therefore, in late 1980s, efforts have been made to restructure the traditional electricity market into open market system. The objective behind these reforms is to change the way of operation and business of the electricity market from vertical integrated mechanism into decentralized deregulated mechanism in order to introduce fair competition and improve economic efficiency. Moreover, economists proposed that the vertical integration of power system from supply to end-users is no longer exist due to the liberalization of the electricity market. Therefore, the EU has enforced the unbundling of electricity companies in order to deregulate the electricity market under the DIRECTIVE 2009/72/EC [1].

Currently, in the liberalize energy market, an energy supplier (ES) is a market participant which buys electricity from generators through the wholesale market and/or forwards and/or has its own generation portfolio and sells electricity to end-users. Furthermore, the ES can offer consumers either fixed or dynamic tariff. Nevertheless, transmission and distribution network operators operate in a regulated environment by charging a yearly fixed grid tariff from consumers, independent of energy consumed. An overview of the existing market structure is shown in Fig. 1.

Later in last decade, the concept of demand response (DR) was introduced by the US Department of Energy, which defines DR as “Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.”

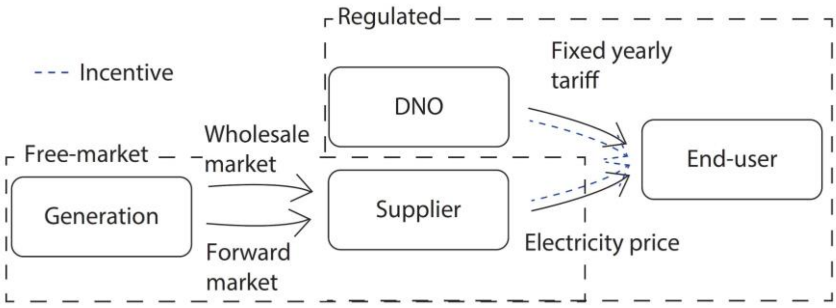

Fig. 1: Overview of the market structure [19].

The goodness of this concept is that the current structure can be left unchanged for the inclusion of DR in this market structure, such that the ES has the possibility to give incentives on top of their current electricity tariff/price. In this way, electricity prices become dynamic at which the consumer can react. In principal, the total energy cost for the consumer will be lower if he alters his load based on the variable price. Hence, it is inferred that demand response can help in mitigating the volatility in electricity market by three ways i.e. load shifting, load controlling and limiting grid reinforcement [2].

Recently, the liberalization of the electricity market has led the ES to use DR as trading commodity in the wholesale electricity market, this concept is currently referred as Market-based Demand Response (mDR). mDR not only allows large consumer to put their value proposition and energy-bid against their DR services but also enables an opportunity for domestic consumers to participate in the retail electricity market via ES. Therefore, this paper made an attempt to discuss about the key phases involved in order to materialize the concept of mDR , in section 2. Secondly, in section 3, the paper identifies the recent researches presented in order to implement the mDR . Lastly, section 4 concludes the paper.

2. Four Phases of Success

Currently, the precise shape and mechanism of market-based demand response (mDR) is under discussion. This section highlights the key four phases i.e. Logical, Physical, Controlling and Fulfilment required for the successful development of mDR as shown in Fig. 2.

2.1. Logical Phase

This phase analyses the total consumption of the end-user and its capability of load dispatching. It also devises the bid, which is a price proposed by the customer considering its value proposition and demand reduction. There are two sub-phases of this phase. In first sub-phase, the capability of load dispatching of each device is analyzed. It also collects the outline proposition from each dispatchable load and develops the aggregated bid. In the second phase, the local demand dispatch problem is solved, thus finding local optimum such that the total energy cost in a given time period should be reduced. Since this phase communicates the optimal final solution to other phases in terms of aggregated bid, so this is a fundamental phase for the development of mDR because it acts as an anchor point for the rest of the mDR cycle.

2.2. Physical Phase

This phase is about the physical development of mDR i.e. the development of physical technical architecture as well as the development of the retail market architecture. The technical architecture is usually a combination of ICT infrastructure and the smart control system that includes all those technologies, which are required to implement the first phase. On the other hand, the retail electricity market is a place where all participants gather their value propositions and strive to find the system equilibrium. Thus, the retail electricity market has two obligations. First, the local needs of all players should be assured. Secondly, the global needs of the wholesale market have to be optimally aligned and assured.

2.3. Controlling Phase

This phase deals with the selection of suitable decision-making approach. There are two approaches, which are generally considered for making decision in achieving mDR namely transitional or transformational approach. The transitional approach usually considers homogeneous modelling of dispatchable loads for scheduling and controlling which means that all devices are modelled as independent atomic load. Independent atomic load is a load model in which load cannot be interrupted once scheduled for a given time period as well as its scheduling does not depend on the scheduling of other loads. However, the transformational approach considers heterogeneous modelling in which dispatchable loads are modelled as dependent non-atomic load. Dependent non-atomic load is one that can be interrupted as well as it depends on the scheduling of other loads.

In the short, this a phase in which ES decides its decision making approach such that the energy should be scheduled and controlled without altering the value propositions of consumers.

2.4. Fulfilment Phase

The final phase incorporates both the strategy and the decision making approach. First, the ES reviews the aggregated bid. If, in case, the aggregated bid does not suit to the final execution then the demand response cycle iterates again till the final stage converges to an acceptable point. Then, once the aggregated bid is accepted, it sends the bid to the retail market for final execution.

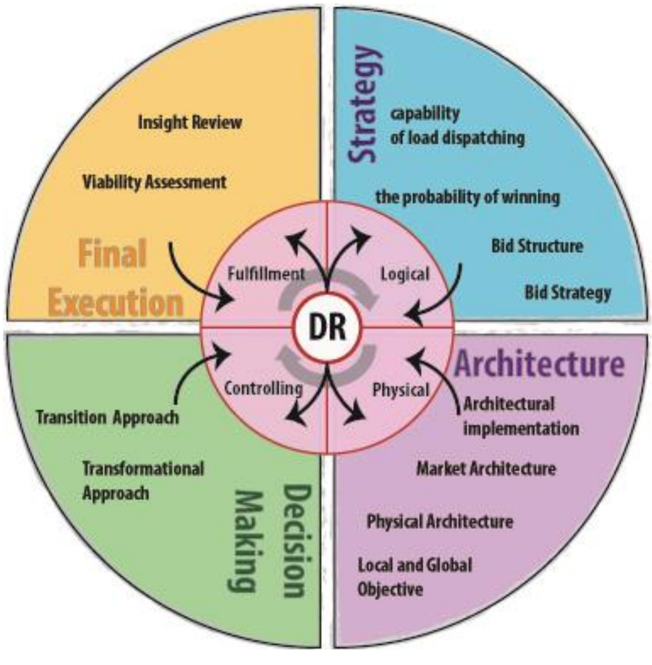

Fig. 2: Four fundamental phases required in implementation of mDR.

3. Market-Based Demand Response

In this section, the paper in the light of literature highlights the work done in each phase, discussed in section 2.

3.1. Logical Phase - Bid Strategy

In ref. [3], Palo Alto Research Centre Incorporated (PARC) presents the distributed control of time shifting-loads over price signals. Furthermore, they optimize the control by considering device parameters (i.e. temperature, cycling power etc.) with an aim to minimize the price paid to the end-consumer. Similarly, EnerNOC is using a methodology of energy bidding for large consumers [4]. Herein, the organization calls the participating consumers to reduce the power available at their disposal during the given time period. In the exchange of this service, incentive payments are paid to the consumer according to the market price. Furthermore, Comverge is the energy service provider that has already implemented the incentive-based load control mechanisms over consumer's thermal appliances [5]. Similarly, EnergyConnect has released the GridConnect platform for commercial or large consumers which has enabled the consumer to manage their bid via website [6].

3.2. Physical Phase - Architecture

mDR programs has been formulated in some papers such as [7, 8]. Ref. [7] presented the economic model for iDR programs by using the concept price elasticity of demand introduced in [9]. According to the concept of price elasticity of demand, consumer would change its demand provided it is paid for the demand reduction as per its value proposition.

However, a new concept is introduced in [10], [11] and [12], where DR is treated as a commodity. Ref. [10] devises a DR Exchange, in which buyers and sellers trade DR in a pool-based market. The market is modified in [11], where a Walrasian market clearing technique is used instead of the former pool-based method. Relatively different approach is presented in [12] where a coupon-based method is formulated where incentives offered to consumers is determined according to the market price.

Additionally, few papers address mDR as a distributed resource in the retail market environment. As [13] evaluates two different interruptible load contracts, namely pay-in-advance and pay-as-you-go, can help to alleviate the supply problems which are associated with spikes of price and demand. Moreover, it could increase the competition between retailers, thus resulting in lower price and less frequent price interruption. Ref. [3], [4] and [14] have implemented a mechanism in which the DR of domestic consumers would be traded as commodity in retail market.

3.3. Controlling Phase - Decision-Making Approach

Recent advances in ICT and decentralized decision making approach have enabled the ES to manage distribution energy resources and dispatchable loads by using mDR.

Ref. [15] considers transformational approach in which authors modelled the load as dependent non-atomic. Moreover, authors presented that such loads can help in mitigating network issues during peak hours.

Whereas [16] uses the same transformational approach to alleviate the uncertainty of pool markets faced by a service provider.

Ref. [17] discusses a concept in which they mixed the concept of energy bidding (first phase) in the transformational approach (second phase). Furthermore, they also present a short-term deterministic model to solve the challenges of supply and demand balancing in the retail market environment.

3.4. Fulfilment Phase - Final Execution

Ref. [14] and [18] shares the experience of market-base DR implementation by using multi-agent systems (MAS). In MAS for the implementation of mDR, each downstream agent communicates a bid as function of demand to the upstream agent, in response downstream agent gets a price signal to act accordingly.

The software applications or agents have an aim to locally match the power supply and demand in the local grid. In this way, the global objective of the agent is to match the supply and demand at run-time environment and is responsible to represent the value proposition and bids of committed customers at whole sale market. The local objective of the agent is to manage the pricing as well as demand dispatch i.e. optimally solve the load scheduling problem. However, in MAS, any agent can have its own decision making approach depending upon its value proposition.

4. Conclusion

In this paper, it is discussed that the unbundling of vertically integrated power system has given a way to many nimble competitors and new markets entrants into the retail electricity market. Due to this liberalization, recently, the concept of mDR has been emerging in order to manage the demand by using energy bidding strategy at demand-side.

Nowadays, the proposed four phases are the key areas of research because these would lead the world towards the successful implementation of mDR. Thus, in the light of the literature, the following points are inferred: (1) the majority of studies on DR are focus on the basic concepts, formulations and technical aspects of DR,(2) though some papers address the economic concept, they mostly assess DR valuations from a customers point of view, (3) less attention has been paid to the applicability of DR by the energy supplier, (4) mostly the transformational approach is considered for decision making, (5) researchers have been looking into an hierarchical architecture of power system where physical layer is managed by top layers in order to mix different phases together.

Thus, this paper will bring the attention of the technical society and energy service providers towards a consolidated approach that arranges the parts and pieces of mDR in a phase-wise solution. The phases discussed in this paper would help the electrical energy society to work as a whole such that the development of mDR would be reality soon.

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