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A Review of Demand Response Opportunities and Challenges for Residential Applications in Smart Grid

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Abstract

Growing energy demands all over the globe and integration of intermittent distributed generations (DG) and impulsive routines of the residential users make the household load demand profile as volatile in nature. Therefore, monitoring the residential loads to control the growing energy demand and additionally balancing of supply-demand with the generation available. The decentralized structure of electricity grid facilitates the provision of Demand Response (DR) from small loads like residential houses or electric powered vehicles have become possible. But, there are nevertheless many demanding situations to the real realization of DR programs for such clients. Based on an in depth survey of the literature, this paper tries to demonstrate on exclusive load scheduling strategies, the characteristic of aggregators in the realization and enlargement of DR in the modern grids. The major security and privacy issues are addressed in network system. The overcharging and over discharging of Electric Vehicles (EVs) are monitored and controlled by the Demand Response Aggregator (DRA) model. The uncertain problems like pricing, load demand variations, EV characteristics and intermittent nature of power sources are taken into a problem formulation technique of aggregator model. DR resources are flexible and better cost effective solution to handle this variability of renewable energy resources. Moreover, ancillary services are provided for grid stability and reliability requirements. Also, clustering of consumers in different groups is necessary for DRA in targeting the program and consumer participation which makes them beneficial in optimizing performance. Reduction of loads is done by shifting of loads, load curtailment, onsite power generation and energy storage systems. This survey reports deals with the demand response implementation, challenges, advantages and analysis in the domestic loads.

Keywords: *Aggregators, Demand Response, Distributed Generation, Electric Vehicles, Load Scheduling, Power Monitoring, Smart Grid.*

I. INTRODUCTION

DR is considered as one of the essential elements of smart grid implementation along with energy conservation programs [1, 2].The definition of DR by using FERC (Federal Energy Regulatory Commission) is "The adaption of electricity needs to time pricing or incentives which consequently can enhance the performance and reliability of electricity networks" [3]. The fantastic usage of electric automobiles (EVs), the mass rollouts of advance metering systems and the large investment in renewable technology resources have substantially encouraged the DR research in recent years. The enormous penetration of EVs in the electrical grid may cause an increase of the peak load and they also can deliver electricity again to the grid within the vehicle-to-grid (V2G) mode [4]. Therefore,

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EVs can be seen as flexible loads that can consume as well as store energy, which makes them an appropriate source of DR implementation. On the opposite hand, smart meters (SMs) because the essential parts of advanced metering infrastructures (AMIs) have been deployed hugely in unique elements of the arena in recent years [5]. The records supplied via the SMs may be utilized to enhance DR programs. The high penetration of green energy resources in electrical networks, which have inherently intermittent natures, might jeopardize the system protection, makes using DR greater sensible. All of these elements have prompted an increase within the DR quantity and a bent to make use of the top notch capacity of residential loads for DR applications in conjunction with huge consumers (commercial facilities and commercial homes) that historically had been taken into concern the principle resources of DR.

Long or short term DR applications of small loads are best viable in the event that they can be “aggregated” nicely. So, these days in distinct electricity market structures a brand new entity known as “aggregator” has been included to work along with transmission and distribution operators and energy agent. However, there are nonetheless many unsolved questions concerning the role of those aggregators the interactions of them with consumer and system (broker) operators, and the demanding situations that they in practice face. DR programs are normally categorized as: price (time) - based DR and incentive (event)-based DR [1, 6]. In price-based (DR) approach electricity pricing varies depending on the usage instance. The price-based DR programs concern about the critical peak pricing and time of use pricing, hence cost of electricity units of users with different cost for different usage instance of day (on-peak, mid-peak, off-peak) [7].

Incentive-based approach gives rewards to users for reduction of demand when the system under stress and instances like peak load or system contingencies. Foremost incentive-based applications are interruptible/curtailable (I/C) load and direct control. Direct load control (DLC) can be remotely cycled or grew to become off with the aid of the utility, and can commonly be deployed easily [8]. In I/C approach, clients get hold of a discounted rate for agreeing to lessen load demand when the grid reliability is at risk. There are also numerous unique rate-based or incentive-based programs for DR with which huge was used by big customers in industrial sectors [9].

II. OVERVIEW OF DEMAND RESPONSE UNDER THE FRAMEWORK OF SMART GRID

One of the primary endeavours of smart grid implementation is to make the conventional grid structure in to decentralized and operate to an energy efficient energy and cost-effective grid. Both the objectives can only be met if the unpredictable demand is matched with the variable renewable energy generation and increasing the number of participating users (or devices) in DR programs. DRA (Demand Response aggregator) is considered as a promising way for the exposure of small customers or loads to wholesale electricity markets and act as sub-set of broad DSM strategies.

The principal purpose of the existing DSM techniques is specifically curtailment of shiftable loads to attain peak demand saving [10]. Therefore, whole domination of the carrier provider makes the DSM strategies less attractive to the customers as their privateness subject are at endangers. Whereas, the DRA goals to manage the usage of the customers even as thinking about the users’ possibilities.

It can manage DR and can be paid on the relevant nearby spot charge for this response. Generally bulk consumption users like factories and commercial consumers had been considered for DR aggregations [11]. But growing demands in recent years greater interest has been paid to the aggregation of residential loads and EVs. The DRAs, on behalf of residential consumers, can participate in specific markets. Once the market is cleared, the DRAs acquire the DR schedule and require the customers with everyday gives to lessen loads at some stage in the shrivelled DR periods. A basic arrangement of DR associated to DRA is illustrated in Fig.1.

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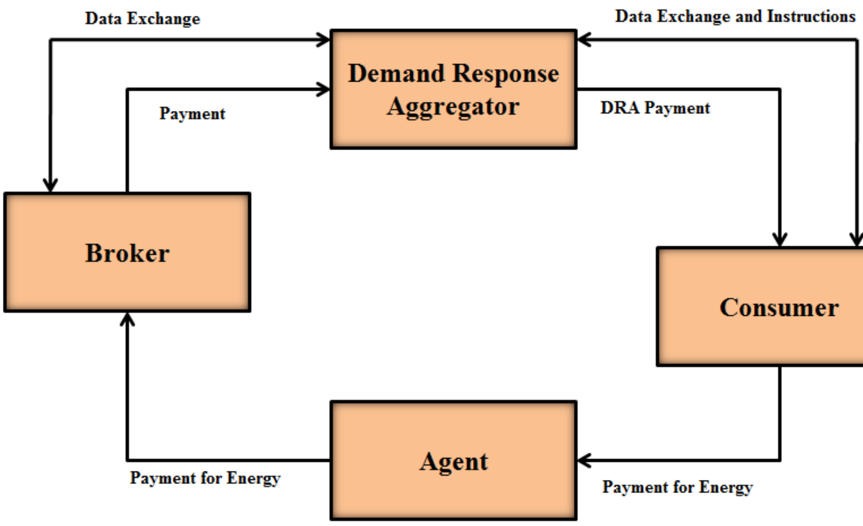

Fig. 1. Demand response aggregator model

In practice, aggregators may be linked to other aggregators at higher and lower levels. So, for instance, a massive constructing may additionally act as a lower level DRA for its occupants and then be connected to an upper DRA. As every other example [12], it's far feasible to have two distinctive DRAs for TCLs and EVs and at higher stage they can be merged by one aggregator.

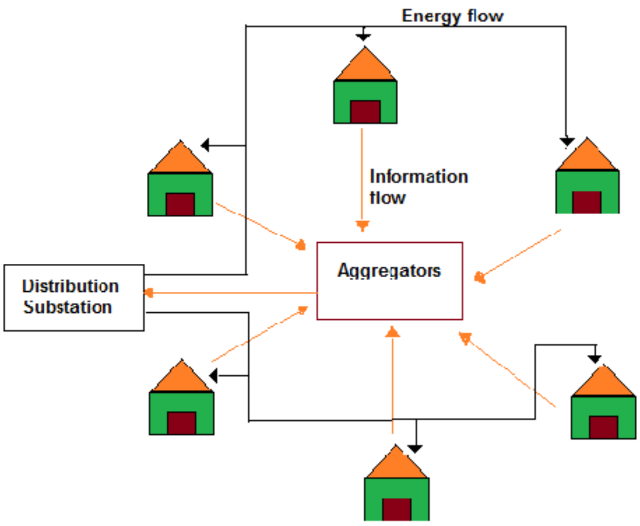

Fig. 2. DR centralized controlling schemes

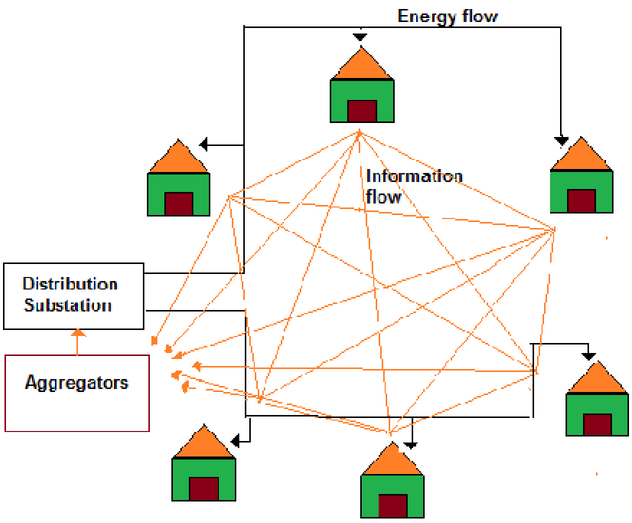

Fig. 3. DR decentralized controlling schemes

Depending upon the adopted application strategies the DR schemes can be classified into below mentioned subcategories.

1) Centralized Control

In the centralized control schemes supplier will coordinating the consumer loads i.e. reduction of the peak demand and consumer will communicate only with the aggregators. Consumers communicate about their choice of load profile to the aggregator and based on that energy provider controls the shiftable loads and dispatch schedule as presented in Fig. 2. Main advantage of this control scheme is that it takes care of the overall system condition while scheduling the loads to avoid any line overloading or voltage dips. Whereas privacy breach is the main drawback of centralized control approach.

2) Distributed or Decentralized Control

In these control design, end users are permitted to plan their consumption pattern once request obtain from the operators. Hence this control scheme makes the consumers as active participant towards the DR program as shown in Fig. 3. As right here management of load is carried out by means of the consumers, in those controlling schemes energy company proclaim the actual load based actual real time prizing on a rolling basis to avoid unbiasing to any unique incentivize the users for violating or obeying their registered DR program respectively.

III.RESIDENTIAL DEMAND RESPONSE AGGREGATOR MODELING AND APPLICATIONS

According to the previous articles residential loads are mix of critical demand (e.g. lighting loads, refrigerators etc.), thermostatically controlled loads (e.g. HVAC, electric water heater etc.), flexible but uninterruptible loads (like washing machine) and shiftable & priority loads (e.g. clothes dryer). In resistant loads the DRA performs the aggregation of small DR; therefore, no interest is paid to the resource of DR, the methodology of aggregation [19-22]. For example, in [14] DRA offers multiple conventions to users and ask for maximize its rewards for partaking in the market. But this procedure does not state a special kind of appliance and [16] describes the interaction of several DRAs in a two-level leader-follower framework in which energy scheduling problem for a load serving entity that serves both inflexible and flexible loads is discussed. A few numbers of works are available about the aggregation process of residential loads. In [17] used a smart-link which includes various nodes allowing as many DRAs in a hierarchical way. For example, in a system with a two-level hierarchy of nodes, the upper DRA connects with the suppliers and three bottom DRAs which are responsible for the illumination, white goods, and HVAC and heaters respectively. In [18] implements a multi-agent game approach to residential DR aggregation which shows the communication of self-interested resistant loads with a DRA in order to incorporate two separate sub-issues of DR aggregation with home energy management systems (HEMS).

1) Demand Response by EVs

EV charging points can be managed by a DRA who make finest decisions for discharging and charging of EVs in order to reduce cost of charging and also to keep away from voltage and overloading problems in the grid [28-30]. The use of various modern technologies like GSM, GPRS, RFID and Ethernet etc makes it possible to connect DRAs to EVs and collect all dynamic as well as static data of batteries to manage and decrease the total cost of energy [20]. This data may include the type of battery, SoC (State of Charge), and real time discharging/charging levels. By agreeing to such a charging management scheme, EV owners benefit from lesser energy rates for charging and ancillary service markets [29]. The authors in [21] suggest a distributed DR algorithm for EVs to shape the cumulative daily demand profile of the system while maintain the peak energy demand as same as no EVs in the system, without any changes in the users' commuting behaviours. In[22]adopts optimal algorithm for charging start time, which meets charging demand and also significantly reduces peak and filling valley, reducing the impact of EV charging on the distribution network.

2) Prerequisite of Ancillary services

The shiftable loads can generally reacts very promptly. Such shiftable loads are good choice to giving ancillary services which includes spinning reserves and non-spinning reserves and regulation of frequency. While spinning reserves are provided to injection of power to maintain the network frequency inside the limits for frequency regulations and counterbalance the power shortages [2]. According to the order 719 by FERC, an independent system operator is essential to allow demand resources to contribute in ancillary service markets [23]. As [23] implies, the spinning reserves with loads can be attained via curtailment time to be short, hence it avoids disturbance of users' comfort. The articles [24, 25] pointed the techniques to organize aggregation of TCLs to control energy imbalances and frequency. In [24] uses state estimation methods for tracking performance of various TCLs, and [25] employs a model predictive controller to determine the TCL set points.

3) Advantages of Demand Response for intermittent resources

The widely accepted renewable sources such as photovoltaic and wind are intermittent and undispatchable; these green energy generations can participate in a race with conventional generation methods in the market. The DR programs have ability to handle the above said intermittent behaviours. The integrating DR programs with renewable energy generations can handle the occasions, such as during windy nights, when more wind driven renewable power can be generated than the actual demand in such situations shifting some daytime loads to night times and facilitates greater renewable generation penetration [2]. In [13] estimate the combined procedure of a wind forms with the loads which take part in balancing markets and intra-day. Also, [26, 27] examine the optimistic benefits of DR on the wind form a short term trading.

4) Contest among DRAs

Only very few articles has addressed the relationship and communications among the aggregators. In [21] imply the relationship and communications between the market operator, several aggregator, and end-residential customers on a market hierarchal structure. Also [28] addressed for a two level market model interface of several aggregators in a micro grid environment.

IV. DR AGGREGATION CHALLENGES

The proper transportation for the bidirectional transfer of data among the system operator and DRA and the customers and between DRA's data centre is the primary pace for DR realization [24]. The use of present internet communication network has been recommended for data transfer between aggregators and buildings (HEMS or devices). But such network doesn't fit in to power networks. The proper solution for adding DR aggregations is by implementing of AMIs. The cost should be considered carefully for implementing such infrastructures and other necessary equipments for the DR management. In the literatures numerous works have been addressed the data exchange between the DRA and end-users. Hence, scalability problem may occur in a large scale employment [21].

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Centralized and de-centralized approaches vary in functional complexity, execution times and optimization techniques [20]. As recommended in [23], a potential way to employ AMIs and transmit one common signal to all loads. The propagation delay is a further challenge connected with AMIs as they will influence both the performance of grid and stability [29]. When DR program providing spinning reserves, a fast response times are needed or regular control updates are issued at the instance [23]. Eventually, privacy and security problems occurred when AMIs and SMs in the majority of cases belong to other entities like retailers/agent or market operator/broker. Before and after DR event there may be an increased consumption pattern occurs called “lead” and “rebound” effects [2]. Lead effect is caused by the anticipation of a DR event, for example a building can be pre-cooled to cut the air conditioning load in afternoon. After the DR event completing, the increase in power consumption contrast to the base-loads represents the rebound effect. Also, during the DR periods there is possibility to occur load unbalance between the phases because of asymmetrical DR distribution on each phase [2]. DR programs generally disturb consumer’s consolation. Hence, attractive incentive- based packages are wished to steer users to get concerned in DR programs. Many current top demand management applications that make use of DLC are disruptive and may have large consequences on the user’s comfort [23].

For example, during the summer days the more consumption of power, so, little period of interruption in the air conditionings irritating them when their services are most in needed. Besides this, the price-based programs usually initiate reliability problems and in addition new peaks of demand by shifting power to cheaper off-peak hours from expensive peak hours. Also, complexity of dynamic pricing end-customers may be doubtful to contribute in DR programs [31]. Another problem occurs if wrongly modelling the baseline loads because calculation of load to be curtailed based on baseline loads, which insist the proper technique for modelling the baseline. Consumption pattern of customer, rough handling of sensitive loads and willingness to participate in DR are other important issues that significantly affect DR policies [30].

They can also incur penalties if the declared quantity of DR can't be met. Finally, the excessive degree of variability of the system and controllers inside the consumer side and within the network imposes real demanding situations for DR aggregation and demands proper requirements and communication structures that are interoperable among unique gadget and manipulate structures [29]. In precise, there may be a need to outline a right structure for DR aggregation including appropriate standards and protocols to attach diverse retailers in a hierarchical shape and to allow moving of information and commands. The efforts like open automated call for reaction (Open ADR) [2] or the shape proposed in [17] are a number of these examples.

V. CONCLUSION

The present study addressed a deep survey on administrative and practical challenges that should be undertaken to incorporate electric vehicle owners and residential customers load in DR programs. The survey points out that the responsibility of demand response aggregators; inspect the opportunities and challenges for actual aggregation and the realization of demand response programs for small-scale consumers. The literature survey states that the DRA studies till now, through appearing software program simulations. Whereas actual converter control topologies integrated with an efficient load control program on a sensible hardware prototype remains left.

VI. FUTURE SCOPE

The study should focus the characteristics of reverse power flow and its improvements in operational requirements. The intermittent nature of RESs should be taken into account, while calculating the grid stability. Moreover for the decentralized control scheme, efficient communication tools need to be strengthened.

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