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Research paper

Demand response programs in smart grids – survey

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Abstract

The smart grid in this century has an essential role in changing the philosophy of the electrical power engineering. In the past, the generation must be equal to the demand under any situation but with the introduction of the non-conventional grids everything is changed, and the customers should consume energy in the same amount to what already generated from the generation units. The tool to achieve all that is the demand response (DR) strategy. DR can alter the consumption pattern of the consumers to make it flatting instead of the sharp curves that lead to additional costs coming from the increasing generating in the periods of the peaks in the load curve. In this paper, the demand response programs listed and discussed with an indication to the documents that deal with each type.

Keywords: *Smart Grid; Demand Response; Demand Side Management; Load Scheduling; Smart Metering and Bidding Strategy.*

1. Introduction

The electrical power is the most efficient useful energy image among all the other energies and can be helpful to all types of the consumers. The generated electricity in the remote generation stations transferred through the transmission lines to the destination areas by a massive electrical grid spread throughout. In the regular power grid, the energy flows in one direction from the source to the loads and this is called the conventional power grids [1], [2]. The new alternate scheme is the smart grid that illustrated in Fig.1. This modern grid has two ways to transfer the energy and the essential data from the generation station to the consumers and vice versa, and that created a smart electrical power network. The unconventional electrical grids have many names like the intergrid networks or the intelligent power delivery networks besides the smart grids and that a well-known name [3].

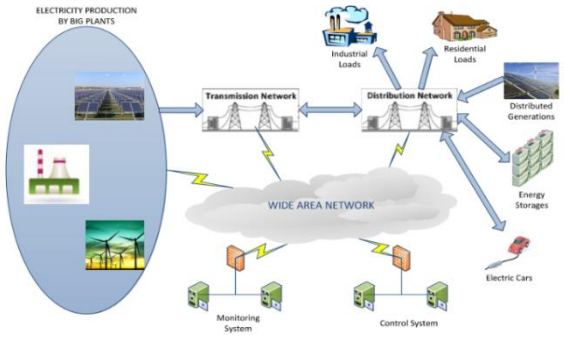

Fig. 1: Smart Grid.

The intergrid network can define as the grid that can make the users already connected (generators and the clients) producing a specific response to achieve a cost reduction in the generation and the electrical charges paid by the consumers. Besides all that it can ensure to provide power with secure and high quality as the European Union states. [4]. The difference between the old and new electrical power grids shown in Table1 [5].

Table 1: Features of the Traditional and Nontraditional Grids

Old Grids	New Grids
Electromechanical	Digital
Communicate by one way	Can communicate in two ways
Central generation stations	Include generation in distribution areas
There small number of sensors the monitoring is manual	There sensor in all the grid
Restoration is manual	Auto monitoring
Encounter blackouts and failures	Auto healing
Partial control	Islanding and Adaptive mode
The choice of control is limited	Control on all the network
	Unlimited control choices

Depending on the modern information ways, the smart grids can transfer power in intelligent ways and counter many critical events happened in the network. In general, it can solve any state raised in the generation or the transmission or the distribution [6]. The operating theory of the electrical generation from power station changed. The conventional way for generation aimed to supply the entire load in case of need in spite of how much watts the consumer needs. The current opinion now suggested making the consumer consume watts precisely in the same amount of available power produced from generation stations. The new philosophy will achieve optimal dispatch between the supply and the demand load. This balance is not permanent, but it can change due to many factors like load varying or the outages [7]. Nowadays, the way to satisfy the increased load by building new generation stations, using new storage units and applying the demand response programs(DR) [8][9]. One can define the DR as the difference in the usage of electricity by the consumers of the end-user from there a usual pattern of energy consumption to another one depending on price signal or some incentives [10]. The DR can grant useful features like the reduction in the load, penetration of the renewable resources in the conventional grid and work as an ancillary service in the needing time [11]. The matching between the supply of the power system

and the requested loads regarded as a conventional solution [12]. Adding new additional generation stations regarded not a good solution because this achieves the balancing for a specific period and leads to power losses [13] [14]. Besides that, the method of new power plants not likely used because it helps to complicate the problem of the increased greenhouse gases [15] [16]. The reports emphasise that the most renewable energy resources are the photovoltaic and the wind because it can generate low-carbon electrical power [17]. The problem of the renewable resources it is not economical and has intermittent nature expense [18]. The essential factor that both of them rely on is the weather state. That makes it not reliable and cannot utilise everywhere, and of course, it is non-predictable sources. [19] [20]. The old solution to achieve the supply and demand balance is by increasing the electrical power generation to be equal to the power requested by the loads, but the DR make the loads consume an amount of energy not more than the amount generated already from the power stations [21]. So everything or all the modifies on the consuming power of the consumers - all the activities that applied in the destination to reducing the load profile can be called by the Demand - side management (DSM) [22]. DSM generally indicates to the programs performed to manage the consumed power of the end-user consumers that achieved by the electrical utility [23] [24]. The advantages of DSM can cover the consumers as well as the utilities also. It can assist the market of electricity to work more effectively [25], and that eventually reduce the price of the wholesale market as a result of the reduction of the usage by the consumers [26] [27]. Moreover, the significant point about the DSM that it can allow the generation in the distribution area or as it called the distribution generation (DG) to penetrate the national grid and that can make the generation and transmission more economical [28]. The interests that are coming from the DSM are many, but the most effective among them that it can lead to a noticeable reduction in the emitting of the CO2 gas and help to heal the blackouts and the operating cost of the utility [29]. One of the central DSM actions is DR concurrently with energy-efficiency and conservation programs [22] [28] [30].

2. Demand response (DR)

2.1. Meaning of DR

DR means all the changes that happen in the pattern of the consumption for the end-user energy consumers because of applying variable prices in every period or by using the motivations like the incentive payments to urge them to lower their usage from electrical energy in the dangerous situations that can threaten the system reliability [31] [32].

2.2. Classification of DR model

The first classifications of the DR states that the DR may be dispatchable demand response (DDR) or a Dynamic pricing demand response (DPDR). The two categories are exhibited to the residential and also to the commercial consumers as they shown in Fig.2 [33] [34].

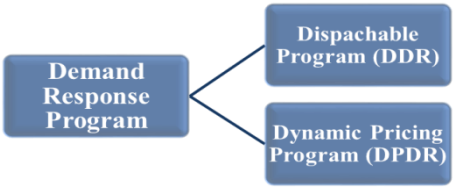

Fig. 2: The Main Categories of the DR.

In the first type, the customers or the participators in the program reduce their consumption according to an order from the utility. This type the reduction is previously intended, and the participant should obey the order or punished. One example of this kind is the direct load control on the devices of the consumer in the emergency cases. In the second type, the consumer is free to reduce their consumption whenever it like depending on the price of the Kwh in a specific period or the retail cost [35]. The second classification of DR programs says that it can divide into two main classes: economic-based or it named as Price-Based Programs (PBP) and the emergency-based, or it also called by Incentive-Based Programs (IBP). The first type can adept the consumer behaviour by using signals that doing a direct control over their loads while the second type can make the user use less energy by establishing many rates for each period [36]. This paper classified the DR into three branches. The first branch deals with the control mechanism that achieves the demand response. The second one deal with programs that make the customers shifts their usage depending on some payments. The last one deal with those DR programs that care about the decision variable as is shown in Fig.3.

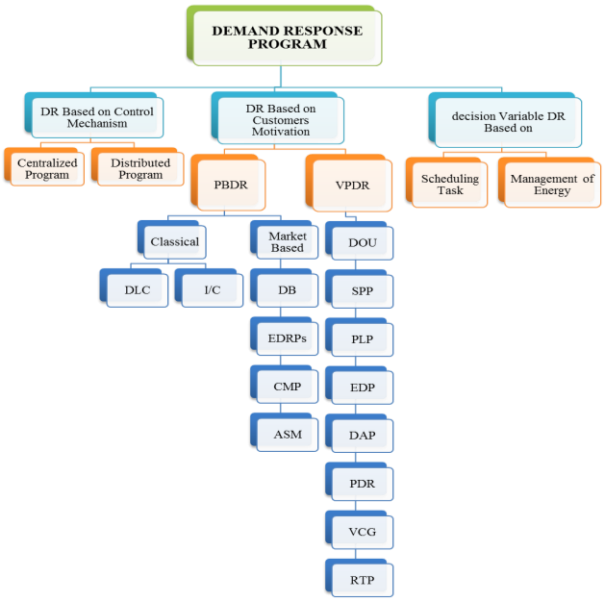

Fig. 3: The Main Categories of the DR.

2.2.1. Strategy of control process

The DR program that depending on the control process can subdivide to a central and distributed DR programs. The essential difference between them is which place the DR will be executed [37]. In the first category, the utility is the responsible for the decisions to make some loads in the active mode or make other loads in scheduling as the circumstances in that time required. In this strategy, the participators who desire to joining to the central mechanism program divided into groups. Each consumer separated from the others, and when some new users added to the group, the utility does not need the information about the others in the same group [38]. In centralised schemes, there is a needing to communicate between the utility and the participators only as it clear in Fig.4.

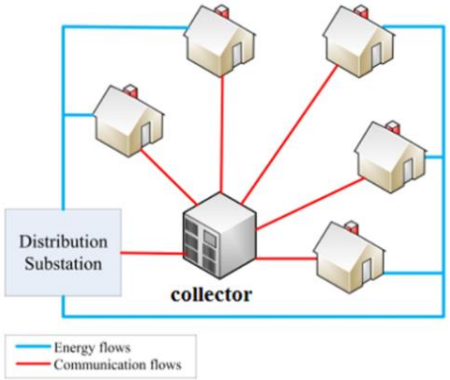

Fig. 4: Centralized Control Mechanisms.

In [38] and [39] the collector as is shown in Fig.4 is the responsible for taking the decisions for the scheduling loads. the centralized

technique can be used effectively for load managing in the buildings [40] and to arrange the charging of the plug-in hybrid electric vehicle (PHEVs) in the charging stations [41], [42] and also to control the devices with a thermostat [43].
Microgrid defined as a group of loads and micro-resources operating as an individual controllable item that gives power to its local area. Microgrids present a new model for the operation of distributed generation and have the capability to operate either in grid-connected or isolated mode. In the microgrid of the islanded mode, the controller is a central controller, and it can aid to combine the DG units with the general or utility network (macro network) [44]. In [45] authors explained the optimal power flow linked energy management systems to separate microgrids to achieve the optimal generation and peak load dispatch. There is an analytical model for intelligent loads in (DR) schemes, that combined into centralized unit commitment (UC). In [46] Milad Latifi and others used the centralized schemes in their paper. They used one method of the optimization technique to reduce the total cost that represents the aggregated value and at the same time achieve maximum profits for the retailer taking into the consideration obeying all the constraints. As an alternative, the second branch of the DR that based on the control mechanism is called a distributed scheme that shown in Fig.5. In this type, the data of the load for each participator not aggregated in one point (the collector) only but there is an interconnection between the consumer to make them exchanging information among them in addition to the essential connection with the collector [47]. Many researchers have been discussed the distributed control mechanism in the smart grid. For example, [48] the authors using Gaussian belief propagation (GaBP) solver and the process of interior primal-dual for producing quick algorithm used in distributed smart grids. In [49], authors give the solution for applying the continuous distributed optimisation in the models of Distributed Demand Response (DDR). The point one care for, distributed optimisation makes some challenging problems present themselves, like the presence of an ideal communication network, mainly when utilising wireless communication. Also, the total performance of the DR program that influenced by the communication channel properties.

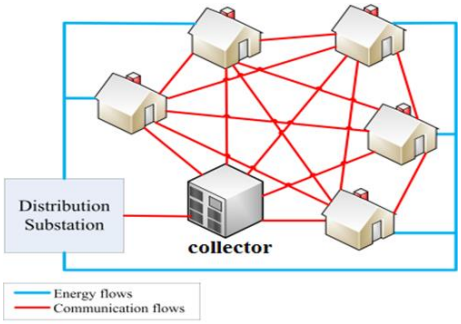

Fig. 5: Non-Central Control Mechanisms.

In [50], The authors address the DR problem in a multi-microgrid distribution system. The problem expressed in a distributed manner. The single agent role in the system is to solve its problem in coordination with their neighbours by transferring the power solution in each iteration step. Suigu et al. In [51] the authors use the HVAC (heating, ventilation and air conditioning) and distributed control algorithm together to examine the effect of the DR when applied to the structures that are not personal nor industrial first and with the multizone second. The DR papers mentioned above and regarded that its deal with the control strategycan summarize in the table2.

Table 2: Researches Discussed the DR Based on Control Mechanism

Control mechanism	DR Scheme
Centrlized	[41], [46], [47]
Distributed	[49], [50], [51], [52]

2.2.2. Payments motivation DR

One of the practical ways that make the end users changing their load consumption pattern is by giving payments as motivation offers, and that urge the consumers to participate in this category of the DR. This kind of DR can divide into two groups: variable periods-based demand response (VPBDR) and payments-based demand response (PBDR). The first class is dealing with the DR on a different slot of time that means the rate of electricity changed according to the market price or the peak load periods. The second class used the incentives to urge the consumers for reducing their consumption. The first class designed for the domestic end users while the latter is for the industrial loads [52]. Fig.3 shows two basic categories of DR options depending on the motivation offers.

2.2.2.1. Variable periods-based DR

The programs under this type allow to the consumers to participate in non-constant rates of electricity for several periods during the specific time [52][53]. The participators in this program get the price information, and they have the decision to reduce the consumption in the high price periods to minimize the cost of the electricity bill. It is sub-divided into many groups as is illustrated in the Fig.3.

- Duration of Use (DOU):

The term DOU that used in this paper have a well-known name used in many other kinds of research and they call it by the time of use (TOU). In this kind, the price is declared before time because it is a fixed rate. The time of this category is determined according to the season days, weekdays or until according to many times in one day [54]. The DOU impose there is a different fee for the energy consumed in various durations periods. These fees are constant for each period as depicted in Fig.6. The rate of the power in the peak load duration is expensive more than the same consumed energy in the times of the low loading on the utility [55]. In [56] The using of DOU prices when applying the smart meters in the nonconventional grids of Saudi Arabia in the future studied from different aspects. In [57] the authors create a comparison between using the DOU and the pricing of electricity in the real- time by using the fuzzy logic manner. In [58] electricity tariff depending on Eskom Megaflex DOU structures are studied and implemented. This paper [59] has shown the effectiveness of using the DOU demand response program in the improvement of the hubs of energy. Besides that, the article discussed the capabilities of the storage devices and the inverters in the energy hub.

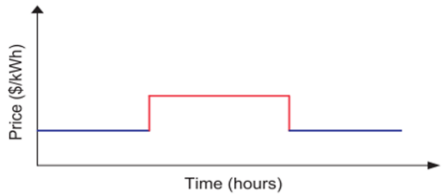

Fig. 6: Schematic Sketches of Time Varying Price (Time-of- Use).

- Serious peak pricing (SPP):

This type also called the critical peak time (CPP) in many papers. It has a point of similarity with the DOU because both of them have a fixed rate in various consumption periods. The difference occurs when there are an even is happening in the system and in that case the cost will changed in that period only [60] as illustrated in Fig.7.

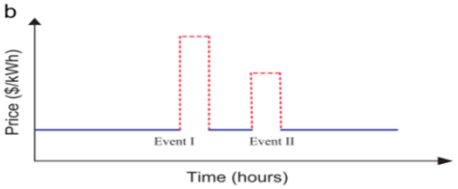

Fig. 7: Schematic Sketches of Time Varying Price (CPP).

In [61] Electricity generation system in Thailand depended on costly LNG to generate electricity. For that reason, the authors

propose a method to discover an optimal CPP scheme for Thailand take in mind the marginal generation cost to reduce the need for large generation and instead for that make the consumers load equal to the generated power. In [62] The mixing between the EDE and GWO lead to produce the HGWDE. The authors depending on HGWDE, RTP, and SPP to decrease electricity cost and peak load demand. In [63] The researchers targeted the typical public buildings that have a storage system and DG units to apply the SPP and estimate the best cost that the consumers should pay by a proposed model. In [64] This paper research the influences of the not enough reserve of the generation in the power system after the 2015 crisis in Poland. The suggested solution for the problem was using the SPP program in the residential sectors to avoid the issues similar to that one. Depending to [65] the electric vehicles (EV) is in increasing in China, and that makes a problem. To cure the issue SPP model and particle swarm optimization algorithm is used to determine the days or hours with peak load. The paper result is to reduce the peak load that leads lessens the electricity price.

Eventually, SPP can classify into two types: the first one is the Extreme Day pricing (EDP) and the Extreme Day SPP. In [53] the author regarded EDP and (peak load pricing) PLP is one class, and there is no difference between them. In this class, not low prices for energy announced for the extreme day and it stays for all the other hours during that day. In other days a flat rate will be used [7], [66], [67].

- Peak Load Pricing (PLP):

In this type, the 24h separated in some stages and there is a determined cost for each stage among them. The energy prices for the daytime advertised to all the participators in this program before one day at least [68]. In [69] the application of a cost-benefit framework was to estimate the diversity to a rate structure based upon PLP proposed. The use of the frame with some hypothetical examples also demonstrated. In [70] the authors analysed a peak load pricing in a network with General conditions for market equilibrium existence and uniqueness.

- Peak Time Rebates (PTR) or Peak Day Rebate (PDR):

In this type, the participators are free in deciding for reaction with the emergency cases or not. In the usual situation, end-users should pay a regular tariff, but if they desire to obtain payment (rebate cash), they should reduce their consumption under the threshold of the baseline [54], [53]. In [71] this paper is dealing with the residential end-users from the view of what the efficiency of applying the PTR in that sector and study the correctness of Customer Baseline (CBL). The paper [72] Examined the effect of participating the end-users consumers in the PTR program on the market for electricity. In [73] The authors investigated the results of two demand response programs to see the effect of the loss aversion on them. The PTR and RTP are studied to test it as a suitable choice for decrease the load consumption. In [74] Vuelvas et al. explained the rationalising behaviour in the case of the end-users chooses to participate in the PTR program. The sequences revealed that the consumers would consume energy to the baseline limits when the retail price is bigger than the incentives. Mohajeryami et al. In [75] showed the effect of Customer Baseline Load (CBL) estimation that is one of the critical factors to implement the demand response programs and in this paper the authors cared about PTR. The proposed method in the article was to group the consumers in clusters and each cluster contains more than two hundred consumers.

- Vickrey-Clarke-Groves (VCG) scheme:

In this technique, the central system asked the end-users to transmit their consumption from the energy for the price estimation goal in each period. A payments cash provided to the consumers to urges them to deliver an actual and accurate load consumption. One of the essential features of this type of demand response can reduce the using of electricity consumption, [76] or it can also move their consuming to those periods with unheavy loads [77]. Sessa et al. in [78] targeted the market of electricity that prompted by the control reserves (it is a unit aimed to achieve the optimal dispatch between the power generated and the power consumed) to create a VCG mechanism serve those markets to enable the operator to choose the best bids. Nekouei et al. in [79] implemented a game theory frameworks in the market of electricity that DR program applied in it. To ensure all the end-user submit their real and trusted energy consuming the researchers used the VCG program to the DR aggregator. In [80] the aim is to minimise energy consumption expense and decrease peak demand and as an outcome of that form the load curve. The authors used various controlling methods in the intelligent grid to guide multiple domestic loads. The result showed that the peak load would decrease to more than sixty percent and that to a cost reduction by a rate reach seventy-three percentage.

- Day-Ahead Pricing (DAP):

Day- advanced pricing given as an opportunity to schedule electric loads to take advantage of prices that varied with time [81]. It lets users arrange their energy usage at the beginning of a day and still makes it possible for electric companies to achieve the load balance as well [82]. There are other papers deal with the DAP as is shown in table3.

Table 3: Papers Deal with DAP.

Papers
[83] , [84] ,[85]

- Real time pricing (RTP):

In this, participator in this program receive a different price for the electricity in each hour, and that price reflects the cost of the energy in the wholesale market as is shown in Fig.8. RTP consumers notified about the price of electricity before one day or may before one hour depending on the nature of the program they already joining [7].

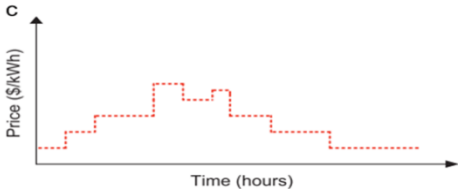

Fig. 8: Schematic Sketches of Time Varying Price (RTP).

In [86] the authors proposed a function to do a tradeoff between energy consumption and room temperature for a conventional air-conditioning in a small office building. This function implemented in an illustration experiment involving the optimum operation of RTP. In [87] the writer of this paper discussed Real-Time Pricing (RTP), clients can decrease the bill money by consuming energy in the period of the inexpensive price. Doing that needs an intelligent socket that has the ability to be on or off according to the favorites of the end-users and how much the cost of the energy in each time. The main aim to this paper is about the nonconventional socket which can autonomously turn on/off. In [88] the authors achieve a complete home energy management system HEMS able of scheduling loads based on RTP data and user-defined preference. The [89] is showing the critical points that may be encountered using the RTP. These obstacles were coming from the charges of the gregarious acceptability. In [90] a study to analyze smart meter data for residential consumers under the usual or ordinary pricing and the consumers joining to the RTP program.

2.2.2.2. Incentive-based DR programs (IBDRP)

IBDRP fund to engage the end users and for that decrease their energy consumption as a request from program administrator in the critical times that either when the system encounter reliability problem or high electricity prices [30]. IBDRP has two primary types:

1) Classical IBDRP

In this type, the end-users can obtain a rate of discount or a credit on their bill as a participating fee when they are joining to this type of DR programs, and this kind itself can divide into two classes:

a) Interruptible/ Curtailable Load programs (I/C).
b) Direct Load Control programs (DLC).

2) Market-based IBDRP

The consumers of this program can obtain cash money according to their efforts in the energy consumption reduction during the crisis

time when there are dangerous states present a hazard to the system [7]. It can divide into four classifications:

a) Demand Bidding (DB).
b) The Emergency DR Programs (EDRPs).
c) Ancillary services market (ASM).
d) Capacity Market Program (CMP).

- Direct load control (DLC):

The object is to reduce the pressures on a grid by emitting some portion of the loads during high load times by system administrator remotely [91]. The Table5 shows another example of papers that applied the DLC with their objectives and the result obtained.

- Interruptible/Curtailable Load (I/C):

This program grants the participators a bill credit as a reward for their agreement for reducing the consumption under the firm power level (FPL) that specified by the utility [92]. In [93] The authors create a model of multi-agent that can develop the market performance. To do that they are combining various DR programs like I/C and EDRP. In [94] the writers have shown that the using of DR programs like I/C and CAP can achieve advantages to the end-user beside that can reduce the consumption of energy. The [95] talked about EDRP and I/C programs and employed it as interruptible load contracts (ILC) that used in the unit commitment program (UC) . In [96] the emphasis was on I/C and CAP and develop an economic model. The model helps to recognise and use the appropriate DR program that can improve the load curve and suitable for the customers.

Table 5: Papers Applied the DLC Program

Author	Objective	Result
Imani et al. [97]	Examine the impact of the DLC program on 11 buses microgrid and investigate the effect of placing the battery on various buses.	Urge the clients in the load area to decrease their load at peak hours which lowers the entire operating cost. Besides that, Reduces the microgrid operation expense increases customer's advantage and peak reduction and energy reduction.
Piovesan et al.[98]	The search for the best DLC for the SBS powered by nonconventional sources in the mobile network of two-tier.	Mitigating and Controlling the consumption of the energy that happened in the succeeding generation of the cellular network that caused by the Huge using of SBSs.
Bayram et al.[99]	Applied of DLC program for the air-conditioning in ideal Qatari villa in the summer of 2017	Notable energy request decreases can achieve by diminishing AC units for fifteen to thirty mints at units with active occupants, while other economies if AC cut for an hour or more at units whose residents have a summer vacation.
Chandran et al.[100]	compare between the classical DLC and modern fuzzy method.	DLC only take in the consideration the load reduction and not care for the end user satisfaction. In the author side, the programs that depend on the fuzzy logic can accept the consumer comfort as one input.
Cheng et al.[101]	Achieve the hybrid energy generation system (HEGS) with the best planning in microgrid (MG) and by using the DLC.	The MG overall planning cost dramatically decreased and the peak load demand of the consumers becomes less.
Erdinc et al. [102]	Introducing a new approach that funding the participators energy credits to urge them to reduce their consumption during the peak durations.	proposed strategy performed a full price decrease of more than 10%, which can regard as a significant factor that can work to make the joining of the end-users to the DR programs increased.
Hucheng et al.[103]	Build an analytical model heater of water and also the consumption of water depending on the DLC program.	The power network load rate can improve, and at the same time the peak load can decrease by using the proposed model.
Saitoh et al.[104]	Estimate the applicability of various customers' devices by using a simulator operate in real time to the DLC program.	Evaluate the impact the DLC to help the control of the power system by using the equipment of the real customers.

- Market Based IBDRP – Demand Bidding (DB):

DB can be regarded as the most effective kind among all the DR programs to make the load curve nearly flat in the smart grids [105]. The role of the DB appears when there is a pressure on the power system. It urges the large energy consumer to offer curtailment in energy and bidding on it to obtain monetary awards [106]. Many papers discussed this type of DR. As an example of that, paper [107]. This paper argued a trustful bidding protocol for the motivation type of the DR system. For achieving that the researchers proposed using the cryptographic and without any third-party. In [108] the authors suggested a model to know the price of least billing for the demand with the less effect on their comfort. In this model, the demand regarded as an agent they bid to the market of energy. The scheme achieves a reasonable reduction in the cost compared with the uncontrolled one. [109] the authors take the loads that can shift in time in the consideration. They create a mathematical model for the bidding in the energy. The model after that developed to be suitable for the multi-agent system. The scheme has an important effect in smooth the scheduling of the loads and helping to achieve the dispatch between the supply and the demand. In [110] Tarasak et al. applied the DB to manage the hotel consumption of energy. The consequent of this research appears that the program affords an economic profit and promotes the scheduling of the loads. In [111] the authors Proposed an extension to the construction of the bidding besides that introduced a new type of biddings. The result shows that the applying of the new bidding types can obtain a Meaningful economic interest.

- Market Based IBDRP - Emergency DR (EDRPs):

It`s DR programs that offer a motivation payments to the end-user customers in the situations of the power system suffering from critical reliability problem for reducing their usage [112]. When an unusual case happened in the electrical power system, the operator notified the engaged customers for a reduction in their usage and the time of response depending on the type of event. The amount of payment agreed about it in the beginning [113]. In [114] proposed a method to deal with the multiple loads inside the buildings and the datacenters that participate in the EDRP. The result of simulation proves that the way used in this paper can make the overall price reduce by more than forty-eight percent if we compare it to the conventional approach and at the same time achieve all the constraints. The paper [115] discussed the influence of the level of the joining the end-users in the EDRP. Also, the article also discusses the effect of the false incentive amount in the implementation of EDRP. Results show what the influence of the various participation levels on the operation cost and the consumer advantages. [116] discussed what the role of EDRP in the case of the collapse of the generation unit. The result of the approach makes the operator to schedule a reliable generation before one day, and that leads to making the consumer feel comfort in the emergency cases. In [117] the under speed load shedding (USLS) and the EDRP are unified in a model to enhance the short-term voltage stability (STVS). The result illustrates that the USLS can effectively improve the STVS. In comparison with the conventional model of the under-voltage load shedding (UVLS) scheme, the proposed model can achieve quicker voltage recovery and shed fewer load.

- Market Based IBDRP - Capacity Market Program (CMP):

This type of DR directed to that category of consumers that can produce a determined reduction in their energy usage. The participator in this program get a notification before one day from the event take place, and they punished if they do not obey the reduction agreement [67]. CMP can view as a type of insurance. When the end user committed to reducing it used when notifying, he will receive guaranteed payments. Not just that but in sometimes the participator gets payment to be on call only ready to achieve the

load reduction [118]. There are other papers the CMP mentioned in it shown in Table 8

Table 8: Papers CMP Mentioned in it

Papers
[119] , [120]

- Market Based IBDRP - Ancillary Service Market (ASM):

The mechanism that the ASM work according to it urges the end-users to reduce their consumption and bidding by that in the market and by this method they can represent an operating reserve. In the case of the consumer, bidding admitted, the operator pays them the price of the market to ensure them stay on call.When there are necessary to them the Independent System Operator (ISO) call them and paid to them the wholesale market price [118]. In [121] the authors deal with the vehicles that electrically charged and discharged by regarded it as a soft adaptable energy storage loads; that can be a source for the ASM. They were using the stochastic optimisation to examine the effect of ASM and the virtual power plant (VPP) depending on Nash equilibrium. In [122] the authors suggested a bidding strategy for the EV . This tactic reduces the load on the dispatch centres beside that allow to landlords of EV to engage in the ASM bidding immediately. In [123] the barriers that might limit the active involvement of new players in the ancillary services market are investigated, and the market potentialities quantified for a real portion of the Italian power system has been discussed.

The programs mentioned above can classify into

1) Voluntary programs.
2) Compelling programs.
3) Market clearing programs.

And the above three classes shown in Fig.9.

Fig. 9: Anther Classification of DR Programs.

when the end-users opt to reduce their consumption or not without any punishments if he does not decrease their energy usage, this can call it by the Voluntary programs. in the second class, the customers in compelling programs will pay a fine if they do not obey the order od reduction their usage from electricity during the critical times [124]. The third one have the same strategy used in the DB and ASM programs.

2.2.3. Decision variable DR methods

There are two categories under this type of the demand response:

1) Task scheduling program
2) Energy management program

- Task Scheduling Based DR

This class aimed to control the time that specific loads will be with it in an active state. The electrical loads subdivided into two parts: the loads that the consumer can not switch it off like the refrigerators and the lightning. In the other hand, there are many loads can the consumer manage pause, move it to work in another period of the day and switch it ON/OFF like water-heaters or the PHEVs. the primary purpose for all those programs to ensure the system work in stable condition and the optimal dispatch between the supply and the loads is to take place by shifted or reduced the consumption in the critical or peak load times [125]. There are many kinds of research on this type of DR program like [126] that explained the Industrial production processes because it considered as one of the primary energy users. The authors proposed two algorithms to manipulate the DR constraint to reduce their effect on the production as much as possible. Kai Ma et al. in [127] discussed the households electrical energy consumers and tried to achieve scheduling in power for them. The simulation showed there is a tradeoff between what the client must to paid and its discomfort. Vardakas et al. in [128] examined more than three models for achieving scheduling in the power demand. The purpose for all these models is to decrease the peak energy consumption in the smart grid and that accomplished by doing programming for all the operation of the user devices. In [129] the authors discussed the make adjustable electric loads a schedule in the nonconventional power grids to achieve the flat demand on the generation station in all the situations. In [130] the authors create a task scheduling model to manage the appliances of a home with intelligent devices by using the convex programming (CP) technique. The result showed that the schedule-based and the other devices could be energy scheduled at the same time. In [131] The authors presented the solution that can decrease the customer bill of energy. The paper takes the case of there are various home devices need to be scheduled under the unsteady peak pricing. The result showed that the strategy followed in this paper achieve the mentioned purpose. In [132] studied how to mitigate the profile of the power demand and how to minimise the operation cost after long-running. The aim achieved by using a model depending on the communication between the administrator and the premises of the consumer.

- Energy Management Based DR

This type targeted specific loads to reduce their energy consumption by a particular mechanism. That will lead to solving the problem of the peak load in some periods by reducing their energy consumption of the controlled appliances to a specific level until the risk on the system finished [133]. This realised by controlling the appliance's work to absorb less power during system stress [125]. In [134] in this paper and depending on the forecasting of the weather, there is a model have to schedule the consumption in the energy for the (HVAC) systems. The result showed that the scheme achieved an excellent reducing in the value of the consumed power and besides that in short time calculation. In [135] this paper discussed the how to improve the agent system to be a device with scheduled operation taking into the account the contract limitations. In [136] the authors used the consumption of energy scheduling (ECS) algorithm to perform better and faster solution. The stated algorithm and depending on the liability of the consumers can determine how much each one should pay. In [137] The authors deal with the problem of how the utility administrator manage the usage of a collection of smart homes. The authors treat this problem as an optimisation problem and make the load scheduling as the constraints for that problem. The result appears that the energy usage will reduce and increase the user comfort. In [138] the authors proposed a mechanism that can perform an optimal billing. The tool determines the fees that each consumer should pay depending on the energy consumption. The proposed strategy also gift some consumers depending on their obeying the scheduling rules. In [139] the authors used the utility function in a case study for three load devices for simulating the energy consumption scheduling. There was an overestimated result in cost minimisation of the DR. In [140] the researchers develope algorithms to investigate the situation of the consumers who are care just for themselves and struggle to decrease their future energy consumption price. The result of the proposed algorithm can induce the consumers to operate the shiftable loads in the times when the system is not highly loaded.

3. Conclusion

DR can achieve a vital success to make the demand equal to the generation and lead to optimal dispatching in the electrical power

system. In this paper, we divided the DR into three parts. The first part divided the DR programs according to the control mechanisms that applied and the second one split it depending on the way that the final consumer will be motivated to participate in the DR programs. The last category broke it depending on the decision variables.

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Abbreviations

Abbreviations	Meaning
EDE	Enhanced differential evolution
GridPIQ	Grid project impact quantification
GWO	Gray wolf optimization
HEGS	Hybrid energy generation system
HGWDE	Hybrid gray wolf differential evolution
IBDR	Incentive-based DR
IBP	Incentive-based programs
ILC	Interruptible load contracts
ISO	Independent System Operator
LNG	Liquefied natural gas
MG	Microgrid
PBP	Price-based programs
IBDR	Incentive-based DR
IBP	Incentive-based programs
RAN	Residential area networks
SBSs	Small base stations
STVS	Short-term voltage stability
TBDR	Time-based DR
TBDR	Time-based DR
DOU	Duration of Use
TS	Tabu search
UC	Unit commitment
USLS	Under speed load shedding
UVLS	Under voltage load shedding
VPP	Virtual power plant

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