Demand Response Services in Electricity Markets of US and Canada

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This work was carried out as part of the CIGRE Working Group C5.26: *Auction Markets and Other Procurement Mechanisms for Demand Response*

SUMMARY

Demand response (DR) is an important tool for Independent System Operators (ISOs) to reduce the peak demand and electricity price spikes, balance the intermittency of renewable energy resources (RES), and increase power system resiliency, efficiency and reliability. Of late, there has been considerable interest from the load-side participants to offer their services for DR provisions in electricity markets. This paper presents a comprehensive review of the current frameworks and programs for DR to participate in various electricity markets in US and Canada. The modalities of DR participation in each ISO are classified based on:

- Their mode of procurement, *i.e.*, through fixed period contracts or auctions based offers.
- Their participation time-frame (day-ahead or real-time) and operational domain (energy, ancillary services, or capacity) [2].
- Type of DR program, *i.e.*, economic DR program, or emergency / reliability DR program [3]. The economic DR program involves submission of an offer whereas the emergency DR is only called upon during times of system stress, such as extreme weather events or transmission outages.

The other details considered are the type of customer participation (individual or aggregated), minimum reduction requirement (kW/MW), minimum duration, type of trigger signal (price based, loss of resource, frequency changes etc.), payment rates/terms (market price, fixed price, etc. In addition, some of the challenges and potential solutions for implementation of DR under market paradigms are discussed.

KEYWORDS

Demand response, electricity markets, spinning reserves, locational marginal price

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1. INTRODUCTION

Demand Response (DR) has emerged as an important tool for Independent System Operators (ISO) for reliable operation of electricity markets, and there has been considerable interest from load-side market participants to offer their services for DR provisions. DR is a promising solution to alleviate the system impact from sudden peaks because of its flexibility, characterized by fast response time, ramp rate, capability to provide upward or downward response, and controllability of response [1]. It is also possible to use DR as a spinning reserve resource because the natural response capabilities of these loads match the response speed, duration, and frequency required to provide spinning reserve; typically only for a few times a year with average deployment time between 9 to 11 minutes [2].

DR is defined as "*changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized*" [1].

2. DR WHOLESALE ELECTRICITY MARKET PARTICIPATION

DR can participate in three types of electricity markets: energy, ancillary services, and capacity market, to offer their services. The energy market participation of DR can be via two options, the first being through explicit market mechanisms or programs for individual customers, or DR aggregators acting on behalf of many customers, to bid or offer their services directly into the wholesale market and thus be dispatched by the ISO in the same way as generators. This option for DR to participate may involve submitting a bid curve (price and quantity pairs) reflecting the customer's willingness to pay for energy, or price-quantity based curtailment offers.

The second option for DR is through price-responsive loads *i.e.*, customers who react to prices by adjusting their demand, but without bidding into the wholesale market. As in any other market, electricity customers tend to reduce their consumption if prices rise. These customers may be said to have provided DR in the sense that they purchase less electricity when prices are high than they would have done if prices had been lower.

DR can also participate in the ancillary service markets for providing products such as spinning, non-spinning and regulation reserves. These products are required to ensure that the system is robust to outages and other unexpected changes in supply or demand. Depending on the nature of the ancillary service product and the technical design, DR participants may be eligible to provide these services.

For DR provisions in the capacity market, some market designs include a mechanism for procuring capacity that is independent of the energy market. DR providers are paid to be available to generate or curtail load and avoid emergency events over and above the revenues that they earn in the energy market.

3. DR PROGRAMS IN VARIOUS ISOs IN US AND CANADA

In this section, a comprehensive review of the current frameworks and programs for DR to participate in various electricity markets in US and Canada is presented. The modalities of DR participation in each ISO are classified based on:

a) The type of DR program, *i.e.*, economic DR programs, or emergency/reliability DR program [3]. The economic DR program involves the submission of an offer whereas the emergency DR is only called upon during times of system stress, such as extreme weather events or transmission outages.
b) Their participation time-frame (day-ahead or real-time) and operational domain (energy, ancillary services, or capacity) [2]. The difference between providing DR services in energy, ancillary service and capacity markets need be understood. If DR is cleared in the

energy market, it has to be dispatched in real-time operation, whereas when DR is cleared in ancillary service market or capacity market, it will provide that capacity and is dispatched only if needed.

c) Their mode of procurement, *i.e.*, fixed period contracts or auctions based on offers. The DR procured, can be from price responsive demand or specific load curtailment offers. For DR procurements through contracts, details such as period of contract, frequency of service provisions, have been examined. While for participation through auction, the type of offer structure, offer parameters, and bidding time-frame are considered.

The other details such as minimum resource size, reduction requirement (kW/MW), minimum duration, type of trigger signal (price based, loss of resource, frequency changes etc.), payment rates/terms (market price, fixed price) etc are also included.

3.1 New York ISO (NYISO)

The following are the four types of DR programs in the NYISO [4], [5]:

3.1.1 Day-Ahead Demand Response Program (DADRP)- the underlying product associated with and offered by this program is energy. The price is established in the day-ahead market clearing process. Although participation in this program is voluntary, for participating loads DR to dispatch instructions are mandatory. Participation in this program does not require telemetry; interval metering is adequate. Demand reduction is measured compared to a predetermined base line. If the participant fails to reduce demand from the baseline as scheduled, its consumption during the scheduled curtailment period is charged the higher of the day-ahead and the real-time price.

3.1.2 Demand-Side Ancillary Service Program (DSASP)- the underlying products offered by demand-side resources under this program are regulation, spinning, and supplemental (non-spinning) reserves. In addition to interval metering, real-time telemetry is also required to enable NYISO to monitor availability and performance of the resource.

3.1.3 Emergency DR Program (EDRP)- this program involves demand reduction under emergency conditions declared by NYISO. Participation in this program does not require telemetry, interval metering is adequate.

3.1.4 Installed Capacity (ICAP) Special Case Resources (SCR)- similar to EDRP, this program involves load reduction under emergency conditions (i.e., the demand-side resources under this program are not dispatched just for economic reasons to displace a more expensive resource). The resources are compensated as ICAP resources and must perform when asked to curtail by NYISO. An individual demand-side resource can participate in either the EDRP program or the SCR program, but not both, during the same period. Other characteristics of this program are as follows.

TABLE-1: Summary of DR Programs in NYISO

	DADRP	DSASP	EDRP	ICAP
Minimum resource size	1 MW	1 MW	100 kW	100 kW
Minimum reduction	1 MW	1 MW	100 kW	100 kW
Trigger	Price-based	Price-based	Extreme emergency operating conditions	Extreme emergency operating conditions
Response Time	2 hours	2 hours	15 min – 2 hours	2 hours
Compensation	Day-ahead LMP	Respective reserve market clearing price	Maximum of real-time load zone LMP or 500 $/MWh for the MWh amount curtailed	Maximum of real-time load zone LMP or 500 $/MWh for the MWh amount curtailed

3.2 PJM Market

The following are the two types of DR programs in the PJM [8]:

3.2.1 Economic DR Program: through this program the loads can offer DR in the day-ahead and real-time energy market, and capacity offers for reductions in the synchronized reserve, and regulation reserve markets.

3.2.2 Emergency DR Program- customers who voluntarily reduce their usage in the energy market are compensated.

TABLE-2: Summary of DR Programs in PJM

	Economic DRP	Emergency DRP
Minimum resource size	0.1 MW (energy service) 1 MW (reserve service)	100 kW
Minimum reduction	0.1 MW (energy service) 1 MW (reserve service)	100 kW
Trigger	Price-based	Extreme emergency operating conditions
Response Time	1 hour (energy), 5 min/ 10 min (reserve)	1 to 2 hours
Compensation	LMP for energy/ reserve market clearing price	Maximum of real-time load zone LMP or $500/MWh for the MWh amount curtailed

3.3 ISO New England (ISO-NE)

The DR programs facilitated in the ISO New England markets include the following [7]:

3.3.1 Real-time Demand Response (RDR) Program- although participation in this program is voluntary, for participating loads, following the dispatch instructions is mandatory.

3.3.2 Real-time Price Response (RPR) Program- this is the emergency DR program through voluntary energy reduction during periods of high real-time prices.

3.3.3 Day-Ahead Load Response Program: This is an optional program available to resources participating in RDR and RPR programs.

TABLE-3: Summary of DR Programs in ISO-NE

	RDR	RPR	Day-ahead Load Response
Minimum resource size	100 kW	100 kW	100 kW
Minimum reduction	100 kW	100 kW	100 kW
Trigger	Price-based	Extreme emergency operating conditions	Price-based
Response Time	5 min to 1 hour	5 min	30 min
Compensation	Greater of real-time LMP or $50/MWh whichever is higher	Greater of real-time zonal LMP or $500/MWh	Day-ahead market LMP Bid Price: 50 $/MWh (min); 1000 $/MWh (max)

3.4 Midcontinent ISO (MISO)

The DR programs in MISO is from two categories of resources [9]:

3.4.1 Demand Response Resource Type I (DDR Type I)- this program is available to physical interruptible load. The DRR Type I resources may supply energy or contingency reserve (i.e., spinning or supplemental reserves), but not regulation. They can be committed (ON or OFF), but not dispatched. They can be committed for energy or cleared for contingency reserve, but not both at the same time (for the same hour). Their energy offer may include the targeted demand reduction (MW), shut down cost ($) and hourly curtailment cost ($/h), but no energy ($/MWh) curve. They can offer contingency reserve ($/MW/h). They cannot set the energy LMP, but can set the ancillary service market clearing price.

3.4.2 Demand Response Resource Type II (DRR Type II): These include behind the meter generation or controllable load. Their market participation requirements and opportunities are comparable to generators. They are committable and dispatchable. They may supply energy, contingency reserve, and/or regulation.

3.5 CAISO

In CAISO, there are two types of DR resources, Proxy Demand Resource (PDR) and Reliability DR Resource (RDRR) [6]. The PDRs bid for energy curtailment and non-spinning reserves in the day-ahead and real-time markets while RDRRs bid for energy curtailment only, in the day-ahead market. The DR resources participate through an economic (market-based) program available to loads that register as participating loads with CAISO.

3.6 Electric Reliability Council of Texas (ERCOT)

ERCOT's DR programs include the following [10]:

3.6.1 Voluntary Load Response- in this program the decision to reduce consumption from scheduled or anticipated load by the customer is in response to the real-time market prices.

3.6.2 Load acting as a Resource (LaaR)- program pertains to controllable loads.

TABLE-4: Summary of DR Programs in MISO, CAISO and ERCOT

	MISO	CAISO	ERCOT	
	DRR Type-II		Voluntary Load Response	LaaR of ERCOT
Minimum resource size	100 kW	100 kW (energy service) 500 kW (reserve service)	100 kW	100 kW
Minimum reduction	100 kW	100 kW (energy service) 100 kW (reserve service)	100 kW	100 kW
Trigger	Price-based	Price-based	Price-based	Loss of resource
Response Time	5 min to 2 hours	10 min, 15 min or 1-hour	15 min	15 min
Compensation	LMP	LMP	LMP	LMP

3.7 Independent Electricity System Operator (IESO), Ontario, Canada

The DR participation in electricity market of Ontario, Canada, started in 2016. The IESO conducts an annual DR auction with two settlement periods (six months each), namely Winter and Summer, where the participants submit price-quantity bids of the curtailable load. On settlement of the DR auction, the selected loads are contracted on long-term (six months), for being ready to be curtailed at 1-hour notice and are dispatched in the real-time energy market or real-time operating reserve market [11].

Auction Process: The IESO publishes a Pre-Auction report two months prior to the start of the offer submission window. This report includes information such as the target procurement capacity, the maximum/minimum clearing prices, capacity limits, the zonal requirements, etc. During the offer submission period, the interested participants submit offers in the auction. Thereafter, the IESO processes all submitted DR auction offers, and determines the clearing price and quantities on a zonal basis. The selected participants, called Demand Response Market Participants, are eligible to provide DR capacity and receive an availability payment. The IESO deploys the contracted DR in real-time, if needed.

The total DR capacity procured from different DR programs, and the peak reduction capability in various ISOs during 2017 are shown in Fig.1 and Fig.2, respectively.

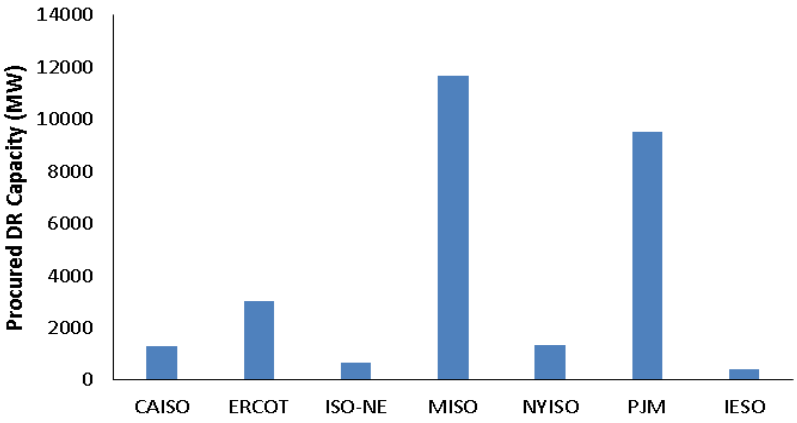

Fig.1 Total procured DR capacity in different ISO in 2017.

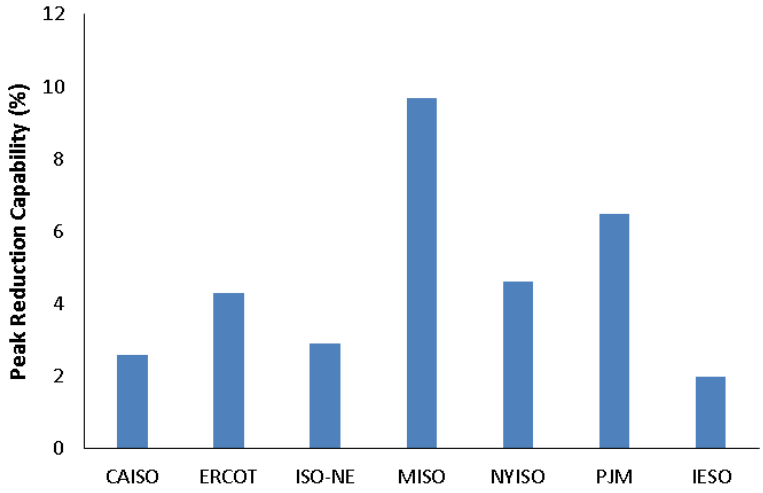

Fig.2 Peak reduction capability as a result of DR participation in different ISO in 2017

4. CHALLENGES WITH DR PARTICIPATION IN MARKETS

With the benefits that DR offers to the power system, there has been a significant increase in DR procurement across ISOs during the last few years. To promote DR participation in electricity markets, in recent years there have been some policy interventions. For example, the FERC Order 745 issued in 2011 [1] requires ISOs to facilitate the participation of DR in electricity markets, at par with other participants, with monetary compensation based on LMPs. However, the following challenges have been noted in recent years with DR participation in markets:

- The participation of DR in energy services is declining, which is attributed to less attractive monetary gains.
- The DR provider has to choose from amongst the currently available participation options in electricity markets such as price responsive demand bids or curtailable-based DR offers. Also they have to determine the bid/offer structure to appropriately offer the available DR capacity simultaneously for services such as energy and reserves.

Thus, in order to overcome the aforementioned challenges for DR participation, there is a need to appropriately design the bid/offer structure, develop novel frameworks and mathematical models for DR participation in electricity markets.

5. CONCLUSIONS

In this paper a comprehensive review of the current frameworks and programs for DR to participate in various electricity markets in US and Canada was presented. The modalities of DR participation in each ISO were classified based on mode of procurement, participation time-frame (day-ahead or real-time) and operational domain (energy, ancillary services, or capacity), and the type of DR programs.

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