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A NOVEL DEMAND RESPONSE MARKET CLEARING AUCTION MODEL FOR INDEPENDENT SYSTEM OPERATORS

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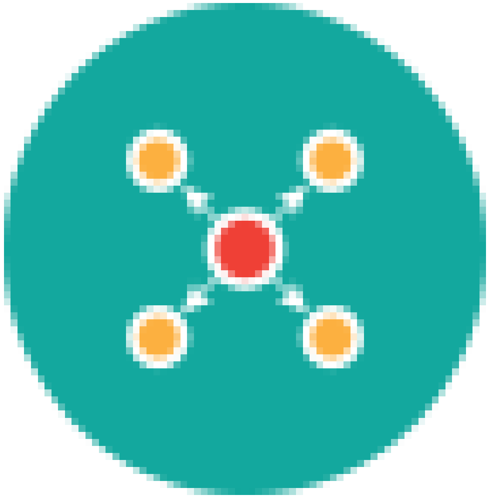
Outlines

- Introduction
- Problem Description
- Problem Formulation
- Case Study
- Conclusions

Demand Response

- Demand response refers to the ability of customers to actively respond to price signals and system conditions by increasing or reducing their electricity consumption.
- Smart grid technologies support greater levels of demand response by providing better monitoring, control, and automation of almost all aspects of consumers' energy use.
- In Ontario, the First Demand Response Auction offered in December 2015, replacing the DR3 program



Introduction

- DR allows the Independent System Operator (ISO) to tap into existing infrastructure, such as factories or hospitals, and procure reserves and energy balancing services.

- DR programs are being implemented by ISOs to alter the load shape in response to price signals or operator requests during critical conditions. Many ISOs are transitioning the procurement of wholesale DR from a contract-based method to a market-based approach referred to as DR Auction to improve customer participation.

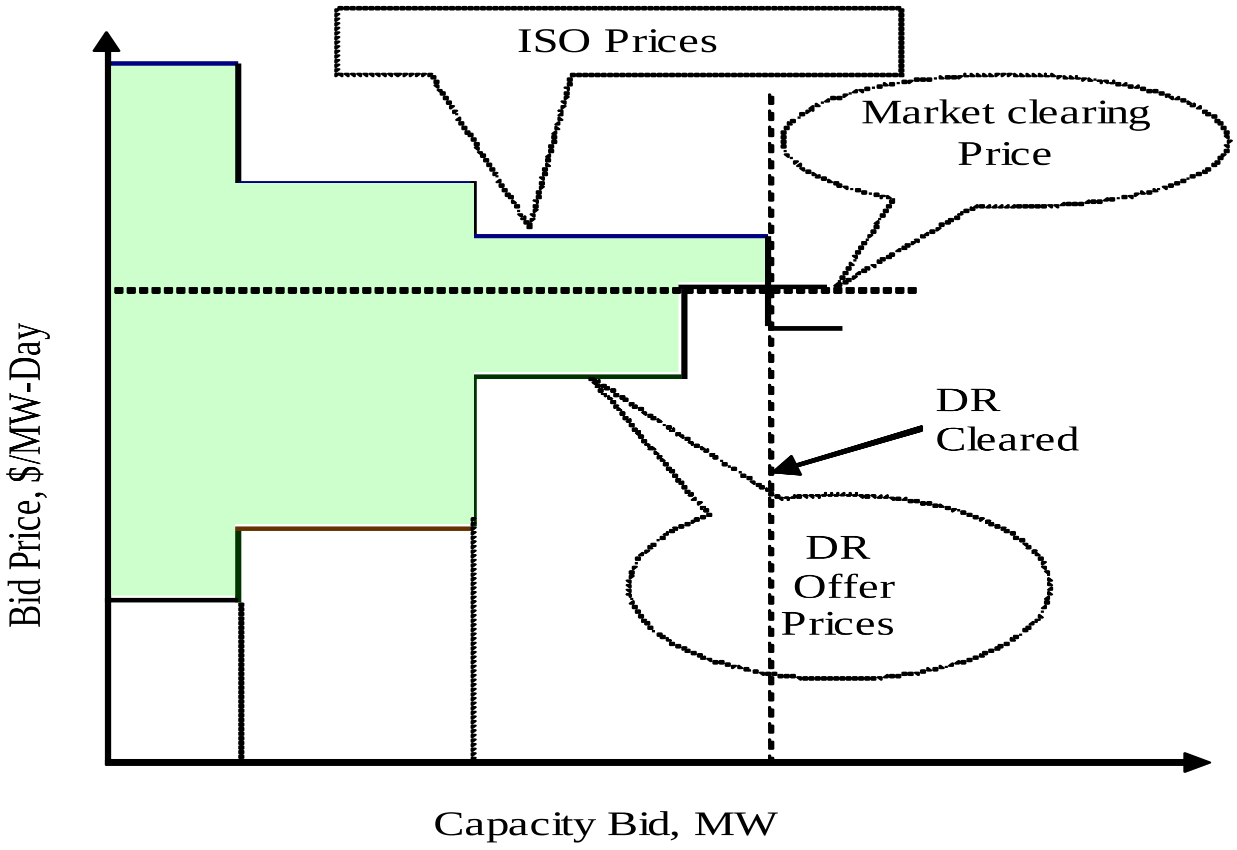
Problem Description

- DR markets are envisioned to provide an enduring mechanism to develop and expand upon DR resources. Therefore, how to implement the DR Auction in deregulated electricity markets, is worth consideration.

- In the context of energy and ancillary service markets facilitated by the ISOs/Regional Transmission Organizations (RTOs), the DR market can offer energy, ancillary services, and/or capacity, depending on the ISO/RTO market design and applicable operational standards.

- To address the problems induced by the demand-side participation features together with deregulated electricity markets, this paper presents a new auction mechanism, which develop a mixed integer linear optimization model for DR markets.

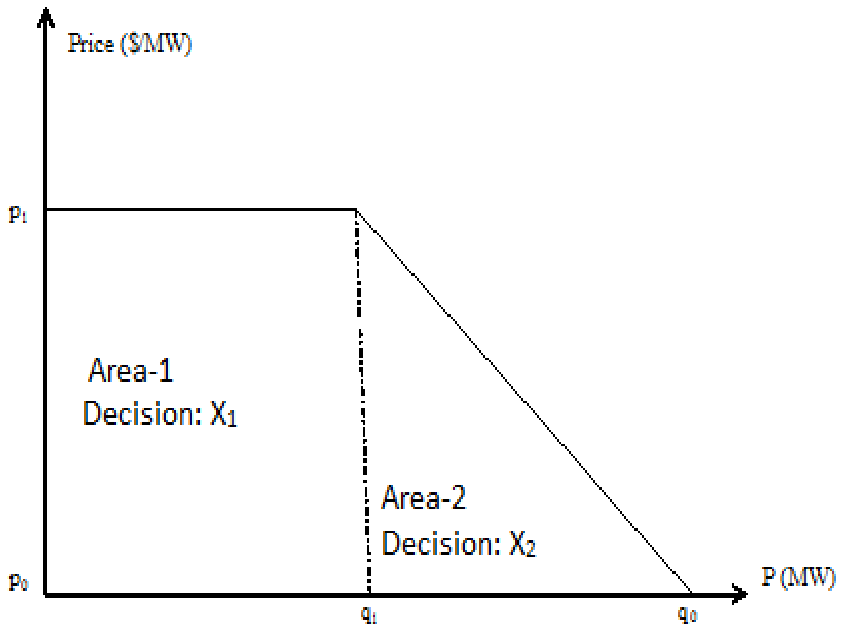
Why DR Auction?

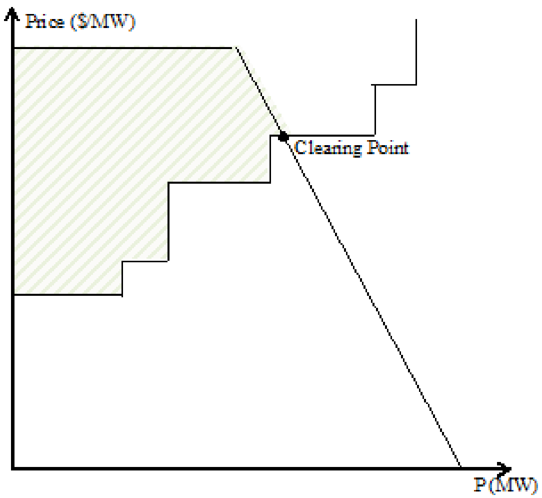


Objective Function

Maximizing the Social Welfare

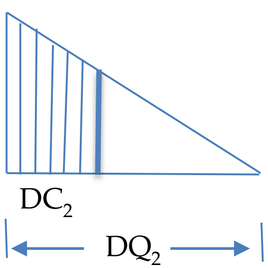
$$\max\ J = \overline{DRP_1} X_1 DQ_1 + \frac{1}{2}(p_1 - p_0) DQ_2 X_2 - \sum_{i\in I}\sum_{p\in P}\sum_{l=1}^{N_{l_p}} DRP_{i,p,l} DRQ_{i,p,l} U_{i,p,l}$$

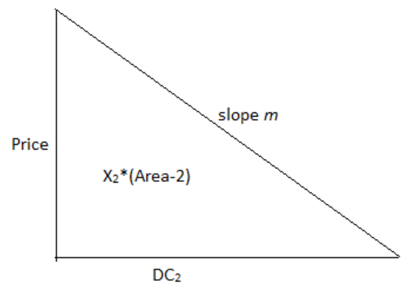




Model Non-Linearity

$$\frac{1}{2}(\text{Price})DC_2 = X_2(\text{Area - 2}) = X_2\left[\frac{1}{2}(p_1 - p_0)DQ_2\right]$$





The DR auction model is a *mixed integer nonlinear programming* (MINLP) problem which is extremely difficult to solve for such a large scale problem and there is no guarantee for global optimum

Non-Linear Equality Constraint:

$$DQ_1 X_1 + DC_2 = \sum_{i \in I} \sum_{p \in P} \sum_{l=1}^{N_{l_p}} DRQ_{i,p,l} U_{i,p,l}$$

$$DC_2 = \frac{p_1}{m} - \sqrt{p_1^2 - (p_1 - p_0)^2 X_2}$$

Model Constraints

DR Procurement Balance: $DQ_1X_1 + DC_2 = \sum_{i\in I}\sum_{p\in P}\sum_{l=1}^{N_{l_p}} DRQ_{i,p,l}U_{i,p,l}$

Limit on DR Procurement by Zone: $\sum_{p\in P}\sum_{l=1}^{N_{l_p}} DRQ_{i,p,l}U_{i,p,l} \le \overline{DRQ}_i$

Limits on DR Procurement for System: $CL_{Min} \le \sum_{i\in I}\sum_{p\in P}\sum_{l=1}^{N_{l_p}} DRQ_{i,p,l}U_{i,p,l} \le CL_{Max}$

Virtual Limit: $\sum_{l=1}^{N_{l_p}} DRQ_{i,p,l}U_{i,p,l} \le PRL_{i,x} \quad \forall p = x$

Adaptive DR Price Cap: $DRP_{i,p,l}U_{i,p,l} \le \overline{DRP} - mDC_2$

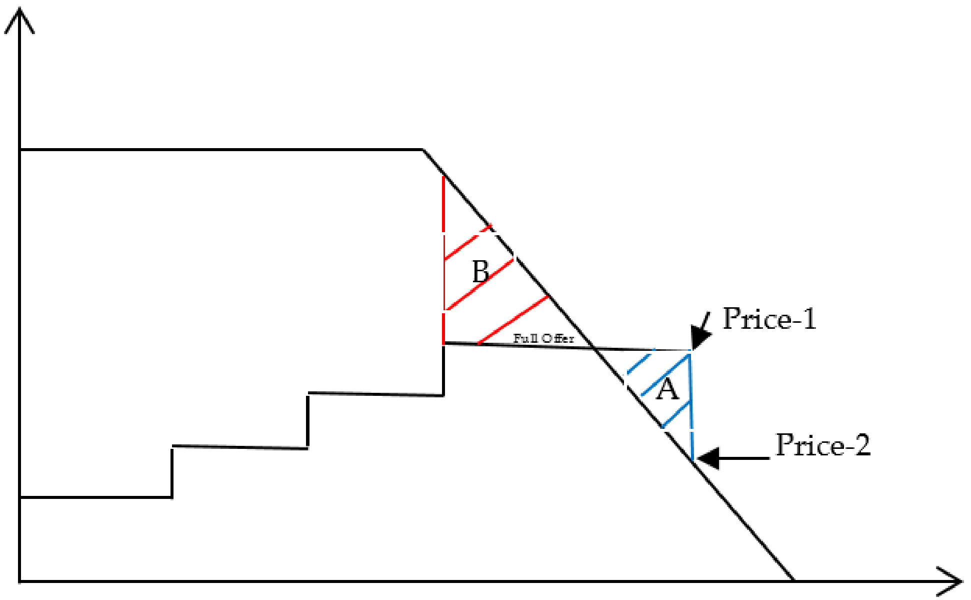
Constraint for Continuous Selection of Offers: $U_{i,p,l} \le U_{i,p,l-1} \qquad \forall l = 2,\ldots,N_{l_p}$

Partial Clearance of Offer: $\sum_{l=1}^{9} U_{i,p,l} = 9U_{i,p,'10'}$

Model Insights/Challenges

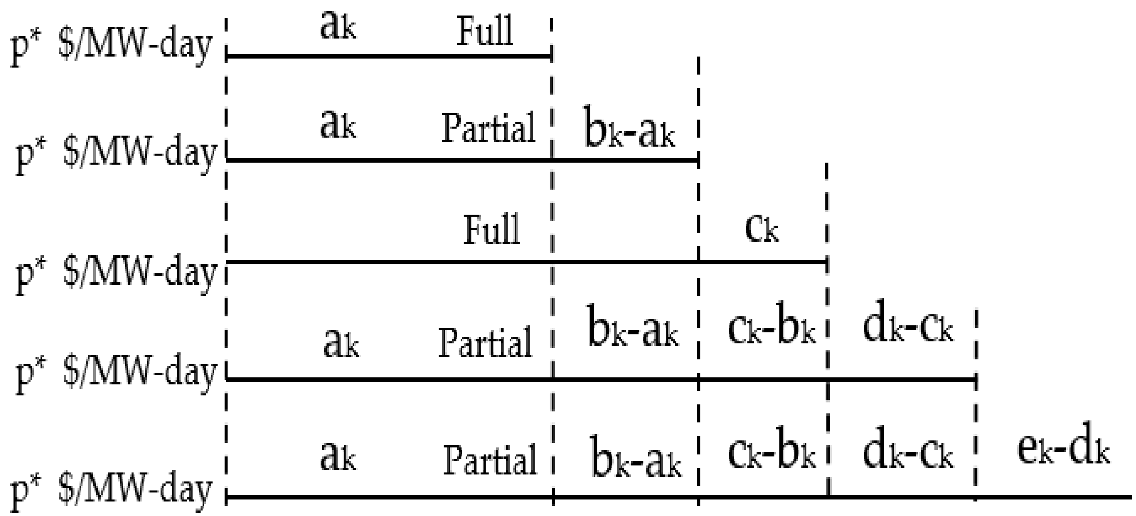
- *Adaptive DR Price Cap*

$$DRP_{i,p,l}U_{i,p,l} \leq \overline{DRP} - \sum_{j=2}^{N_d} W_j DP_j$$



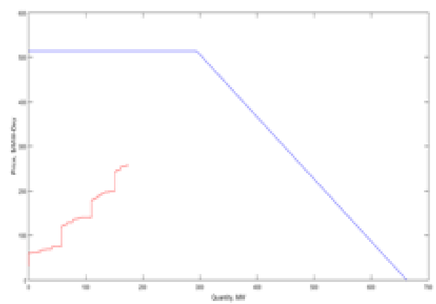
Tie-Breaks (Pre-Processing)

Let us assume we have five offers that have the same price (p^*=10$/MW-day) and those offers have different quantities (a_k, b_k, c_k, d_k and e_k) (i.e. 2 MW, 3MW, 5MW, 8MW and 10MW). Also let us assume that those offers have different submission times and we will assume they submit their offers in the following order (T3, T5, T2, T1, and T4) respectively.

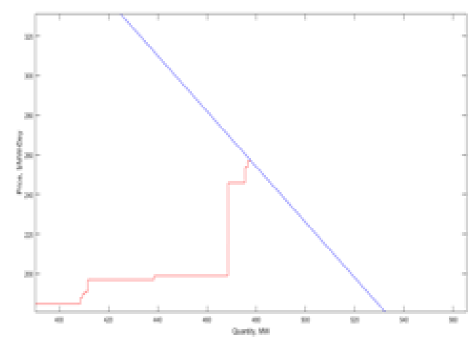


Case Study

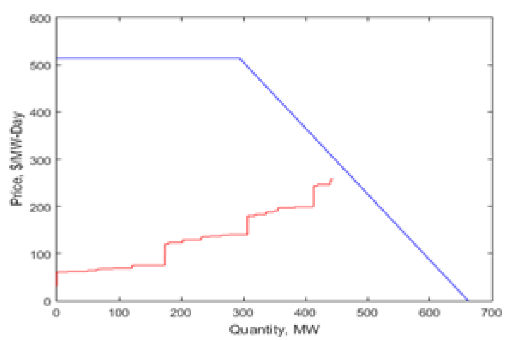
Case-Study	Description
Case 1	DR Auction Cleared at a Quantity Less than Maximum Quantity at the Highest Price
Case 2	DR Auction Cleared on the ISO DR curve. No limit on zonal DR
Case 3	Same Input Data as Case-2, but Imposing Zonal DR Limits
Case 4	DR Auction Cleared at a Quantity Greater than Maximum Quantity at the Highest Price



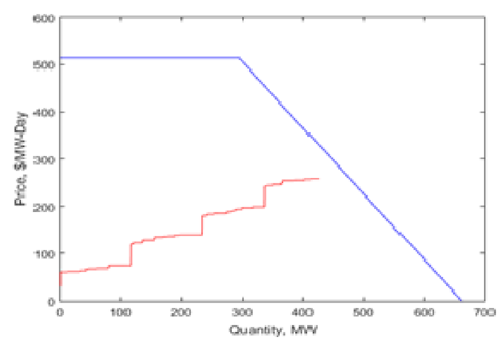
Case-1



Case-2



Case-3



Case-4

Conclusions

- This paper provides an overview of the proposed DR Auction Engine, with particular focus on the mathematical model developed to clear the auction.
- This paper presents the details of the proposed optimization model including descriptions of how the optimization problem is modeled and the methodology for data processing required to address partial offers and other considerations.

Thank You…..

Questions?