Applied Valuation of Demand Response Under Uncertainty: Combining Supply-Side Methods to Value Equivalent Demand-Side Resources

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Valuing Demand Response

- In today's rapidly changing energy markets, the role of direct load control programs are increasing being viewed as an underutilized resource capable of providing numerous benefits to our electricity grid and to our society as a whole.
- Although different names are used to describe these programs, we use the term Demand Response (DR) to include the overarching segment of load participation resources.

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Valuing Demand Response

- Although the overall benefits of demand response programs have been classified, there continues to be a debate as to how these benefits should be valued.
- In this paper we advance the idea that demand programs are better valued using the methods and tools of the supply-side commodity markets rather than the traditional demand-side Standard Practice Manual tests.

Why is DR Important?

- The value and effectiveness of DR resources largely depends on the purpose to which it is applied which may include:
  - The needs of the electrical system
  - The willingness of the customer to participate
  - The communications and equipment used to achieve the reductions

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Seven Purposes of DR

- There are at least seven basic purposes of DR:

1. The most basic is to reduce electric demand
2. Some DR resources can be used as operating reserves (similar to spinning and non-spinning reserves)
3. DR can be used to defer investment in generation, transmission and distribution systems

Seven Purposes of DR

4. DR is used to mitigate transmission congestion and provide distribution load management
5. DR is used in emergency situations or system reliability when reserves drop below safe levels
6. DR reduces energy prices and mitigates market power
7. DR can be used to reduce harmful emissions benefiting the environment

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Three Important Attributes of DR

- The purposes of DR suggest that there are at least three important attributes. These are:
  - The duration of the resource
  - The certainty of response
  - The speed of response

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Valuing Demand Response

- The value of DR depends on various cost and benefit components and variation around weather and control strategy.
- The value can be derived from load shifting (choreographing), economic load reduction, or emergency curtailment.
- From the perspective of the utility economic load reduction operates in two markets – energy and ancillary.

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Valuing Demand Response

- The value has an intrinsic and an extrinsic component.
  - The intrinsic value is based on expected (forecast) savings (weather) and prices.
  - The extrinsic value is based on the potential weather related savings from uncertain weather conditions. It equals the area under the value probability distribution from the expected to the extreme.

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Valuing Demand Response

- Real-option techniques allow demand response programs to be compared to traditional fossil supply resources and valued accordingly.
- The unique characteristics of different demand response programs allow direct comparison to unique fossil resources.

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Value Continuum of DR

- DR Programs can be viewed as falling along a continuum of value:

Emergency Curtailment
Economic Dispatch
    Energy (base-load)
    Ancillary
        Load Following
        Spinning
        Non-Spinning
Load-Shifting (choreographing)

Most Valuable

Least Valuable

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DR and ISO/RTO Responsibilities

- The reliability responsibilities of ISO are to maintain system frequency and voltage. Doing so has two main components:
  1) Regulating Reserves - Instantaneous balancing of load and supply minute by minute
  2) Contingency Reserves - Identification of dispatchable reserves that will allow quick rebalancing of the system in the event of generation or transmission outages

  – Normal operation of the control area is typically handled by deploying regulating reserves. System restoration responsibilities are typically handled by three contingency-reserve services (spinning, supplemental and replacement reserves).

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  – Unique DR resources can operate in either of these.

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The Real-Option Value of DR

- The promise of real-time load reduction can be thought of as a strip of European call options. The strike-price is given by a contractually agreed upon threshold price between the energy provider and the energy consumer.
- The DR option imposes constraints on the option that prevent us from using standard closed form option calculations. We can, however, use Monte Carlo simulation to model the constraints.

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Valuing Customer Choices

- As with a financial option, the DR option requires specifying a strike price, an amount of demand to be curtailed, market volatility, discount rate, and the time period over which the option is valid.
- Additionally, the DR option participant can specify several constraints: the number of continuous hours curtailed, the maximum number of curtailments over a particular period of time, the total hours available for the year, and others.

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Valuing Customer Choices

- Although these options can greatly increase participation by allowing the customer to better manage the negative consequences of power interruptions, they also reduce the relative benefits of the demand response resource compared to availability of a new CT.
- The more limiting the set of customer options, the less likely the program will cost effectively offset alternative fossil fuel generation.

Option Premium

- The DR option has only one net present value. However, the program can be designed to distribute incentive payments in different ways: through a single upfront payment, an ongoing reduction in the participant’s monthly utility bill, a fixed payment when the option is struck, a market value payment when the option is struck, or a combination of these.
- In our example, participants receive a premium payment spread over the participant’s summer bill and a fixed energy credit for curtailed energy when the option is struck.

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Model Price Process

- In our Monte Carlo simulation, we test three different price processes: Geometric Brownian Motion (GBM), GBM with Jumps, and Mean Reversion Jump Diffusion.

- We test two price scenarios:
  - Scenario 1: The curtailment lasts four continuous hours Price volatility equals 68%, and Underlying bilateral forward price equals $0.080/kWh ATC (around the clock).
  - Scenario 2: The curtailment lasts four continuous hours, Price volatility equals 98%, and underlying bilateral forward price equals $0.120/kWh ATC.

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Intrinsic vs. Extrinsic Value

- A financial option contains both an intrinsic and an extrinsic component.
- For example, if the underlying bilateral value of forward summer peak electricity is 9 cents per kWh, and the strike price is 8 cents per kWh, the option is “in-the-money” by one cent. Its intrinsic value is one cent.
- The extrinsic value depends on the market volatility, time to expiration, etc. The extrinsic value measures the probability of prices exceeding 9 cents on the expiration date of the option.

Avoided Cost Benefits

- In our example, the monthly premium payment is equal to the sum of the intrinsic value *and* the extrinsic value of the option. The energy credit, paid when the option is struck, will equal the participant's strike price.
- The premium payment and the energy credit combined equal the expected cost avoidance *benefit* from not purchasing the participant's electricity on the day the option is struck.

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Results

	68% Vol and $0.080 Underlying			98% Vol and $0.120 Underlying		
	Mean Reversion w/ Jumps	**GBM**	**GBM w/ Jumps**	**Mean Reversion w/ Jumps**	**GBM**	**GBM w/ Jumps**
Option Value	$ 0.121	$ 0.111	$ 0.117	$ 0.198	$ 0.185	$ 0.203
Strike	$ 0.058	$ 0.058	$ 0.058	$ 0.058	$ 0.058	$ 0.058
Intrinsic	$ 0.022	$ 0.022	$ 0.022	$ 0.062	$ 0.062	$ 0.062
Extrinsic	$ 0.041	$ 0.031	$ 0.037	$ 0.078	$ 0.065	$ 0.083
Strike	$ 0.068	$ 0.068	$ 0.068	$ 0.068	$ 0.068	$ 0.068
Intrinsic	$ 0.012	$ 0.012	$ 0.012	$ 0.052	$ 0.052	$ 0.052
Extrinsic	$ 0.041	$ 0.031	$ 0.037	$ 0.078	$ 0.065	$ 0.083
Strike	$ 0.090	$ 0.090	$ 0.090	$ 0.090	$ 0.090	$ 0.090
Intrinsic	$ -	$ -	$ -	$ 0.030	$ 0.030	$ 0.030
Extrinsic	$ 0.031	$ 0.021	$ 0.027	$ 0.078	$ 0.065	$ 0.083

- As expected, the results indicate that demand response is more valuable in markets with higher underlying prices and higher price volatility. Additionally, we see that at some point, a participant can set their strike price so high as to eliminate any value.

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Calculating the Incentive Payment

- We can use the table shown above to determine a participant's monthly premium and fixed energy credit by multiplying the value shown by the number of times curtailed every month and the amount of demand curtailed when the option is called.

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Calculating the Incentive Payment

- For example, if in advance of the price event the demand response participant chooses a strike price of 6.8 cents, a 500 kW curtailment for four hours, and permits five curtailments per month, in our higher volatility market (representing critical supply deficit and high market prices) the participant would receive a guaranteed $1,303.98 monthly credit and up to an additional $680.00 fixed energy credit if called five times.

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Calculating the Incentive Payment

- The total three month summer season benefit would equal $5,951.94. If the participant chooses three monthly curtailments rather than five the monthly premium is $782.39 and the fixed energy credit would be $408.00 if called three times. The total three month summer season benefit would equal $3,571.17.

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