Using Distributed Energy Resources for Multiple Applications Via Capacity Rights

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The following are my own views and not necessarily those of the Electricity Advisory Committee, the U.S. Department of Energy, or anyone else.

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Outline

1. Introduction and Background
2. Distributed Energy Resources and Regulatory Practice
   - Illustrative Cases
   - Policy Issues
3. Potential Fixes
4. Concluding

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Introduction

- Distributed energy resources (DERs) are flexible resources, with value potential along the full electricity supply chain
- Capturing this value is key to economic viability and efficient investment and use
- Today's regulatory and market structures are not up to this
- Aim: Survey and discuss ways to address these shortcomings

Distributed Energy Resource Applications

1. Wholesale/bulk power system energy services
2. Capacity deferral
   - Generation
   - Transmission
   - Distribution
3. Ancillary services
4. End-user applications
   - Tariff management
   - Power quality
   - Voltage support
   - Backup energy
5. Renewable integration

Importance of ‘Value Stacking’

- Illustrative analysis of distributed energy storage system deployed in PJM service territory [Xi et al., 2014, Xi and Sioshansi, 2016]

	Operating Profits [cents/week]			
Case	Arbitrage	Regulation	Avoided Load Curtailment	Total
Arbitrage	42.84			42.84
Outages	41.61		4.62	46.23
Distribution Deferral	34.31		144.48	178.79
Frequency Regulation	39.07	296.04		335.11

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Difficulty in Value Capture

1. Value streams accrue to different agents, none of which may own the DER
2. Value streams are monetized in very different ways

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Restructured ‘Market’ Design

Market-Priced Services

- Energy
- Ancillary services
- Generation capacity

Regulated Services

- Transmission capacity
- Distribution capacity
- Power quality
- Service reliability

Regulatory Treatment of Assets Differs

- Energy is priced in the market $\Longrightarrow$ generators recover costs through wholesale prices
- Distribution and transmission are regulated $\Longrightarrow$ recover costs through the ratebase/cost-of-service regulation

Distributed Energy Resource Applications

1. Wholesale/bulk power system energy services $\Longleftarrow$ market-priced
2. Capacity deferral
   - Generation $\Longleftarrow$ market-priced
   - Transmission $\Longleftarrow$ market-priced/regulated
   - Distribution $\Longleftarrow$ regulated
3. Ancillary services $\Longleftarrow$ market-priced/regulated
4. End-user applications
   - Tariff management $\Longleftarrow$ market-priced
   - Power quality $\Longleftarrow$ regulated
   - Voltage support $\Longleftarrow$ regulated
   - Backup energy $\Longleftarrow$ regulated
5. Renewable integration $\Longleftarrow$ market-priced

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Lake Elsinore Advanced Pumping Station (LEAPS)

Proposal

- 500 MW PHS plant in southern California between LA and SD
- Adjoining transmission corridor

Developer Sought

- Ratebasing transmission and LEAPS investments
- System operator dispatching LEAPS based on congestion needs

Policy Decision

- Denied ratebasing of LEAPS, allowing ratebasing of transmission corridor *only*
- Denied system operator dispatch of LEAPS, to avoid loss of market-independence

Western Grid

Proposal

- Batteries in California to address thermal overloads, provide voltage support, other transmission services
- Services provided solely based on system operator instruction, as done with capacitors providing reactive power

Developer Sought

- Ratebasing investment

Policy Decision

- Ratebasing granted

Oncor

Proposal

- Oncor, a Texan T&D utility, proposed building 5 GW of distributed batteries in its service territory
- Texas law prohibits T&D utilities owning assets that participate in wholesale markets

Developer Sought

- Revision to ownership prohibition
  - Batteries are not worth the investment cost on the basis of unregulated distribution deferral and voltage support benefits *only*
  - Economically prudent if they could also participate in the wholesale market and earn energy and frequency regulation revenues [Chang et al., 2014]

Policy Decision

- Legislative term ended without any action

Common Themes

- Ratebased assets participating in the wholesale market can harm price formation, scarcity pricing, investment, *etc*.
  - Ratebased cost recovery akin to a subsidy
  - Especially problematic in an energy-only market, such as Texas
  - T&D utilities may have strong incentives to inefficiently overuse DERs to suppress peak prices [Sioshansi, 2010]
- System operators dispatching DERs harms their market independence
- There's no way to combine value streams that are market contingent and regulated
  - How would distributed batteries capture energy arbitrage, frequency regulation, and distribution-deferral benefits (*cf.* earlier simulation results)?
  - Harms financial viability of projects, as in Oncor's proposal

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Too Small to Matter

- Premise: DERs are too small to matter
- Allow ratebased DERs to participate in the wholesale market
  - All of the value streams can be captured
  - Some proposals pass wholesale revenues to ratepayers, others are opaque about this
- Revisit the issue later if and when DERs matter
- Proposed by AEP North Texas with batteries for distribution relief

Fixed Allocation

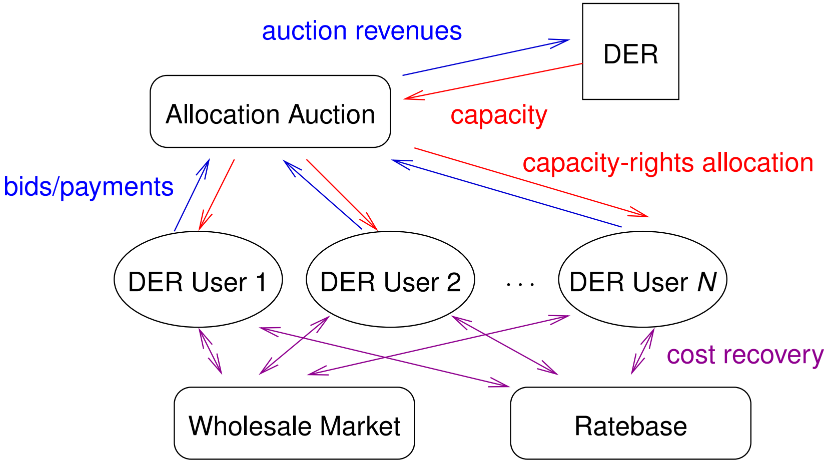
- Premise: Value and cost can cleanly broken down
- Determine the breakdown of value generated by DERs and allocate costs accordingly

Example

- A rooftop solar panel installed on a customer building by a third party
  - 70% of total value generated from reduced customer demand charges
  - 10% from providing frequency regulation
  - 20% from voltage support
- 70% of cost to customer, 10% to developer (who sells frequency regulation wholesale), and 20% to the utility

- Allocations have to be determined *ex ante* for dispatchable resources (*e.g.*, distributed energy storage)
- Invariably incorrect

Capacity Rights



Concept

1. DER owner auctions-off capacity rights to third parties who want to use the resource
2. Cost recovery of capacity rights by third parties based on their intended use
   - T&D utility buys rights for **distribution relief**, cost would be recovered through ratebase
   - A power marketer buys rights to **provide frequency regulation**, cost recovered through wholesale energy sales and purchases
3. Because different parties use the rights for different purposes, the **full asset value** can be captured through the auction

Auction Model

- Rights allocation need to be simultaneous feasible if they are physically exercised
- This may be tricky with dispatchable resources if the rights are not obligations

Illustrative Example: Energy Storage [Sioshansi, 2017]

$$\begin{aligned} \max \ & \texttt{value of rights allocated} \\ \text{s.t. } & \texttt{storage SoC balance} \\ & \texttt{storage energy limits} \\ & \texttt{storage power limits} \end{aligned}$$

▸ Detailed Formulation

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Pricing Rules

- Lagrange multipliers associated with power and/or energy limits of DERs, depending on the type of capacity right
- Clear analogue to locational marginal pricing

Detailed Pricing Rules

Auction Properties

Proposition

The allocation and prices are equilibrium-supporting in the sense that each capacity-right owner wants to follow the capacity uses that are specified by the allocation.

Proposition

The DER owner earns non-negative revenues from the allocation of capacity rights. Moreover, the net revenues earned by the DER owner equals its imputed marginal value.

Side Note

Financial Storage Rights [Taylor, 2015]

- Treat storage as shared public infrastructure, akin to transmission
- System operator dispatches storage along with generation and transmission
- System operator defines and sells financial storage rights
- Financial storage rights attach a value to moving energy through time, as opposed to space

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Financial Storage Rights Model [Taylor, 2015]

$$\min_{p,\theta,e,u^+,u^-} \quad \mathcal{F}(p) \quad \text{subject to}$$

$$\lambda_{i,t}: \quad p_{i,t} = \sum_{j \in \mathcal{S}_i} \left(u^+_{j,t} + u^-_{j,t}\right) + \sum_j b_{ij}(\theta_{i,t} - \theta_{j,t}) \tag{1}$$

$$\xi^l_{i,t}, \xi^u_{i,t} \geq 0 \perp \underline{p}_{i,t} \leq p_{i,t} \leq \overline{p}_{i,t} \tag{2}$$

$$\mu_{ij,t} \geq 0 \perp b_{ij}(\theta_{i,t} - \theta_{j,t}) \leq \overline{s}_{ij} \tag{3}$$

$$\gamma^{+,l}_{i,t}, \gamma^+_{i,t} \geq 0 \perp 0 \leq u^+_{i,t} \leq \overline{r}_{i,t} \tag{4}$$

$$\gamma^-_{i,t}, \gamma^{-,u}_{i,t} \geq 0 \perp \underline{r}_{i,t} \leq u^-_{i,t} \leq 0 \tag{5}$$

$$\chi^l_{i,t}, \chi_{i,t} \geq 0 \perp 0 \leq e_{i,t} \leq \overline{c}_{i,t} \tag{6}$$

$$\sigma_{i,t}: \quad e_{i,t+1} = \alpha_{i,t} e_{i,t} + \eta^+_{i,t} u^+_{i,t} + \eta^-_{i,t} u^-_{i,t} \tag{7}$$

$$\sigma_{i,0}: \quad e_{i,1} = 0. \tag{8}$$

Integrating Concepts

- Financial storage rights have two shortcomings
  1. Require the system operator to dispatch storage, which they don't want to do
  2. Can only capture the value of storage uses that the system operator models, *i.e.*, through $\mathcal{F}(p)$
- The first is a non-issue
- Can the second be overcome by collecting bids from third-party users of storage (or other DERs), as in the auction model proposed?

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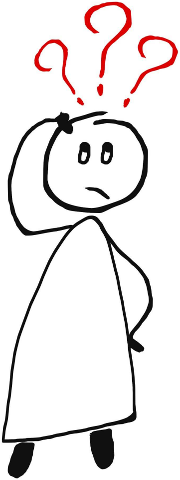
To Conclude

- Distributed energy resources break the traditional classification of assets from the perspective of cost recovery
- Combined with today's regulatory and market paradigms, this limits financial viability of distributed energy resources and yields inefficient investment and use of distributed energy resources
- Some proposals to ignore or address these issues exist, but are flawed or limited
- Allocating capacity rights is proposed as an alternative mechanism for cost-recovery and value capture

Questions?



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Storage-Capacity Rights

Illustrative Example

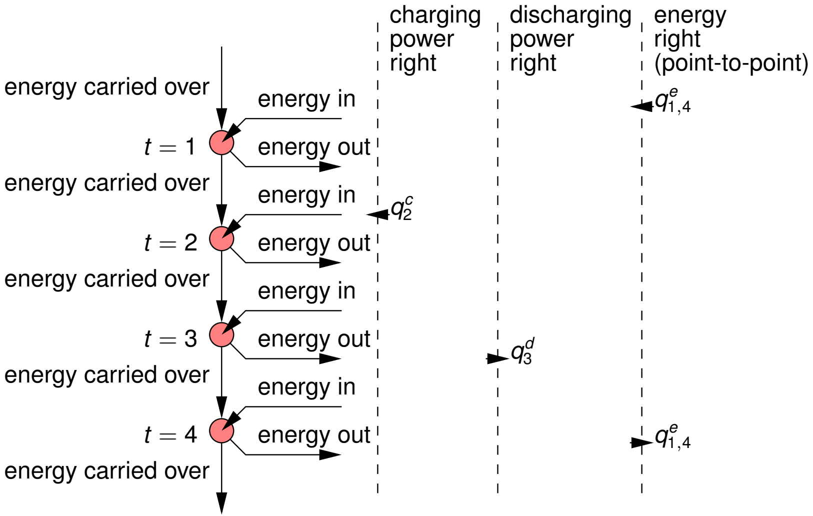
Power-Capacity Right

- Entitles the holder to inject energy into or withdraw energy from storage at a given point in time
- Applications for which times of use are known *a priori*
  - Energy arbitrage
  - Capacity relief

Energy-Capacity Right

- Entitles the holder to inject energy into and withdraw energy from storage at given points in time *and* keep the energy in storage between injection and withdrawal
- Applications for which times of use are not known *a priori*
  - Backup energy
  - Contingency reserves

Illustration of Rights



Auction Model

$$\max_{q,s} \sum_{t=1}^{T} \sum_{n \in N_t} (\pi^d_{t,n} q^d_{t,n} - \pi^c_{t,n} q^c_{t,n}) + \sum_{t=1}^{T} \sum_{t'=t+1}^{T} \sum_{m \in M_{t,t'}} \pi^e_{t,t',m} q^e_{t,t',m}$$

$$\text{s.t. } s_t = \eta^s s_{t-1} + \sum_{n \in N_t} (\eta^c q^c_{t,n} - q^d_{t,n}) + \sum_{t'=t+1}^{T} \sum_{m \in M_{t,t'}} \eta^c q^e_{t,t',m} - \sum_{t'=1}^{t-1} \sum_{m \in M_{t',t}} q^e_{t',t,m} \qquad (\lambda_t)$$

$$\sum_{t'=1}^{t} \sum_{t''=t+1}^{T} \sum_{m \in M_{t',t''}} q^e_{t',t'',m} \le s_t \le H \cdot \bar{R} \qquad (\sigma^-_t, \sigma^+_t)$$

$$-\bar{R} \le \sum_{n \in N_t} (\eta^c q^c_{t,n} - q^d_{t,n}) + \sum_{t'=t+1}^{T} \sum_{m \in M_{t,t'}} \eta^c q^e_{t,t',m} - \sum_{t'=1}^{t-1} \sum_{m \in M_{t',t}} q^e_{t',t,m} \le \bar{R} \qquad (\gamma^-_t, \gamma^+_t)$$

$$0 \le q^c_{t,n} \le Q^c_{t,n}$$

$$0 \le q^d_{t,n} \le Q^d_{t,n}$$

$$0 \le q^e_{t,t',m} \le Q^e_{t,t',m}$$

Model Overview

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Pricing Rule

Hour-t power-capacity charging rights priced at

$$-\eta^c \lambda_t - \eta^c \cdot (\gamma_t^- - \gamma_t^+)$$

Hour-t power-capacity discharging rights priced at

$$-\lambda_t - (\gamma_t^- - \gamma_t^+)$$

Energy-capacity rights consisting of an hour-t injection and hour-t' withdrawal priced at

$$\eta^c \lambda_t - \lambda_{t'} - \sum_{\tau=t}^{t'-1} \sigma_\tau^- + \eta^c \cdot (\gamma_t^- - \gamma_t^+) - (\gamma_{t'}^- - \gamma_{t'}^+)$$

▸ Pricing Overview

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