Q14 Report:
Project DE-OE 0000839

Flexible Service Contracting for Risk Management within Integrated Transmission and Distribution Systems

Iowa State University Project Team

PI Zhaoyu Wang & Co-PI Leigh Tesfatsion
Grad Research Assistant: Swathi Battula

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Presentation Outline

- Project goals
- Project publications and reports
- Q14 project task & activities: Summary
- Q14 project task & activities: Details
- Q15 planned activity
Project Goal 1

- **Goal-1 (Done):** Develop an IDSO-managed bid-based *Transactive Energy System (TES)* design (Refs. [2,3,5,6,8])

![Diagram of Local Intelligent Software Agents (LISA) for an IDSO-managed bid-based TES design with Grid-Edge Resource (GER) participants](image)

*Fig. 1: Illustrative communication network of Local Intelligent Software Agents (LISA) for an IDSO-managed bid-based TES design with Grid-Edge Resource (GER) participants*
Project Goal 2

- **Goal-2 (Done).** Develop swing contracts permitting IDSOs to offer flexible reserve (dispatchable down/up power paths) into ISO-managed wholesale power markets (Refs. [4,9,12])

Fig. 2: One among many possible power paths an IDSO could be dispatched to deliver during day D+1 if its swing contract offering flexible down/up power & ramp is cleared in a day-D DAM
Project Goal 3

- **Goal-3 (Done).** Develop a platform permitting evaluation of our proposed IDSO-managed bid-based TES design within an *Integrated Transmission and Distribution (ITD)* system (Refs. [1,5,7,8,10,11])

![Diagram of ITD TES Platform V2.0](image)

*Fig. 3: Partial agent hierarchy for the ITD TES Platform V2.0*
Project Goal 3 ...

- Transmission component for the ITD TES Platform V2
  - AMES V5.0  [https://github.com/ames-market/AMES-V5.0](https://github.com/ames-market/AMES-V5.0)

Fig. 4: Partial agent hierarchy for AMES V5.0
Project Goal 3 ...

Fig. 5: Key software components for the ITD TES Platform V2.0
**Project Goal 4**

- **Goal-4 (In Progress):** Use ITD TES Platform V2.0 to evaluate the IDSO-managed bid-based TES design (Ref. [6] & ongoing work)

*Fig 6: ITD TES Platform V2.0 modeling of an IDSO-managed bid-based TES design*
Project Publications & Reports (Q14 in Blue)


### Q14 Project Task & Activities: Summary

<table>
<thead>
<tr>
<th>Q14 Task</th>
<th>6/30/2020</th>
<th>6/30/2020</th>
<th>Q14 Activities</th>
<th>Comments on Q14 Activities</th>
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<tr>
<td>Verify and evaluate the proposed flexible contracting system</td>
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<td><strong>A1</strong>: Final revision, uploading, and proofing of the manuscript for our customer-centric bid-based TES design paper [6], to appear in the <em>IEEE Transactions on Smart Grid</em> (2020)</td>
<td><strong>A1-A4</strong>: Links to our forthcoming journal publications [6] and [7] and to our new/revised working papers [10] and [11] are provided below in our listing of project work to date.</td>
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<td><strong>A2</strong>: Final revision, uploading, and proofing of the manuscript for our ERCOT Test System paper [7], to appear in <em>Applied Energy</em> (2020)</td>
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<td><strong>A3</strong>: New WP release [10] of documentation for AMES V5.0, the transmission system component of the ITD TES Platform V2.0.</td>
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<td><strong>A5</strong>: Continuation of ongoing conceptual and ITD TES Platform work focusing on the modeling of IDSO-managed bid-based TES designs, with a particular focus on swing-contract formulations permitting IDSOs to function as linkage entities between T-systems and D-systems</td>
<td><strong>A5</strong>: This Q14 report focuses on work undertaken for activity A5.</td>
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Q14 Project Activities (Goal 4): Details

- Suppose an IDSO operates at a T-D interface for an ITD system.
  - The IDSO can submit bids into the T-system wholesale power market for purchase/sale of power and ancillary service supply.
  - The IDSO manages a bid-based TES design for the D-system to service the power needs of retail customers.

**Challenge:** Can T-system bids & a D-system bid-based TES design be formulated in a manner that permits the IDSO to align system goals/constraints with customer goals/constraints?

- **Preliminary affirmative test cases** are reported in Ref. [6]:
Test Case Features

- ITD system consists of 927 households populating an IEEE 123-bus distribution system connected to a 5-bus transmission system.
- Each household seeks to maximize its own net benefit subject to local physical constraints.

Fig. 7: Hierarchy of basic attributes characterizing a household
Test Case Feedback Loop

Fig. 8: ITD Feedback loop for each household test case
The IDSO is the top-level *Local Intelligent Software Agent (LISA)* in a LISA communication network for D-system households.

Fig. 9: Each household $h$ has an HVAC system managed by a price-responsive HVAC controller (the edge LISA for $h$).
TES Design Implementation

- The IDSO seeks to align/achieve D-system and household goals by iteratively implementing the following *Five-Step TES Design*:

**STEP 1:** The HVAC controller for each household h collects data on h at a *Data Check Rate*.

**STEP 2:** The HVAC controller for each household h forms a state-conditioned bid function Bid(h) for HVAC power demand or HVAC ancillary service supply (power absorption) and communicates Bid(h) to the IDSO at a *Bid Refresh Rate*.

**STEP 3:** The IDSO combines the household bid functions Bid(h) into a vector AggBid of one or more aggregate bid functions at an *Aggregate Bid Refresh Rate*.

**STEP 4:** The IDSO uses AggBid to determine price signals that it communicates back to household HVAC controllers at a *Price Signal Rate*.

**STEP 5 (Control-Step):** The HVAC controller for each h inserts its latest received price signal into its latest refreshed state-conditioned bid function Bid(h) at a *Power Control Rate*, which triggers an ON/OFF power control action for the HVAC system.
Fig. 10: Staggered implementation of the five steps comprising the Five-Step TES Design for household test cases. Each action time-rate is commonly set equal to $1/\Delta t$ with time-step $\Delta t = 300s$ for each household test case reported below.
Fig 11: Depending on its state at the start of a control-step $n$, a household $h$ either (a) offers to supply ancillary service as a function of price received or (b) demands power for usage as a function of price paid. A **negative price** denotes a supply price received and a **positive price** denotes a demand price paid.
Household Classification Into Types

- Classification is based on correlated physical attributes
  
  - **Low Structure Quality:**
    - HVAC system with a relatively poor performance rating
    - House that has a relatively small size
    - House that has relatively poor thermal insulation
  
  - **Medium Structure Quality:**
    - HVAC system with an average performance rating
    - House that has an average size
    - House that has average thermal insulation
  
  - **High Structure Quality:**
    - HVAC system with a relatively good performance rating
    - House that has a relatively large size
    - House that has relatively good thermal insulation
IDSO Peak-Load Reduction Test Cases

- The IDSO on day D specifies a *Forecasted Peak Load (FPL)* for total household load (fixed + price-sensitive) during day D+1, assuming a flat hourly retail price (12₵/kWh).

- The IDSO on day D sets a *Target Peak-Load Reduction (TPLR)* for day D+1 with $0 < TPLR < FPL$.

- The IDSO implements *peak-load price control* on day D+1 by means of the Five-Step TES Design in order to maintain total household load at or below

  \[
  \text{Target Peak Load} = [FPL - TPLR].
  \]

- All households in the same state at the start of a control-step $n$ receive the same price signal at the start of $n$.

- The TPLR for all peak-load reduction test cases is set to 0.5MW.
Fig. 12: Total household load outcomes on day D+1 under peak-load price control (relative to flat-rate pricing) when all households have Low structure quality type.
Fig. 13: Total household load outcomes on day D+1 under peak-load price control (relative to flat-rate pricing) when all households have Medium structure quality type.
Fig. 14: Total household load outcomes on day D+1 under peak-load price control (relative to flat-rate pricing) when all households have High structure quality type.
Peak Load Reduction Test Cases ...

Fig. 15: Retail price outcomes on day D+1 under peak-load price control for the three cases depicted in Figs. 12-14 for which all households have the same structure quality: namely, all Low, all Medium, or all High.
IDSO Load-Matching Test Cases

- The IDSO on day D submits a fixed demand bid into the day-D DAM consisting of a 24-hour load profile L(D+1) for total household load (fixed + price-sensitive) during day D+1.

- The IDSO’s goal is to ensure that total household load realized on day D+1 does not deviate from L(D+1). In pursuit of this goal, the IDSO implements price control on day D+1 by the Five-Step TES Design.

- A (1/3, 1/3, 1/3) mix of household structure quality types is used for each load-matching test case.

- All households in a power demand state at the start of a control-step \( n \) receive the same positive price signal at the start of \( n \).

- All households in an ancillary service supply state at the start of a control-step \( n \) receive the same negative price signal at the start of \( n \).
IDSO Load-Matching Test Cases ...

Fig. 16: Ability of the IDSO to match total household load on day D+1 to a target load profile, given by the IDSO's fixed demand bid submitted into a DAM on day D. No ancillary service procurement is needed for this load matching.
Fig. 17: Ability of the IDSO to match total household load on day D+1 to a different target load profile, given by a different fixed demand bid submitted by the IDSO into the DAM on day D. Ancillary service procurement is needed during some control steps in order to achieve this load matching.
Q15 Planned Activity

- We have received a no-cost continuation for our project work through September 2020.

- During this period we will continue to address the following two key questions for Goal-4, our final project goal:
  - Can our proposed IDSO-managed bid-based TES design facilitate the participation of IDSOs as ancillary service providers in U.S. RTO/ISO-managed wholesale power markets, such as ERCOT?
  - Can swing contracts provide useful support for this IDSO participation?