Energy Systems Innovation Center

WASHINGTON STATE UNIVERSITY

Evaluating the Risk of Enabling Energy Storage Systems to Provide Multiple Services

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Introduction

Motivation

- Battery Energy Storage Systems (BESS) can provide multiple grid services simultaneously, which can increase revenue and grid benefits through efficient utilization.
- It is imperative that there is no failure in the providing of service; it will not only result in payment reduction but may also lead to a disqualification of service by the operator.

The motivation for the work was to improve an existing multi-service optimization algorithm to become risk-aware in its calculation. This is critical for ensuring proper service for grid reliability.

Challenges

The coordination for providing multiple services requires consideration of the available energy and power capacity of the BESS, as well as the inter-temporal constraints and deployment uncertainties of the services.

Objective

The proposed strategy is implemented in a real-world feeder and evaluated using a co-simulation architecture. The evaluation quantifies the trade-offs involved in providing multiple services, which can improve grid reliability and encourage BESS implementation through revenue stacking.

Look Ahead Problem Formulation

Objective: Maximize Revenue

$$\underset{p_t, r_t^+, r_t^-}{Max} \sum_{t=1}^{T} \lambda_t p_t + \beta_t^+ r_t^+ + \beta_t^- r_t^-$$

Model Constraints:

- Power & Energy coordination between the BESS and the grid
- Rate of change of energy in the BESS
- Regulation up and down capacity with respect to BESS capacity
- State of Charge (SOC) dynamics of the BESS

$$l_t = l_{t-1} - \frac{1}{E_s} P_t^{batt}$$

$$\underline{L_t} \le l_t - \frac{r_t^+}{\eta^+ E_s} \le \overline{L_t}$$

$$\underline{L_t} \le l_t + \frac{\eta^- r_t^-}{E_s} \le \overline{L_t}$$

$$\underline{L_t} \le l_t \le \overline{L_t}$$

In order to incorporate the uncertainties with regulation requirement, two uncertainty factors (τ^+, τ^-) are introduced that estimates the depth of deployments for RegUp & RegDown services

The SOC dynamics are split between the three markets the BESS will participate in: regulation up, regulation down, and the Day-Ahead (DA) market.

$$l_t^+ = l_{t-1}^+ - \frac{1}{E_s} P_t^{batt} - \tau^+ \frac{r_t^+}{\eta^+ E_s}$$

$$l_t^- = l_{t-1}^- - \frac{1}{E_s} P_t^{batt} + \tau^- \frac{\eta^- r_t^-}{E_s}$$

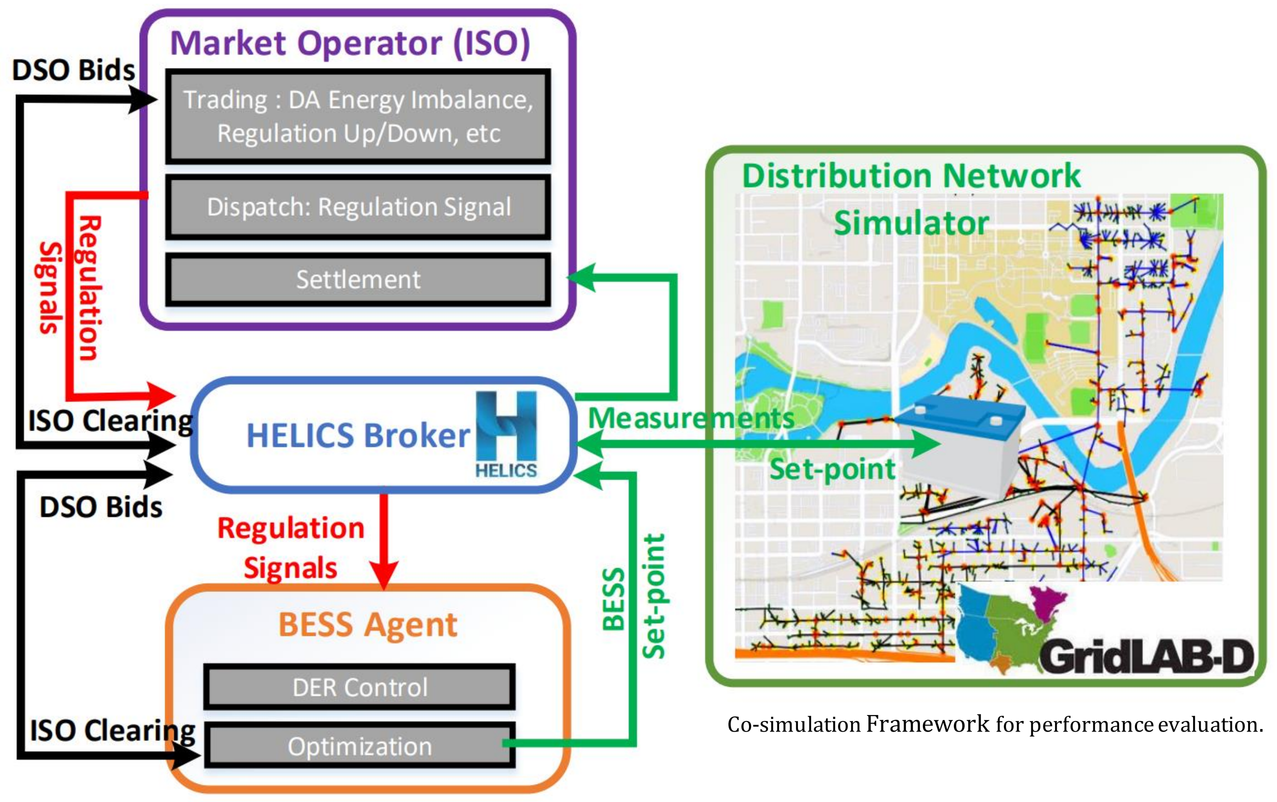
$$l_t^\pm = l_{t-1}^\pm - \frac{1}{E_s} P_t^{batt} - \tau^+ \frac{r_t^+}{\eta^+ E_s} + \tau^- \frac{\eta^- r_t^-}{E_s}$$

$$\underline{L_t} \le l_t^+, l_t^-, l_t^\pm \le \overline{L_t}$$

Co-Simulation Framework

The operational strategy is implemented using a HELICS based co-simulation framework enabling the agents to adjust operation of the BESS devices based on the regulation deployments.

Co-Simulation Framework



Co-simulation Framework for performance evaluation.

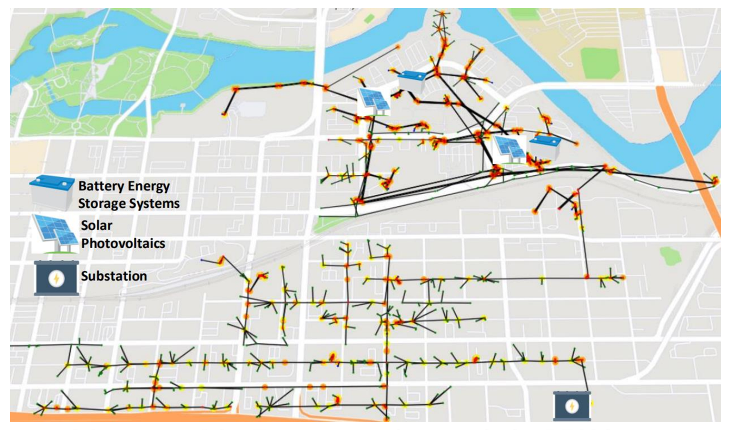
- **System Operator** is implemented as a self-contained Python agent that facilitates the market processes for providing grid services, procuring the required regulation reserves in the Day-Ahead Market and dispatching the BESS's reserved capacity based on synthetic regulation signals generated by the SynAS module. These signals are used to realistically simulate the BESS's performance in the market.
- **Settlement design** takes into account the market clearing price (MCP) for individual services and includes penalties for performance failures. This helps gauge the impact of overestimating the BESS's service potential.

$$C_{net}^{DA} = \sum_{t=1}^{T} \lambda_t^{DA} * p_t + \sum_{t}^{t\epsilon T^+} \beta_t^{+DA} * r_t^+ + \sum_{t}^{t\epsilon T^-} \beta_t^{-DA} * r_t^-$$

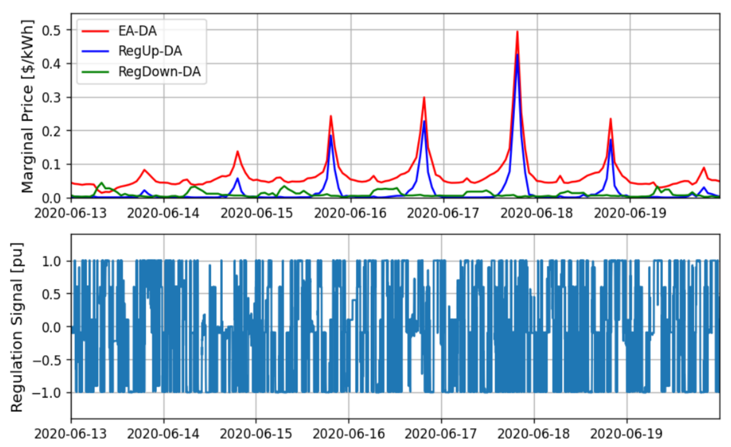
Use-Case Description

The approach is implemented on a real-world system, located in WA, USA and is evaluated for a range of uncertainty factors:

- **$\tau^+, \tau^- = 0$ (High-risk):** Does not ensure BESS availability for both RegUp & RegDown commitments.
- **$\tau^+, \tau^- = 0.5$** : Ensures BESS availability for a 50% depth of RegUp & RegDown deployments.
- **$\tau^+, \tau^- = 1$(No-risk):** Ensures BESS availability for the full range of RegUp & RegDown commitments.



Schematic of the Test system along with the BESS locations.



CAISO LMP and Regulation Signals over one-week period.

Evaluation & Results

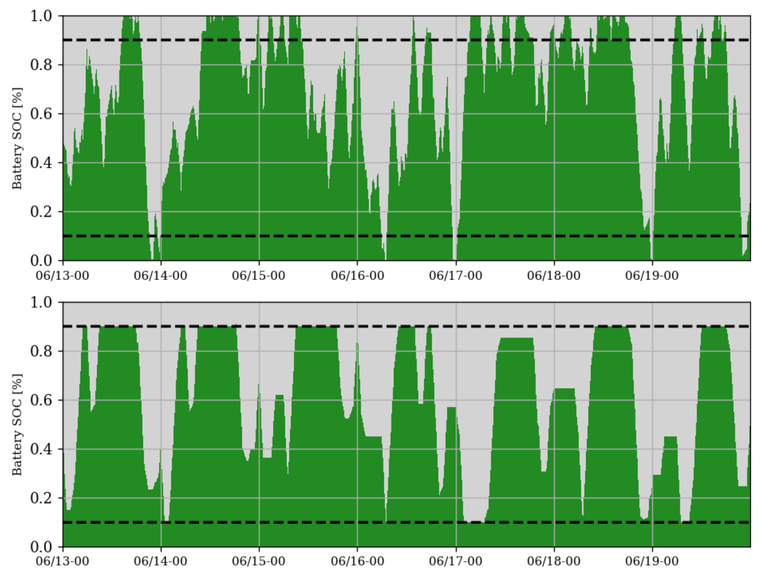
- During the High-risk case ($\tau^+, \tau^- = 0$), the BESS were only able to provide their committed services 78.9% of the time due to over-estimates of energy availability.

Evaluation & Results

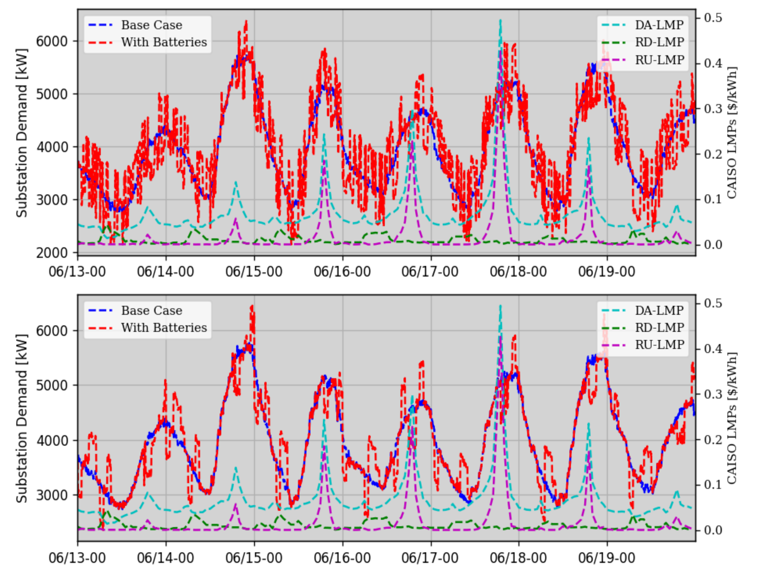
Battery Performance Over a Range of Uncertainty Factors

τ^+	τ^-	Service Provision	Safe Limits DA	Revenue Expected DA	Revenue Actual	BESS Cycles BESS1	BESS Cycles BESS2
0	0	78.9%	73.1%	$1,837.5	$1,313.0	6.2	7.1
1	0	91.2%	38.2%	$1,294.4	$1,248.4	2.1	2.9
0	1	93.2%	44.7%	$1,393.1	$1,370.2	2.7	3.0
0.5	0.5	100%	97.2%	$1,133.0	$1,133.0	3.5	4.1
1	1	100%	100%	$947.4	$947.4	3.9	4.9

- During the ($\tau^+, \tau^- = 0.5$) case, the BESS were able to generate 20% more revenue than the No-risk case while maintaining a 100% servicing provision. BESS can leverage extra revenues if the deployment uncertainties can be appropriately estimated.



SOC of the BESS1 for the High-risk (top) & No-risk (bottom) cases.



Net feeder demand for the High-risk (top) & No-risk (bottom) cases.

- Heavy commitments in the High-risk case could cause frequent deployments leading to a very high volatility in the feeder demand.

τ^+	τ^-	Service Provision	Safe Limits DA	Revenue Expect. DA	Revenue Actual	BESS Cycles BESS1	BESS Cycles BESS2
0	0	77.6%	71.8%	$2,815.35	$2471.74	15.19	17.64
1	1	100%	100%	$1,226.81	$1,226.81	8.89	10.43

- The High-risk case overestimates the service potential of BESS as it doesn't consider the energy availability due to possible deployments.

Conclusions

- The proposed approach enables the BESS to provide their committed services by responding to the service deployments at all times and thereby guarantees service provision to the system operator.
- Results also indicate that the deployment uncertainties, when not considered, would over-estimate the BESS's potential, leading to failures in service-provision.
- Future extension of this work would aim towards including network constraints and battery degradation in the formulation, in addition to real-time regulation markets and network services like voltage regulation.

Acknowledgments

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