

A Blockchain Based Co-Simulation Framework for Integrating DERs into Wholesale Electricity Markets

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This paper proposes a blockchain-based solution for the distributed energy resource (DER) coordination use case to support Federal Energy Regulatory Commission (FERC) Order 2222. The use case enables small-scale DERs to participate in wholesale market operation through DER aggregators while enabling local distribution system operators to enforce distribution system constraints in a secure and traceable manner. This use case was deployed and tested on Unified Testing Platform (UTP) developed under the Blockchain for Optimized Security and Energy Management (BLOSEM) project. The BLOSEM UTP is the first-of-its-kind, rapid, blockchain-based deployment and testing platform for grid applications. For a proof of concept, the framework's validity was demonstrated using the IEEE 13-bus test feeder and a blockchain-based co-simulation framework to coordinate among DERs, DER aggregators, distribution system operators (DSOs), and independent system operators (ISOs).

1. Introduction

- FERC Order 2222 mandates ISOs to integrate DER aggregators as a new category of market participants on behalf of the DERs.
- Researchers have been investigating and experimenting with Distributed Ledger Technology (DLT) to satisfy future grid needs, such as grid modernization and the clean energy transition.
- DLT is a distributed computing/networking technology that can be used as a trust anchor in a multi-ownership ecosystem (where multiple actors might have competing interests).

2. Architecture

- **Unified Testing Platform (UTP):** Under the BLOSEM project, a modular and reconfigurable testing environment called UTP was developed and can simulate a wide variety of real-world use case scenarios.
- **UTP core services:** Abstract the flow of data and commands between the blockchain and grid emulation environments in a system-agnostic manner. Core services are control and data flow, logging and monitoring, testing and validation, etc.
- **Blockchain services:** Enable the demonstration and maturation of the UTP core services by deploying different configurations of Hyperledger Fabric.

3. DER Use Case Description

The secure and reliable integration of DERs into wholesale markets requires coordination among different entities, such as DERs, DER aggregators, DSOs, and ISOs. The presented DER control and coordination use case focuses on enabling the integration of DERs into wholesale markets via aggregators while enabling generation output management, ensuring secure and reliable distribution-level operation. This use case (1) provides the secure registration and capability qualification of DER resources, (2) avoids duplicate bids from DERs by preventing double counting, and (3) enables reliable system operation by validating bids in terms of physical constraints.

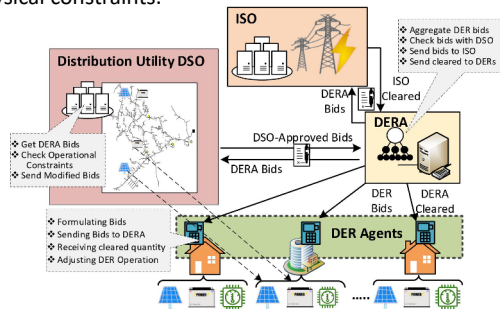


Figure 1. Conceptual overview of the DER coordination use case

4. Implementation Detail

The use case implementation is divided into three components: UTP-based components, co-simulation framework, and blockchain components.

- The UTP-based components use the Amazon Elastic Compute Cloud (EC2) instance for Blockchain services, Amazon Web Services (AWS) relational databases for storage, AWS elastic load balancing for data flow, and Splunk for monitoring.
- The Hierarchical Engine for Large-scale Infrastructure Co-Simulation based framework is used for market and feeder agents.
- Hyperledger Fabric with custom smart contracts are deployed on the IBM cloud.

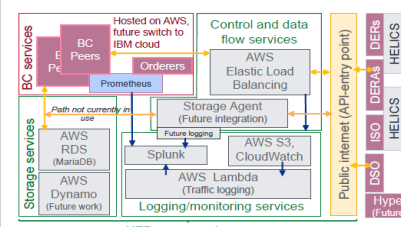


Figure 2. UTP-focused service overview as used in the DER use case

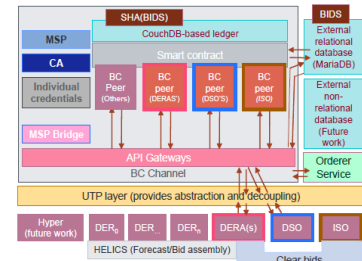


Figure 3. Blockchain-focused architectural overview for the DER use case

5. Experiment Design and Result

The performance of the proposed mechanism is demonstrated using the test feeder, and the blockchain metrics are extracted from Prometheus.

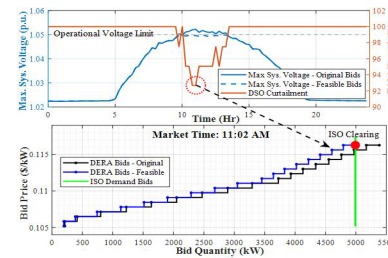


Figure 4. DSO computed system voltage and curtailment on a market day (top) and market clearing for a particular interval (bottom)

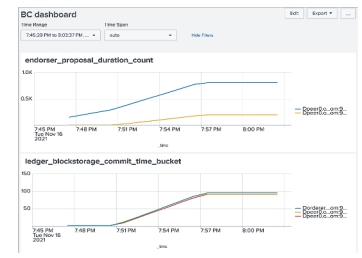


Figure 5. Splunk dashboard tracking peer-level blockchain metrics

6. Conclusion and Future Direction

- This work presents a DER integration use case that facilitates end-to-end interactions to support FERC Order 2222 implementations by providing secure and scalable interconnection capabilities to disparate grid entities via blockchain.
- The framework's validity has been demonstrated using the IEEE 13-bus test feeder and a blockchain-based co-simulation framework to coordinate among DERs, DER aggregators, DSOs, and ISOs.
- Future work aims to expand the use case for a multi-settlement (day-ahead and real-time) ISO market and achieve integration with hardware-in-the-loop simulators.