A Computable Multilayer System Stack for Future-Proof Interoperability

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Abstract

The future decarbonized power grid will make increasing use of distributed energy resources (DERs) controlled using data collected at an extremely granular level compared to today's coarse bulk power system models. However, the centralized system by which security constrained economic dispatch is implemented at the transmission level cannot be directly applied to a distribution system comprising five orders of magnitude as many nodes engaging in complex scheduling and bidding behavior. Emerging data processing tools such as distributed state estimation algorithms, multiparty computation, blockchains, zero-knowledge proofs and machine learning hold the promise of collecting and processing the necessary data efficiently and securely. In particular, the implementation of transactive energy mirrors the decentralization of the world wide web from a data processing perspective, with similar toolsets required to develop secure, robust algorithmic markets making personalized decisions based on locally relevant datasets. The development of cryptographic tools and data processing infrastructure to build these decentralized markets is advancing rapidly. Meanwhile, capital must be deployed in

the power system to purchase assets with decades-long lifespans. In order to balance the uncertainty caused by rapid progress with the need to build working systems today, we present a Computable Multilayered Power System model designed to enable future-proof interoperability. In our five-layered design, each layer performs one of the essential functions needed to run a power system: State Estimation (SE), Optimization and Dispatch (OD), Transaction (TR), Auditing and Recording (AR), and Regulation (RE). The specification of this architecture defines the datastructures by which information is exchanged between layers. This ensures that each layer has access to the data and settings required to perform its function, but ensures future-proof compatibility by allowing that function to be performed according to any algorithm. Communication between these layers and devices in the field may be performed using existing standards such as IEEE 2030.5 and Sunspec Modbus. The five-layer model is amenable to hierarchical implementation, making it compatible with architectures such as laminar coordination frameworks. However, alternative implementations of the layers allow microgrid control, security constrained economic dispatch, building energy management or a sparse implementation such as managing a subset of smart devices on a distribution feeder. Separation of Auditing and Regulatory functions from other tasks allow novel concepts such as zero-knowledge proofs to be readily implemented, and tariff structures or optimization parameters easily changed in the regulatory layer without the need to update other layers manually. Transactions may be billed using existing methods, or the transaction layer may use digital payment channels without affecting other layers. Additionally, multiple layers such as Transaction and Auditing may be combined if performing these functions together is desired. As new modular tools are developed which offer increasingly efficient methods of coordinating DERs, this functional separation of concerns will enable their implementation while maintaining compatibility with existing and future systems.