

## **A Transactive Network Template for Decentralized Transactive Energy Systems**

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The complexity of launching a new transactive energy network is overwhelming. Successful recent examples might include Independent System Operators. These have probably been successful because 1) the rules of these markets were codified and accepted by market participants, and 2) the market networks are notably shallow in that they have but one centralized price discovery mechanism. How might still deeper, more distributed networks of transactive agents might be facilitated? Price discovery mechanisms and computations in these networks should become fully decentralized. The many transactive agents that make up the distributed transactive energy networks might reside not only with load serving entities and wholesale providers who participate today, but also at many additional levels of the electricity distribution circuit—in appliances, devices, residences, businesses, industries, substations, transformers, generators, and distributed energy resources of any type.

To facilitate the creation of such distributed transactive energy networks having fully decentralized price discovery, the panelist formulated a transactive network template. The transactive network template is a metamodel of the object classes that are needed to configure and instantiate the perspective of one transactive agent within a network of such transactive agents. The principal objects, besides the agent object itself, include models of assets that are owned by the agent, modeled representations of other neighboring transactive agents, and a market module. The principal behaviors of the system are divided among responsibilities to schedule price-responsive power, balance supply and demand, and coordinate with neighboring transactive agents using transactive signals. Reference implementations of the transactive network template may be coded in various languages and implemented on various platforms. The transactive network template may be improved to include new assets, objectives, and even price discovery mechanisms through class inheritance and extension. A key to extensibility in a network is found to be the requirement of certain basic behavioral responsibilities and information interfaces, while allowing substantial flexibility concerning just how those responsibilities are performed and how required information is calculated.

So far, a single reference code implementation has been created using Python, and a reference field implementation has been completed on the Pacific Northwest National Laboratory (PNNL) campus. The campus network agents model the local electric municipality, the PNNL campus, and campus buildings. Prices become differentiated by hour at these locations due to time-of-use wholesale electricity prices, wholesale demand charges, distribution energy losses, municipal demand charges, dynamic demand, and the price responses of the building control systems. The primary price-responsive elements are a set of commercial building control systems. Prices and flexible demand participate in a rolling series of 24 forward hourly intervals.

Work continues to improve the transactive network template on several fronts: First, the market module is to be improved to accommodate commodities other than electricity and to demonstrate value exchange between the various commodities. Second, it must be demonstrated that the transactive network template can accommodate different alternative price discovery mechanisms and protocols.