An Overview to the Transactive Energy Roadmap

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The GridWise Architecture Council was formed by the U.S. Department of Energy to promote and enable interoperability among the many entities that interact with the electric power system. This balanced team of industry representatives proposes principles for the development of interoperability concepts and standards. The Council provides industry guidance and tools that make it an available resource for smart grid implementations. In the spirit of advancing interoperability of an ecosystem of smart grid devices and systems, this document presents an overview of the Transactive Energy Roadmap. The roadmap itself considers drivers of change, triggers for transactive energy system deployment, and required infrastructure for deployment at scale. This document explains the organization and structure of the roadmap and is recommended reading before reading the roadmap itself. Please see the www.gridwiseac.org website for more products of the Council that may be of interest.

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Introduction

It has been said that if Thomas Edison could see the electric industry today he would recognize it as being much the same as 100 years ago, but that may not be the case for much longer. The century old paradigm of large scale generation and distribution is starting to change as renewable resources make more of an impact. New distributed devices, both consumer and utility-owned, impact the grid directly and also interact with each other. Preparation to integrate these new resources and technologies through consideration of operational and policy changes built around measured and effective choices has already started. For example, the industry is undergoing a fundamental shift from a “load following” paradigm, where central generation adjusted to varying demand, to a “supply following” paradigm, where responsive demand absorbs variable generation such as solar and wind. During the transition to a more highly distributed system, the industry can't afford to design purely for either extreme. A key to success is the use of technologies that support flexible coordination of centralized and distributed elements. One such approach is provided by transactive energy systems.

The need for transactive energy systems is being driven by economic, technological and customer preference opportunities that were just beginning to exist five years ago. With today’s enhanced performance and declining costs for many renewable energy sources and storage technologies being deployed, these increased uses of distributed energy resources is here to stay. Distribution systems were not designed for large scale deployment of distributed energy resources with potential power flows in multiple directions. Ad hoc arrangements have worked so far, but as the combined effects of changes often outside of regulatory and utility observation and control become significant, a more robust response to maintaining and enhancing safety, reliability, and resilience of distribution energy systems and markets is required.

GWAC TE Roadmap

The GWAC transactive energy roadmap outlines a vision and path forward to achieve deployment of transactive energy systems at scale as an operational element of the electric power system to facilitate the integration of distributed energy resources and dynamic end-uses such as connected buildings. It also considers the application of transactive energy systems for the coordination and control for end-uses, for example, in managing energy in buildings and campuses.

The roadmap considers drivers of change, triggers for transactive energy system deployment, and required infrastructure for deployment at scale. Gaps in technology and infrastructure that may require investment are identified.

The roadmap captures potential changes over time (***Stages***) and organizes them by business and technical ***Tracks***. Within each Track it also groups potential changes into ***Swim Lanes*** that identify what it is that we hope to see, what it takes for this to occur, what we see as a result, and what these features do to add value.

Stages

The roadmap is based on considering what is required to support increasing levels of distributed energy resource penetration in electrical distribution systems. The roadmap considers the overall vision in three stages primarily characterized by the level of market development around distributed energy resource (DER) penetration. These stage definitions allow one to determine the characteristics that determine what stage a given distribution system is in. One should note that there are implications for the relationship between the distribution utilities and the bulk power system and that given the regional nature of the bulk power system, that all distribution utilities within a given region will not usually find themselves at the same stage.

Stage 1

In stage 1 there is limited DER penetration. DER value is administratively set, for example, via net metering tariffs. DER has minimal but perceivable impact on distribution system operations.

Stage 2

Levels of DER penetration grow as prices continue to drop. Net metering tariffs begin to be replaced with market interactions that establish the value of the DER assets. Aggregated DER or large DER assets interact with bulk power markets based on a limited number of value streams. DER penetration has manageable impact on distribution system operations.

Stage 3

DER penetration grows impacting distribution system operations and requiring new means for asset owners to realize return on investment. Stacked value streams are realized through DER participation in local, distribution level, markets. The stacked value streams have spatial and temporal variability reflected operational needs in the distribution and bulk power systems.

Roadmap Tracks

The roadmap tracks generally follow the GridWise Transactive Energy Framework's breakdown of considerations for transactive energy systems into the four areas of:

Regulatory and Policy

This track describes the actions needed by regulators and other policy makers to enable TE systems as envisioned in each of the three stages. The objective of the actions in this track is to establish an environment that enables transacting parties to understand rules of engagement and compensation in addition to performance requirements. The actions also focus on achieving a consistency of approach across jurisdictions as much as possible to promote interoperability. The actions described may be carried out by different policy-making bodies depending on the individual jurisdictions and types of utilities.

Many of the actions described in this track support development and implementation actions described in the Business Models and Value Realization track and to a limited extent, the actions included in the System Design and Architecture and Physical and Cyber Technologies and Infrastructure.

Business Models and Value Realization

This track focuses on the various stakeholders, their roles in TE and how their business models need to evolve for them to provide and realize value in each of the three stages. While the regulatory and policy track describes the actions policy makers need to take to establish the needed TE environment, this track focuses on the actions to assess and implement needed business model changes by various stakeholder types.

System Design and Architecture

This track focuses on system design and architecture actions necessary to support each stage specifically dealing with information interoperability to support TE valuation, and operation and control aspects to understand and manage the impacts on the electric grid. This track depends on the business model to define required information exchange between TE parties in content and timing.

Physical and Cyber Technologies and Infrastructure

This track focuses on the changing Cyber-Physical needs and required actions through the progression of the three stages. This track addresses the technical layers of the GWAC Stack and the physical layers of the Control Abstraction Stack. It includes the activities aimed at the electrically connected network and the communications networks that are necessary to monitor and control the electric grid. This track depends on the information exchange requirements considered in the system design and architecture track to ensure the ability to exchange information in support of transactions without detrimentally affecting the reliability of the electrical network.

Each of these areas is informed by the drivers for change such as increased penetration of rooftop solar, battery storage, electrification of transportation, etc.

Swim Lane Definitions

For each of the roadmap tracks there is a separate table that describes the features of that track by each of the three stages. Also, for each stage there are four swim lanes (rows) that provide a more detailed breakdown of the features not only by stage but also by different perspectives. These perspectives are:

- **Vision** – what it is that we hope to see during this stage
- **Enablers** – what it takes for the vision to occur
- **Results** – what we see resulting from how the enablers are being used
- **Benefits** – what these results do to add value (when compared with the status quo)

Organization of Material

In order to show the impact of changes based on the use of Tracks, Stages, and Swim Lanes the roadmap is organized into sections based on Tracks. In addition to the Tracks mentioned above, the roadmap contains an additional Overview section which captures some of the key concepts from the other tracks. It provides an executive summary for the roadmap.

At the start of each section (except for the Overview) there is a list of three to five main concepts that were considered important to see represented in the section. These core concepts state the fundamental concept in as timeless (stage free) manner as possible so that one can then apply the concept by stating how it manifests through the stages. These manifestations are documented in tables. Also included in the core concepts are condensed encapsulations of the transactive energy principles described in Section 3.3 of the GWAC TE Framework

Within each section there are four tables, one for each swim lane. The tables consist of multiple rows of information. Each row of information captures something that represents a change or evolution occurring over time with three columns to describe what is seen in stages 1, 2, and 3 as the examples below show.

	Stage 1 Persistently Demonstrated	Stage 2 Broadly Applied	Stage 3 At Scale
Vision *what it is that we hope to see during this stage*	Early scenario 1	Mid scenario 1	Late scenario 1
	Early scenario 2	Mid scenario 2	Late scenario 2
	Early scenario 3	Mid scenario 3	Late scenario 3

	Stage 1 Persistently Demonstrated	Stage 2 Broadly Applied	Stage 3 At Scale
Enablers *what it takes for the vision to occur*	Early scenario 1	Mid scenario 1	Late scenario 1
	Early scenario 2	Mid scenario 2	Late scenario 2
	Early scenario 3	Mid scenario 3	Late scenario 3

	Stage 1 Persistently Demonstrated	Stage 2 Broadly Applied	Stage 3 At Scale
Results *what we see resulting from how the enablers are being used*	Early scenario 1	Mid scenario 1	Late scenario 1
	Early scenario 2	Mid scenario 2	Late scenario 2
	Early scenario 3	Mid scenario 3	Late scenario 3

	Stage 1 Persistently Demonstrated	Stage 2 Broadly Applied	Stage 3 At Scale
Benefits *what these results do to add value*	Early scenario 1	Mid scenario 1	Late scenario 1
	Early scenario 2	Mid scenario 2	Late scenario 2
	Early scenario 3	Mid scenario 3	Late scenario 3

The information in the tables was produced by a working group and from workshop sessions. The core concepts thus provide a means to check for gaps (where a concept has not been invoked) or duplication (where a concept has been used multiple times). Although the core concepts provide a basis for verifying the completeness of the initial draft of the roadmap, multiple invocations of concepts is inevitable in cases where different rows have different scope but some overlap also. Future versions of the roadmap may seek to tighten this up but they have been included in the first draft for completeness of vision.

Appendix A: Core Concepts

The challenge here is to state the fundamental concept[1] in as timeless (stage free) a manner as possible. **Note**: items in ***bolded italics*** represent condensed encapsulations of the TE principles described in Section 3.3 of the TE Framework[2].

[1] The concepts presented in this overview document may change by the time the roadmap is finalized

[2] GridWise Transactive Energy Framework Version 1.0, PNNL-22946, January 2015 (http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf)

Regulatory and Policy

- **RP1** - Support for retail power markets with ***non-discriminatory participation***[3]
- **RP2** - Consistency of regulation/minimum requirements from state to state
- **RP3** - Dynamic exchange of information and value (including real-time retail tariffs) between wholesale and retail markets across the T&D interface
- **RP4** - Intra- and inter- jurisdictional market monitoring and oversight functions are described in policy (and regulation)

Business Models and Value Realization

- **BM1** - Incentives and opportunities exist for all stakeholders with all ***parties accountable for standards of performance***[4]
- **BM2** - A means exists to optimally assign value when comparing alternatives (for example wires and non-wires alternatives)
- **BM3** - Business models align values across the participating entities in an ***observable and auditable***[5] manner
- **BM4** - Opportunities exist for value creation (services) across multiple streams

System Design and Architecture

- **DA1** - A standard set of definitions and interface structures based on Laminar Decomposition for all X2G operations, for transactive exchanges within and across all structural layers
- **DA2** - Transition from centralized to decentralized based on ***highly coordinated self-optimization***[6]
- **DA3** - ***Reliability and control***[7] are assigned value when integrated into all TE systems that interact with the grid
- **DA4** - Buildings and facility-grids feature more prominently over time
- **DA5** - Modeling and simulation solutions for TES produce consistent results with each other and can exchange data

Physical and Cyber Technologies and Infrastructure

- **PC1** - Improved measurement, verification, and situational awareness
- **PC2** - Affordability of devices and communications enables ***scalable, adaptable, and extensible***[8] deployment
- **PC3** - Distributed devices securely integrated into control schemes
- **PC4** - Ability for consumer devices to support sub-cycle to long term activities (markets/operations)
- **PC5** – Explicit, well defined, trust models that define identity, authentication, service level agreements, and privacy need to be built into all TE systems.

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[3] **TE Principle:** Transactive energy systems should provide for non-discriminatory participation by qualified participants

[4] **TE Principle:** Transacting parties are accountable for standards of performance

[5] **TE Principle:** Transactive energy systems should be observable and auditable at interfaces

[6] **TE Principle:** Transactive energy systems implement some form of highly coordinated self-optimization

[7] **TE Principle:** Transactive energy systems should maintain system reliability and control while enabling optimal integration of renewable and DERs

[8] **TE Principle:** Transactive energy systems should be scalable, adaptable, and extensible across a number of devices, participants, and geographic extents