# ENABLING PROSUMER-CENTRIC TRANSACTIVE ENERGY MANAGEMENT

Marija Ilic, Institute for Data, Systems and Society, Massachusetts Institute of Technology (MIT), 617-324-0645, ilic@mit.edu
Rupamathi Jaddivada, Laboratory for Information and Decision Systems, MIT, 412-378-1479, rjaddiva@mit.edu

## Overview

At present, large number of small electricity users do not participate in system-level power balancing at value. Up until very recently, they have been served by the local utilities at fixed electricity tariffs. In some parts of this world, these have been time-of-use tariffs. Only recently, alternative service providers, such as LSEs, have begun to be formed as an alternative to utilities' service to small end-users. On the other hand, consumers are beginning to deploy their own DERs such as solar PV and back-up small generation. Most of the state regulation considers such customers as sufficiently small and allows them to connect to the utility grid. However, as more and smaller customers become both producers and consumers (prosumers), it is necessary to establish systematic framework for their technical integration with the grid and for providing incentives to participate in system-level power-balancing and electricity markets.

Enabling prosumer participation in supply-demand balancing at value, is generally referred to as Transactive Energy Management (TEM). GridWise Architecture Council defines Transactive Energy (TE) as 'a system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter' [1]. Responsibilities need to clearly be demarcated for providing efficient, green and reliable electricity at right prices. This further depends on the objectives of interest. For instance, developing and developed countries may have different set of objectives, such as the former may need basic access to power while the latter may be interested in maximum utilization of green energy. The business models, the tariffs and possible compensation mechanisms should be designed such that the objectives of economic viability and technological implementability are aligned. These decisions need to be consumer-centric if social welfare or energy democracy is desired. Implementing this shift from traditional energy management systems to TEM is indeed a daunting task. As the number of prosumers increases, the task of establishing well-functioning rules, rights and responsibilities (3Rs) becomes overly complex [2].

## Methods

Modelling and Implementation Framework for TEM: Two interrelated methods underlie the proposed TEM framework. The first concerns basic modelling approach to capturing prosumer integration at value in end-to-end markets, and the second is use of this modelling approach for market implementation by means of temporal and spatial lifting techniques.

*Modelling of prosumers and their physical and economic interactions:*
This paper offers one possible approach to modelling economic and control mechanisms underlying TEM so that large number of prosumers can be integrated while ensuring economic viability. The approach requires end-to-end transparent information exchange between stakeholders. As the first step, behavioural and technical characteristics of prosumers need to be communicated for near-optimal system efficiency. Recent research concerns possible prosumer characterization which can be defined as utility functions for quality of service [3] or for power and energy consumed/produced [4]. We have recently shown that since prosumers are extremely heterogeneous and complex their characterization should be standardized in terms of commonly understood technology-agnostic market specifications [5]. Because of this, the second characterization of utility functions in terms of power and energy is selected. This makes it possible to characterize all market stakeholders using the same type of market interface specification.

*Economic mechanism underlying TEM implementation:*
This approach is a natural outgrowth from today's electricity markets, and it is further generalized to include characterization of prosumers. To ensure quality-of-service (QoS) through market incentives it is essential to define these specifications over several time horizons and for different prosumer grouping. As a result, the underlying modelling only requires multi-temporal and multi-spatial specifications in terms of power contributing to useful work (P), energy (E) and wasted reactive power (Q) and the corresponding prices; these specifications form the basis for defining a stratum of temporally-differentiated energy market commodities, such as long-term, short-term, day-ahead-market (DAM) and real-time market (RTM) energy derivatives [6]. Similarly, spatial aggregation of prosumers leads to spatially differentiated energy derivatives, such as nodal, zonal and larger area-level energy

derivatives. This then defines the specific market architectures in support of TEM and market derivatives such as QoS. It can be shown that depending on volatility of prosumers and electric power grid system in place, near-optimal architecture is obtainable, and its granularity of derivatives offered is system specific, provided sufficient market granularity QoS is ensured at value. This is not the case in today's markets because prosumers do not necessarily meet specifications in terms of P, Q and E.

Most important, this framework is simple enough to enable prosumer participation and provides well defined economic incentives. Because of this, it can then be used to identify the right regulation policies that align with economic and technological objectives. In doing so, several market products which have been missing in the present industry practices, such as the ones corresponding to temporal flexibility, risk minimization and prosumers choice will be identified. Furthermore, the approach lends itself to assessing different market architectures, such as the level of aggregation required, relevant communication protocol and suitable market products. Depending on system characteristics and stakeholder characteristics, the near optimal architectures are different, but they are designed using the same modelling and implementation principles.

## Results

For illustration purposes we will use a distribution feeder in Texas, which has data available for different spatial and temporal granularities [7]. We will illustrate the use of modelling to characterize its prosumers, comprising solar Photovoltaics (PVs), water heaters, Heating, ventilating and Air-Conditioning units (HVACs), and Electric Vehicles (EVs). Three different architectures for enabling TEM are simulated and their effectiveness is analysed using performance metrics stated in [4]. First market architecture resembles today's centralized whole sale markets; the second architecture represents fully decentralized peer-to-peer TEM; and the third market architecture is the so-called Dynamic Monitoring and Decision Systems (DyMonDS) framework that supports multi-layering and minimum interactive information exchange protocols in terms of P,E and Q [8, 9]. A quantitative risk analysis depends on how the system is designed and its effects on operation. This is one of the important performance metric that will be assessed for implementation of reliable services within such multi-layered energy systems.

## Conclusions

Market architectures for systematic integration of prosumers requires rethinking market design. In this paper one possible approach to having the same principles for modelling and implementation of such markets is offered. It can be used to assess basic information exchange and performance for vastly different electric power systems. For one given system, we illustrate its use for comparing effects of market designs on market performance.

## References

[1] Melton, R.B., 2013. Gridwise Transactive energy framework (draft version) (No. PNNL-SA-22946). Pacific Northwest National Laboratory (PNNL), Richland, WA (US).
[2] Kleindorfer, P.R., 2004. Economic regulation under distributed ownership: the case of electric power transmission. Harvard Electricity Policy Group.
[3] Ilic, M., 2002, June. Model-based protocols for the changing electric power industry. In Proceedings of the Power Systems Computation Conference.
[4] Ilic, M., Jaddivada, R., Miao, X. , Transactive Energy Report, Massachusetts Institute of Technology, MIT Final Report on NIST project, May 2018
[5] M. D. Ilic, R. Jaddivada, Multi-layered interactive energy space modelling for near-optimal electrification of terrestrial, shipboard and aircraft systems, submitted to Annual Reviews in Control, April 2018
[6] Wu, Z. and Ilic, M., 2008, July. The effects of multi-temporal electricity markets on short-and long-term bidding. In Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century, 2008 IEEE (pp. 1-8). IEEE.
[7] Street, P., 2015. Dataport: the world's largest energy data resource. Pecan Street Inc.
[8] Ilic, M.D., 2007. From hierarchical to open access electric power systems. Proceedings of the IEEE, 95(5), pp.1060-1084.
[9] M. Ilic, R. Jaddivada, X. Miao, N. Popli, Toward multi-layered MPC for complex electric energy system, in Handbook on Model Predictive Control, Birkhauser, 2018, Ch. 3.6., *(To Appear)*