TeMIX: A Foundation for Transactive Energy in a Smart Grid World

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Abstract

Transactive Energy Market Information Exchange (TeMIX) is a standards-based architecture and protocol for real-time and forward transactions of electricity products. With interval metering, improved communications, smart devices, smart controls, and TeMIX protocols, many electricity transactions can be executed automatically in high volumes and at high speed.

TeMIX enables decentralized decisions and control at the edges of the network. Using TeMIX, customer devices such as air conditioners, plug-in electric vehicles, customer generation and storage automatically interact with distribution grid devices such as transformers, high voltage transmission networks, generation and storage. TeMIX thus enables a smart grid that can quickly adapt to high levels of variable renewables, plug-in vehicles, and storage.

This paper provides a high level description of TeMIX operational services for use by smart devices, customers, suppliers, distribution and transmission operators and intermediaries.

1. TeMIX BACKGROUND

TeMIX is described in an OASIS[1] Technical Committee white paper [1]. TeMIX supports transactive energy markets as shown in Figure 1. Transactive markets allow any party (customer, generator, transmission operator, marketer, etc.) to transact with any other party to the extent regulatory policy permits. Vertically integrated, cost-of-service, entities and their customers also can employ TeMIX protocols.

Interval metering provides granular measurements of electricity usage, generation and network flows over short intervals of time. High speed, secure Internet communications enables electronic messaging with smart devices and market participants. With these advances and TeMIX [1], it is technically feasible to transact electricity on intervals of years, months, days, hours, minutes and seconds.

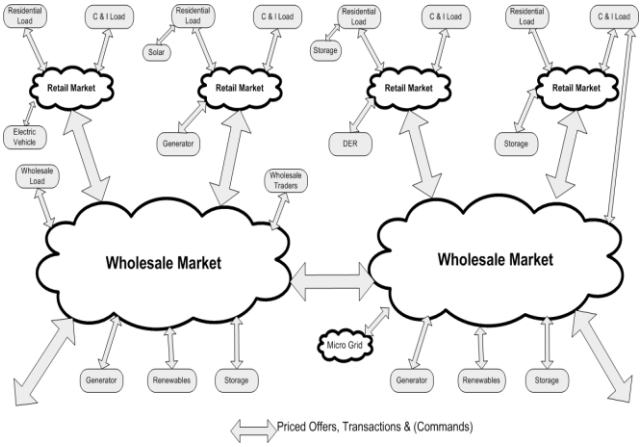

Figure 1 : Transactive Energy Markets

Standard protocols can spawn rapid change. The TCP/IP Protocol enables global, high speed internet messaging and data transfers. The Financial Industry Exchange (FIX) Protocol (http://www.fixprotocol.org) enables global, high speed, high volume messaging for financial transactions. The TeMIX Protocol enables high speed, high volume messaging for electric energy transactions.

TeMIX draws on and informs the work of three OASIS Technical Committees overseen by the NIST Smart Grid Interoperability Panel[2]. These OASIS committees have recently published Committee Draft standards [2-4] for public review. The three committees are WS-Calendar, Energy Market Information Exchange (EMIX) and Energy Interop.

2. TeMIX ARCHITECTURE AND PROTOCOL

The TeMIX architecture and protocol facilitates the process of negotiation, contracting and delivery of electric energy

[1] Organization for the Advancement of Structured Information Standards, http://www.oasis-open.org .

[2] National Institute of Standards and Technology, http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/WebHome

between parties. A generator takes the role of a seller or a buyer relative to previous net sales. A customer takes the role of a buyer or a seller relative to previous net purchases.

Figure 2 shows parties that can transact with each other using a TeMIX Protocol network. The parties include generators and customers, intermediate parties such as exchanges, traders, brokers, aggregators, retail energy providers (REP) and transmission and distribution operators.

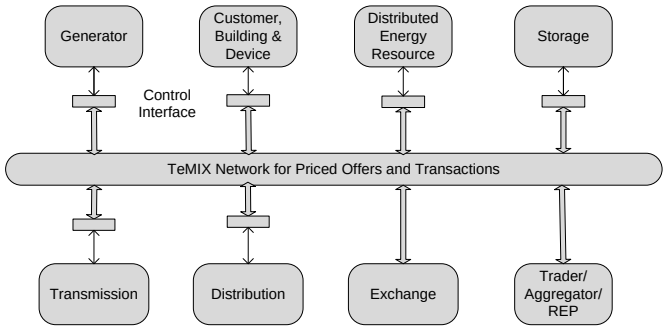

Figure 2 : A TeMIX Network

TeMIX communications employ a series of tenders (priced offers or bids) leading to a transaction (contract)[3]. TeMIX also supports option contracts (similar to a demand response or grid operator ancillary service contract) wherein a one party may purchase a right to exercise a call (command) for performance by another party.

TeMIX energy tenders (offers) and transactions (contracts) use the EMIX information model [3] that describes energy products, delivery location, sequences of delivery intervals, prices, quantities and other contractual terms.

TeMIX uses Transport products as defined in EMIX. Transport products convey prices and energy losses associated with distribution and transmission services that move power from one grid location to another.

3. TeMIX POWER AND TRANSPORT PRODUCTS

TeMIX employs a transactive subset of the electricity products identified by EMIX [3]. Transactive products (1) specify the rate of delivery of energy (power) within each delivery interval, and (2) obligate both the buyer and seller to perform at the specified rate. Variations in power within a metering interval are not measured.

Transactive power transactions (contracts) are additive, as illustrated in Figure 3. The figure shows transactions on a sequence of three intervals. Year-ahead and then month-ahead transactions establish a day-ahead position in each interval. Actual metered usage is reported and real-time, balancing purchases are determined. Requirements tariffs often used for retail sales are not additive transactions because the resulting contract positions are variable.

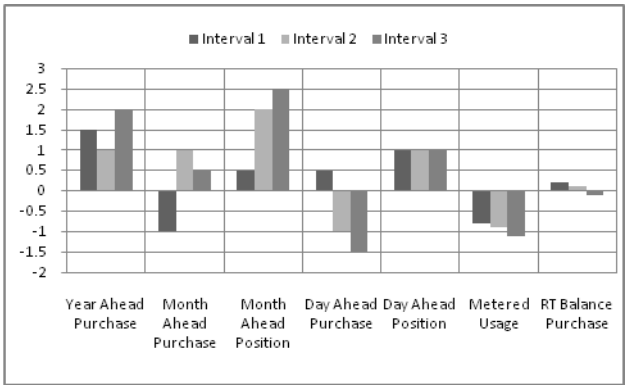

Figure 3 : Additive Property of Transactive Products.

The additive property of transactive power and transport products allows automated processing of sequences of tenders (offers) and transactions (contracts). Tenders and transactions can be messaged at high rates and can be processed automatically. Transactive products offer a solid foundation for retail forward and dynamic pricing, distribution grid operations, transmission operations, and wholesale forward, real-time markets.

4. TeMIX TRANSACTIVE OPERATIONS

TeMIX supports decentralized decisions and coordination using near continuous, simultaneous communication of TeMIX tenders (priced offers) among Parties. Decision making is similar for all parties and devices but will be implemented at a level of detail that is practical in relation to the value of smart controls for each device. Transactive operations for (1) end devices, (2) transport, and (3) intermediary services are described below.

4.1. End Device Transactive Operations

An end device produces or consumes and may store electric energy. Large grid-scale generators, variable wind and solar renewables, and grid scale storage are end devices. Distributed generation and storage are end devices. Residential, commercial and industrial customer air conditioning, heating, pump, lighting, and electronic equipment are end devices.

End devices are active (on / off, or variable control) or passive. Some devices respond rapidly while others require lead time and longer ramps.

Figure 4 illustrates the transactive operation of end devices. Power input and output and services to the party are determined by control signals.

[3] The terms tender and offer, and transaction and contract are used interchangeably in TeMIX [1] and the OASIS Draft Committee Standards [2-4].

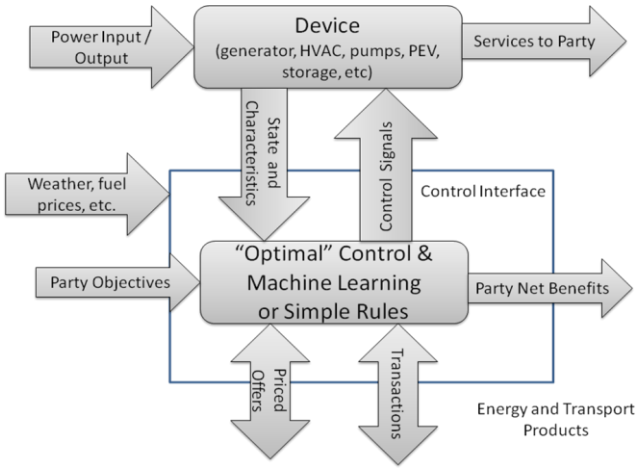

Figure 4 : End Device Transactive Operations

The control interface shown in the figure and in Figure 2 has three functions: (1) determine the device's optimal operating levels, (2) receive and make optimal forward tenders (priced offers) and (3) enter into optimal forward transactions (contracts) with other parties. End devices may also employ transport products to transact at other locations.

Details of the optimization algorithm are beyond the scope of this paper. The optimization considers party objectives, current state and characteristics of the device, and external variables such as weather and fuel prices. The optimization may employ models and forecasts based on machine learning algorithms (http://en.wikipedia.org/wiki/Machine_learning).

Control may be hosted in embedded processors in the device or at energy management systems controlling several devices at a site. Control may also be hosted by a utility or third party at remote sites. Many devices will use simple rules for operation to mimic optimization.

4.2. Transport Transactive Operations

Transport products or services move energy from one location to another. TeMIX transport products are defined in EMIX [3]. A party delivering power at a retail location will typically purchase both distribution and transmission transport products in addition to purchasing the energy.

Prices of transport products typically reflect both the losses and scarcity of transport capability. If many plug-in vehicles overload a distribution transformer parties that have previously purchased or been allocated a transport product for the transformer may enter into further transactions to increase their position or sell their position to others.

Transport transactive operations are similar to end device operations. As shown in Figure 5 the transmission and distribution grid may have some control flexibility. The primary role of optimization for transport products is to determine the tenders (priced offers) to other parties and to determine which tenders to accept from other parties.

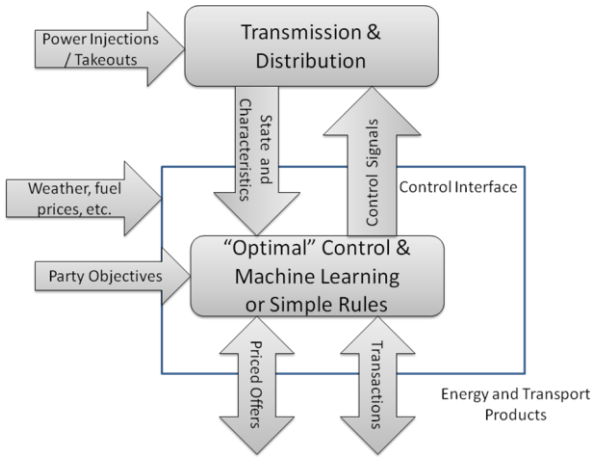

Figure 5 : Transport Transactive Operations

Both transport and energy products are transacted by the control interface for transport. A Transport operator may buy energy at some locations and sell energy at other locations and also offer a price to move energy from one location to another. Details of this optimization are beyond the scope of this paper.

4.3. Intermediary Transactive Operations

Intermediary parties (exchanges, marketers, aggregators and retail energy providers) hold portfolios of energy and transport products and transact with other parties as shown in Figure 6.

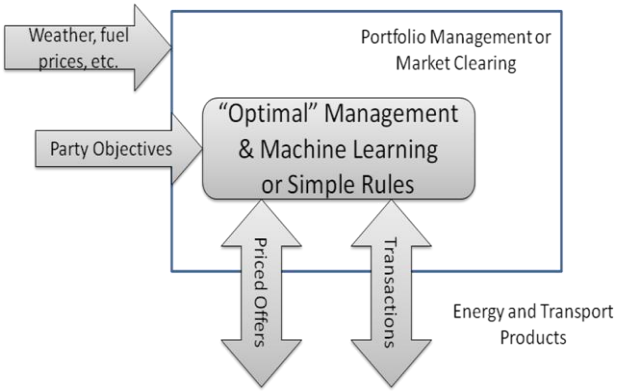

Figure 6 : Intermediary Transactive Operations

Some intermediary parties may operate at cost without taking significant positions, while others may conduct arbitrage or speculate for profit. An exchange may simply match willing buyers and sellers for a fee. Intermediary parties will use portfolio optimization for tenders and transactions.

5. TeMIX INTERACTIONS

TeMIX interactions are similar to the interactions among bilateral and exchange trading partners in forward wholesale electricity markets. Such markets interact successfully with wholesale ISO and RTO markets and with competitive and cost-of-service retail energy providers.

TeMIX extends the transactive wholesale model to retail customers. Customers are offered transactive forward contracts and real-time balancing services at dynamically changing prices. Transactive retail products allow retail customers to automatically manage devices to (1) save money, (2) use more variable renewables, and (3) hedge price volatility with forward transactions.

ISO/RTOs receive, but do not make tenders. Such tenders are often 3-part bids and curves associated with specific resources and resource characteristics such as ramp rate limits. Day-ahead and real-time auctions are conducted by ISO/RTOs to award energy transactions to resources and customer loads. Such auctions introduce time lags into the market balancing processes. And end customers generally prefer to receive tenders rather than post tenders in auctions.

ISO/RTOs may evolve away from multi-party tenders towards accepting and posting single-part tenders and near-continuous market clearing. Until then, intermediary parties will provide such services. OASIS EMIX and Energy Interop draft standards [2, 3] apply to both transactive and current ISO/RTO operations thus facilitating such interactions.

Demand response programs are primarily event-based and are designed to correct pricing flaws in retail rates. TeMIX provides the flexibility to correct these pricing flaws directly. Additionally, TeMIX option contracts can support market stability and react to contingencies. OASIS draft standards also apply to demand response programs facilitating interactions between transactive operations and demand response programs.

TeMIX offers the prospect of high volume tenders and transactions on intervals of minutes and seconds. Such transactions will engage many more devices than the current ancillary service products of the ISO/RTOs and ultimately replace some ancillary service products. The ramping needs of variable renewables will require faster and sustained 24-7 responses from grid devices.

Implementation of TeMIX will be evolutionary and involve regulatory policy. Federal and state regulatory policy can speed implementation of TeMIX and also set participation rules. Such rules can facilitate liquidity, mitigate market power, assure grid reliability, and ensure open transactive markets. Demonstrations of TeMIX for retail pricing, distribution grid management, renewables integration, and other applications will support the further development of transactive energy markets.

References

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[2] OASIS Energy Interop Committee Draft 01 http://www.oasis-open.org/committees/download.php/40427/energyinterop-1-0-spec-cd-01.pdf

[3] OASIS Energy Market Information Exchange (EMIX) Committee Draft 01 http://docs.oasis-open.org/emix/emix/v1.0/csd01/emix-v1.0-csd01.pdf

[4] OASIS WS-Calendar Committee Draft 01 http://docs.oasis-open.org/ws-calendar/ws-calendar/v1.0/CD01/ws-calendar-1.0-spec-cd-01.pdf

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Biography

Dr. Cazalet is a leader in the design of markets for electricity and the analysis of transmission, generation and load management investments. Dr. Cazalet has decades of electric power and related experience as an executive, board member, consultant, and entrepreneur.

He is a former Governor of the California Independent System Operator (http://www.caiso.com) and a founder of MegaWatt Storage Farms (http://www.megawattsf.com), The Cazalet Group (http://www.cazalet.com), Automated Power Exchange (APX) (http://www.apx.com), and Decision Focus, Inc.

Dr. Cazalet has successfully promoted storage technology legislation and regulatory policy both in California and at the Federal level. He has advocated new electricity market designs to promote the integration of renewables and the use of price responsive demand as well as storage to support high penetration of variable renewables.

Dr. Cazalet is co-chair of the OASIS Energy Market Information Exchange (EMIX) Technical Committee and a member of the OASIS Technical Committees on Energy Interoperation and Scheduling.

Dr. Cazalet holds a PhD from Stanford University focused on economics, decision analysis, and power system planning, and degrees in engineering from the University of Washington.