Abstract

This paper outlines the state of current market management system functionality as the needs of a competitive electricity market continue to evolve. As national market operators balance finite fossil fuel and renewable sources with an increasing population size, energy demand is at an all time high. Systems that manage these energy markets continue to adapt to address the numerous factors and complexity affecting the grid, in an effort to achieve:

- Market competition – a balance in the supply of wholesale electricity, including generation and demand response, where there is an ideal harmony between provider profits and consumer savings
- Energy security – maintaining affordability of energy and durability of supply
- Sustainability – a steady provision of energy that meets the demands of the present without compromising the needs and health of future generations.

The current generation of market management systems has made significant technological strides to facilitate various market rules and designs towards competition. The aggregation of this functionality has helped ensure sufficient amount of transmission capacity in the market, as well as the elasticity of demand with respect to price.

In an effort to continually improve operations, this paper also explores growing trends that will impact the next generation of market management systems.
Executive summary

Supply and demand – the foundation of today’s electricity markets
The basic concepts of supply and demand are the foundation of today’s electricity markets, where power generation is designed to meet residential and business consumption. Traditionally, governments regulated all aspects of the market’s value chain (generation, selling, transmission and distribution), creating monopoly positions and resulting in economic inefficiencies. Consumers are then impacted, facing increasing electricity costs and inconsistent quality of service.

With growing energy consumption, greater population density in major cities and finite resources for electrical generation, an efficient market between supply and demand is much harder to achieve, particularly under regulation. As a result, many governments have deregulated their electricity markets in an attempt to promote competition, lower costs, ensure long-term capacity and foster innovation. The foundation of these energy policies stresses security of supply, competitiveness and sustainability.

Systems continue to adapt to address the electricity market
Market deregulation has led to the formation of Independent System Operators (ISO) and regional transmission operators (RTO), who manage how transmission capacity and electricity generation are bought and sold in a competitive market, balancing generation and consumption and maintaining system stability.

In order to uphold the competitiveness and reliability of these markets, operator organizations rely on market system applications and technology to manage day-to-day energy trading. In a continued effort to fine-tune a competitive model, these market management systems (MMS) continue to adapt to address the many electrical grid factors influencing a true electricity market.

The energy industry is undergoing a period of long-term transformational change, where new technologies, increased penetration of renewable energy sources, changing energy policies and interdependent and interconnected markets are cultivating a highly intelligent and complex electricity market. It is critical for developers of market management systems to anticipate these trends and drivers through the evolution of modern, next generation market solutions.

Elements of a successful EMM system
An effective energy market management (EMM) system should meet the growing functional complexity of grid and market operations. It should be flexible enough to be leveraged as separate components or as a fully integrated system. In addition, an EMM system must take into account three key market roles:

1. The public – the public is the consumer of electric energy, driving demand.
2. Market participants – the market participants are those who generate electricity, providing supply.
3. The market operator – the market operator coordinates the dispatch of generating units to meet expected consumer demand.

Operating an energy market requires balancing the complex interests of these three roles. Public interests include reliability of the electric energy supply and the macroeconomic desire for the lowest electric energy price. Concurrently, market participants need to optimize their investments, increase operational efficiency and have timely access to highly accurate market information. Lastly,
market operators require precision in running complex operations, dexterity in adjusting to market rules and proficiency in coordinating grid security while providing highly available market operations.

Market operators require a modern EMM system that incorporates the latest market clearing technology. Through a set of modular, high performance market components and engines, the ideal EMM system lowers market prices, optimizes business processes and increases grid reliability for locational marginal pricing (LMP)-based centralized markets.

An effective EMM system needs to be highly adaptable and configurable to meet a wide range of market designs – from a simple economic dispatch-based market to a complex security constrained unit commitment (SCUC) market. It should also provide a very high degree of flexibility to adapt to changes in market rules within any chosen market structure.

Integration platform
Just as the use of industry standards is critical to any integration architecture, an integration platform is a key component to an effective EMM system and should use a service-oriented architecture (SOA) with XML-formatted messages (based on the CIM [Common Information Model] market extensions) and a message-oriented middleware.

Case Study
A leading North American ISO that controls and coordinates the power supply in a deregulated electricity market was looking for an EMM system.

As the impartial operator of the grid, the nonprofit ISO opens access to wholesale power markets designed to diversify resources, lower prices, and grants equal access to thousands of circuit-miles of power lines. Every five minutes, the ISO forecasts electricity demand, accounts for operating reserves and dispatches the lowest cost power plant unit to meet that demand while allocating space on the power lines. As the nerve center for the power grid, the ISO matches buyers and sellers of electricity, facilitating nearly 30,000 market transactions every day to ensure enough power is on hand to meet demand.

The challenge
The standards required of an independent transmission operator with a line length of approximately 40,000 kilometers, connected to 1,400 generators, are extremely high. The Siemens solution provides a means of optimizing the secure provision of power, balancing out capacity between the operators and avoiding system overloads.

The solution
Siemens was selected by the ISO to provide an EMM system and services for the day-ahead integrated forward market and real-time market operations. The solution encompasses network planning in several forecast stages and longer-term market monitoring designed to avoid costly safety reserves, as well as short-term bottlenecks.

The ISO realized an estimated savings of $52 million each year through its utilization of mixed integer programming instead of traditional Lagrange based methods. These savings can be passed on to electricity customers due to the ISO’s nonprofit status. The ISO rated the Siemens software as exceptional, because it can accommodate an extremely large volume of model data, a large number of power plants and various outline conditions. At the same time, it also meets the high performance and reliability standards required.
The new market design is based on a full network model of the grid that allows operators to see and manage congestion well before it becomes real time. This is inherently more complex, but the Siemens systems manage this complexity and simplify day-to-day interactions with ISO customers.

Since the previous system did not check to see if day-ahead schedules were feasible, some congestion remained opaque until the power was already flowing in real time. That was hard on operators, affecting reliability and increasing costs. The full network model, coupled with locational marginal pricing (LMP), allows the ISO to address congestion in a day-ahead timeframe.

**EMM trends – a look to the future**

As the energy industry and electricity markets continue to evolve, the ISO case study represents a timely snapshot of where market system technologies align with new market operator requirements. Factors such as the influx of alternate energy sources, changing energy policies and increased consumer influence and participation in the electricity value chain are all driving new functional needs for operators.

While Siemens has accomplished much with its second generation EMM, it continues to evaluate potential directions in the industry affecting future market system designs. A few of these trends are described below.

**Extending the market horizon**

The forward looking day-ahead market’s time horizon is currently one day and takes into consideration the impact of prior commitment of units with very long start-up times. The ability to make commitment decisions that look out two to three days ahead can drive resource efficiencies and accurately reflect the impact of start-up costs for energy resources that have long start-up times.

Independent ISOs have expressed interest in this trend, where an initial effort towards multi-day unit commitment is already underway. The goal is to extend the RUC process from a 24-hour to a 72-hour timeframe. This would allow market operators to determine if it is viable to keep a resource online during off-peak hours, rather than cycling the resource off.

There are several design issues that hinder multi-day unit commitment which include the need for bidding and bid replication rules, as well as software performance and solution time requirements. There may also be limitations on economic advantages that can be achieved by using separate market clearing, RUC and ELC processes.

**Managing the uncertainty of renewable energy**

The successful management of various renewable energy sources into large power systems is critical to addressing climate change and rising energy security concerns. As countries disaggregate their vertically integrated electricity monopolies and introduce competition, the restructuring process will accommodate high levels of renewable energy penetration. The inclusion of these new resources into the traditional electricity market redesign has led to an integrated approach to addressing overall price and technical performance, environmental sustainability, energy security and end-use efficiency.

However, the characteristics of renewable energy (wind, solar, biomass, geothermal, etc.) differ from conventional power generation. They create a unique set of challenges for the electricity market and require new market design and optimization methods. These include:
Renewable energy sources are variable and lack storage capabilities, requiring accurate forecasting of availability and electricity production. Some resources are currently forecasted and scheduled on an hour-ahead basis and financially settled in a real-time market. One goal is to create price incentives such that renewable energy can be scheduled in the day-ahead markets.

Increased utilization of renewable energy may increase risk during abnormal electricity market operating conditions. There is a need for mathematical models that can predict market behavior with these energy sources.

Generators of renewable energy sources are smaller in size and require a greater number of installations and owners. Applicable commercial contracts and technical requirements are needed for connected generators.

Negative pricing on resource adequacy is a significant issue impacting renewable energy. At certain times of the year, when renewable energy generation is high and loads are low, energy prices can turn negative. These negative prices signify the opportunity cost associated with a lack of dispatch flexibility. If prices become too depressed where they cannot cover variable generation operating costs, these renewable resources will exit the market and jeopardize resource adequacy and reliability.

Specifically for photovoltaic (PV) energy sources, market operators are challenged with maintaining the voltage quality in the distribution grid to accommodate increasing amounts of PV penetration. There is a need for more system flexibility to balance the variability of these renewable sources.

Future generations of market design must eliminate these unnecessary barriers, reduce risk and encourage the investment in processes and technology to mitigate the impacts of variability with renewable energy sources.

**Seam management and interconnections**

Seams are categorized as inefficiencies that hinder the transfer of energy between adjacent wholesale electricity markets, mainly due to incompatibility in market rules and designs. With the maturation of electricity markets, the elimination of seams can assist in ensuring greater market liquidity and managing resource adequacy. Some examples of seams include scheduling transmission access, pricing models, system operating rules and transmission tariff services.

As energy consumption grows, trade across markets leveraging existing infrastructure can meet supply and demand challenges more efficiently. For instance, the lack of uniformity in scheduling requirements for transmission services is a significant limitation for bids of energy into real-time, interconnected markets. Common standards for transmission services scheduling and energy bid treatments would enable greater trade flows.

Regulators will strive for increased alignment of market rules, traded energy products and transmission system operator (TSO) formation to improve market synergy. The energy industry is already seeing new cross-border interconnections being built across countries in Northern Europe. The goal is to leverage more, relatively inexpensive electricity between countries to create more stable prices and step up competition in the electricity market to the benefit of customers.

The current generation of MMS is often not fully compatible, creating unnecessary workload in operations between neighboring markets. Future market systems must focus their efforts on interoperability and open standards.
Optimization of scheduled outages

The capacity for accurate and comprehensive outage scheduling is critical to the reliable operation of a transmission system. A market operator coordinates outage schedules for maintenance, repair and construction of the grid to maintain system reliability, maximize schedule feasibility and optimize resource planning. With this capability integrated within the market system, operators can streamline their entire outage coordination, planning and communications processes.

Ideally, an outage optimization function will be the system of record that supports and manages both transmission and generation outages. Some of the goals and objectives for this capability include:

- Implementation of more precise data to allow market participants to accurately describe outage details without relying on basic text descriptions
- Simplification of the process for creating and updating outages to decrease complexity of user interaction
- Improvement in the market system’s ability to respond more effectively to evolving requirements in the outage process.

Replacing existing TSO functionality for transmission outages, while improving situational awareness and system analysis capabilities is an initial step in outage scheduling and optimization. This capability can then be extended to manage generator outages.

Siemens Spectrum Power™ EMM System

Siemens has evolved a second generation EMM system to meet the growing functional complexity of grid and market operations. The cornerstone of the Siemens Spectrum Power EMM system is its unique mathematical- and constraint-program that addresses security constrained unit commitment and economic dispatch, a complex optimization problem. Coupled with a modular approach to market operations, the Siemens Spectrum Power EMM functionality can be leveraged as separate components or as a fully integrated system.

Utilizing modern market clearing technology, Siemens helps market operators meet the interests of the public, market participants and market operators through its EMM system. The Siemens Spectrum Power EMM System also lowers market prices, optimizes business processes and increases grid reliability for LMP-based centralized markets through a set of modular, high performance market components and engines. Although each component can be individually applied to an existing MMS to preserve existing system investments, these components are best deployed as an integrated solution.

In order to work with a wide range of market designs, the Siemens Spectrum Power EMM system is highly adaptable and configurable. In addition, modern IT solutions from Siemens ensure that the networks of the individual operators and their electricity supplies are optimally matched to utilize price advantages to benefit the consumer and safeguard supply.

The following sections summarize the key components comprising the Siemens EMM System.

Market Clearing Engine (MCE)

The MCE is a second generation key market component of the Siemens Spectrum Power EMM system and is based on the SCUC software. For the first time ever, the MCE does not impose artificial limitations on the design of centralized electricity energy markets. The MCE considers bid-based generation and demand response on an equal basis, along with resource and system constraints to arrive at an optimal solution. It is now possible to include all
relevant production, load, network and resource constraints when clearing the central spot market simultaneously for energy and ancillary services. This solution approach, known as co-optimization of energy and ancillary services, produces the lowest overall clearing prices while meeting all physical constraints and grid security objectives.

Siemens MCE technology utilizes advanced mixed integer programming (MIP) techniques combined with a separable quadratic interior point method to obtain the optimal SCUC solution. The MIP-based SCUC represents this next generation of market functionality when compared to the traditional Lagrange relaxation-based SCUC. The MCE reaches the ideal solution without manual interaction or arbitrary heuristics, producing this consistently and independently of the operator.

These breakthrough technologies enable market designs based on a full AC network model, allowing market operators to manage congestion well before it reaches the real-time phase. While inherently more complex, the Siemens solution is capable of managing the day-to-day intricacies between market operators and participants, making them simpler and more transparent. The handling of a large number of transmission constraints is one of the most important aspects in achieving feasible schedules and avoiding the high cost of congestion management in real-time, when available resources may be scarce and expensive.

The MCE design allows the use of the same optimization engine for SCUC, a reliability commitment, a security constrained dynamic dispatch or a security constrained economic dispatch. This built-in flexibility enables the use of the same market-clearing engine in multiple market structures, such as a day-ahead market or a real-time market.

**Market Quality System (MQS)**
This module performs after-the-fact complex energy calculations for various types of energy and provides billing-ready energy calculations to the settlement function. MQS classifies different energy into appropriate categories and assigns designated charge codes. It allows manual editing of any imperfect market energy data to account for any late arrival of data, failures of market functions or business process, and correction of bad data.

The results of the reprocessing performed by the MQS are then sent to the billing and settlement system.

**Billing and settlement**
A billing and settlement processing engine automatically synchronizes all market reference data (participants, commodities and services, zones, resources, settlement intervals and billing periods, etc.) with other market operation components. It captures, validates and saves market clearing results, schedules, bids/offers and measurements at the required intervals (e.g., 1, 5, 10, 15, 30, 60 minutes) to support full details behind each settlement line item.

Siemens leverages several key partners to supply this market system component.

**Market Participant Interface (MPI)**
An MPI is a highly automated bid processing and notification infrastructure for efficient bid collection, validation and posting of market clearing results.

**Market Information Repository (MIR)**
An MIR strictly adheres to a standardized data model, resulting from a collaborative effort by key stakeholders to expand the CIM to include market operations.
Market Rules Engine (MRE)
An MRE is an integral part of the MPI that enables an implementation independent and flexible means to define complex bid validation rules and to enforce compliance by all market participants.

Information Model Manager (IMM)
Spectrum Power IMM is an efficient, IEC- and CIM-compliant model creation and maintenance tool that includes incremental merging of models provided by market participants and transmission service providers.

Transmission Security Assessment (TSA)
The Spectrum Power TSA engine utilizes a full AC network model, including transmission constraints that guarantee satisfaction of reliability criteria during market operation.

Historical Information System (HIS)
The HIS is a high performance data warehousing system for archiving of all market data and related operational data, including revenue information from meters.

Integration platform
The Siemens vision includes systems integration for an enterprise architecture, where Spectrum Power EMM is the core application, built upon a CIM foundation with non-proprietary interfaces to other applications.

As the Siemens EMM system is implemented, an enterprise service bus (ESB) represents the fundamental software model residing between the new market system modules and existing operations systems, enabling communication and seamless interaction. This ESB replaces existing point-to-point connections with fewer, secure and more reliable interfaces that are simpler and cost-effective to maintain and expand. This eliminates “spaghetti code” and allows the market operator the speed and flexibility to change its processes and systems to address market changes.

Specifically, Siemens implementation of the core ESB leverages the CIM, a standard developed by the utilities industry allowing for operations systems to exchange information over the electrical network.

Conclusion
This paper summarizes the energy industry’s transition towards a deregulated market and the unlocking of the vertically integrated electricity value chain to competition. National energy policies leverage this competition to spur lower electricity prices, security of supply and energy sustainability. The end result is an electricity network balancing the needs of market participants (generation) with public demand (consumers).

It is the market operator’s role to facilitate this supply and demand balance, ensuring smooth grid operations, efficient electricity forecasting and scheduling, minimization of transmission congestion, and a competitive auction/
bid market. EMM systems are the primary tools a market operator uses to effectively manage the scope of these responsibilities.

EMM systems have evolved with each generation to meet many market operational requirements. The innovative use of MIP modeling techniques to obtain the optimal SCUC solution alone is a significant achievement from first to second generation EMM systems.

However, there will always be existing market challenges, as well as new industry trends and disruptive factors that will mandate system improvements. It is here where Siemens continues to assess and understand market directions to meet future needs with the next generation of modern EMM systems.

The value of EMM solutions from Siemens

Expertise in building complex software solutions – spanning the entire value chain of the power system sector – has given Siemens a competitive advantage designing, implementing and integrating Smart Grid enterprise market solutions for our customers within real-time operational domains, while at the same time complying with industry standards.

The Siemens Spectrum Power EMM system provides customers with an effective market management solution, containing the elements and tools needed to integrate all their operational needs by defining an environment with common layers of a user interface and data modeling, and rules and services to interface with external or enterprise applications.

The Siemens strategy brings together proven utility expertise, certified integration processes and a strong engineering knowledge of market operations and power flow. The Siemens Smart Grid Division encapsulates technological best practices and open standards, while meeting the requirements for a scalable, reusable and highly available Smart Grid enterprise architecture.

The Siemens Smart Grid Division

Siemens recognizes that Smart Grid doesn’t just mean smart meters. It’s about the big picture of improved energy delivery, informed consumption and reduced environmental impact. That’s why we are proud to be the only company that offers a complete spectrum of products, solutions and services for the protection, automation, planning, monitoring and diagnosis of grid infrastructure, including products, complete solutions and services for rail electrification.

Siemens is bringing to market solutions that can evolve over time, are scalable and are compliant with industry standards for interoperability and security. We are making the Smart Grid a reality by partnering with utilities and cities to implement their Smart Grid visions.

For more information, visit www.usa.siemens.com/smartgrid.

For more information about Siemens Smart Grid on our mobile website, please scan the QR code below.
Notes
The information provided in this brochure contains merely general descriptions or characteristics of performance which in case of actual use do not always apply as described or which may change as a result of further development of the products. An obligation to provide the respective characteristics shall only exist if expressly agreed in the terms of contract.

All product designations may be trademarks or product names of Siemens AG or supplier companies whose use by third parties for their own purposes could violate the rights of the owners.