

Use of Common Information Model (CIM) In Electricity Market at California ISO

Enamul Haq, Dagmar Haller, Khaled Abdul Rahman and Becky Iverson

Abstract—The California Independent System Operator Corporation (CAISO) is in charge of managing the electricity flow along California's open-market wholesale power grid. The CAISO implemented a nodal LMP Electricity Market based on the full network model and upgraded its infrastructure with new state of the art technology in 2009. The implementation of the new market system utilized the Service Oriented Architecture (SOA) and enterprise service bus-based technology to integrate many of the CAISO systems to assure grid reliability and efficient and economic operation of the electricity market. The CAISO systems are acquired from different application vendors and this created an integration challenge. This paper summarizes how CAISO leverages IEC TC57 Common Information Model (CIM) for the network models and enterprise wide messaging in integrating different applications from different vendors. The paper will also outline how CAISO created CIM extensions for different market and grid applications and network models used by CAISO.

Index Terms—Common Information Model (CIM), California Independent System Operator Corporation (CAISO), Full Network Model, Market CIM Extension

I. INTRODUCTION

THE California ISO is a not-for-profit public benefit corporation in charge of managing the electricity flow along California's open-market wholesale power grid. In a massive initiative to improve the electricity markets, a new electricity market system has been designed in order to assure grid reliability and more efficient and cost effective use of resources. The new electricity market system went in operation in April 2009.

The new electricity market is a nodal market and uses a full network model including a detailed representation of the CAISO controlled grid and an equivalent network model outside CAISO. The grid reliability network model includes the entire WECC network and consists of the detailed representation of the CAISO control grid and a simplified representation of the WECC (Western Electricity Coordinating Council) bulk power system. Creating and maintaining two different network models within the same network model building tool created an interesting challenge [1]. This paper will outline how these two different network models are maintained using the CIM standard at CAISO.

The new electricity market system has a day-ahead market component and a real time market component. A new bidding system and a settlement system were also procured as a part of this project. The various components of this new electricity market system were acquired from different vendors, which created an integration challenge. The CAISO met this challenge by leveraging SOA technology and adopting the IEC CIM standard as a communication platform. The CAISO used the IEC CIM standard to create SOA based messages required for multi-vendor systems to not only communicate with each other but also to integrate with existing legacy systems. In some cases it was necessary to extend the standard CIM to effectively map the legacy system data. The translation of legacy system data to CIM classes and vice versa was done by smart adapters. This paper will describe the key systems in the CAISO Electricity Market and how their communication is based on the common CIM standard.

II. NETWORK MODELS AT CAISO

The CAISO maintains two separate network models:

- The CAISO grid reliability network model, which is used by network applications programs included in the EMS
- The market network model used by the IFM/RTM and CRR market systems

This section describes how these two CIM-based network models are maintained.

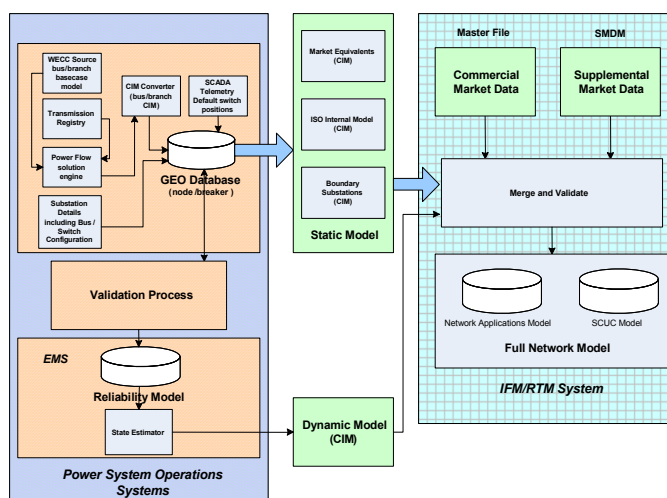


Figure 1: CAISO Network Model Validation Process

The grid reliability model includes a detailed representation of the CAISO controlled network and a simplified representation

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of the WECC bulk power network. This network model starts with the bus branch seasonal model from WECC in GE-PSLF format. This bus branch model is converted to a simplified CIM based breaker model using a substation mapping file. In this process pseudo breakers are introduced in the breaker-node CIM model. This simplified model is then imported into the modeling tool and merged with detailed representation of the substation and relevant parameters are updated [6].

A similar process is used for the market model, i.e. it starts with a bus branch model of the equipment that only belongs to the market network model in GE-PSLF format. Both the grid reliability and market models exist in the same modeling tool. A new class called “ModelType” was introduced in the modeling tool with attributes “Both”, “EMS Only” and “Market Only” to identify the network model elements in CIM that belong to either grid reliability or market network models. The equipment that is common to both models is tagged as “Both”, the equipment that is unique to the Market model is tagged as “Market Only” and the equipment that is unique to the reliability model is tagged as “EMS Only”.

All of the equipment in the grid reliability model that lies within the CAISO controlled area is also common to the market model and is therefore tagged as “Both.” However, if there is equipment in the internal CAISO model that is unique to the market model and not in the grid reliability model, this equipment is tagged as “Market only.” This equipment usually consists of very small market units which can’t be modeled in the reliability model.

In the modeling tool a substation one line diagram can be viewed with equipment belonging to the market model or the reliability model or both. By assigning a color code to the equipment, the model type is easily identified.

The modeling tool can selectively export either network model in RDF CIM/XML format. Because it is difficult to read network model information in CIM/XML format, the CIM topological model is converted to an access database composed of CIM-like tables with associations to CIM classes. This format greatly simplifies troubleshooting network modeling issues. These access files are also used to compare attributes between model builds and output the differences. The difference files are very helpful in detecting any data errors in the model and users do not need to be familiar with the CIM standard to interpret the data. The only CAISO CIM extension used in the topological model to keep track of the network model version is the “ModelDescription” class. This CIM class has attributes of “CurrentVersion” and “PreviousVersion” to hold data for the current version and the previous version of the network model.

III. KEY SYSTEMS AT CAISO

The CAISO Electricity Market differentiates between the following markets:

- Day-Ahead Market, which includes the Integrated Forward market (IFM) and the Residual Unit Commitment (RUC)

- Real-Time Market processes, which include Hour-Ahead Scheduling process (HASP) and the Real-Time Market (RTM).

The types of products and services that are traded in the CAISO Markets, on a high-level, are described as Energy, Ancillary Services, RUC Capacity and Congestion Revenue Rights (CRR).

While the IFM is a market for supplying / purchasing Energy and procuring Ancillary Service products for each Trading Hour of the next Trading Day, RUC is a reliability function for committing resources and procuring RUC capacity not scheduled in the IFM. These processes produce a Day-Ahead Schedule [4].

The Real-Time Market processes are implemented as multi-interval optimization functions and have the goal of minimizing the cost of dispatching Imbalance Energy and procuring additional ancillary services when applicable. The actual Market Clearing Price for each Trading Hour and financially binding commitment and dispatch instructions are the result of a sequence of Real-Time processes. Unlike IFM, which has a time horizon spanning the next Trading Day, the time horizon of the RTM applications is variable and spans the current and next few Trading Hours at most.

Newly added systems from different vendors as well as various existing legacy systems make up the components of the new system supporting the CAISO Electricity Market. Interfaces among the different systems were implemented as web services. In order to facilitate a common communication platform amongst these inhomogeneous systems, the structures of message payloads were based on IEC series of standards 61970, 61968, EMS Application Programming Interfaces and the draft IEC standard CME (CIM Market Extension). CAISO extended both the 61970 and 61968 CIM standard packages to define its data and message requirements. The use of CIM standard packages and various CAISO extensions will be discussed later in this paper.

Table 1 provides a summary of the key systems of the CAISO Electricity Market where CIM Standard or CIM extensions were used to define content of the web services XML payloads that are exchanged between these systems.

Table 1: Key Systems at CAISO [3]

| CAISO System | System Name |
|--------------|-----------------------------------|
| ADS | Automated Dispatching System |
| ALFS | Automated Load Forecasting System |
| COMT | CAISO Outage Modeling Tool |
| CMRI | CAISO Market Results Interface |
| CRR | Congestion Revenue Rights |
| DRS | Demand Response System |
| EMS | Energy Management System |

| | |
|-------------|--|
| IFM & RTM | Integrated Forward Market and Real Time Market |
| Master File | Primitive Data Manager |
| MDS | Market Definition Service |
| MQS | Market Quality System |
| OASIS | Open Access Same Time Information System |
| RLC | Reference Level Calculator |
| SaMC | Settlements and Market Clearing |
| SIBR | Scheduling Infrastructure & Business Rules |
| SLIC | Scheduling Logging for the ISO of California (Outage System) |
| PRIP | Participating Intermittent Resource Program |
| CAS | Control Area Interchange Transactions Scheduling System |
| ETCC | Existing Transmission Contracts Calculator |
| OMAR | Operational Meter Analysis and Reporting |

IV. USE OF CIM STANDARD AT CAISO

In the CAISO Electricity Market, all major functional areas rely on the CIM standard and its extensions. Since the introduction of the original Market System in April 2009, the functionality has been enhanced by several new initiatives such as ‘Demand Response,’ ‘Multi-Stage Generator’ and ‘Convergence Bidding.’ The messaging and data for all of these initiatives have been conceptually designed and modeled based on the CIM Standard and its extensions. With respect to the confinement of this paper, some key examples have been chosen to highlight the application of CIM and its extension in the CAISO Electricity Market.

A. Modeling of Reference Data

The Master File is a general repository of quasi-static data needed to operate and support the CAISO Market. The Master File contains data that remains unchanged for relatively long periods of time. Below are examples of Standard CIM classes that have been further extended for use in the CAISO Market:

1) Registered Resource

There are three major registered resource types in the CAISO Market, generator, load, and inter-tie. Based on the CME (CIM Market Extension) model, CAISO reused the registered generator and registered load concept, and created an extension to represent the registered intertie resource. In order to enable market participants to provide updates to Generator and Intertie Resource Data through an API, the underlying Resource Data Templates have been translated into XML messages built upon standard CIM concepts such as the Registered Resource, Registered Generator, Startup Cost and Time Curves, Heat Rate and Ramp Rate Curves. Several extensions have been made to complete the design; amongst

them are the following examples:

- The CurveSchedules concept has been further employed to model the Startup Energy and Startup Fuel Consumption of a generating resource, as well as the relationship between Fuel Cost and Unit MW Output.
- Various resource capacities related to operating limits, economic limits, regulation limits, de-rated/re-rated limits.
- Resource Certifications for a specific product type.

2) Multi-Stage Generator

The Multi-Stage Generator (MSG) concept has been introduced to model resources with more than two operating states (Combined Cycle Gas Turbine plants and generating units with multiple operating ranges) and represents an extension of the two-state (on/off) model for generating units. Based on multiple Generating Units, which is a CIM Standard class, a new CME class has been defined describing a certain configuration of generating units as one state of a Registered Generator. CIM extensions were created to model each configuration in which the MSG resource can operate as a Logical Generator and to define a prescribed set of feasible transition paths and costs among the states.

3) Price Node

A pricing node or an aggregate pricing node is a pricing location for which market participants submit their bids, offers, buy/sell transmission rights, and settle. It is directly associated with a connectivity node, which is represented by a CIM Standard class, for the purpose of connecting the location to the network model. In the CME model, a pricing node can also represent a trading hub or aggregated resources. In the MRTU program, a conscious decision was made to explicitly model such pricing node as an aggregated pricing node which is represented as an extended class [3].

B. Modeling of Market Instruments

The types of Market Instruments available in the CAISO Market are Bids (either Supply Bids or Demand Bids), Self-Schedules, Inter-SC Trades and Congestion Revenue Rights (CRR) [5].

1) Bid

The CAISO extended the standard bid model based on the CME to include the following:

- Bid schedule to allow a product bid to use specified bid price curves for different time intervals
- Intertie bid for inter-tie resource.
- Self schedule values to be used for specified time intervals.
- A mechanism to represent values that can change hourly within the context of a daily bid
- Different distribution factors for an aggregated pricing node.

2) Convergence Bid

The Convergence Bidding concept allows Market Participants to submit virtual supply and/or demand bids in the Day Ahead Market. Modifications have been made to process these virtual

bids, perform the day ahead market run including physical and virtual bids, communicate the physical and virtual awards to downstream systems, and to provide the ability to correct the awards post market run.

In contrast to physical market bids, virtual bids are defined on a pricing location level, and are not necessarily of the same type of physical resources behind this pricing location. For example, virtual demand bids from different Scheduling Coordinators can be submitted on a pricing location linked to a generator and vice versa. Virtual bids are subject to credit checks via an interface with a new Credit Tracking System. This credit check is used to determine the validity of a virtual bid for inclusion in the Day Ahead Market run.

The design of several of the existing CIM messages defined for the physical market have been leveraged and adopted for use in the virtual market. As part of this effort, the Standard CIM has been extended with several additions such as:

- Standard CIM class Bid has been extended to define a VirtualBid class, which is associated with the Standard CIM class Pnode. The existing EnergyProductBid object could therefore be re-used in Virtual Bid.
- CIM extensions have been created for various interfaces with the new Credit Check System (credit checks for virtual bids and CRR portfolios).

3) CRR

Congestion Revenue Rights are financial instruments enabling holders of such instruments to manage variability in Congestion costs. Congestion costs occur under a Congestion Management protocol that is based on Locational Marginal Pricing. The financial concept of Congestion Revenue Rights has been modeled as a CIM extension, inheriting from the standard CIM class "Document."

C. Modeling of Market Operations

At the core of the CAISO Electricity Market stands the Market System (IFM/RTM). It supports market activities such as the buying and selling as well as transmission of Energy or Ancillary Services and management of transmission congestion.

1) Market System

A number of extensions were made to the CME model to support input data to the market system as well as output data. The extensions include the following:

- Implemented a mechanism to define the Ancillary Service Requirements for a market region and market product as input to the market solution.
- Implemented a mechanism to define transmission entitlements (TOR/ETC/CR) for a point of delivery, point of receipt, by contract and flowgate.
- Implemented a mechanism to publish the distribution factors that were in effect at the time of the market solution.
- Market Awards were extended to support multiple products (Energy, Spin, Non-Spin, Regulation)

- Additional output capability was implemented to allow for losses, market power mitigation, residual UC, and awards on a resource basis to be supplied.
- Additional output capability was implemented to provide dispatch and commitment information to the market participants via an automatic dispatch system.

2) Automatic Dispatch System

The Automated Dispatch System is an application developed by CAISO to communicate Real-Time Dispatch Instructions to Scheduling Coordinators (SC). SCs are able to accept or decline intertie dispatches. While the public Internet is the method of transmitting instructions and their corresponding response information between the ISO and the SC, the internal communication has been designed via CIM based messages and employs CIM extensions that model the Dispatch Response per Registered Intertie resource as well as the Load Following MW for follow-up or follow-down instructions Per Registered Resource.

3) Automatic Load Forecasting System

Load Forecast data is being provided to downstream systems with various time horizons and aggregations by ALFS. While the aggregation subjects, Aggregated Nodes for the Real-Time & Day-Ahead Load Forecast and TAC (Transmission Access Charge) Areas for the Two-Day Load Forecast are CIM extensions, both messages utilize the standard Area Load Curve concepts.

4) Participating Intermittent Resource Program

The CAISO PIRP is a voluntary program which provides certain settling benefits to an Intermittent Resource, such as a wind-energy generator. In return, a PIRP resource takes on certain scheduling-related responsibilities. To facilitate this program, the Intermittent Resource Schedules have been created as CIM extensions, indicating whether a Registered Resource is eligible for the PIRP program for a given hour.

5) Reference Level Calculator

The Reference Level Calculator is an adaptor facilitating the communication between the external Default Energy Bid (DEB) Calculator and MRTU downstream systems. The DEB Calculator provides the Day-Ahead and Real-Time Default Energy Bid curves, Minimum Load curve, Default Start-up Bid. The related entities have been built as CIM extensions based on the standard CIM Curve Schedule. Energy Price Index and Gas Price Index used in the DEB calculations have been modeled as CIM extensions as well.

6) Scheduling & Logging of Outages

The SLIC system, which applies to Generating Units, allows Market Participants to notify CAISO when a Generating Unit's properties change due to physical problems. This outage data is accessed directly by the Real-Time processes to override some of the Master File data. The standard CIM concept of Equipment Outage has been extended to model entities required to represent modified Maximum and Minimum Output of a unit, as well as modified Ramping capabilities of the unit. Further CIM extensions have been

created in order to model Unit Substitution Requests that can be submitted via API by market participants.

7) Control Area Interchange Scheduling System

The CAS system accounts for energy flow across all Inter-ties. Several types of DAM and RTM interchange transactions at Scheduling Points, such as Ancillary Services Bids, Energy Schedules, or Energy Self-Schedules including ETC and TOR Self-Schedules, must be e-tagged. The CAISO will match and validate the e-Tags with corresponding market reservations. The resulting Interchange Schedules have been modeled as CIM extension and are based on the CurveSchedule class from CIM standard.

D. Modeling of Analytical Data (Reporting)

The CAISO implemented two web interfaces: One providing public Market information such as Load Forecasts and Locational Marginal Prices, the other providing Scheduling-Coordinator specific, private information such as schedules and awards.

1) Open Access Same Time Information System

The OASIS provides a web interface for Market Participants to retrieve public Market information, including Demand Forecast, AS Requirements, Aggregate Schedules, Transmission Interface Limits and Flows, Locational Marginal Prices, and Regional Ancillary Services Market Prices. In order to support OASIS reporting capabilities on market data, OASIS consumes CIM-based messages provided by the new Market Systems, as well as Forecast Data and Reference Data.

2) Post Transaction Repository System

The CAISO Market Results Interface or CMRI is the reporting interface that contains private market information resulting from the CAISO Market Processes: MPM, IFM, RUC, and HASP. This includes schedules and awards, resource specific prices, default and mitigated bids, unit commitments and instructions. In addition to those mentioned above, post-market or after-the-fact information can be accessed from CMRI. Several CIM extensions have been created to support the report related entities; examples include:

- Conformed Dispatch Notice containing a summary of Day-Ahead and Real-Time market results of RMR Units.
- Unit Commitment displaying resources that are self-committed by the CAISO market
- Default Bid Curve reporting information on reference curves used in the Market Power Mitigation process by the market system
- Expected Energy results (post-market) from the energy accounting process
- Mitigated Bid displaying segments of the mitigated bid as a result of the Market Power Mitigation process
- Start-up Shut-Down Instructions detailing resources with start-up or shut-down instructions from the Day-Ahead Market and/or RUC process.

E. Market Network Model

1) Network Model

The IEC TC57 61970 standards define the common power system modeling (CPSM) profile based on CIM for the network model exchange. The MRTU program adopted this standard to send the network model to the market system [6].

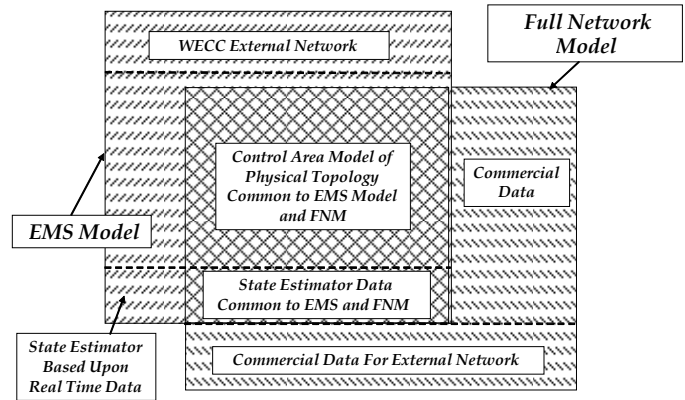


Figure 2: Comparison of the Market and EMS Models

2) State Estimator Solution

The state estimator solution is a critical and time sensitive component. Since performance is essential, the MRTU program did not use the CIM measurement model to represent the state estimator result directly. Instead the following extensions were made:

- Switch status (open or close) is modeled to directly associate with Switch class
- Injections (active and reactive power) are modeled to directly associate with EnergyConsumer and SynchronousMachine.
- The regulation conditions (regulation status and regulation voltage) are modeled to directly associate with SynchronousMachine, Transformer (LTC and Phase Shifter) and Compensator (Regulating Shunts)
- Tap positions of transformers and the number of in-service sections of compensators are modeled to directly associate with TapChangers and Compensators.

3) Breaker Model versus Bus-Branch Model

Many applications in the MRTU program follow the breaker model defined in the CIM. However, there are cases where bus-branch model is used. This requires a relationship between the connectivity node associated with pricing node and the bus. The MRTU program augmented the bus-branch model with RDFID that uniquely represent a branch or a connectivity node. For example branch data (line and transformers) contains the same RDFID as in the network model file. The bus model knows RDFIDs of all the connectivity nodes referenced by the pricing node. In this case, there is no CIM extension. The problem is resolved by using the same RDFID in both breaker model and bus-branch model.

CAISO realizes that the IEC TC57 is working on some of the areas mentioned above. For example, the state estimator modeling and the CIM for planning modeling are well underway. CAISO would like to contribute the CIM extensions to the CIM community and the IEC standard by sharing experiences with other CIM users. At the same time, CAISO is closely watching the CIM development and constantly evaluating the CIM updates.

V. CONCLUSIONS

The CIM model is leveraged at CAISO as a primary input to define the enterprise wide messaging. This paper outlined how the CIM standard is used in maintaining different network models in a single modeling tool at CAISO and how the different systems were integrated using CIM based messages. The application of the CIM and its extension in CAISO for defining the enterprise wide modeling and messaging demonstrates that CIM is a powerful industry standard for a utility/customer to build a semantic model that resolves many of the issues that occur in large projects.

VI. REFERENCES

- [1] **Buddy Marshall, Martin Miller, Enamul Haq**, A CIM-Based Multi-Model Maintenance Tool , 2007 IEEE PES General Meeting, June 24-28, Tampa, Florida , USA
- [2] **Xiaofeng Wang, Shawn X.K. Hu, Enamul Haq, Harry Garton**, Integrating Legacy Systems within The Service-oriented Architecture, 2007 IEEE PES General meeting, June 24-28, Tampa, Florida, USA
- [3] **Enamul Haq, Dagmar Haller, Esmeralda Rodriguez**, Use of CIM Standard in Power System Modeling & Enterprise Wide Messaging at California ISO, 2010 IEEE PES General Meeting, July 25-29, Minneapolis, Minnesota, USA
- [4] **CAISO Business Practice Manual for Market Operations**, version 13, October 1, 2010
- [5] **CAISO Business Practice Manual for Market Instruments**, version 9, October 6, 2010
- [6] **CAISO Business Practice Manual for Managing Full Network Model**, version 2, October 14, 2009

VII. BIOGRAPHIES

Dr. Enamul Haq (SM '92) received BS ('73) and MS ('77) degrees in Electrical Engineering from Bangladesh Engineering University, MS ('89) degree in system (computer) science from LSU and Doctor of Electrical Engineering degree ('81) from Bucharest Polytechnic Institute. Dr. Haq is engaged with the Power System Technology Development (PSTD) Group of California ISO as a senior advisor since July 2000. His interests are in power system training simulator, network modeling using CIM, advanced power system applications and market interfaces. He has over 35 years of experience in research, teaching and power industry.

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