Use of a Operator Training Simulator in Testing New Real-Time Market of California ISO

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Abstract
This paper describes the challenges faced by the California ISO in testing the integration of the new California Real-Time Nodal market with the Energy Management System. The paper addresses how an operator training simulator was used for testing the real time market and some critical functions of EMS. CAISO's EMS dispatcher training simulator was modified and coupled with CAISO's Market Applications to act as a real time Market and Grid Operation Simulator. This new simulator provides realistic behavior of the physical network of California ISO grid in response to the instructions from the real time market.

***Index Terms*— Real-Time Market, Operator Training Simulator, Full Network Model, Modified Operator Training Simulator**

I. Introduction

In response to the California energy crisis of 2000 and 2001 and other identified market inefficiencies, the California Independent System Operator (CAISO) initiated the Market Design 2002 (MD02) project and its subsequent Market Redesign and Technology Upgrade (MRTU) project. On June 24, 2004, the ISO Board of Governors approved two parallel programs, managed as one ISO initiative in order to gain economic and technical efficiencies:

1) Market Improvements to assure grid reliability and more efficient and cost effective use of resources.
2) Technology upgrades to strengthen the entire ISO computer backbone.

Some of the challenges encountered to ensure effective operation of the newly re-designed CAISO's Real-Time Market, which is coupled with full network model, call for:

1) An efficient testing tool to validate the Real-Time Market design and implementation prior to go-live operation.

An efficient training tool for the CAISO operators so that they can better understand the new market design changes and react quickly and decisively to routine and emergency conditions.

Depending solely on functional testing without validating the market design and implementation in an integrated environment with EMS is not a wise decision in such a complex environment. In addition, conducting Operator Training sessions using only Operator Training Simulator (OTS), without closing the loop with the market applications, doesn't fully satisfy the business need, and will not produce well-trained operators.

Due to the time constraints and urgent need for this simulation tool, the CAISO was looking for a solution with the following minimum characteristics:

- **Realizable**: CAISO has procured Market Applications to perform Day ahead (DAM) and Real-Time Market (RTM) operations under the new MRTU initiative, and at the same time CAISO has an existing OTS system. So, due to the time constraints, the new tool had to readily use the available hardware and software at CAISO.
- **Scalable**: the simulator has to have the capability to support a production grade CAISO EMS network model while simulating the Grid Operations, and the Market Full Network Model while simulating Market Operations.
- **Realistic**: the User Interface (UI) for such a simulator has to resemble the actual UI for EMS as well as the Market Application software. With realism in the UI and the scenarios testing, it is believed that the Operator will be better prepared for real-life critical situations. In addition, the simulation results have to produce realistic results reflective of the market dispatch.

A quick scan of the marketplace exposed a lack of vendor's products in this area. However, CAISO's need for such tool for training and testing purposes was critical. CAISO decided to support an effort to modify the existing CAISO's OTS to allow the integration with the RTM system of MRTU.

The focus of this paper is to discuss the CAISO's modifications of the conventional Operator Training Simulator (OTS) to simulate the behavior of the CAISO physical network, as well as some of the key EMS functions, in response to instructions from the Real-Time Market (RTM) system. The Modified Operator Training Simulator (M-OTS) is also used to test the response of the RTM system to simulated events on the physical power system.

II. The Need for a Real time Market And OTS System

The current CAISO market utilizes a zonal model. In this model, CAISO manages congestion only on major inter-ties and two large internal paths (Path 15 and Path 26). It uses adjustment bids to mitigate the congestion while minimizing the cost of schedule adjustments and keeping each Scheduling Coordinator's (SC) schedule in balance.

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The zonal congestion model has several shortcomings including:

- Clearing the forward markets by ignoring the intra-zonal constraints creates infeasible schedules. In real-time, these schedules become difficult to manage and cause undue operational difficulties.
- Congestion management cannot be done before real-time for many generation pockets.
- Since intra-zonal constraints are not considered in this model, out-of-sequence or exceptional dispatches, that lack transparency, are needed in real-time to address intra-zonal congestion management.

The new market design under MRTU calls for the use of the Full Network Model (FNM) instead of the zonal model. The use of the FNM addresses the shortcomings of the zonal model and provides additional benefits such as:

- Provide adequate incentives to invest in new generation capacity at the right location by sending transparent, and accurate Location-based Marginal Price (LMP) signals
- More reliable operation of the transmission system
- Mitigate market power abuse including local market power.
- Send the proper signals for investment in demand response and transmission planning

When moving from a real-time zonal market including all the settlement structure to the RTM nodal market, there are significant logistical, technical and tariff related issues prior to performing a fully functional test using the production system, including dispatch of actual resources. A robust RTM and OTS simulation tool provides engineers, operators, market participants and regulators the opportunity for testing to gain confidence that the RTM system is ready for reliable and efficient grid and market operations.

Due to the critical nature of the RTM and the significant paradigm shift from a Real-Time zonal market to a nodal market utilizing FNM, the CAISO and it's stakeholders required as realistic simulation as possible in order to:

- Gain operational confidence in the integrated system,
- Ensure market outcomes using new market bidding behavior are consistent with reliable operations,
- Evaluate the interaction of market results with traditional EMS AGC control, and
- Test the validity of dispatch results including consistent market prices with system and network constraints.

Using a Modified OTS (M-OTS) that is capable of processing market commitments, dispatch, reserve procurement, and is able to produce a realistic State Estimator results that are then used by the Market System in a closed loop simulation with a high degree of stability over a variety of load patterns is critical in satisfying the need to prove out a new market system in an integrated environment.

The use of an M-OTS provides the additional value of being able to simulate transmission outage conditions that can be used to evaluate the efficiency of the market results as well as provide important training opportunity.

Anything short of an M-OTS will not address important aspects of the integration with the new RTM structure such as short-term unit commitment, unscheduled flow with neighboring balancing authorities, interaction between the real-time balancing market, regulation and ACE, reserve management, load forecasting, determination of load distribution factors, resource dispatch compliance and performance.

III. CAISO'S M-OTS SYSTEM

Traditionally, the conventional OTS is designed for training grid operators based on pre-determined scenarios created by an instructor. All equipment parameters are setup before starting the simulation. Some of these parameters can be changed via events during simulation.

Real time market simulation is described in [1], which has an OTS that works in a closed loop fashion with the market system driving the OTS, the OTS simulates the network by acting on market system directives and sends back the updated network model to the market system via Real-time Power Flow.

Another real-time market simulation is described in [2]. Most of the data is received from external systems and cannot be setup beforehand for the simulation. It is not feasible to create manual OTS events in response to the triggers received from these external systems owing to the large amount of data and calculations involved in converting the data from the market model to the network model.

This section describes the modifications and key characteristics of CAISO's M-OTS. CAISO's conventional OTS was modified to automate the conversion of market system directives to OTS events with minimal user intervention. A secondary challenge was to use the same Common Information Model based network model (CIM) for both the production system and the OTS so that there is no need to maintain separate models for the simulator and the production systems. Enhancements were made to retrieve data from multiple external interfaces and to use this data for triggering changes to the OTS operation in real-time. The following sub-sections describe an overview of the changes that were made to create a real-time market simulator utilizing CAISO's M-OTS. It should be mentioned that the features mentioned in the following sub-sections sometimes overlap with each other in terms of their usefulness. They were needed in the various stages on the M-OTS development. Though, some features were only useful in the initial phases of the integration, their value should not be underestimated.

1) Simulation Clock Time

OTS has the ability to start simulation at any time that is specified by the user. The real-time applications in OTS run with the clock time that is specified by the OTS when the system is in simulation mode. In a real-time simulator environment, though OTS can control the clock time of EMS applications, it cannot control the clock time of the external interfaces. To avoid a time mismatch between the external systems and EMS, the M-OTS needs to be in sync with the wall clock time.

2) Load Forecaster Interface

The ability to use flat load profiles in simulation is very useful in the initial phases of the project since it provides an ability to test and debug the OTS and market systems in a closed loop. Traditional OTS also has the ability to create load curves based on various patterns and instructor entered peak loads. This ability is useful in simulating pre-determined scenarios for testing the market system. The ability to use the existing load profiles and the ability to manipulate the load curves by time-shifting and MW shifting is useful in the initial integration of the M-OTS with the RTM when suitable power flow cases are not available to initialize the M-OTS.

For real-time operation, the M-OTS interfaces with the Load Forecasting system to retrieve the load curves for the current date. Since a traditional OTS creates load profiles as part of the initial setup, the M-OTS needs the ability to manipulate the load profiles during simulation. The M-OTS uses load data exports from the Load Forecasting system to manipulate the load profiles when simulating.

3) Modeling of Dynamic Schedules

Dynamic schedules are modeled in automatic generation control (AGC) as pseudo generators to account for generators outside of CAISO area that are partially controlled by CAISO. There was no equivalent of this model in OTS. Dynamic Schedules were added to the OTS model to function similar to physical generators in the internal area. When a dynamic schedule resource receives a schedule, that value is incorporated as a part of the corresponding external area control error (ACE) calculation. In addition, the status and analog points associated with the measurements of the pseudo generator are updated from the results in the OTS. This allowed CAISO to control the dynamic schedules as if they were physical generators in the system responding to AGC regulation.

4) Real-Time Market Interface

The Real-Time Market (RTM) system is the external system that sends generator dispatches (which includes dynamic schedules) to the EMS every five minutes. In the production environment, these dispatches are sent to the field for the generators to follow the operating point. The M-OTS extracts the dispatch operating target (DOT) values and the generator ramp profiles from the dispatch and uses them to control the generators in an automatic fashion. The interface also controls startup and shutdown of generators as and when the appropriate control is received. The operator is notified if there are any dispatches for pseudo generators not in the network model. The operator is also notified of dispatch values that violate the network model such as exceeding the generator rating. The operator can de-rate the resources in the RTM based on these hard constraints.

5) AGC Interface

For generators identified as regulating resources by RTM, AGC controls the resources in response to the frequency and transaction changes in between the dispatches. The training OTS has the functionality to keep individual generators on internal AGC control. In the M-OTS, this functionality is extended to include regulation of dynamic schedules. When the interface indicates that a generating resource is regulating, the resource is transferred to AGC control. When the interface indicates that the resource is not regulating, the resource is transferred back to manual control allowing the RTM to dispatch the resource.

6) CAS Interface

The Control Area Scheduling (CAS) interface sends scheduled tie-line flows to the EMS. The M-OTS retrieves these schedules, and converts them to appropriate transactions between CAISO and the associated external control area. This affects the ACE calculation for the associated external control area causing the generators in that area to respond to the scheduled transactions.

7) OMS Interface

The Outage Management System (OMS) records outages that are currently scheduled. These outages change the topology of the network and affect the market commitment and dispatch. In order to simulate the real-time conditions, the M-OTS retrieves these outages and creates switching actions based on the outages at the appropriate time.

8) Initial Power Flow Case

The M-OTS needs a power flow case to initialize the simulation. If the initial power flow is very different from the loading condition or the expected generation pattern, there is a possibility that the power flow that is executed by the M-OTS will diverge when the RTM is integrated with the M-OTS. To avoid this, a method of creating a power flow case from the day-ahead schedules was created.

The Power Flow interfaces directly with the DAM, CAS, OMS and the load forecaster to retrieve generation, interchange schedules, outages and load, respectively, for the selected time and create a base power flow case. This power flow case is used to initialize the M-OTS. This ability to create the power flow cases on the fly allows the M-OTS to be initialized at any given time.

In addition, traditional OTS has the ability to create power flow cases from the current load conditions. This is useful when the simulation needs to be restarted for software changes but the current generation pattern has widely differed from the results of the DAM.

9) OTS Debug Mode

The M-OTS needs the ability to function in a debug mode where some or all external systems are not available. In debug mode, the external interfaces are completely blocked. Instead, the data received from the external interfaces is simulated by M-OTS Instructor using data entries. This mode is very useful in testing the M-OTS for given test cases to ensure that the M-OTS behaves as per the specifications. This allows the Instructor to ensure the validity of the software and model changes that are made to the M-OTS before integrating with the market.

10) External Area ACE Control

The network model used by CAISO simulator is an equivalenced network model where most of the external areas are replaced by equivalent boundary generators. A boundary generator is in generation mode when the external area is exporting power to CAISO and is in pumping mode when the external area is importing power from CAISO. Since there is no data available to perform an economic dispatch for these boundary generators, the economic dispatch function was disabled for these boundary generators in M-OTS.

In addition, since the normal external area AGC does not have the ability to control pumps, the external area AGC function of the traditional OTS is disabled in the M-OTS. It is replaced by a manual dispatch to directly control the boundary generators based on the Area Control Error.

11) OTS Instructor Intervention

When the simulation is started, the M-OTS automatically registers with the external interfaces but it does not start to process the market system directives. The EMS integrates with the market system by sending the state estimator solution and telemetry data. After receipt of these data, the external interfaces start sending the directives to M-OTS. When the instructor is satisfied with the quality of the data that is received, the instructor manually activates the M-OTS to close the loop with the market system. The M-OTS provides the instructor with data that is useful in determining whether the RTM has successfully integrated with EMS.

In addition, the M-OTS also provides the instructor with information on directives that cannot be executed due to modeling constraints (such as limit violations) or due to network topology constraints (such as an upstream breaker of a generator being open). This feature aids the instructor in identifying the model data mismatch between the EMS and the RTM.

The M-OTS also allows the instructor to simulate test scenarios such as non-compliance of a generator to the market directive, loss of a tie line, etc. The instructor can block/unblock individual market directives. For example:

- To simulate non-compliance of a generating resource, the instructor blocks the market directive for the specific resource and then controls the resource using M-OTS events.
- To simulate the loss of a tie-line, the instructor blocks the market directive for a specific boundary generator. The manual dispatch of the boundary generators identifies the loss of the tie-line and distributes the tie schedule to other boundary generators in that area thereby simulating an overload on the other tie-lines.

12) Real-Time Calculations

In a production environment, not all data for the network model is telemetered. This data is sometimes calculated using real-time calculations. In the M-OTS environment, these calculations can cause issues since M-OTS has the calculated values for all points in the network model. The solution was to disable these real-time calculations in M-OTS environment. In addition, there is some telemetered data that is not part of the network model (and hence cannot be simulated by the OTS) but is used by real-time applications such as AGC. The solution is to create real-time calculations that work only in the M-OTS environment. An option is provided so that specific calculations could be enabled or disabled in the M-OTS environment.

13) Extended operation time

A real-time M-OTS simulator runs continuously for extended periods without interruption with huge number of triggers from the external interfaces as compared to a conventional OTS system. The conventional OTS was not envisioned to operate for these extended times.

The M-OTS is modified to continue simulation beyond the specified period of load data by replicating the original load data for future times. Also, some data and process queues in OTS that are normally not cleared are purged periodically to make room for new data. Typically, at the instance when new data is received from the external interfaces, there is a huge burst of M-OTS events that are created. Unlike a traditional OTS, the M-OTS has the ability to consume this huge burst of events without any performance issues.

IV. Market Simulation and M-OTS Setup Description

Figure 1 shows the Market Simulation Environment setup and shows how the different interfaces and subsystems interact between each other.

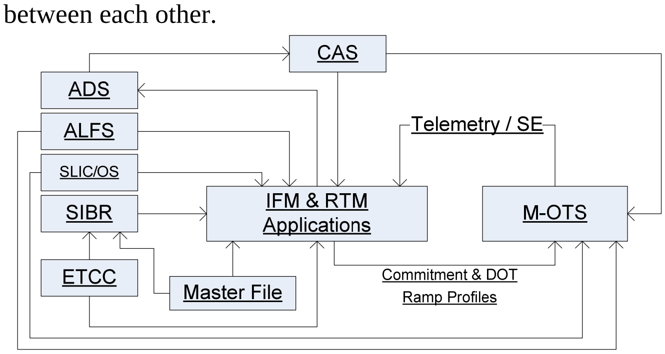

Figure 1: Market Simulation Environment

The following is a brief overview of the subsystems or components of the Real Time Market (RTM):

1) Hour Ahead Simplified Process module (HASP) executes at the top of every hour and optimally determines hourly inter-tie energy and ancillary services dispatches for the next study hour.
2) Short Term Unit Commitment (STUC) is responsible for optimally committing medium start units
3) Real-time Pre-Dispatch (RTPD) runs every 15-mins and optimally commits/de-commits fast start units and procures ancillary services.
4) Full Network Model: All of the above modules utilize the FNM and the latest SE solution to determine the most recent topology and switch positions. An AC power flow including contingency cases is executed for each study interval (up to 18). This results in a set of linearized constraints (loss sensitivity factors and shift factors) which are utilized to resolve congestion resulting from binding flowgates (branch groups, lines, transformers, and other equipment monitored by the application) and nomograms. This process is iteratively executed a configurable number of times (currently 3).
5) Real-Time dispatch (RTD) uses the commitment and A/S procurement determined by RTPD, STUC and the output provided by HASP to optimally dispatch resources. RTD uses State Estimator values and or telemetry as a starting point from which its initial conditions are determined, RTD assumes that no substantial topology change happened since the last RTPD run, as long as RTD doesn't receive a contingency event signal, and will utilize the set of linearized constraints passed from RTPD to resolve congestion.
6) Other Interfaces:

- The Very Short Term Load Predictor (VSTLP) is an application based on neural network technology. It uses five-minute averages of actual Load from telemetry data for the last 13 months as historical input. VSTLP provides Load prediction for a period of two hours: The Extended Very Short Term Load Prediction (ELP) is similar to VSTLP except that it provides load prediction for a longer period of time (5 hours).
- Scheduling Infrastructure & Business Rules (SIBR) supplies RTM with bids submitted by the market participants and Day-Ahead cleared results after going through a rigorous validation process to make sure they comply with the proper market business rules.
- Control Area Scheduler (CAS) is the application where all System Resource Schedules, Awards, and Dispatch Instructions are logged. HASP Energy Schedules and AS Awards, and Exceptional Dispatch Instructions are first sent by RTM to ADS and CAS, and then confirmed by CAS for use in future RTM runs. Hourly CAS data is also sent to EMS.
- Existing Transmission Contract Calculator (ETCC) determines the Available Transfer Capability (ATC) for all Transmission Interfaces
- SLIC/OS provides resource and network outage management to be used by EMS, Real-Time and Day-Ahead (IFM).
- The Automated Dispatch System (ADS) communicates Real-Time Dispatch Instructions to market participants. ADS facilitates the receiving and generally responding to in-hour Dispatch Instructions in Real-Time, and receiving confirmation of accepted pre-Dispatch Instructions.

In order to expedite the various testing efforts and due to tight schedule it was necessary to setup multiple market simulation environments with M-OTS integration. The following essential activities mandated the presence of four systems:

- Market Simulation system runs as a production system and mainly used by the market participants
- Testing environment where all the new software fixes and new features are tested in an integrated fashion.
- Staging environment which is used to verify the stability of the software patches that had passed validation in the testing environment before these patches are applied to the market simulation environment. This system is also used by the operators for training.
- Network Model work environment where all the new network models are verified before they are applied to any of the other environments. In this environment rigorous verification of the market model is done including verification of power-flow solutions.

To setup the simulation, a set of load forecast curves are agreed upon between the M-OTS and the RTM applications. RTM uses 15-mins and 5-min load curves whereas the M-OTS will use the hourly average values corresponding to the load. The market in turn will take into account losses and remove pumping load. M-OTS will start from a basecase snapshot from the current production state estimator solution which captures the system topology. When the simulation is initialized, the initial conditions including generation pattern between the two systems may be far apart. This is mitigated by running the market using M-OTS feedback as initial conditions for several intervals. Once the two systems are fairly close to each other, M-OTS is allowed to use the market dispatches to drive its unit commitment and dispatches. During this process, having accurate CAS schedules is critical. Once RTM and M-OTS systems are synchronized, M-OTS will start ramping generating units up / down according to the dispatch targets provided by RTM and the market will start to use initial system conditions from M-OTS including the state estimator solution which captures the changing system topology as outages and other types of operator's switching actions start to take effect.

V. REAL TIME MARKET SIMULATION TEST SCENARIOS

The new market system calculates look-ahead dispatches based on the state estimator solution, telemetry and breaker status simulated by M-OTS. Initial synchronization between RTM and M-OTS was the hardest challenge due to generation and network topology mismatch between M-OTS and market systems. This was resolved by tuning the power flow base case and data synchronization between external interfaces.

High level simple point to point tests were performed to verify the XML payloads and messages between the M-OTS and RTM system. The RTM system broadcasts relevant information through the integration layer to the M-OTS, and the M-OTS publishes simulated telemetry and state estimator solution feedback to the RTM system.

Data flow from source systems to target systems via the integration layer can have multiple points of failures, so it was difficult at first to troubleshoot without full visibility of each point of failure. As the time progressed CAISO were able to validate all EMS messages using the M-OTS. Once the point to point payload testing was complete, the CAISO proceeded to close loop testing with RTM system.

Network model validation was the most critical piece of the entire testing. Data population to mimic real time data from field was also a challenge because network model and AGC were not using same data reference for control due to market rule to monitor point of delivery or point of injection into the CAISO grid. One-to-many relations of market resources mapping to physical network resources were also a crucial part of testing to build bridges between market scheduled resources and detail network model.

Following are few test cases used during the close loop simulation to validate bid to bill:

1. Make a smooth transition for both RTM and M-OTS at the very first start of the close loop simulation.
2. Verify the ability to run the simulation using a fixed flat load forecast. Having flat load will not result in a fixed dispatch. In this case it is expected that the dispatches will be stable during the hour while it will change during hourly transition due to changes in bids and hourly ties dispatches.
3. Verify that the two systems see the same total system generation and load and no generating units are missing or deviating causing large mismatches between the two systems.
4. Verify that forced or unscheduled transmission outages that are reflected in the SE solution are also considered and properly handled in the Market Application system.
5. Verify that forced unit outages are properly detected by market and that RTM will see the unit as disconnected and will dispatch several other units to compensate for the loss of this unit.
6. Verify the consistency of the AC powerflow solutions in both the M-OTS and the Market Applications system.
7. Validate that AGC can maintain frequency and grid reliability.
8. Validate the CPS and reserve criteria.
9. Verify system handling of large, inter-hour load changes.
10. Verify market LMPs at the interconnection points where self-schedules and bids exceed interconnection capability.
11. The Compliance Department was able to collect information from historian to analyze results.
12. Outages submitted by the external market participants were monitored and enforced under the close loop simulation.
13. Start-up, unit ramp up-down, unit regulation and shut-down logic were simulated using M-OTS such that The impact of the RTM unit commitment decisions on the electrical system, over a time horizon, could be observed via the integration with the M-OTS.
14. Verify market LMPs under well known system conditions, high impact line outages, and tie line outages.
15. Verify market LMPs when system is in Over-generation, or under-generation situations.

Due to space limitations, sample numerical test results are not shown here, but will be shown during the presentation.

VI. CONCLUSION

One of the tough challenges encountered in implementing the CAISO's MRTU initiative was that of validating the Real-Time Market design, and implementation prior to go-live. CAISO coordinated an effort to modify its existing conventional OTS environment to allow for the processing of Real-Time Market commitments, dispatch, and regulation reserve procurement using the new MRTU Real-Time Market System. The M-OTS system produces State Estimator solutions that are passed to RTM system in a full closed loop simulation with high degree of stability over a variety of system conditions and load patterns.

The CAISO open system architecture and the use of integration layer have simplified the integration of two major products, OTS and Market System, procured from two different software vendors with different technologies. This integration of M-OTS and the market systems validated the decision and design that CAISO is adopting for the MRTU project.

Possible M-OTS future work includes the capability of starting the simulation from current on-line conditions and market directives. This feature will reduce the initial time required to synch RTM and M-OTS and gives CAISO opportunity to run a simulation system that is parallel to the on-line production.

VII. REFERENCES

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VIII. Biographies

Dr. Enamul Haq (Sr. member IEEE) received BS (73) and MS (77) degrees in Electrical Engineering from Bangladesh Engineering University and MS (89) degree in computer science from LSU. He holds a Doctor of Electrical Engineering degree from Bucharest Polytechnic Institute. Dr. Haq is engaged with the EMS group, California ISO as a senior advisor since July 2000. His interests are in power system training simulator, network modeling using CIM and market interfaces. He has over 30 years of experience in research, teaching and power industry.

Mark Rothleder, P.E. received his BS degree in Electrical Engineering from the California State University, Sacramento. Mark has taken post-graduate coursework in Power System Engineering from Santa Clara University and earned an MS in Information Systems from the University of Phoenix. He is a Principle Market Developer for the CAISO and, is currently in a lead role in the implementation of market rules and software modifications related to the CAISO's Market Redesign and Technology Upgrade ("MRTU"). Prior to joining the CAISO, Mark worked for eight years in the Electric Transmission Department of Pacific Gas & Electric Company, where his responsibilities included Operations Engineering, Transmission Planning and Substation Design. He is a member of IEEE.

Bassem Moukaddem is a Senior Market Engineering Specialist at the California Independent System Operator. He received his Bachelor of Electrical Engineering and Bachelor of Science in Biology from the American University of Beirut. Was Project Engineer at ABB Market Information Systems Santa Clara, CA from 2000 -2005 and is currently involved with the Forward Markets / Real-time of the Market Redesign and Technology Upgrade project at CAISO.

Sirajul Chowdhury received his BSEE (1990) from the University of Oklahoma. He worked at Landis & Gyr as a senior power system engineer from 1990 to 1999. He has been working at California ISO since October 1999 as a senior EMS engineer. His professional interests include control system, energy market, Automatic Generation Control, and real-time system design and development.

Dr. Khaled Abdul-Rahman received his BS (86), and MS (90) degrees in E.E from Kuwait University, his Ph.D. in E.E. from Illinois Institute of Technology, Chicago, IL in 1993. He is currently Independent Principal Consultant in Electricity Markets and Power Systems. Previous experience includes working on projects at Siemens Energy, Sargent & Lundy, Oracle Consulting, OATI, ABB, ESCA, FPL, IPC, ARTO, ECCO, CAISO. Currently, Dr. Abdul-Rahman is involved in design, implementation, and testing of Forward and Real-Time Markets for CASIO MRTU project under a sub-contract from Siemens.

James G. Frame received the BEE and MSEE degrees from the University of Minnesota in 1978 and 1981 respectively. He joined Siemens Energy (formerly Control Data Corporation) in 1981. He is currently working in the Market Management group. His professional interests include electricity markets, congestion management, locational marginal pricing, ATC calculations, optimal power flow, numerical methods for power systems, and optimization techniques. He is a Senior Member of the IEEE.

Ashmin K. Mansingh received his MSEE from Indian Institute of Technology in Bombay, and MS in Computer Science from the University of Minnesota in 1996 and 2000 respectively. He joined Siemens in 1996. He is a Staff Level Engineer working in the Electricity Market Management group. His professional interests include optimization techniques, Automatic Generation Control, and real-time system design and development. He is a member of the IEEE.

Dr. Tushar Teredesai (M'1997) graduated with distinction from the M.S. University of Baroda, Vadodara, received his Master's from Indian Institute of Science, Bangalore and Ph.D. from Illinois Institute of Technology, Chicago. He is currently a Senior Applications Engineer in Network Applications and Simulation group at ABB Network Management, Sugar Land. His professional interests include OTS, Market System Simulation, Outage Scheduler and Advanced Power System Applications.

Dr. Norman Y. Wang (M'1986) was born in China on August 14, 1944. He received his B.Eng.Tech. with first class honor and Ph.D. degrees in Electrical Engineering from the University of Wales Institute of Science and Technology, Cardiff, U.K., in July 1971, and September 1974, respectively. Between 1974 and 1978 he was a Project Engineer at the GEC Power Transmission Division of GEC Power Engineering, U.K. From 1978 to 1989 he was a Planning Engineer at China Light and Power Co.Ltd., Hong Kong. Currently, he is a Principle Consultant Application Engineer at ABB Inc., Sugar Land, Texas. His main fields of interest include Power System Control, Power System Analysis, and Dispatcher Training Simulator. Dr. Wang is also a member of The Institution of Engineering and Technology (IET), United Kingdom.