

Management of Available Transfer Capability with Growth in Renewable Resources

James E. Price, *Member, IEEE*

Abstract — The California ISO's functions include energy and related markets that provide non-discriminatory access to transmission facilities that have been placed under the CAISO's operational control. The calculations of Available Transfer Capability (ATC), and management of market schedules to remain within ATC, are critical parts of the CAISO's functions. This paper first describes these functions. An emerging challenge in management of California's transmission grid is an increasing reliance on renewable generation, to achieve aggressive targets to reduce the current heavy reliance on natural gas as a fuel for electric generation and to reduce emissions of carbon dioxide, which will result in profound changes in markets and system operations. Among these challenges is that new renewable generation often involves remote resources, which affects the utilization of existing transmission, requires new transmission and increases some ancillary service requirements that must be deliverable through the transmission system. Achieving California's renewable energy goals will include imports of intermittent resources, requiring coordination among system operators throughout the western states. Strategies for maintaining high utilization of California's import capability are examined.

Index Terms—available transfer capability, dynamic transfers, dynamic scheduling, renewable resources

I. INTRODUCTION

CALIFORNIA Independent System Operator (CAISO) is a balancing authority (among other functions) serving approximately 30 million people, having a historic peak demand of 50,270 MW in July 2006, from sources including about 50,900 MW of generation capacity, 8000 MW net imports per hour (annual average), and 2400 MW of demand response & interruptible load. The CAISO manages about 26,000 circuit-miles of transmission lines, and 41 interties connecting to adjacent areas. The CAISO will continue these functions while California implements a Renewables Portfolio Standard and other policies that promote the development of environmentally friendly power. The use of renewable energy (wind, solar, geothermal, biomass and small hydroelectric generation) is planned to increase from approximately 11 percent of the total energy previously delivered to California electric customers, to 20 percent of energy from renewable

resources in the 2010 to 2012 timeframe, and then increasing to 33% renewables by 2020. By 2020, the overall renewable resources would increase from a historical level under 6000 MW to more than 25,000 MW in 2020. [1] [2]

Some of this energy will be from renewable resources located outside the CAISO balancing authority area, which will be imported into the CAISO from adjacent areas. In cases where external balancing authority areas provide regulation, operating reserves, and other balancing services to these transactions, the imports to the CAISO would be static schedules for the duration of hourly or sub-hourly intervals. In other cases, the renewable resources would be dynamically transferred to the CAISO, with deliveries that may constantly vary within the traditional scheduling intervals. For dynamic transfers, the CAISO will need to implement flexible scheduling and dispatching procedures to avoid situations in which transmission would be reserved for the maximum potential delivery from dynamically transferred intermittent resources that would have lower average deliveries.

This paper first reviews the CAISO's practices for administering available transfer capability (ATC) through its markets, and then discusses measures that the CAISO is implementing to maintain high utilization of ATC as its resource mix includes an increasing amount of renewable resources. The appendix to this paper briefly summarizes the CAISO's overall market structure, and business practice manuals contain extensive descriptions. [3]

II. OPERATIONAL AND MARKET PRACTICES FOR AVAILABLE TRANSFER CAPABILITY

The CAISO's market structure provides for the calculation and publication of ATC in advance of market bid submissions, then updates ATC to reflect market conditions as the market timeline progresses from day-ahead through real-time. The ATC calculation follows the calculation of Operational Transfer Capability (OTC), which represents the total transmission capacity of designated transmission interfaces based on a variety of limitations that are considered in engineering studies. The following subsections describe these processes, and identify factors that affect the calculation and use of ATC. Further detail is described in the CAISO's Planning Standards, Methodology and Compliance procedures. [4]

Transmission Ownership Rights and Existing Transmission Contracts

The CAISO recognizes the ownership of transmission capacity that is within its balancing authority area but has not been placed under CAISO operational control as Transmission Ownership Rights (TORs). The CAISO also recognizes Existing Transmission Contracts (ETCs) that transmission owners identify as encumbrances of the CAISO controlled grid based on contracts that predate the CAISO's initial operation in 1998. For TOR capacity on inter-ties to adjacent balancing authority areas, the CAISO reduces the ATC available for scheduling in the day-ahead and real-time markets by the amount of the TOR. The ATC is also reduced for ETC capacity on interties, but only to the extent that the ETC scheduling rights extend beyond the timeframe of the market that is running. For TOR and ETC capacity within the CAISO balancing authority area, the CAISO does not set aside capacity, but instead provides a high priority in the market optimization to source-to-sink schedules that the TOR or ETC holder identifies as using its rights, which ensures that the TOR or ETC holder can fully utilize its rights. In financial settlements, the CAISO reverses congestion costs that the source-to-sink schedule would otherwise incur. In the allocations and auctions of congestion revenue rights (CRRs), the CAISO reserves capacity for TORs and ETCs as point-to-point CRRs that are held by the CAISO.

ATC Calculation Before Day-Ahead Market

Before the day-ahead market closes for a trading day, there are no pre-established ETC or TOR schedules, net energy schedule, or ancillary service schedules on transmission interface. Therefore, the CAISO publishes the ATC for a transmission interface as:

$$\text{ATC} = \text{OTC} - \text{Total Transmission Interface ETC Capacity} - \text{Total Transmission Interface TOR Capacity} - \text{CBM} - \text{TRM}$$

Where:

Total Transmission Interface ETC or TOR Capacity = the sum of all the ETC and TOR capacity rights on the transmission interface, and

Capacity Benefit Margin (CBM) and Transmission Reliability Margin (TRM) are as discussed below.

The CAISO determines, and publishes on its OASIS web site, the OTC, ATC, and scheduled derates of transmission interfaces seven days in advance, in particular by 18:00 two days before the trading day, based on known network conditions and temperature forecasts that lead to line derates. By 08:30, before the day-ahead market closes at 10:00, the CAISO updates and publishes the available ETC capacity and ATC. The ATC is updated whenever OTC or the other factors change. Since it is common for bilateral transactions outside of the CAISO balancing authority area to take place by 05:00, the CAISO coordinates with other balancing authorities to communicate changes to OTC that occur after 05:00. Generally, the CAISO can make changes that impact its markets due to outage conditions up to 08:00, and provide

information back to market participants. If a change in OTC reduces ETC rights, any ETC self-schedules that have been submitted are revalidated, and the market participant that schedules the ETC is informed of any required adjustments. If changes due to outages occur after 08:00, they are entered into market systems on an exception basis, only if they can be fully coordinated with other affected transmission operators and balancing authorities, and entered into all systems affected by the change, before 09:00:

ATC Calculation Between Day-Ahead and Real-Time Markets

Between the day-ahead and real-time markets, the ATC on each transmission interface for a trading hour is calculated as follows:

$$\text{Import ATC for interties} = \text{Import OTC} - \text{Total Import ETC Capacity} - \text{Total Import TOR Capacity} - \text{Day-Ahead Net Energy Scheduled Import} - \text{Total Day-Ahead Upward Regulation/ Spinning Reserve/ Non-Spinning Reserve Import Awards} - \text{CBM}$$

$$\text{Export ATC for interties} = \text{Export OTC} - \text{Total Export ETC Capacity} - \text{Total Export TOR Capacity} - \text{Day-Ahead Net Energy Scheduled Export} - \text{Total Day-Ahead Downward Regulation Import Awards} - \text{CBM}$$

Where:

Day-Ahead Net Energy Scheduled Flow is the net scheduled energy flow on the transmission interface in the relevant direction, from the day-ahead market.

For each transmission interface in the import or export direction, the Total ETC or TOR Capacity is the sum of the expected day-ahead ETC or TOR schedules in that direction.

ATC Calculation After Real-Time Market

After the completion of the real-time market (after the trading hour), the ETC and TOR capacity is no longer reserved, and the ATC calculation becomes the following:

$$\text{ATC} = \text{OTC} - \text{Real-Time Net Energy Scheduled Flow} - \text{CBM}$$

Where:

Real-Time Net Energy Scheduled Flow is the average scheduled real-time energy flow on the transmission interface in the relevant direction during the trading hour.

CBM and TRM

The CAISO's market design maximizes the release of transmission capacity to the day-ahead market while providing for sufficient transmission capacity to deliver operating reserves for all load obligations and to maintain the reliability of the CAISO controlled grid. Thus, the CAISO does not regularly use TRMs or CBMs, and these values are normally set at zero. Load serving entities (LSEs) in California are under resource adequacy (RA) requirements for load scheduling, and the supply resources under RA contracts to the LSEs are subject to must-offer requirements. LSEs pre-schedule load sufficient to cover projected real-time needs in the day-ahead and hour-ahead market timeframes. Normally, any deviations from these forward schedules are then supplied or balanced by the CAISO's real-time energy Market.

If market operations on previous days have required real-time schedule curtailments on the affected path, the CAISO may implement a TRM during certain conditions that may otherwise result in transmission curtailments and/or firm load interruptions, or a CBM to reserve transmission capacity to provide for reliable delivery of energy and to meet CAISO's real-time load responsibility and generation reliability requirements, or to reestablish operating reserves, without real-time schedule curtailments and firm load interruptions. A TRM would reserve transmission capacity in the day-ahead market to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system operating conditions, to preclude real time schedule curtailments that might otherwise be necessary due to load forecast error, anticipated uncertainty in transmission system topology, unscheduled loop flow, simultaneous path interactions, variations in generation dispatch, or use of operating reserves. Use of a CBM would occur only after all non-firm sales have been terminated, direct-control load management has been implemented, customer interruptible demands have been interrupted, the LSE calling for its use is experiencing a generation deficiency, and its transmission service provider is also experiencing transmission constraints relative to imports of energy on its transmission system. [5]

III. ISSUES AFFECTING ATC WITH INCREASING RELIANCE ON RENEWABLE ENERGY

As noted in the introduction, the CAISO will face new issues in managing ATC as California implements the Renewables Portfolio Standard, increasing the use of renewable energy from approximately 11 percent of the total energy previously delivered to California electric customers, to 20 percent of energy from renewable resources in the 2010 to 2012 timeframe, and then increasing to 33% renewables by 2020. Some of this energy will be from renewable resources located outside the CAISO balancing authority area, which will be imported into the CAISO from adjacent areas. To manage dynamically transfers of renewable resources to the CAISO, with deliveries that may constantly vary within the traditional scheduling intervals, the CAISO will need to implement flexible scheduling and dispatching procedures to avoid situations in which transmission would be reserved for the maximum potential delivery from dynamically transferred intermittent resources that would have lower average deliveries. The CAISO has addressed these impacts, among other issues, in a recent stakeholder process to improve its existing market mechanisms for dynamic transfers. [6]

Recommendations from Dynamic Transfers Stakeholder Process

Through this stakeholder process, the CAISO has developed a set of proposals to:

1. Clarify tariff provisions for conventional resources,
2. Extend the existing use of dynamic scheduling for imports of conventional resources to include dynamic transfer of intermittent or "renewable" energy resources

into the CAISO from other Balancing Authority Areas (BAAs) and to dynamic exports, and

3. Incorporate pseudo-tie service in the CAISO tariff, including intermittent resources, predicated upon the successful culmination of the two present conventional resource pseudo tie pilots.

These proposals encompass a variety of needs for integrating intermittent dynamic transfers, including:

- Transmission reservations: To account for the variation in renewable resources' output, allow dynamic transfers to specify maximum deliveries exceeding their expected average delivery. Given that the ISO provides hourly firm transmission and requires external transmission to be procured only for each operating hour, discourage excess transmission scheduling through settlement of congestion charges and the Grid Management Charge for the greater of scheduled and actual delivery.
- Congestion management: To efficiently dispatch all ISO resources over the real-time operating horizon, offer a scheduling option to intermittent resources to update their expected energy profile availability by 5-minute intervals, for a forward-looking two-hour period, to manage variability within operating hours and maintain high transmission utilization by dispatching other resources.
- Dispatchability requirements and curtailment rules: Ensure that dynamically transferred resources can immediately respond to interchange schedule (e-Tag) curtailment and decremental dispatch instructions and orders in the event of real time inertia derate or contingency event. Develop operating procedures to reflect characteristics of new resources, and use operating orders to facilitate compliance with reliability needs.

These market enhancements address the concern of how to maintain full transmission utilization, while recognizing the variability of intermittent resources' output, and NERC and WECC standards that do not apply to schedules within the CAISO. Electronic tags (e-Tags) for dynamic scheduling contain capacity values for both expected delivery and maximum delivery. The CAISO's market software has previously managed dynamic schedules using only the value for expected delivery, and this has represented the transmission reservation for purposes of the CAISO market. However, if (1) a dynamically scheduled intermittent resource were to schedule its average, expected delivery, (2) its reserved transmission matches its energy schedule, and (3) other interchange schedules were accepted up to its inertia's full capacity, the intermittent resource may be unable to deliver more than its initial expected energy schedule. A contrasting concern is that market participants could submit excessive self-schedules to obtain flexibility for exceeding their actual expected, but intermittent, deliveries to the CAISO. In this event, the CAISO's market systems could expect that it would receive more energy from the intermittent resources than they would actually be expected to produce,

and may fail to commit sufficient dispatchable capacity to maintain the required energy balance. Excessive scheduling for the purpose of obtaining flexibility for intermittent deliveries could also result in unused transmission capacity that could be used by other market participants.

The ISO is responding to these concerns of avoid reducing the utilization of the ISO's import capacity, by implementing a recallable transmission mechanism for real-time dispatch of dynamic transfers, as described in NERC's Available Transfer Capability Definitions and Determination and as shown in the attachment to this paper. [7] This mechanism applies the following principles to the forward and real-time scheduling of dynamic transfers:

- The sum of "non-recallable scheduled" plus "recallable scheduled" transmission cannot exceed the total transfer capability,
- "Non-recallable reserved" itself cannot exceed the total transfer capability,
- Non-recallable service has priority over recallable service, and
- Reserved transfer capability may be used by recallable scheduled transfers.

The applicability of these principles is illustrated through a series of examples in the next section.

IV. APPLICATION OF ATC PRINCIPLES WITH INCREASING RELIANCE ON RENEWABLE ENERGY

A series of examples using the PLEXOS software (commercial desktop with extensive capabilities for market modeling and transmission planning – see www.energymax.com) demonstrates how the principles in the CAISO's dynamic transfer processes will allow dispatchable dynamic transfers to use recallable transmission beyond their own forward-market transmission reservations, which the ISO will award for 5-minute intervals through real-time dispatch, when other dynamic transfers are not fully using their reserved capacity in real-time. The examples illustrate the results of scheduling and dispatching intermittent and dispatchable dynamic resources in greater detail, and suggests that in practice, the impact of dynamic transfers' transmission reservations that remain unused in real-time would be limited. [8]

Case 1 – As a point of reference to isolate the impacts of dynamic transfers on intertie scheduling from impacts from simply having new generation in the CAISO market, this reference case places wind and solar generation within the ISO area rather than in other states.

Case 2 –Dynamic transfers of renewable resources (1485 MW of new wind and 2150 MW of new solar) are added in Arizona, southern Nevada, and New Mexico, without allowing transmission reservations or restricting other imports except by ATC. This case establishes an additional benchmark for comparison with cases 3 to 5, by showing the impact of adding these low cost MWh without other market design features.

Case 3 –Dynamically transferred resources are allowed to submit economic bids for transmission capacity reservations beyond their energy schedules. Transmission reservations apply in pre-scheduling timeframes, but not to routine dispatch within operating hours. This results in higher reservations of intertie transmission capacity, as discussed further in the discussion below. (Because of modeling software limitations, case 3 establishes MW schedules, but prices from case 3 and not meaningful.)

Case 4 – To simulate real-time dispatch, with hourly intertie schedules fixed at prescheduled amounts from Case 3, this case represents a real-time dispatch scenario, in which hourly intertie schedules are limited to the pre-scheduled amounts determined in Case 3. Dynamic transfer schedules within operating hours are not limited by the transmission reservations that could limit hourly intertie schedules following Case 3.

Case 5 – Recognizing dynamic transfers of dispatchable resources, a significant part of the CAISO's proposals for dynamic transfers is allowing economic bids for dispatchable resources to be dispatched above their pre-scheduled transmission reservations, as "recallable" transmission that is firm for 5-minute intervals, but not scheduled beyond the timeframe of successive 5-minute intervals.

The simulated LMPs are similar in cases 1, 2, and 4, and are shown in Fig. 1 for a series of four days representing calendar quarters. The data points for the three scenarios are indistinguishable in most hours.

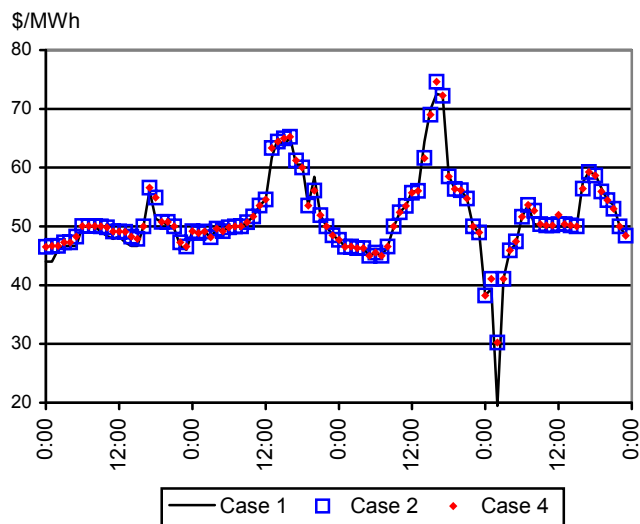


Fig. 1. Hourly Market Clearing Prices for Cases 1, 2, and 4

Fig. 2 compares the results of case 2 (second reference case) and case 4 (real-time dispatch, after transmission reservations limit hourly intertie schedules) for one of the modeled interties, to illustrate the effectiveness of the proposed market mechanisms. The results indicate that simply the addition of low cost resources that would compete for the existing intertie capacity would produce congestion at the Palo Verde scheduling limit in a number of hours, but the final transmission utilization in case 4 is indistinguishable in

shunt capacitor switching, within the design capability of the existing equipment. The wind data shows that voltage changes of this magnitude will be rare, and will not occur in rapid succession. There is no significant risk of tap hunting or rapid on/off cycling of shunt devices.

The frequency of occurrence of intermittent changes in dynamic schedules, if the full COI capacity were scheduled with renewable energy and voltage control were limited to online generation and SVC action, is:

Expectation	Frequency	Decrease in delivery from 5000 MW wind profile	Spring ΔV	Summer ΔV
	Once per year	-1672 MW	0.038 pu	0.037 pu
99.9%	Once every 2 weeks	-780	0.018	0.017
99%	Once every 1.5 days	-301	0.007	0.007
95%	Four times per day	-148	0.003	0.003
90%	Eight times per day	-108	0.002	0.002

The dynamic analysis at COI showed that an extreme test, driving all of the dynamically scheduled wind generation at a characteristic frequency with a peak-to-peak magnitude that exceeded the interface limit, still resulted in damped oscillations. At magnitudes greater than 3000 MW peak-to-peak, some protective relays operated depending upon the system condition and fault event. The study has found that there is no credible wind variation that can cause oscillatory destabilization of an otherwise stable system. Details of this part of the CAISO's study may be found in [9].

In the similar analysis of the WOR interface, where the maximum allowed power flow, and thus the theoretical maximum dynamic schedule, is 10,100 MW, the study represented intermittent dynamic transfers on WOR by a 15,000 MW DC/ 11,550 MW AC aggregate solar PV profile. The statistical analysis showed that that 99% of the time, the expected 10-minute drop in solar PV generation would be 412 MW or less, resulting in a 0.004 pu change in voltage. This is too small to result in additional transformer tap motion or shunt capacitor switching. The maximum once-per-year drop is 523 MW, which would result in a 0.005 pu change in voltage. The dynamic analysis of the WOR interface again shows that driving all of the dynamically scheduled solar PV generation with a peak-to-peak magnitude that exceeds the interface limit still results in damped oscillations, with some operation of protective relays, and increased duty of nearby SVCs depending upon the system condition and fault event.

Thus, under extreme conditions (e.g., once per year), it may be possible to trigger larger than normal shunt capacitor switching, transformer tap motion, SVC response, and/or protective relay operation, but the expected variability from the wind and solar PV generation when dynamically scheduled up to the overall maximum will not result in large changes in voltage or excessive duty on voltage regulating

devices. Based on considering high levels of imports of intermittent resources during both normal and abnormal operating conditions, the analysis shows that within the CAISO's footprint, no limits are required on dynamically scheduled variable generation other than the existing interface limits. Neighboring Balancing Authorities may have limitations within their systems that could impact the level of renewable resources that may be dynamically transferred to the CAISO.

APPENDIX: OVERVIEW OF CAISO MARKET

In its market structure that is effective as of April 1, 2009, the CAISO performs congestion management of firm transmission schedules, balances supply and demand, and performs other reliability functions in its system, through a financially binding day-ahead market for trading and scheduling energy, a residual unit commitment process, a real-time market that includes an hour-ahead scheduling process, market power mitigation measures, and resource adequacy requirements. The day-ahead market co-optimizes energy and ancillary services procurement, subject to transmission (ATC) and other operational constraints. There is no requirement for market participants to schedule balanced supply and demand within their own portfolios, and market participants can buy and sell from the market. (Load-serving entities are subject to resource adequacy requirements, and their contracted resources are obligated to submit bids to the market.) Once the CAISO has established final day-ahead schedules, the CAISO compares them to its projected load forecast, including forecasts for certain local areas, and secures additional resources through a "residual unit commitment" process.

The real-time market updates the energy scheduling and capacity procurement, using updated demand forecasts for the next five hours, and knowledge of outages and other operating conditions (including updated ATC). In both the day-ahead and real-time markets, scheduling priorities are recognized. These include priority uses such as supply schedules that maintain system reliability, use of pre-existing transmission contracts, and bids that are submitted as price-takers in an initial "scheduling run". Penalty prices for these bid segments are kept from affecting final market prices, though, by freezing the affected schedules and re-optimizing by setting prices in a "pricing run", using economic bids that are limited by caps and floors. Another instance where separate optimization runs serve different purposes is in the real-time market, where a real-time unit commitment process runs on 15-minute intervals, and a separate real-time economic dispatch process runs on 5-minute intervals to determine output levels.

The CAISO balancing authority area comprises three large investor-owned utilities (Pacific Gas and Electric Company (PG&E) in Northern and Central California, and Southern California Edison Company (SCE) and San Diego Gas and Electric Company (SDG&E) in Southern California), plus

smaller municipal utilities. Commercial trading is supported by “trading hubs” within the CAISO balancing authority area, corresponding to the three large congestion zones used in the previous market design (“NP15” in Northern California, “SP15” in Southern California, and “ZP26” in a portion of Central California), which are separated by two internal constraints, Path 15 and Path 26.

One fundamental feature for ensuring operational efficiency and enhance reliability is the Full Network Model (FNM) to represent the physical transmission topology and associated transmission constraints in the CAISO balancing authority area, and in balancing authority areas that are adjacent to the CAISO. The enforced transmission constraints include about 1900 flowgates and 35 nomograms, which include combinations of network flows and generation capacity, and include flowgate constraints based on temporary outage conditions. Another foundation is the state estimator, which is a component of the Energy Management System (EMS) system and provides the CAISO with a near real-time assessment of system conditions, including portions where direct measurements of real-time conditions are unavailable. The FNM and state estimator allow the real-time market to start its dispatch from the current system status, and allows the day-ahead market to base its inputs on stored state estimator solutions. Alternating current (AC) network analysis supports the security constrained unit commitment (SCUC), to ensure that interactions between real and reactive power flows are considered. Thus, SCUC minimizes bid costs while respecting the physical characteristics of selected resources and transmission constraints, considering the marginal effect of losses due to injections at each location in the grid.

Integrating the FNM, SCUC, and the state estimator allows the market optimization to ensure the feasibility of day-ahead as well as real-time schedules, and promotes consistency between day-ahead schedules and real-time energy flows. Among the alternative approaches to market operations using a FNM are locational pricing, managing flowgates, and zonal pricing after determining feasible operating ranges for supply resources. The method implemented in MRTU is locational marginal pricing (LMP). LMP is widely used in wholesale electricity spot markets, and directly and transparently calculates the actual cost of serving consumers at each transmission “node”, including the costs of producing energy, congestion (i.e., the effects of transmission bottlenecks), and losses (i.e., energy lost as it travels over the wires). The CAISO produces LMPs at 3,000 or more locations in the CAISO, which are paid to generation and other dispatchable resources. For non-dispatchable load, the CAISO calculates a load-weighted average price for each of three major utility service territories.

Structuring the market on LMP pricing involved addressing several concerns. One is the potential for high LMPs due to congestion in constrained areas. The market design includes local market power mitigation that: (1) pre-determines network constraints as “competitive” or “non-competitive”, (2) uses separate market runs to identify generators whose

output is incremented with all constraints enforced, relative to their output with only “competitive” constraints enforced, and (3) mitigates these generators’ bids to a pre-determined reference price if the bids exceed the reference price. Nevertheless, variation still occurs in congestion costs. Market participants can use congestion revenue rights (CRRs) to protect or “hedge” themselves from high priced locations. CRRs are awarded through an allocation process for load serving entities, followed by an auction process for all market participants. The CRR allocation and auction processes use the same base FNM as the day-ahead market, and enforce typical ATC values for transmission constraints.

Further details of the market design are provided in business practice manuals, which are available at <http://www.caiso.com/235f/235f939f8dc0.html>.

ACKNOWLEDGMENT

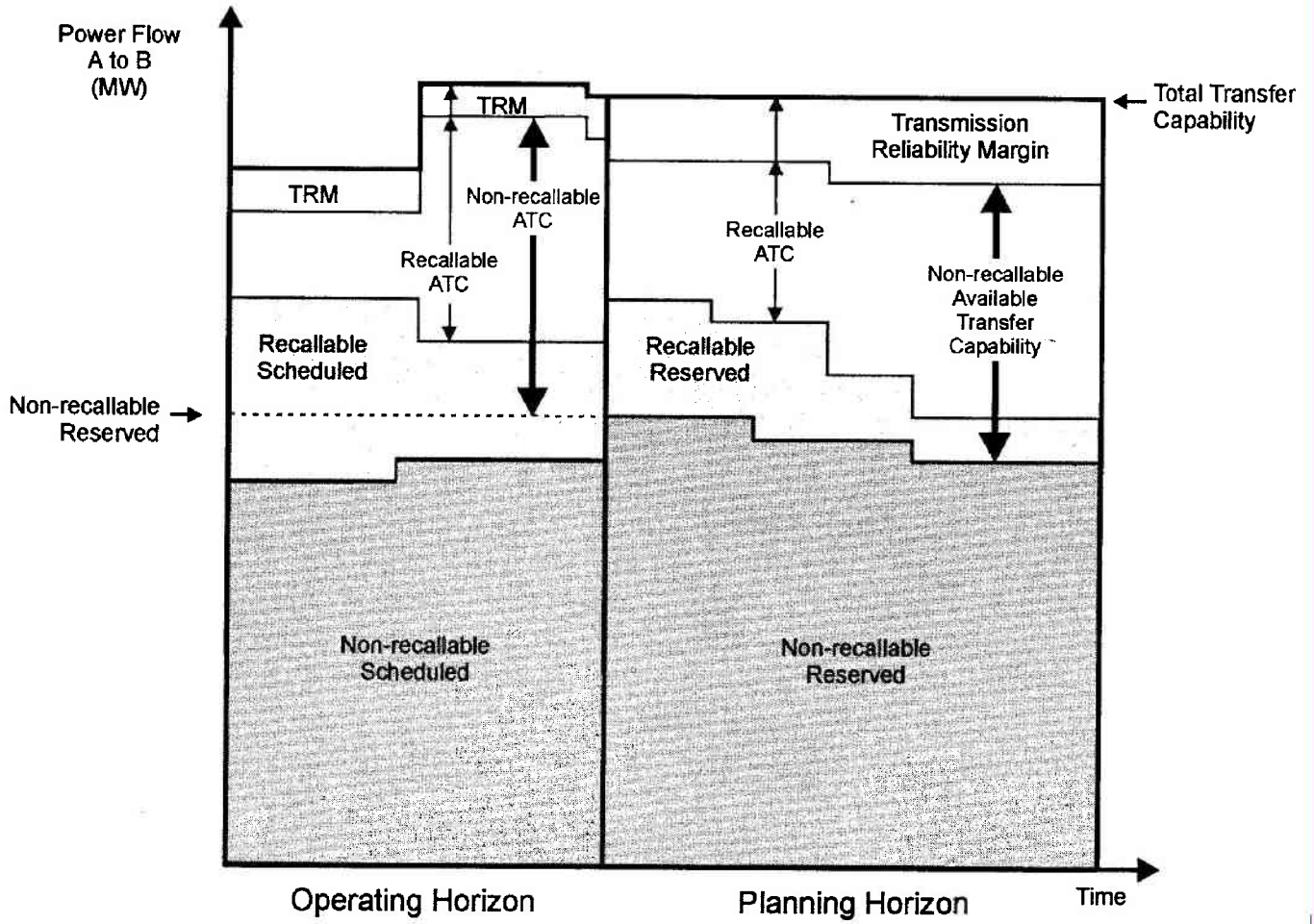
The CAISO’s work on integration of network modeling into the CAISO markets and integration of renewable energy resources extends throughout multiple departments of the CAISO. The author thanks the CAISO staff members who have contributed to these projects.

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James E. Price, Ph.D., received the B.S. degree from California Institute of Technology, and the M.S. and Ph.D. degrees from Stanford University. He worked for the California Public Utilities Commission, and California Office of Economic Policy, Planning, and Research, in a variety of areas including rate design, market development, and resource planning, before coming to the CAISO. He is currently a Lead Engineering Specialist in the Market and Infrastructure Development Department of the California ISO.

ATTACHMENT 1. TTC, ATC, AND RELATED TERMS IN THE TRANSMISSION SERVICE RESERVATION SYSTEM. [7]







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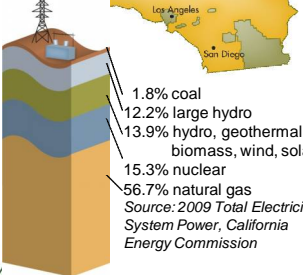




California ISO provides open, non-discriminatory access to transmission grid



■ ISO Control Area
■ Non-ISO Control Area





1.8% coal
 12.2% large hydro
 13.9% hydro, geothermal, biomass, wind, solar
 15.3% nuclear
 56.7% natural gas
Source: 2009 Total Electricity System Power, California Energy Commission

Responsibilities:

- Reliability, grid planning, outage coordination
- Market development, operations, monitoring




CAISO manages approximately 80% of California's electricity load



- 55,183 MW in-state power plant capacity
- 10,000 MW import capacity
- 50,270 MW record peak demand (7/24/2006)
- 25,526 circuit-miles of transmission lines
- 30 million people served
- 286 million annual megawatt-hours of electricity delivered annually
- 38,000 generation & transmission outages per year
- Over 30,000 day-ahead market transactions per day, similar volume for real-time market

California ISO
Shaping a Renewed Future

CAISO markets match supply & demand for reliability in day-ahead through real-time

 <h3>Day Ahead Market</h3> <p>Hourly market for 24 hours of next day</p> <p>Establish energy and ancillary service schedules</p> <p>Manage congestion (transmission access) using Full Network Model (FNM)</p> <p>Determine residual unit commitment requirements</p>	 <h3>Hour Ahead Scheduling</h3> <p>Prior to real-time (RT) market, schedule energy and ancillary services for static interchange for 24 individual hours</p> <p>Manage congestion using FNM</p> <p>As one of 4 RT pre-dispatch processes, establish unit commitment & advisory schedules for internal & dynamic resources</p>	 <h3>Real Time Market</h3> <p>Manage energy flows on transmission grid with telemetry and 1-minute state estimator solutions</p> <p>Update FNM for RT conditions</p> <p>Dispatch balancing energy/ ancillary service</p>
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California ISO
Shaping a Renewed Future

Operational and Market Practices for ATC



- Transmission Ownership Rights (TOR) and Existing Transmission Contracts (ETC)
 - Capacity set aside in market processes while valid
- Capacity Benefit Margin (CBM) and Transmission Reliability Margin (TRM)
 - Normally set to zero in CAISO market
- ATC calculations for CAISO market:
 - ATC prior to day-ahead market = Operational Transfer Capability – TOR – ETC – CBM – TRM
 - ATC prior to real-time subtracts day-ahead schedules




California ISO
Shaping a Renewed Future

Meeting Reliability Portfolio Standards involves refined Dynamic Transfer rules

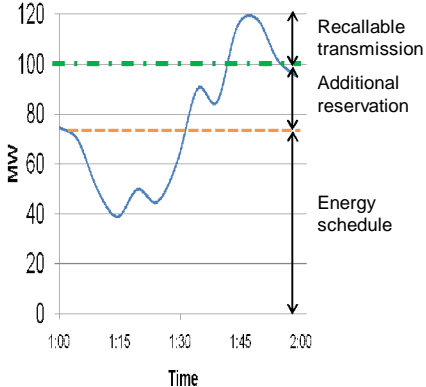
- Issues of congestion management in ISO markets:
 - Data and forecasting requirements
 - Dispatchability requirements
 - Curtailment rules
 - Transmission reservations and utilization
 - Locational modeling and pricing
- Supporting analyses:
 - Meaningful compliance, transmission utilization




Slide 5


California ISO
Shaping a Renewed Future

Transmission & congestion management proposals maximize transmission use

- Dynamic scheduling allows (but does not require) transmission reservation exceeding expected energy – room for variable delivery.
- Options for 5-minute real-time scheduling of recallable transmission allow filling unused capacity while managing congestion.
- After economic dispatch, operating orders ensure compliance for reliability.




Slide 6


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Transmission reservations are part of interchange scheduling

If capacity is available, dynamic transfer can exceed initial (non-recallable) reservation, as recallable schedule.

- Non-recallable reservations cannot exceed capacity
- Non-recallable schedules + recallable schedules cannot exceed capacity
- Reserved capacity may be used by recallable schedules
- Non-recallable reservations + recallable use can exceed capacity

Source: NERC's "Available Transfer Capacity Definitions and Determination"

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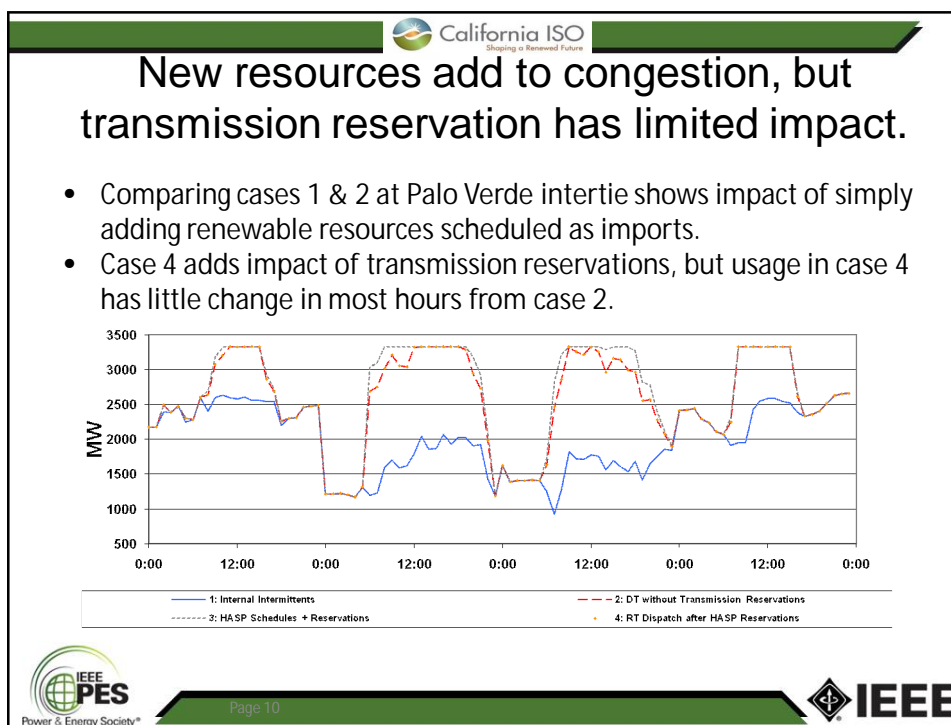
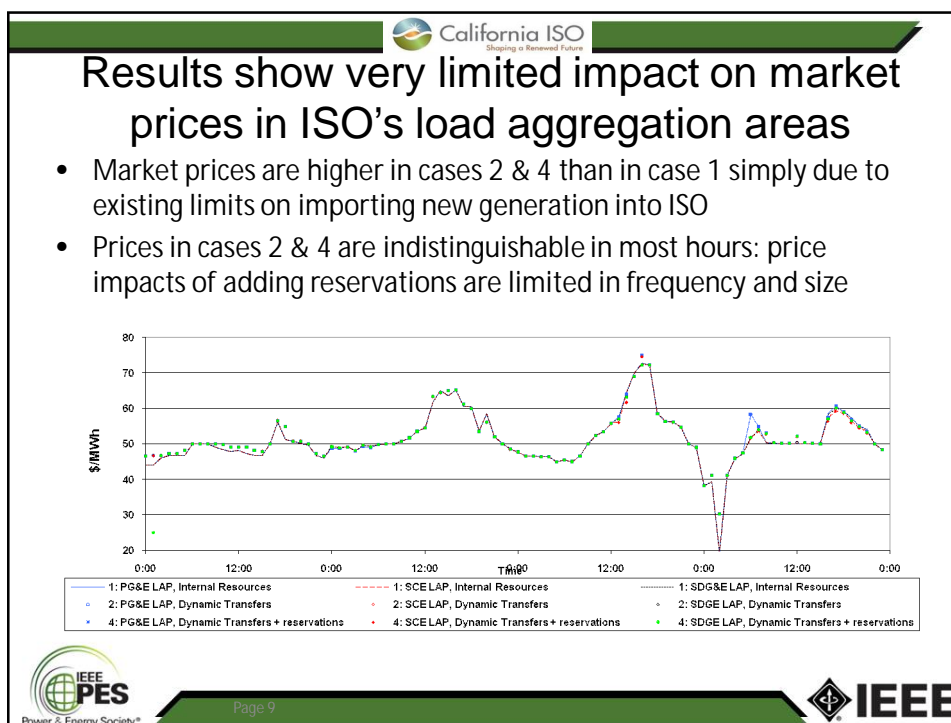
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Market impact study: PLEXOS model establishes benchmarks and simulates market

1. Reference case, internal intermittent resources: adding wind & solar generation within ISO isolates impact of dynamics from simply having new generation
2. Add renewable dynamic transfers without transmission reservations: adding low cost MWh without new market design features establishes additional benchmark
3. Dynamic transfers bid for transmission reservations beyond their energy schedules: represents pre-scheduling in DAM & HASP, before RT dispatch
4. RT dispatch, with hourly inertia schedules fixed from Case 3: in RT dispatch, hourly inertia schedules are limited to their pre-scheduled amounts

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Dynamic Transfer Capability study examined limits on variability of resources

- Study reviewed potential limits on transfer of variable resources while shaping and firming energy within ISO:
 - Impacts to existing path limits that accommodate planned hourly variations from 20 minute ramping period
 - Voltage control issues
 - Risk to stability or excitation of low frequency modes of oscillation
- ISO concluded no limits need to be applied within the ISO's BAA at this time but will monitor operational issues and coordinate with other BAAs on regional issues affecting dynamic transfer capability.