INCORPORATION OF WIND POWER RESOURCES INTO THE CALIFORNIA ENERGY MARKET

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Abstract

The California ISO (CAISO) Participating Intermittent Resources Program (PIRP) was released to production on August 18, 2004. This achievement is an important milestone in the ongoing team effort of the CAISO engineers and managers to implement a new integration approach that allows intermittent resources (i.e., wind and other resources with an uncontrollable primary energy source) to become competitive market players in California.

The PIRP creates conditions for intermittent producers to bid into California forward market without incurring ten-minute imbalance charges when the delivered energy differs from the scheduled amount. Instead, participants are assessed deviation charges based upon monthly net deviations between the metered and scheduled energy. An unbiased forecast of hourly energy results in a net energy deviation over an entire month that approaches zero.

A key ingredient to implementing the new scheduling methodology is the near real time, state-of-the-art forecasts. SCs representing Participating Resources use these forecasts as the energy schedules submitted to CAISO. The CAISO team is working closely with the SCs and AWS Truewind Company (the wind forecasting company) providing wind generation forecasting services.

At this moment, eight projects in San Gorgonio and Solano County participate in PIRP: Cabazon (40.92 MW), High Winds (162 MW), Green Power (16.5 MW), Mountain View I, II and III (44.4, 22.2 and 22.44 MW, respectively), Wintec (1.5 MW), and White Water Hill (61.5 MW). The program is rapidly expanding. Several more projects in California have expressed interest in joining the program.

This paper contains a brief description of the CAISO PIR Program as well as a discussion of the experience gained by the project development team.

I. INTRODUCTION

The intermittency and relatively low predictability of the wind generation resource causes various problems for its incorporation into the modern power grids. These are transmission interconnection, operational, and energy market issues. This paper focuses on the market integration issues.

A) Qualifying Facilities

Traditionally, wind generation resources in California have been treated as Qualifying Facilities (QFs) that produce "must take" energy for the grid. These QFs can be cogenerators that generate electricity by reusing the steam from manufacturing processes or from independently owned power plants, in conjunction with wind, geothermal, and other renewable sources, to produce energy. Another type of QFs are small power producers like low head hydroelectric power plants. To receive the QF status, a generator must file an application with the Federal Energy Regulatory Commission (FERC). In 1978, Congress passed the Public Utilities Regulatory Policies Act (PURPA). PURPA requires utilities to accept offers from QFs and mandated that utilities pay QFs for the avoided cost of energy production. The avoided cost calculation includes the capacity cost and energy cost. The capacity cost is the construction cost of the new generating facility. The energy cost is the cost of fuel and other variable expenses. Therefore, if a utility does not need new capacity in the near future, its avoided cost is only the energy component. With the new competitive generation build-up, the capacity cost component will be shrinking, and the

QFs will be facing a reduction in their revenues. In 1999, the California Public Utilities Commission permitted the avoided cost energy payments to be based on the market clearing price for QFs that elect this option. This motion was designed as a temporary measure, and it has been facing opposition as an off-market arrangement that benefits some power producers more than others. Current uncertainties associated with the future of the QF program excite more interest among the independent wind power producers to new forms of participation in the energy market. It is also likely that these uncertainties are limiting the growth of investments in renewable power resources.

B) Wind Generators as "Conventional" Market Participants

There are several serious obstacles for the wind power resources to become competitive bidders in the energy market. These include the relatively high production cost, unfavorable generation patterns when the maximum wind generation does not coincide with the maximum energy demand and market clearing price (in terms of their seasonality and daily variations), and difficulties associated with the scheduling of these highly intermittent resources.

There are no formal limitations that prohibit wind power resources to participate in the existing California Energy Market as "conventional" generators. But with the existing market structure, this would result in some significant disadvantages and problems for the participating resources, scheduling coordinators, and the CAISO. We will discuss these issues briefly in order to contrast advantages of the new market arrangement developed by the CAISO.

Wind generators that participate in the CAISO market would be settled just as any other generating unit. A wind generator would submit an hourly schedule for generation in the Day Ahead or Hour Ahead Markets. Deviations from this schedule would be settled based on the CAISO's market energy price every ten minutes. Since wind generators cannot control their output to meet a firm schedule, the likelihood of significant deviations and settlements is high. This option is not very attractive for intermittent resources since the risk of volatile market prices and the cost of deviations from schedule is very high.

C) Rationale Behind PIRP

The CAISO Participating Intermittent Resources Program (PIRP) allows intermittent power producers (i.e., wind and other resources with an uncontrollable primary energy source) to schedule their energy in the forward market without incurring hourly or daily imbalance charges when the delivered energy differs from the scheduled amount. A key ingredient to implementing the new scheduling methodology is to develop near real time, state-of-the-art forecasts. Scheduling Coordinators representing "Participating Intermittent Resources" use these forecasts as the energy schedules submitted to CAISO. Participating wind generators are exempt from the 10-minute settlement of uninstructed deviation charges and instead are assessed deviation charges based upon monthly net deviations between the metered and scheduled energy. The key is to have an UNBIASED forecast of energy production for every hour as this can result in a net energy deviation over an entire month that approaches zero or a very small number [1-3].

D) PIRP Development Process

In 2001, by initiative of the CAISO and the California Governor's Office, the Intermittent Resource Working Group (the Group) was created. The Group created mechanisms for incorporating wind power producers into the California Energy Market. The Intermittent Resource Working Group consisted of representatives from the CAISO, California governmental organizations, EPRI, wind power producers, utilities and scheduling coordinators, power marketers, and associations. This initiative resulted in market design arrangements (Intermittent Resource Proposal) filed with FERC[1] as Amendment 42 on January 31, 2002. On March 27, 2002, FERC approved the Amendment and ordered the CAISO to incorporate the technical standards into the CAISO Electric Tariff.

Based on provisions of Amendment 42 and experience gained with the CAISO prototype forecast algorithm [2] the CAISO developed a detailed specification of PIRP and a Request for Bid (RFB) for a wind generation forecasting service. The RFB was distributed to the leading providers of these services. The selection process was based on more than 25 selection criteria. Based on these criteria, a short list of bidders was established. The CAISO evaluated the test results of the short-listed Bidder algorithms with the test datasets developed by the ISO. Further steps included selection of the winning bidder (AWS Truewind), request approval for expenditures, awarding the contract, acceptance testing of the model, and release of the scheduling process to production.

The PIRP began a pilot operation in June 2004. The complete CAISO PIRP was released to production on August 18, 2004.

II. California ISO New Market Design

A) Brief Description [4]

The CAISO is developing a new set of rules and tools for the new CAISO energy market called Market Redesign and Technology Upgrade Program (MRTU). The ongoing changes are designed to address market flaws in the current energy market and encourage desirable market behavior with an ultimate goal of facilitating a robust and competitive spot market that enhances grid reliability and lowers costs. Phase 1B of this new design became operational on October 1, 2004. Many routine activities of the real-time market have been automated. Market participants are now required to give the CAISO specific operating information about their generator's performance abilities. The CAISO then selects the most economic and reliable mix of resources to balance real time energy needs. As a result, dispatch instructions are more accurate and achievable. When resources do not

[1] The Federal Energy Regulatory Commission, or FERC, is an independent agency that regulates the interstate transmission of natural gas, oil, and electricity. FERC also regulates natural gas and hydropower projects.

comply with their schedules and CAISO dispatches, they may be penalized financially. This helps alleviate the need for CAISO operators to scramble to find replacement, and frequently more costly, energy resources at the last minute. The CAISO dispatch of energy resources is more frequent (every 5 minutes), more specific, and more consistent with the system balancing needs and with the technical characteristics of various generators.

Phase 1B consists of two major components. These include the following.

Uninstructed Deviation Penalties (UDP)

The objectives for instituting UDPs are:

- Improve compliance with dispatch instructions.
- Reduce uninstructed deviations.
- Create more accurate and predictable generator response.

Security Constrained Unit Commitment (SCUC) and Economic Dispatch (SCED)

The objectives for implementing SCUC and SCED are the following:

- Provide a more transparent real time market using the most economic bids available at the time of dispatch.
- Optimize the real-time dispatches over a time horizon of up to two hours.
- Allow real-time unit commitment for short start units
- Recognize generators' limitations.

B) Uninstructed Deviation Penalty (UDP) [4]

The purpose of UDP is to provide an incentive for dispatchable resources to follow their final Hour Ahead schedules, as amended. The UDP for positive uninstructed deviations from the dispatch operating point that exceed certain upper tolerance band are charged at 100 percent of the corresponding market zonal settlement interval ex post price. The UDP for negative deviations that fall below the lower tolerance band are charged at 50 percent of the corresponding zonal price.

Some fluctuations do occur with all types of generating units. In recognition of that fact, each unit is given a tolerance band it is required to stay within. This band is the greatest of three percent of the unit's capacity or five MWs around the unit's dispatch operating point. The penalties are assessed on the energy (MWh) delivered outside the tolerance band for the 10-minute settlement period.

If the wind generation units were being directly exposed to the UDP charges, they would experience significant difficulties while competing in the energy market. The PIR Program helps the participating wind generation units to avoid minute-by-minute UDP and become competitive energy market players.

C) Day- and Hour Ahead Scheduling Timelines

A Scheduling Coordinator (SC) is an entity authorized to submit to the CAISO a balanced energy schedule on behalf of one or more generators, and one or more end-users customers. The energy schedule consists of generation, load, inter-SC bilateral trade and interchange (import or export) schedules. The balanced schedule means that imports plus generation equals load plus exports. SCs submit energy schedules to the CAISO via the Scheduling Infrastructure (SI) system[2]. Figure 1 illustrates the Day Ahead and Hour Ahead timelines for the CAISO scheduling process. The PIRP scheduling process for participating resources is designed in accordance with the CAISO scheduling timeline.

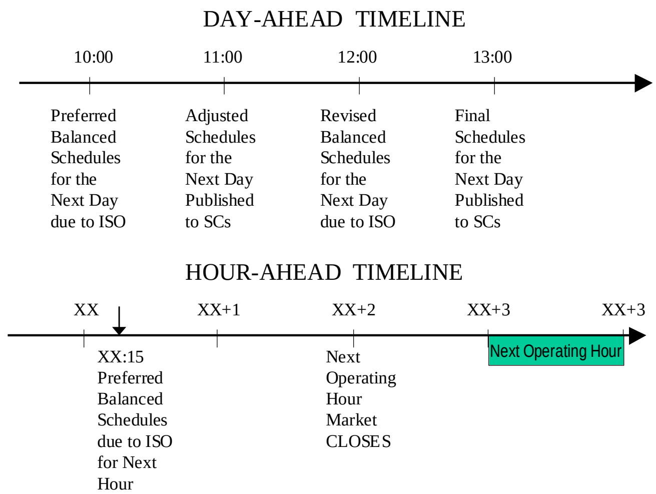

Figure 1 Day- and Hour Ahead Scheduling Timelines

It can be seen from Figure 1 that the Day Ahead schedules (energy schedules for each operating hour of the next day) must be initially submitted by SCs by 10:00 a.m. The Hour Ahead energy schedules must be submitted by SCs two hours 45 minutes before the actual "next operating hour" begins.

III. PARTICIPATING RESOURCES REQUIREMENTS

The PIR Program formulates several strict requirements for the resources wishing to participate in and benefit from the Program.

A) Eligibility and Application Process

A Participating Intermittent Resource must comply with the following requirements [5]:

- Sign the Participating Generator Agreement, Meter Service Agreement, and Letter of Intent [6].
- Have at least a one MW rated capacity.
- May include one or more intermittent resources that have similar response to weather conditions.
- Be electrically connected at a single point on the grid.

[2] The Scheduling Infrastructure (SI) Workspace is the interface between CAISO and market participants. It performs data collection and validation and publishes market information.

- Provide the forecasting service provider with sufficient data to support an accurate and unbiased forecast.
- Provide information regarding the MW generation capacity and associated Wind Turbine hub height for each turbine and information regarding the latitude and longitude location of wind-generation site.
- Comply with the Metering Requirements, Telemetry Requirement and Scheduling Requirements described below.
- Pay a forecasting fee of $0.10 per MWh produced.

B) Metering Requirements [6]

Metering data provided to the CAISO by Participating Resources for use by the forecasting service include the following:

- Wind Speed
- Wind Direction
- Ambient Temperature
- Barometric Pressure
- Aggregate Generation

Each participating project must install the meteorological towers and meters and maintain them. The height of the wind measurements should be at the hub height of the turbines or as close as possible to that height. The anemometers should not be placed near obstacles with a potential for disturbing the flow of the wind. Due to the wind shade, it is not generally recommended to use anemometers attached on the side of the mast. The best way is to fit an anemometer to the top of a mast. The temperature and pressure measurements should be at the same height or at 2 meters above the surface (the standard meteorological level for these measurements). Temperature sensors should be appropriately shielded from solar radiation. It is also important for the sensors to be placed at a location that is representative of the average conditions over the wind plant. This important factor should be carefully considered during instrument deployment. Participating projects can provide information from several meteorological towers installed on their site.

Table 1 summarizes the metering accuracy requirements.

Table 1 Required Measurement Precision from PIR.

Measurement	Units	Precision
Wind Speed	Meters/Second	1 m/s
Wind Direction	Degrees from True North	5 degrees
Air Temperature	Degrees Centigrade (°C)	1 degree C
Barometric Pressure	Hectopascals (hPa)	0.6 hPa
Aggregate Generation	Mega-Watts (MW)	--

The aggregate generation must be measured at the point of delivery to the grid.

C) Real-Time Telemetry and Other Informational Requirements

Participating projects must install and maintain a telemetry system called a Data Processing Gateway (DPG) (See Section V. "PIRP Informational Infrastructure" below), and provide real-time measurements to the CAISO via this system. They must also provide the online capacity information (the total capacity of online generators) via the SLIC[3] system.

D) Scheduling Requirements

The participating intermittent resources must submit schedules coinciding with the forecast provided by the Forecasting Service Provider via the CAISO. If the schedule deviates by more than 1 MW from the forecasted value for any operating hour, the corresponding resource is automatically exempt from PIRP for that hour.

IV. PIRP Scheduling Process

The PIR scheduling process involves four entities – the CAISO, the Contracted Forecasting Service, the Wind Generators and their Scheduling Coordinators (Figure 2).

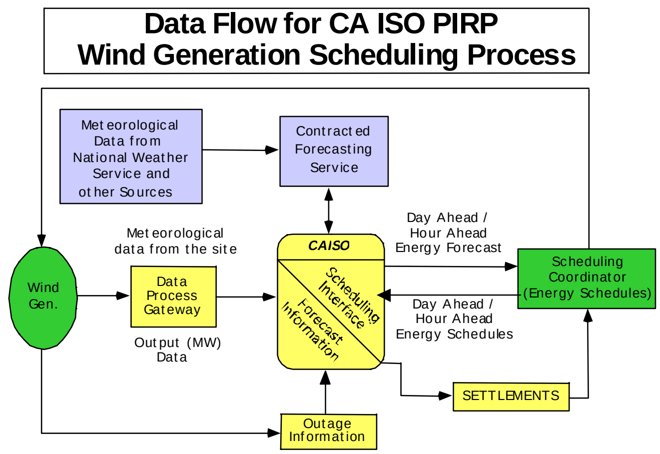

Figure 2 Data Flow for CAISO PIRP Wind Generation Scheduling Process [2,7]

A) The CAISO

The CAISO collects local meteorological data necessary for use by the forecasting service from each participating wind generation operator. This data is submitted by wind generators to the CAISO in real time. It includes wind speed, wind direction, barometric pressure, and air temperature. The CAISO also collects real-time wind generation output data via the Data Process Gateway (DPG). The CAISO gathers generation outage Information from the SC using SLIC. The CAISO provides a data update every ten minutes to the Forecasting Service.

The CAISO Settlement process compares the generation forecasts prepared by the Forecasting Service for each operating hour with the energy schedules submitted by participating wind generators for the same operating hours. If the

[3] This information is put into the "Scheduling Logging for the ISO of California" (SLIC) database by the CAISO outage coordinators after notification of a derate by the wind generation operators.

forecasted generation and the generation submitted in the energy schedules are equal then these resources are flagged for favorable treatment with respect to uninstructed deviations for those operating hours. The CAISO maintains the PIRP Database.

B) Forecasting Service

The Forecasting Service receives data from the CAISO every 10 minutes. It calculates and submits to the CAISO a seven-hour rolling generation forecast for each wind farm each hour. In addition, the Forecasting Service provides a Day Ahead forecast for each hour of the following day (once a day by 5:30 a.m.)

The maximum level of unavailability allowed during and average daily outage duration must be limited by design specification.

The Forecast Service must provide accurate, unbiased results, according to the following requirements.

Mean Absolute Percent Error (MAPE).

$$MAPE = \frac{\displaystyle\sum_{\substack{\text{All Avaialble}\\ \text{Hourly Periods}\\ \text{During a}\\ \text{Calendar Month}}} \frac{Abs(ForecastedMW_i - ActualMW_i)}{PMax_i} * 100\%}{\# ofAvailableHourlyPeriods}$$

Monthly Forecast Bias.

$$Bias = \frac{\displaystyle\sum_{\substack{\text{All Avaialble}\\ \text{Hourly Periods}\\ \text{During a}\\ \text{Calendar Month}}} (ForecastedMW_i - ActualMW_i)}{\displaystyle\sum_{\substack{\text{All Avaialble}\\ \text{Hourly Periods}\\ \text{During a}\\ \text{Calendar Month}}} ActualMW_i} * 100\%$$

where $PMax_i$ is the project's MW capacity.

C) Wind Generation Operators

The wind generators provide real time aggregated wind farm generator output data, along with local meteorological data, to the CAISO. Each wind generation operator must install a DPG unit that transmits this data to the CAISO's EMS system. In addition, the wind generation operator and SC must continue to submit units derate information to the CAISO via SLIC.

The SC receives from the Forecasting Service via the ISO by 5:30 a.m. each day a Day Ahead forecast for each Operating Hour of the next day. In addition, the SC receives each hour a rolling, seven-hour generation forecast starting from the "next operating hour". If the SC wish to receive favorable treatment with respect to uninstructed deviations, they must submit Hour Ahead energy schedules (via their Scheduling Coordinator) that match the Hour Ahead forecasts provided by the CAISO.

D) Scheduling Coordinators

SCs submit energy schedules to the CAISO via the SI system. If these schedules are to receive favorable treatment with respect to uninstructed deviation charges, the generation portion of the schedule must match the forecasted generation provided to the SC by the CAISO. Figure 1 represents an example of the CAISO hour ahead scheduling timeline. According to the timeline, the Forecasting Service must actually submit the Hour Ahead forecasts to the CAISO two hours and 45 minutes before the operating hour begins. Therefore, the forecasts for operating hours, which begins at 2.75 hours and ends at 3.75 hours ahead of time, are the most important forecasts influencing the market. Along with the next operating hour forecast, the Forecasting Service submits predictions for each of the six subsequent hours following the next operating hour. These are used as substitutes in the future when the next operating hour forecast is not available for some reason.

V. PIRP Informational Infrastructure

Figure 3 shows the basic flow of Meteorological and MW Generation data from a Participating Intermittent Resource (PIR) to the CAISO and on to the Forecasting Service Provider. A PIR is required to install at least one meteorological tower. The data stream starts at the PIR (Wind Farm) with each meteorological tower reporting wind speed, wind direction, air temperature and barometric pressure to the DPG. Additionally, MWs generated by the entire Wind Farm and metered at the point of delivery to the Grid is reported to the DPG**.** The DPG is polled by the CAISO's EMS system every four seconds. Those values are then passed on to the CAISO's PI[4] system, where the data points are stored along with their data quality. Data quality can be listed as normal, or in an error state (i.e., telemetry error, alarm, etc.)

Every ten minutes, a PI to PIRP Service is run to collect the Meteorological and MW Generation Data from PI for each Participating Intermittent Resource for the most recently completed 10-minute interval (i.e., at 10:40:00 it will query for the interval 10:30:00 – 10:39:59). This Service provides two functions:

- Provide data quality validation and data range validation.
- Convert individual data points into ten-minute averages.

Data Quality Validation

Each data value stored in PI has an associated data quality tag as mentioned above. The PI to PIRP Service checks the percentage of data quality tag values for each data point (i.e., air temperature) and checks if it exceeds the configured error threshold for that data point. The current thresholds are as follow.

• MW Generation	0%
• Air Temp	20%
• Barometric Pressure	10%
• Wind Speed	5%
• Wind Direction	5%

[4] PI System is a process-oriented database storing all time-varying CAISO parameters.

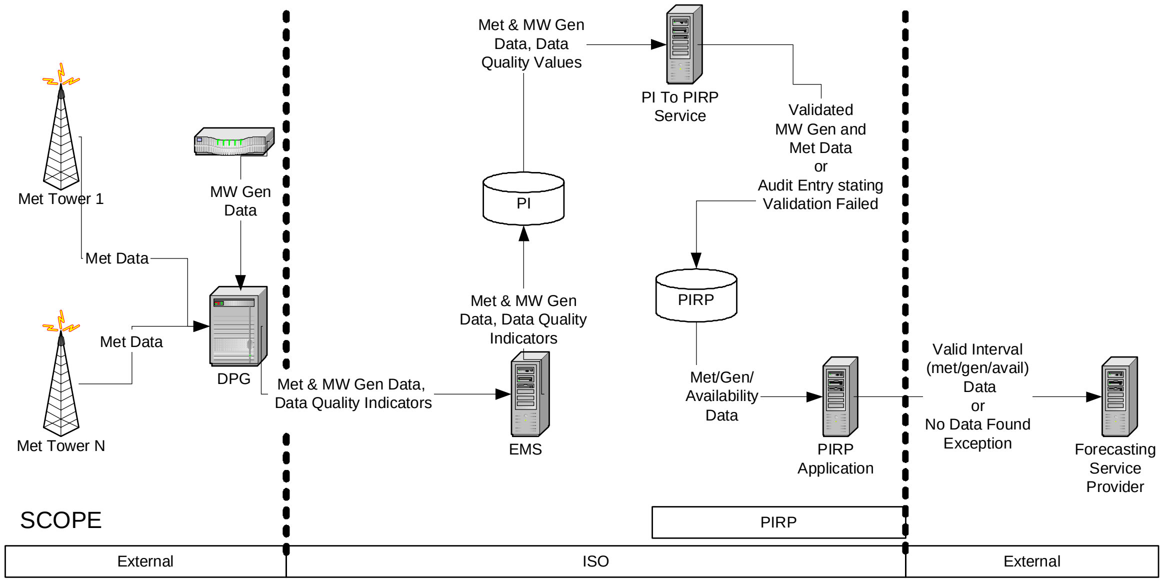

Figure 3 PIRP Informational Infrastructure

For example, if Met Tower 1 for Resource XYZ WIND had 85 percent of its values flagged as 'NORMAL', and 15 percent flagged as 'Telemetry Error' for the Interval, it would still be considered good data as the threshold for air temperature is 20 percent.

Data Range Validation

The interval values for the meteorological data are checked against pre-defined ranges as follows:

- Air temperature must be in the range from -30° to +55° Celsius.
- Barometric pressure must be in the range from 700 to 1100 hPa.
- Wind direction must be in the range from 0 to 360 degrees.
- Wind speed must be in the range from 0 to 50 meters per second.

Valid Interval Determination

The PI to PIRP service considers an Interval of data valid if the following conditions are met.

- The MW Generation data quality error threshold is not exceeded.
- At least one Met Tower for the Resource:
  - Has no error thresholds exceeded for the meteorological data points; and
  - Has no data range values exceed for the meteorological data points.

Only valid Intervals of data are passed on to the Forecasting Service Provider. The data exchange between the CAISO and Forecasting Service Provider is organized via a secure Internet connection.

VI. PIRP Forecasting Service [8]

The PIRP state-of-the-art forecasting service is provided on the hourly and daily basis by AWS Truewind Company.

A) Hourly and Daily Forecast

Hourly Forecast

This forecast is the MW production forecast for each of the next operating hours and six subsequent hours following the next operating hour. The hourly forecast is delivered by 15 minutes after each hour. The next operating hour is the hour that begins two hours and 45 minutes after the forecast delivery deadline (see the Scheduling Process section). Six subsequent forecasts are used by the CAISO as substitutes for any missing forecasts whenever the next operating hour forecast is not available.

Next Day Forecast

This forecast predicts MW production for each hour of the next calendar day. It is delivered by 5:30 AM Pacific Prevailing Time (PPT). (Please see the Scheduling Process section.)

Extended Forecasts

These are MW production forecasts for each hour of days two, three and four after each delivery day. The extended forecasts are produced at 5:30 a.m. PPT on Thursdays, Fridays and on selected days before scheduling holidays.

B) AWS Truewind Forecasting Algorithms [7]

Forecast System Technology

The PIRP forecast system is a custom-configured version of Truewind's eWind forecast system. The system is based on three types of mathematical models.

Physics-based atmospheric models are the first type. These models are computational fluid dynamical models based on the fundamental physical principles of conservation of mass, momentum and energy. The models start from an initial state and simulate the 3-D airflow in the vicinity of a wind plant. The eWind system incorporates several different physics-based models (e.g. MASS, MM5, WRF etc.). The first version of the PIRP forecast system utilizes simulations produced by one model (MASS). Future versions of the PIRP forecast system may employ a suite of physics-based models to generate an ensemble of forecasts. A composite of such an ensemble may yield more accurate forecasts and a measure of forecast uncertainty.

Statistical prediction models are the second type of model used in the PIRP forecast system. These models are empirical relationships between input data (predictors) and the quantity to be predicted (predictand). The models differ by the underlying statistical technique that is employed, the form of the functional relationship between the predictors and predictand as well as by the type or amount of data that is utilized. The modeling techniques used in the PIRP system include screening multiple linear regression and artificial neural networks.

The third type of model is the *Bias compensation scheme*. This scheme serves to minimize the net error for the month by adjusting the forecast to incrementally offset the accumulated net forecast error from the start of the month to the most recently evaluated forecast hour.

Hour-Ahead Forecast System.

The PIRP Hour Ahead forecast system is a sophisticated multi-model algorithm. The core of the system is a large pool of candidate predictors from a variety of sources and a suite of statistical prediction models. A schematic depiction of the main components of the forecast system and the forecast production data flow is presented in Figure 4. The predictors are extracted from a wind plant's meteorological and generation data, local-area weather data and the output of twice per day simulations by a regional physics-based model. The physics-based model data provides information about changes in the regional scale weather conditions and the data from the plant and its proximity provide information about recent trends in the airflow in the vicinity of the plant. The suite of statistical models employs the predictor data to produce an ensemble of predictions of the hourly energy output for the next one to eight hours. A separate statistical model optimally combines all of the individual forecasts into a single forecast. A bias compensation scheme tracks the accumulated net forecast deviation from the start of each month and adjusts each forecast to nudge the month-to-date net forecast deviation toward zero.

Day Ahead Forecast System.

The PIRP Day Ahead forecast system is less complex than the Hour Ahead forecast system. The forecasts are based largely upon regional simulations with a physics-based atmospheric model. A schematic depiction of the major components of the Day Ahead system and the forecast production data flow is presented in Figure 5.

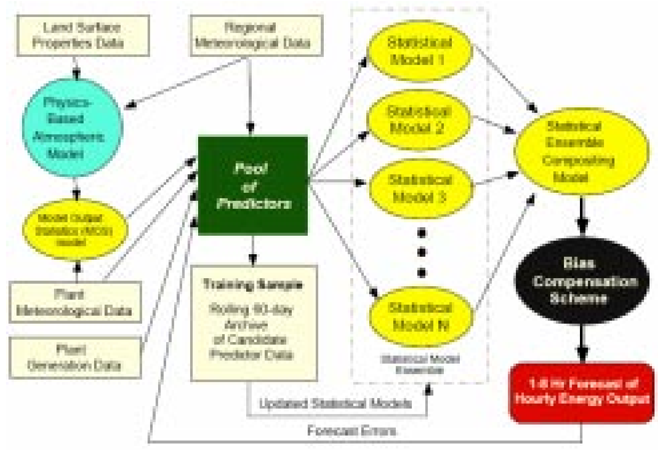

Figure 4 PIRP Hour Ahead Forecast System

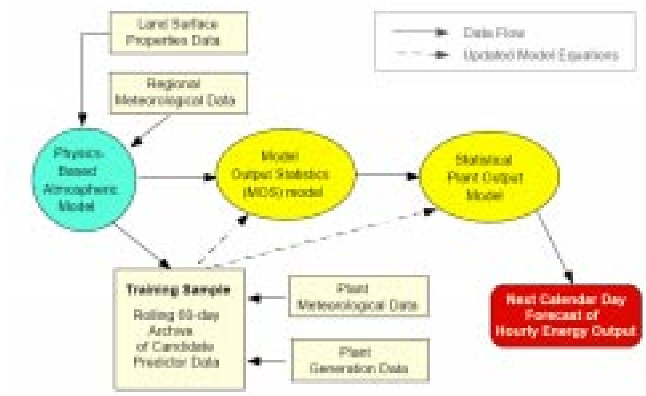

Figure 5 PIRP Day Ahead Forecast System

The grid point output from the physics-based model serves as input to the Model Output Statistics (MOS) module. The MOS module derives and uses statistical equations to transform the grid point data to predictions of wind speed and direction for a PIR's meteorological towers. The MOS-generated hourly wind speed and direction forecasts are converted to predictions of a PIR's hourly energy output through the use of a statistical plant output model. It should be noted that the meteorological and generation data from the plant is only used to train the statistical models in the Day Ahead system. This data is not used to produce individual forecasts. Hence, a near real-time flow of data from the plant is not needed by the Day Ahead forecast system.

C) Bias Correction Procedure

AWS Truewind Company, the CAISO forecasting service provider, implemented an "external" correction procedure to minimize the calendar month bias. The Net Deviation (*ND*, MW) is calculated from the start of a calendar month:

$$ND_j = \sum_{\substack{i=\text{ First Hour}\\ \text{of the Month}}}^{\text{Current Hour j}} \left[Forecast_i^{Adjusted} - Actual\ Production_{\text{i}} \right]$$

where $Forecast_i^{Adjusted}$ is the adjusted next operating hour forecast for the hour *i* and $Actual\ Production_i$ is the actual MW production during this hour.

Bias adjustment is calculated from ND_j for each forecast hour *j*:

$$Forecast_j^{\text{Adjusted}} = Forecast_j - C_j \cdot ND_j$$

The adjustment coefficient C_j phased in between 6th and 10th of a month:

- $C_j = 0$ from 1st to 5th of the month;
- C_j linearly increases to its maximum value from 6th to 10th of the month; and
- C_j remains at its maximum value from 11th to the end of the month.

The optimal value of C_j can be also statistically determined from a rolling one-month sample that concurrently minimizes the Bias and MAE similarly to the approach proposed in [2].

D) Forecasting Service Performance (MAE)

Figure 6 shows the Mean Absolute Error expressed in percent of the project capacity for six month in 2004-2005. A noticeable improvement for the last three month has been observed. In February 2005, the MAE for eight Wind Generators (WG) was less than or equal to 10 percent. The MAE for WG9 has 12.06 percent, which is very close to the required 12 percent.

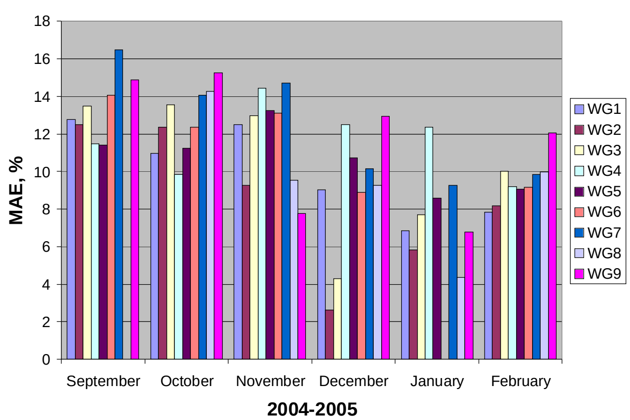

Figure 6 MAE for Nine WG Projects (WG1-WG9) in September 2004 - February 2005

E) Bias Minimization Results

Typically, the AWS Truewind algorithm allows minimizing the bias without a significant increase of the forecast MAE. Figure 7 and Figure 8 show a typical result of applying the Truewind bias minimization procedure. Figure 7 shows the Bias change over one month for one of the participating resources. The black line represents the unadjusted Bias. Due to the averaging effect of positive and negative forecast deviations, the Bias naturally decreases from some significant initial values to some limited end-of-the-month value (-2.12 percent in this example). The Bias correction procedure noticeably reduces its value (to 0.23 percent) as demonstrated with the help of the red line. Figure 8 shows the impact of Bias minimization on MAE. This impact is typically very small. For instance, in the example, the end-of-the-month adjusted MAE is 11.42 percent which is slightly higher than the unadjusted MAE (11.25 percent).

The Bias performance needs more improvement. In February 2005, only three PIRs had their Biases within the required range ±0.6 percent. For the rest of participating generators, the Bias was in the range from 0.66 percent to 2.68 percent. Apparently, these deviations were caused by frequent data unavailability problems and by the fact that some projects had relatively low MWh production over some of the months (recall that the percent Bias is calculated based on the actual MWh production). Improving the data quality and minimizing the Bias are priority tasks in the CAISO PIR Project.

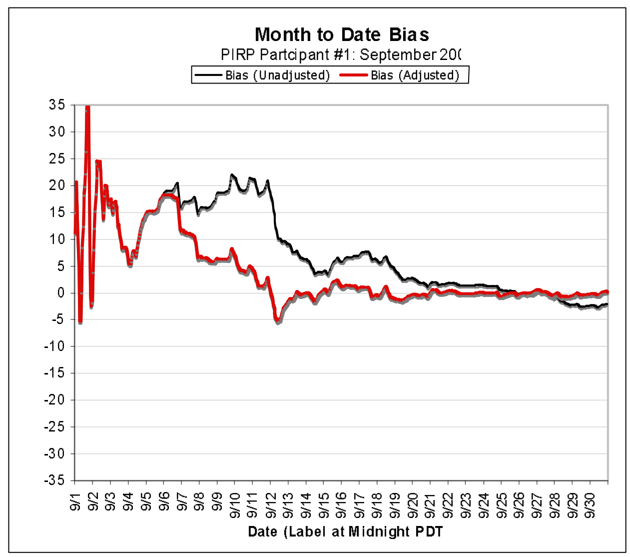

Figure 7 Forecasting Bias Without Minimization

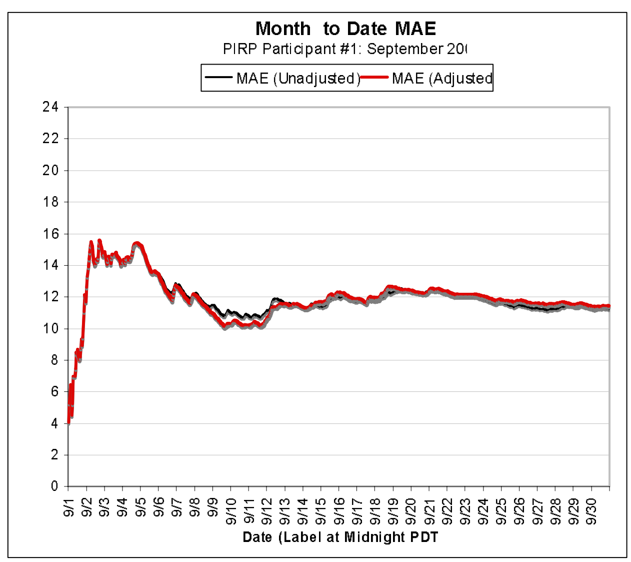

Figure 8 Forecasting Bias After Minimization

VII. Settlement Process

A) *Forecasting Service Fee Requirement*

A charge of $0.10 per MWh is assessed on the metered energy from each PIR. The funds collected are disbursed to the forecasting service company.

B) Uninstructed Energy: Intermittent Resources Net Deviations Requirements

For every settlement period in which such a PIR meets the scheduling requirements (schedule = forecast), the Uninstructed Imbalance Energy associated with deviations by a PIR from its schedule is settled based on the following PIRP rules. In each settlement period where such requirements are met, the PIR is exempt from the charges/payments for Uninstructed Imbalance Energy. Instead, the net Uninstructed Imbalance Energy in each interval is assigned to a balancing account. The net balance in the balancing account sums all deviations per PIR at ten-minute interval granularity across the month. Each PIR is paid or charged for the associated net deviation for the month at a monthly weighted average regional market clearing price. If the above referenced scheduling requirements for PIR are not met, then charges/payments for Uninstructed Imbalance Energy during such settlement periods shall be determined in accordance with the common Uninstructed Imbalance Energy rules and the PIR will also be subject to Uninstructed Deviation Penalties for excessive deviation (See Section II. "California ISO New Market Design").

Charge for Intermittent Resources Net Deviations

This charge type is used at the end of the month to assess the net deviation for all the PIRs per hour/ per interval. The net deviation is charged at the zonal weighted average Market Clearing Price.

Intermittent Resources Net Deviation Allocation Requirement

The difference between the ten-minute deviation charges and the monthly netted deviation charges will be allocated to all the SCs with net negative deviations.

Replacement Reserve[5].

The CAISO calculates a replacement reserve obligation in the region based only on the non-PIR units and exclude PIR units.

VIII. References

[1] R. Abernathy, "Plugging Wind Into The Grid", Public Utilities Fortnightly, June 15, 2003, pp. 29-33.

[2] Y. V. Makarov, D. L. Hawkins, E. Leuze, and J. Vidov, "California ISO Wind Generation Forecasting Service Design And Experience", *Proc. of the 2002 AWEA Windpower Conference*, Portland, Oregon, June 2-5, 2002. – Available at http://www.ee.usyd.edu.au/~yuri/papers.html

[3] *Participating Intermittent Resources Program FAQs*, CAISO, - Available at http://www.caiso.com/docs/2003/07/03/2003070315191117648.pdf

[4] *MD02 Phase 1B for Scheduling Coordinators: User's Guide*. Available at http://www.caiso.com/docs/2004/01/14/2004011411493110167.pdf

[5] *ISO Tariff in the Eligible Intermittent Resources Protocol.* Available at http://www.caiso.com/docs/2002/04/23/2002042316014715675.pdf

[6] *Participating Intermittent Resource Program (PIRP) Project.* Available at http://www.caiso.com/docs/2003/01/29/2003012914230517586.html.

[7] James Blatchford and John W. Zack, "California ISO's Participating Intermittent Resource Program (PIRP): Description and Initial Results", *Proc. Global WINDPOWER'2004*, Chicago, March 2004.

[8] John W. Zack, "Wind Power Production Forecasting for CA ISO PIRP", *California ISO PIRP Workshop*, March 23, 2005. Available at http://www.caiso.com/docs/2005/03/22/2005032215434015268.pdf

[5] Generation that can begin contributing to the grid within an hour.