White Paper Proposal
Wholesale Grid State Indicator to Enable Price Responsive Demand

June 12, 2012

1. Introduction

The smart grid evolution is making it possible for consumers to base their power usage decisions in part on desires to be grid friendly and green as well as managing the impact of their utility rates. End-user devices will have the ability to receive information on energy prices and other system conditions, respond to these signals by adjusting their operations to support grid conditions, and provide savings for consumers. While smart devices will be able to respond automatically to these signals, the choice of how the device responds remains with consumers.

The ability of devices to respond to actual wholesale grid conditions is important for a number of reasons. If consumption is able to be adjusted based on when it is less expensive to consume (i.e., when the grid is less stressed and being served by inexpensive generation resources), and this behavior is consistent, it will be more efficient and less costly to plan and serve load.

This white paper is a follow-on to an initial concept paper for enabling price responsive demand.[1] It reviews the needs for new information that the ISO can provide to facilitate these developments, roles of the ISO and market participants in the process of getting this information to end-use consumers, and an initial proposed structure for the information to be provided. The objective is to provide information to connect wholesale and retail markets by enabling end-use consumer devices to respond to system conditions and thus provide both grid and consumer benefits.

2. Information needs

The type of market information and customer response envisioned in this white paper differs from demand-side participation that is otherwise available in the ISO market. The ISO has established mechanisms by which demand can bid into the energy and ancillary service markets (e.g., the Proxy Demand Resource (PDR) and Participating Load (PL)), receive and respond to dispatch instructions and provide telemetry and metering for operations and settlement. The ISO refers to this type of demand-side participation as “dispatchable” demand.

The focus of this paper is on information needs that enable end-user devices to be responsive to a signal that is consistent with grid conditions that does not require formal wholesale market participation. The ISO refers to this as “price-responsive” demand. Consumer usage would not be dispatched by the ISO, and in many cases would not be visible directly by the ISO, although the ISO will need to understand and model the expected response.

A comparison of the characteristics of these two types of demand is provided in the following table.

[1] Enabling price responsive demand discussion paper, 1/5/2012

	Dispatchable Demand	Price-Responsive Demand
Communication type	Two-way: ISO pushes dispatch signal for imbalance energy and/or ancillary services, and directly observes resource's response	One-way: Consumers pull real-time prices or other information on system conditions
ISO role	Publish dispatch signals to resource Resource's metered response determines instructed energy in financial settlements	Publish near-real-time prices and other information on system conditions Must model expected price response in market commitment and dispatch[2]
Demand-side resources requirements	Meet specific metering and telemetry requirements Provide bids and schedules into ISO market, via scheduling coordinator	Choose to receive near-real-time prices and other information on system conditions Configure devices to automatically respond

There can be a variety of end-user devices that are managed as price-responsive demands, ranging from electric vehicle charging, to management of thermal energy storage and air conditioner cycling systems, to automated timing of consumer appliance operation, and to simple demand reductions during high-priced time periods.

It is anticipated that there are a number of applications for this type of signal and may include:

- Consumers on real-time dynamic pricing rates,
- Consumers on time of use rates that are closely matched to general wholesale conditions, who can save money by reducing their demand during high-price intervals but do not submit market bids,[3]
- Customers on non-varying rates, who want to be "green" by conserving energy resources at times of shortages or to move their energy consumption to times of high wind production, and
- Aggregated customer groups or resources that are optimized through utility or energy service provider programs for local reliability or economics.

The information needs of this range of price-responsive demands can vary between these types of consumers, but users of the information can select the specific information they want to use.

[2] The demand elasticity to the grid state will be analyzed once the index is published to support model development

[3] These customers may also be motivated to respond to system conditions as "green" citizens.

While the ISO already provides market information on day-ahead and current real-time energy and ancillary service prices, and a specific set of forward-looking, advisory prices through the hour-ahead scheduling process (HASP), additional information can be useful for managing the various types of end-user devices, including:

- Look-ahead signals for decision-making across timeframes, and
- Data formats that facilitate intermediaries' ability to modify the signal for specific customer objectives (e.g., utilities that manage retail demand response programs, energy service providers, aggregators, and microgrids).

The next section further explores these attributes. Ideally, the format of this information would provide a consistent signal across regions to support mass market product manufacturing. At this time, there is not sufficient standardization to provide such consistency. The ISO hopes that this white paper will advance the process of reaching such standardization, and recognizes that the data format outlined here may evolve as discussions of standardization occur.[4] The ISO also recognizes that as the ISO and our markets gain experience with price-responsive demand, the data format outlined here may change to reflect that experience.

3. Signal definition

This section presents the components of a locational grid condition index or grid state, which indicates the wholesale market conditions for locations within the ISO grid, and provides forward-looking advisory signals. As noted above, the ISO currently publishes information on market results, which will not change as additional information becomes available through the grid state.

Consumers and service providers could use the existing information to guide energy usage, but the grid state is intended to facilitate such decisions. A number of factors affect the construction of this indicator, but this formulation provides flexibility in the granularity of locations that consumers or service providers choose for managing end-user devices, as an indicator of grid conditions, and provides the available information as a forward-looking signal. As the ISO and market participants gain experience in producing and using this information, refinements can be considered.

General structure

In organized markets, grid conditions can be understood by the magnitude of wholesale prices and their differences across locations. Higher prices indicate that more expensive generation is being relied on to serve the load. As prices approach the market and bid caps, they indicate potential shortages and hence reliability risks. Differences in prices between locations indicate congestion in the transmission system, which prevents lower cost generation from reaching the load in some areas because transmission lines are full. This information can

[4] As part of moving forward to promote grid and consumer benefits, the ISO is actively engaged in the National Institute of Standards and Technology (NIST) Smart Grid Interoperability Panel (SGIP) efforts to develop smart grid standards for national consistency that supports California's objectives. Other steps include developing end-to-end use cases to determine system requirements, specifying and executing pilots to validate the expected grid and consumer benefits, and taking the necessary steps after successful pilots to transition the capability from a pilot to operation.

be captured in a locational grid state that could be adjusted by distribution system operators or energy service providers to provide consistently recognized indications of grid reliability across regions for use by smart devices.

In addition to signals indicating the current status of the grid, a forward looking, advisory or trend signal will help make decisions for adjusting device operations over time. The ISO publishes day-ahead market results by 1 PM each day, for the next operating day, based on conditions that can be expected at that time. Advisory prices for shorter-term indicators of the ISO's real-time conditions begin to be available about 4.5 hours before the operating hour, which may further indicate when the following hours are expected to have unusually high or low prices. The ISO publishes its market results as locational marginal prices (LMPs) for energy at load aggregation points (LAPs), trading hubs, sub-LAPs within LAPs, and individual pricing nodes; as ancillary service marginal prices for regions within the ISO market; and as a system-wide price for flexible ramping capacity.

To form the grid state and advisory indicator signals to end-user devices, the ISO will first compute a composite market price that combines the LMP for each location, and the highest ancillary service price for incremental capacity and the flexible ramping capacity price for the region to which they apply.[5] Just as the market price components have many possible values (being measured in fractions of dollars, throughout a range that can reach hundreds of dollars), the composite market price has many possible values, which will then be grouped into ranges that define the index values, as discussed below. ISO markets produce the LMPs and other market prices for each location in a public and transparent method, so it is clear how the composite market price is created and translated to the grid state.

While the locational element may seem to be an unnecessary complication, it is an important element for managing device responses. It may be possible that some areas actually have an oversupply of energy and need additional load to balance out the oversupply, while other areas are experiencing shortages of supply. The locational element will allow devices in both areas to respond appropriately and to help reduce impacts of the limited transmission capacity, which leads to the congestion reflected in different locational marginal prices.

Representing ISO market results

To apply these principles in designing a grid state formulation to implement in the ISO market, the ISO assembled and analyzed data for the 12-month period from April 1, 2011, to March 31, 2012. Recognizing (as discussed above) that there are diverse applications that may be managed as price-responsive demands, the ISO proposes a formulation that identifies both extremes of low- and high-priced intervals in the real-time market, and provides both immediate and forward-looking data. To provide a distribution of grid state values that separates extreme low and high values from commonly-occurring price levels, the ISO proposes a series of 11 index values defined as follows (explained further following the table):

5 The highest ancillary service price for incremental capacity is upward regulation. Before conversion to an index, the calculation will add each location's LMP (including energy, congestion, and loss components), the upward regulation price that would apply to resources at the location, and the system-wide flexible ramping capacity price.

Device Triggers

Visual Cue	Grid State	Lower Limit	Upper Limit	# of Real-Time Pre-dispatch Intervals, at ISO system level[6]
Blue	0	n/a	<= $-30/MWh	164
	1	> $-30/MWh	<= $0	1167
	2	> $0	< off-peak average	12336 intervals total, 8277 during off-peak hours
Green	3	>= off-peak average	< on-peak average	13297
	4	>= on-peak average	< 1.1 * on-peak average	1937
	5	>= 1.1 * on-peak average	< 1.33 * on-peak average	2360
Yellow	6	>= 1.33 * on-peak average	< 1.67 * on-peak average	1632
	7	>= 1.67 * on-peak average	< 2 * on-peak average	738
	8	>= 2 * on-peak average	< 3 * on-peak average	717
Red	9	>= 3 * on-peak average	< 10 * on-peak average	523
	10	>= 10 * on-peak average	n/a	489

BLUE—use now (i.e. charge EV or battery)

The lowest levels (grouped for presentation as a general level of "blue") can be considered by consumers as good times to use energy for purposes such as electric vehicle charging or refrigeration in thermal energy storage systems. Since the current bid floor is $-30/MWh, market prices below this level indicate that economic bids for supply resources that could be dispatched to balance low demand at a location have been exhausted, and system reliability would be improved if demand were increased.[7] Locational prices below $0 indicate that the ISO would pay loads to increase their demand, since supply resources are willing to pay to produce energy.[8] The upper limit of the "blue" range is the average price during "off-peak" hours of recent days.[9] For this purpose, "off-peak" is used as a 12-hour period (7 PM to

[6] In practice, the grid state levels would be a comparison between interval prices and the average of recent days. For simplicity in presentation, this table compares the interval prices with the averages for the calendar month in which it occurred.

[7] A resource may be paid a bid price less than $-30/MWh upon the submission of detailed information justifying this cost to the ISO and FERC, upon FERC acceptance of the justification. However, energy bids less than $-30/MWh are not eligible to set any LMP. The ISO Board of Governors approved a reduction to $-150/MWh in December 2011, but this tariff change is not currently in effect.

[8] As the ISO implements reductions to the bid floor, the ISO will monitor whether the value of $-30/MWh continues to be meaningful, and adapt the index values as needed.

[9] The number of recent days to be averaged is to be determined. A likely period is seven days, but the ISO seeks stakeholder input.

7 AM) in which energy use for vehicle charging or thermal energy storage may be most prevalent.[10] The average during this period would be a rolling average of recent days, in order to track variations in prices through a simple, transparent mechanism.

GREEN—use freely

Higher grid state levels compare market conditions to average values during "on-peak" hours (7 AM to 7 PM). The general range identified in the table as "green" (i.e., systems are generally not stressed, but market prices are not as low as in the "blue" range) has the largest number of real-time intervals, so three index levels distinguish whether the composite market price is less than 100%, 110%, or 133% of the average on-peak value.[11] These levels allow end-user devices to distinguish conditions within this range of moderate prices, when the devices operate during a number of hours but wish to optimize their time of operation.

YELLOW—use cautiously, defer tasks if possible

In the general range identified as "yellow", market conditions have deviated more from average conditions, and reduction in the use of price-responsive end-user devices would help to stabilize system conditions. The most severe system conditions occur in the "red" range (levels 9 and 10), in approximately 250 hours per year (a total of 1012 fifteen-minute intervals for levels 9 and 10). These levels are defined to allow devices to respond when such response is targeted for a limited number of hours per year.

RED—use sparingly, shut down low priority devices

The presentation in this table includes a count of the number of real-time pre-dispatch (RTPD) intervals published every 15-minutes for each grid state value at the ISO system level, for an overall view of the values' prevalence. (At other locations within the ISO area, the frequency distribution would vary.) This table bases the frequency distribution on RTPD results because these values, when used in consumers' response to the grid state, will enable response times for devices whose variation in demand is not instantaneous. The ISO proposes to provide grid state values (1) for all RTPD intervals, initially populated with day-ahead market results and then updated using the RTPD results that are available at a particular moment, to maximize consumers' ability to plan their energy use over time, as well as (2) for the current real-time dispatch (RTD) interval published every 5-minutes, for use by devices that are capable of rapid response.[12] Consumers and service providers would be able

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[10] The ISO does not define on-peak or off-peak periods for purposes of the day-ahead and real-time markets. The time-of-use periods used in this analysis divide the day into two periods of equal length, in which the on-peak period begins approximately at the time when end users begin day-time activities and the ISO's system demand begins to ramp up to day-time levels, and ends as the system demand decreases. The actual grid state value is based on the composite of a location's LMP, ancillary service price, and flexible ramping capacity price. This value does not depend on whether the time to which it applies would be in the on- or off-peak period.

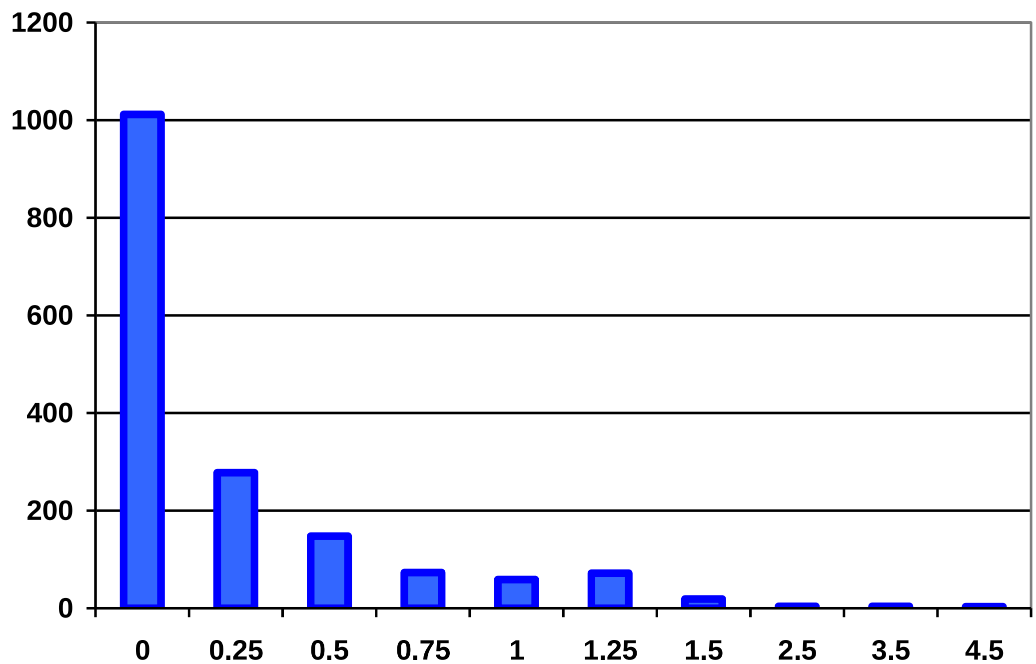
[11] Note that as market conditions vary in the future, it may be possible for the off-peak average to exceed the on-peak average, or for the average composite market price to be less than zero. In the first instance, all hours (both off-peak and on-peak) would be used to compute the averages. This would mean than the off- and on-peak averages would be equal, and there would be no intervals in index level 3. If an average composite market price were less than zero, the grid state values would be defined relative to the $0/MWh level, and there would be no intervals in index level 2.

[12] The RTPD process runs every 15 minutes, with runs at different times within the hour having dispatch horizons ranging from 60 minutes up to 4.5 hours, and produces binding unit commitment for its dispatch

to monitor changes in upcoming intervals' grid state values, and trends from one interval to the next, to anticipate changes in system conditions.

By initially populating the grid state with day-ahead market results and then updating the values when RTPD results become available, the grid state can allow consumers and devices to optimize the timing of energy use. However, limitations on how far in advance the extreme grid state values can be anticipated must be recognized. At one extreme, negative prices for energy can occur when variable energy resources' real-time output exceeds forecasts, due to weather variations. The ISO performs unit commitment for conventional resources based on forecasted conditions, but unexpected variations occur in real-time. At the other extreme of high composite market prices, the following graph illustrates the number of RTPD intervals in which the reliability values in levels 9 or 10 (i.e., the "red" range) can be anticipated:

Number of intervals with grid state = 9 & 10, vs. lead time (hours)



Grid state levels 9 and 10 were reached in a total of 1012 RTPD intervals during this one-year period, indicating that system conditions during the next 15-minute interval would be very stressed, with the composite market price being at least 300% of average. Of these, only 278 had been anticipated during the previous RTPD run, with 15-minutes previous lead time. For 30-minutes of lead time of advance indications that grid state would reach levels 9 or 10, there were only 148 instances, and for longer lead times, less than 10% of RTPD intervals had advance indications of such stressed conditions. For lead times over two hours, there were only four instances when RTPD indicated that level 9 or 10 would occur.

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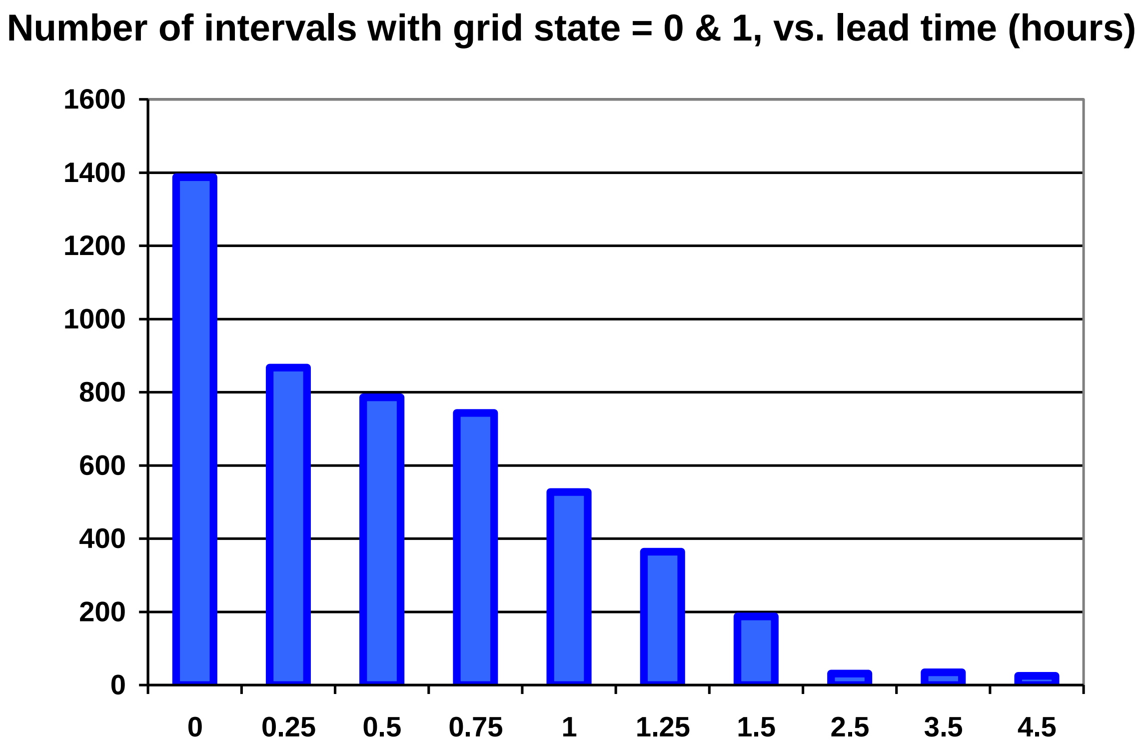
horizon, binding ancillary service awards and prices for each run's first 15-minute interval, and advisory energy dispatches and prices for the remainder of its horizon. The RTD process runs every 5 minutes, with dispatch horizons ranging from 55 to 65 minutes, and produces binding energy dispatches for each run's first 5-minute interval and advisory energy dispatches and prices for the remainder of its horizon.

The ability to anticipate negative grid state values, i.e., levels 0 and 1, was somewhat better during this period, as shown in the following figure. This is the range in which energy-consuming activities, such as electric vehicle charging or thermal energy storage, could economically make use of available supply. Out of 1387 intervals in which the index value was in this range, 867 could be anticipated during the previous RTPD interval (with 15-minutes lead time), and 743 could be anticipated three intervals (45 minutes) in advance. With 1.5 hours of lead time, 187 of these negatively-priced intervals could be successfully anticipated.



Thus, the grid state will be the most useful for price-responsive resources that are able to adjust their operation to high prices on short notice, but more advance planning is possible for response to low prices. In addition to the advance notice of real-time system conditions that RTPD-based signals can provide, an ability to respond to the grid state that reflects 5-minute real-time dispatch conditions will most directly reflect potential energy cost savings.

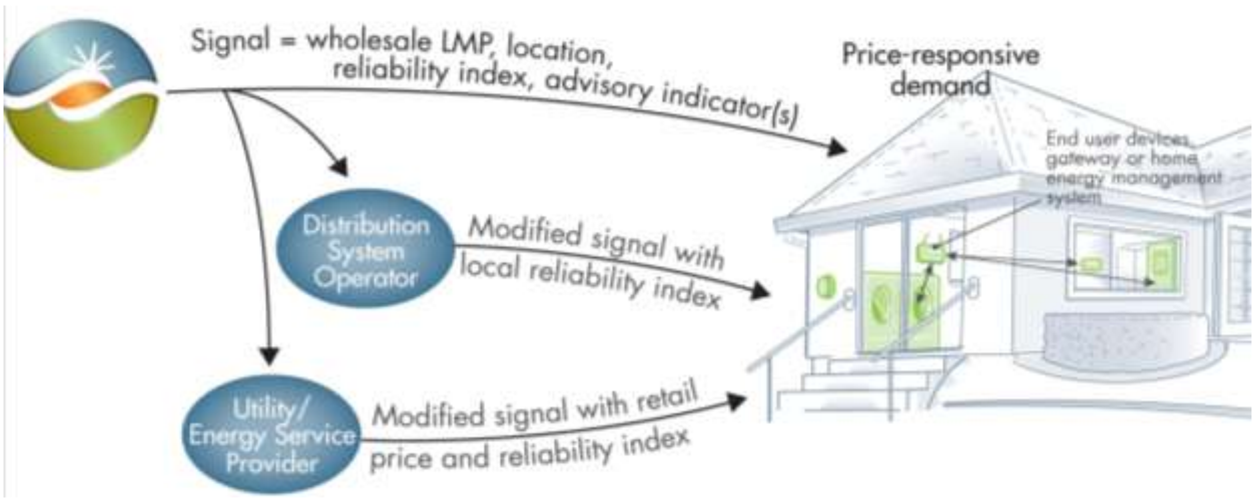
4. Signal publication

The ISO will publish the grid state on its public website. Utilities, energy service providers, application developers, or consumers themselves would choose to access this information to relay to consumers and end-user devices.

The grid state as provided by the ISO would inform consumers and devices of transmission grid conditions and allow the devices to proactively and independently become a beneficial part of grid management, while remaining under customer control. As actually used by consumers, the grid state approach can enable the operators responsible for the reliability of the distribution network to adjust the ISO's reliability indicator to a higher or lower number depending on grid conditions in local areas, and make these signals available to consumers. This ability will become significantly more important as increasing amounts of distributed energy resources are connected to the distribution system and impact local system power flows.

Utilities or energy service providers may further adapt the grid state to meet the needs of retail rate options or demand response programs while remaining consistent with grid conditions.

The following diagram illustrates the choice of signals consumers could have for their device response.



5. Summary

Providing grid signals to devices accomplishes objectives to align end-user device responses based on grid conditions to maintain reliability, empower consumer choice, provide a widely recognizable signal for consistency across regions, and maintain flexibility to adjust the signals for local reliability needs and individual consumer rates.

This white paper develops a mechanism for providing information to indicate system conditions in a usable form to meet these needs. The intent is for this to be a first step to support pilots to understand its effectiveness and impact on load as penetration increases.