HOW IS CALIFORNIA INTEGRATING AND BALANCING RENEWABLE ENERGY TODAY?

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California currently gets 20% of its electricity from renewables, not counting large hydro. By 2020, California's Renewable Portfolio Standard policy requires a 33% share. By 2020, a big part of that 33% will be solar power, which has been growing vey rapidly in recent years thanks to a variety of state and federal incentives. The high share of variable renewable power, both solar and wind, poses a challenge for California's power grid. But California's power companies, the regulatory authorities, and the power grid operator are today addressing this challenge successfully and collectively.

How is California managing to integrate and balance large shares of variable renewables? What market and regulatory mechanisms and frameworks exist to integrate and balance these large shares? These questions must be considered in the context of the "prevailing wisdom" of 15-20 years ago among virtually all electric power companies and power engineers. This "prevailing wisdom" was that going above 5-10% shares of "variable" renewables like wind and solar would spell doom for the reliability of the power grid, and the lights would go out. (And perhaps we might manage 15% according to the thinking of the day.)

The answer is that California has many well-developed innovations, mechanisms and frameworks that are intended to ensure reliability of the power system as variable renewables grow in the future, and to "keep the lights on."

The most important of these frameworks is simply California's electricity market. The inherent flexibility of many of California's natural gas power plants, which altogether provide about 60% of California's power, allows these plants to profit from selling into both the normal day-ahead wholesale market, as well as the "ancillary" markets. The "ancillary" markets could also be called "balancing" markets, and are designed to provide balancing power for short-term fluctuations in demand and generation. Such ancillary/balancing markets are a normal feature of most power markets around the world today, and operate to provide second-by-second, minute-by-minute, and hour-by-hour balancing of electricity supply and demand, even in the absence of renewable energy.

Most of the newer gas turbine power plants built in California have been designed with high levels of flexibility, which enables them to respond quickly to system conditions and profit from selling into the balancing markets. These gas turbines routinely and profitably provide the balancing power necessary to balance variable renewables, through the normal operation of the wholesale and ancillary/balancing markets. (Denmark is another exemplary case for the use of flexible gas turbines. In Denmark, gas turbines of recent vintage are able to quickly ramp output up and down between 50% and 100% of full output, at fast rates up to 3% per minute.)

As part of the electricity market operation, the power grid operator (ISO) has developed two innovative mechanisms for ensuring flexibility and reliability to balance variable renewables. The first of these is more of a mandate, which requires power generators to bid a portion of their most flexible capacity into the market at all times, so that he grid operator can call upon that capacity when needed to balance renewables. Such "must offer" market obligations can be found in many other jurisdictions besides California. For example, Denmark also orders some power plants into "must run" obligations, in which they are kept online and available, but produce as little energy as possible, so they are ready to provide balancing power when needed.

A second mechanism by the ISO is called the "Flexible Ramping Product." This market mechanism has been under development and discussion since 2011 and was expected to begin operating in 2015, after further stakeholder meetings and discussions during 2014. The basic goal of the Flexible Ramping Product is to enable the ISO to shift generation in time, from "low-ramp" periods to "high-ramp" periods.

Of particular concern to the ISO is the "high ramp" period in the late afternoons of the future, when solar output declines rapidly as the sun goes down, and total system demand simultaneous increases towards an early-evening peak. This "ramping problem" has been much-discussed in California, and is depicted as the ISO's well-known "Duck Curve." This curve shows that by 2020, up to 12 gigawatts of ramping capacity, equivalent to more than one-third of California's total power capacity, might need to be switched on over a short 3-hour period in the afternoons.

With the Flexible Ramping Product, the ISO pays generators to remain "off" during low-ramp periods, so that the generator is then available to turn "on" during high-ramp periods, at the request (dispatch) of the ISO. The payments made to remain off during low-ramp periods, coupled with the payments when the generator is used during high-ramp periods, should be sufficient to compensate the generator for lost revenue while "off." The Flexible Ramping Product is designed to allow all types of generators to participate, including wind and solar, and also energy storage.

One key aspect of the Flexible Ramping Product is that it introduces a new scheme for allocating the extra costs of flexibility. The basic principle of this new scheme is this: the market costs of ramping capacity under the Flexible Ramping Product should be paid by those market participants who are creating the need for greater flexibility.

California also has extensive regulatory frameworks in place to ensure system reliability with high shares of variable renewables. The most important of these frameworks is the "Resource Adequacy" (RA) framework, which ensures that adequate balancing capability to integrate renewables will be available at all times. The electric utilities in California (the power generators) must show the regulatory authority, on both a monthly and annual basis, that they have sufficient capacity to meet the needs of the power system.

In 2011, the "Resource Adequacy" framework was strengthened to ensure greater flexibility. The "showing" of adequate generation capacity to the regulatory authority must now also include a subset of "flexible capacity" to provide enough balancing capability for a reliable power system. This is called "Flexible Capacity Need," and is defined by regulation as the capacity needed to "follow" the power system ramping up or down, depending on load and variable generation. The specific amount of "Flexible Capacity Need" is overseen and approved by the regulatory authority, the California Public Utilities Commission (CPUC).

A second regulatory framework in California relates to long-term planning. In the long-term, electricity system operators and regulators must ensure that enough capacity and flexibility remains in the system as power plants are retired and new plants are built. In Germany, regulators currently require some plants to remain in operation even if their owners want to retire them, and these plants are compensated through "capacity payments." The same is true in California, where there is an extensive regulatory framework in place, the Long-Term Procurement Planning (LTPP) process, which ensures that enough flexible capacity will be built in the future, on 10-year planning time scales.

Under the California LTPP framework, the regulatory authority (CPUC) reviews and authorizes the plans of utilities for procuring or building new capacity over the next ten years. It also authorizes power plant retirements, consistent with the needs of the power system. As part of the LTPP, the CPUC and the ISO conduct modeling studies that show capacity ten years ahead, and analyze whether that capacity provides adequate flexibility to accommodate the projected levels of renewable energy and other resources, to ensure system reliability.

Beyond the electricity market and these important regulatory frameworks, a number of other important innovations for flexibility have occurred in California in recent years.

1. Day-ahead weather forecasting. The incorporation of advanced day-ahead weather forecasting into the operation of power system control and dispatch has become common and highly sophisticated in regions with high shares of renewables, such as California, Germany, and Spain. Such weather forecasting can be credited as a major contribution to our ability to integrate and balance high shares of renewables, because it makes variable renewables highly <u>predictable</u> for power system control and dispatch on a day-ahead basis. California has made great improvements in its modeling and forecasting of tomorrow's weather, to be able to predict and dispatch variable solar and wind in the normal day-ahead wholesale market.

2. Distribution system planning and innovation. The distribution system is the part of the grid closest to end-consumers. Historically, distribution utilities have not had to be innovators, as the job of grid expansion and replacement was quite simple. So distribution utilities have not needed an "innovation culture." However, in the future, distribution utilities will need to plan and innovate in a variety of new ways—to manage distributed generation, two-way power flows, demand response, storage, smart inverters, micro-grids, and a host of other trends. Distribution utilities will need to monitor, collect, analyze, and use data in completely new ways, and will need to analytically model their distribution systems to a degree far beyond current practice.

California is now putting itself at the forefront globally of distribution system planning and innovation. And California recognizes this as a clear priority for integrating and balancing variable renewables. Assembly Bill 327, which passed the California Legislature in 2013, requires utilities to submit "Distribution Resource Plans" that recognize, among other things, the need for investment in upgrading the distribution system to integrate cost-effective distributed generation. Assembly Bill 327 and an associated 2014 CPUC regulatory proceeding together represent a new initiative in California to address distribution system planning and innovation. The new regulatory framework should allow distributed renewables to better contribute to overall power system flexibility and reliability, for example through the use of "smart" inverters for solar systems, and "smart" demand-management strategies at the local level.

3. Interconnection standards and cost allocation for distributed generation and storage. California has a sophisticated regulatory framework, called Rule 21, for interconnection and cost allocation of distributed generation. Basically, distributed generation not subject to net metering must pay for the necessary distribution system upgrade costs. But the regulatory framework is evolving to account for distributed energy storage, for "smart" and flexible operation of distributed generation, and for minimizing economic costs. Rule 21 continues to be improved to better support the business case for distributed storage and distributed renewable generation.

4. Energy Imbalance Market. Today, there is a patchwork of 39 grid operators (ISOs) across the Western U.S., with insufficient coordination among most of them. Improving coordination is an opportunity for each ISO to better balance and integrate renewable energy. California and several western states are currently developing a proposal for an "Energy Imbalance Market" (EIM) that would allow surplus renewable generation to flow to neighboring electricity systems more easily, under new market mechanisms.

5. Power grid reliability calculations and dispatch. California's power control and market operations have also evolved an advanced system for balance management and grid reliability. The power control center every 5 minutes makes an updated forecast of the coming period. This rapid updating allows the power control and market operation to quickly respond to changes in renewable output. And the ISO has greatly improved its daily "N-1" reliability calculations, to make sure the lights stay on in the event of unexpected events or outages, even with variable renewables.

It is also worth noting that California experiences very little wind power "curtailment." "Curtailment" is the default option for dealing with wind power variability, in which wind power generation is shut off for periods of time to balance the grid. Curtailment results in economic losses, as the power that could be generated from the wind at that time is essentially wasted, with no economic benefit. Spain makes extensive use of curtailment, partly because it has so much wind power, and partly because its grid is essentially isolated from the rest of Europe (other than Portugal) and thus it can't sell excess wind power to its neighbors. California predicts higher levels of curtailment in the future unless improvements are made in the flexibility of its power system, but currently does not curtail significantly.

Most people think of energy storage when it comes to integrating and balancing renewable energy on power grids. But the truth is, electricity storage is still very expensive, and is not yet necessary for balancing even high shares of 20-40%. California has a well-developed network of pumped hydro energy storage facilities that already provide some electricity storage capacity. And some homes and businesses are starting to integrate small batteries with solar. Overall, California has not yet turned to energy storage as a significant means of balancing renewable energy. However, there is a growing focus on storage, with new regulatory frameworks. In particular, electric utilities are required to collectively add 1.3 GW of storage projects in California by 2020. The first of these projects were just starting in 2014.

Finally, an emerging innovation for integrating and balancing renewables is so-called "demand response." This is the process of varying the level of electricity demand in real-time, using smart-grid technologies and pre-designed operating regimes for what end-use equipment can be turned off, when, and for how long. These operating regimes are specified in contracts with electricity consumers, and allow for reducing demand, or "time-shifting" demand, without infringing on the needed energy services of those consumers. So-called "demand-response aggregators" may simultaneously control the demand of hundreds or even thousands of consumers, under specific contractual and technical parameters. These aggregators can thus vary large amounts of demand in response to signals from the power system operator for balancing power. In this way, demand response functions exactly the same as a balancing power plant, except instead of generating more power, demand response reduces consumption to provide balancing.

In California, there is a large potential for demand response. But so far, California has done only a few pilot projects, particularly for large energy consumers (like oil refineries), and for commercial air conditioning, among others. California has yet to make use of its huge demand response potential.

California continues to grapple actively with the issues necessary to ensure the "lights stay on" in the future. These issues include ramping rates, over-generation, grid reliability frameworks and modeling methodologies, conventional plant retirements, capacity payments, rate design and interconnection, energy storage tariffs and interconnection, demand response, and advanced power system modeling methodologies that account for the presence of high shares of variable renewables. Given the current situation discussed in this article, and the active trends underway, there seems little doubt that California will succeed in balancing and integrating high shares of renewables in the future, while "keeping the lights on."