U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

SOLAR ENERGY TECHNOLOGIES PROGRAM

The Role of Large Balancing Areas in Integrating Solar Generation

Solar Integration Series. 3 of 3

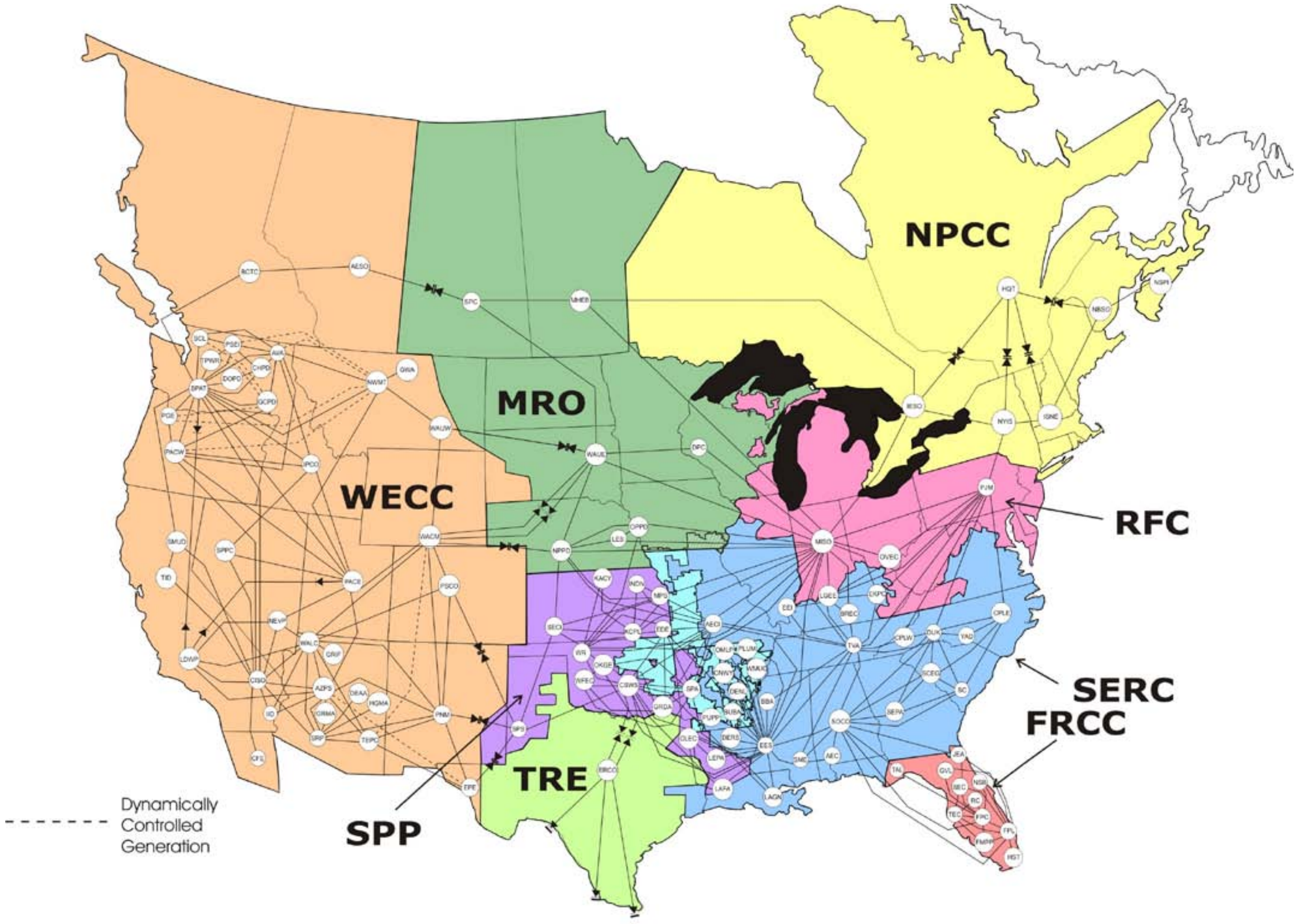
Balancing Areas

There are over 130 **balancing authorities** (BA), or control areas, in the United States. Each is responsible for integrating resource plans, maintaining load-interchange-generation balance within a **Balancing Authority Area** (BAA), controlling transmission flows and voltages, and ensuring that **frequency** is held within the limits that ensure reliable operation of the power system.

The role of the BAA is to ensure **tie line** balance, subject to small permissible deviations, over all time scales. The aggregate load must equal the aggregate supply while accounting for imports and exports. The actions that are required from the operator generally follow the timelines described in fact sheet #1 of the Solar Integration Series.

Balancing areas have been gradually getting larger over the past several decades. This change is motivated by economies of scale and the ability to share various **ancillary services**. BAs carry **contingency reserves**, which consist of extra **unloaded capacity** and demand response that can be called upon quickly in case of emergency, such as a critical line or voltage disruption. Reserve sharing groups have formed over the past few decades, making it possible to reduce the total contingency reserves required among the members. Although these reserve sharing groups cannot be called consolidated BAs, (because they do not address the balancing function) they represent one form of sharing that is becoming common, even in the West, where there has been less consolidation than in the East in recent years.

Regions and Balancing Authorities



Note: *The highlighted area between SPP and SERC denotes overlapping Regional area boundaries*

Courtesy of NERC

The Principle of Statistical Independence

Electric power systems comprise a very large number of components. A typical utility service territory (or market area) includes many thousands of individual customers. The behavior of these customers exhibits some statistical correlation over some time periods, but has little correlation over other periods. During the morning load pickup, customers are generally increasing their usage of electrical devices, leading to an overall increase in electric demand. However, during very short periods of time, on the order of seconds to minutes, some loads are increasing at the same time that other loads are decreasing. There is no correlation between these random events; one customer turns on the lights at the same time as another customer turns off the lights. These events, when they occur simultaneously, have no net impact on electrical demand. This case is perfect negative correlation. More generally, there may be a lack of correlation: sometimes there is coincidence, and sometimes not.

PV solar panels or PV plants that are spread over a broad geographic area have a similar statistical property. During the short time periods of seconds or possibly minutes, one plant may be experiencing an increase in insolation, resulting in more electrical output from the PV plant. At the same moment, another PV plant (or panel) may experience a decline in insolation and power output. The random nature of these events can be captured statistically and formally described as uncorrelated events. It is important to note that if PV location A always runs counter to PV location B, then they are perfectly negatively correlated (correlation coefficient is -1). But if sometimes they move together, and other times move in opposite directions, this lack of correlation has important implications for balancing requirements.

The principle of statistical independence is the reason why each increase in customer demand (resulting from a switched on light, for example) does not need to be matched by a corresponding increase in generation. Because some customers are switching off their lights at the same time when others are turning theirs on, statistical methods can be used to calculate the amount of generation required to match the *aggregate* change in load. The principle of statistical independence over short time frames applies to loads; solar energy; wind turbines; and to load, solar, and wind combined. This document illustrates this concept in several different contexts: load, solar, wind, and all three combined. Forecasts for all three are subject to the principle of statistical independence.

Consolidation or coordination can occur in any combination of ways, including physical or institutional consolidation. In the West, several approaches are evolving that allow for some sharing of variability. Although these limited approaches do not currently involve actual consolidation of BAAs, they do promote the wide-area sharing of variability by means of market or other institutional mechanisms. Variability sharing is an important benefit of large or consolidated balancing areas because some variability is statistically uncorrelated. The text box “The Principle of Statistical Independence” describes this in more detail.

Larger balancing areas can capitalize on geographic diversity and aggregation of solar resources, thereby helping to smooth the variability of solar power production per-unit and increase forecast accuracy.

In addition, larger balancing areas can aggregate greater amounts of variable generation and load. They can also provide access to the response capability of a large utility-scale generation fleet. Because each balancing area only has to compensate for the variability of *aggregate* net electric demand, and because random variations in the demand of individual customers partially offset each other, the total regulation requirement for larger balancing areas is reduced as compared to the total regulation requirement of individual areas. By way of example, the Midwest ISO has reported that its need for regulation reserves decreased from 1,200 MW to 400 MW when it consolidated 26 balancing authorities in its footprint to a single balancing authority, saving $60 million to $80 million annually (Ramey 2010).

The same principle applies to solar generation, although sufficient data to quantify this are not currently available. With larger balancing areas, regulation requirements increase at a slower rate than energy requirements, ultimately resulting in reduced per-unit cost for regulation service. Finally, larger balancing areas have a deeper **stack** of generation and demand resources that can respond to variations in solar output, reducing the overall cost of maintaining grid reliability. The ability of a larger generation fleet to alter its output per unit of time increases linearly with aggregation. Conversely, the *need* for ramping in a BAA that has variable generation increases less than linearly.

Larger balancing areas can be created through the physical combination of individual balancing areas or virtually through balancing area cooperation. Such cooperation may include the sharing of the North American Electric Reliability Council (NERC) reliability requirements or the Federal Energy Regulatory Commission (FERC) **ancillary service** requirements, instead of each balancing area meeting these obligations on their own. Such balancing area cooperation can help share load and generation variability, and lower the costs of integrating variable energy sources such as solar. The impacts of larger balancing areas can also be obtained by large electrical market footprints, as discussed in fact sheet #2 of the Solar Integration Series.

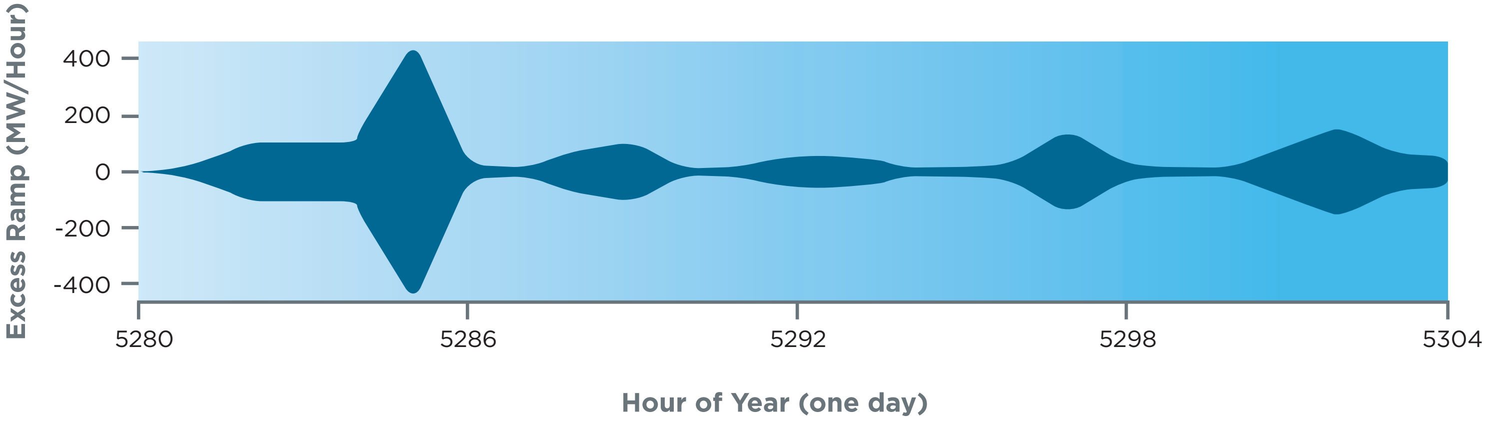
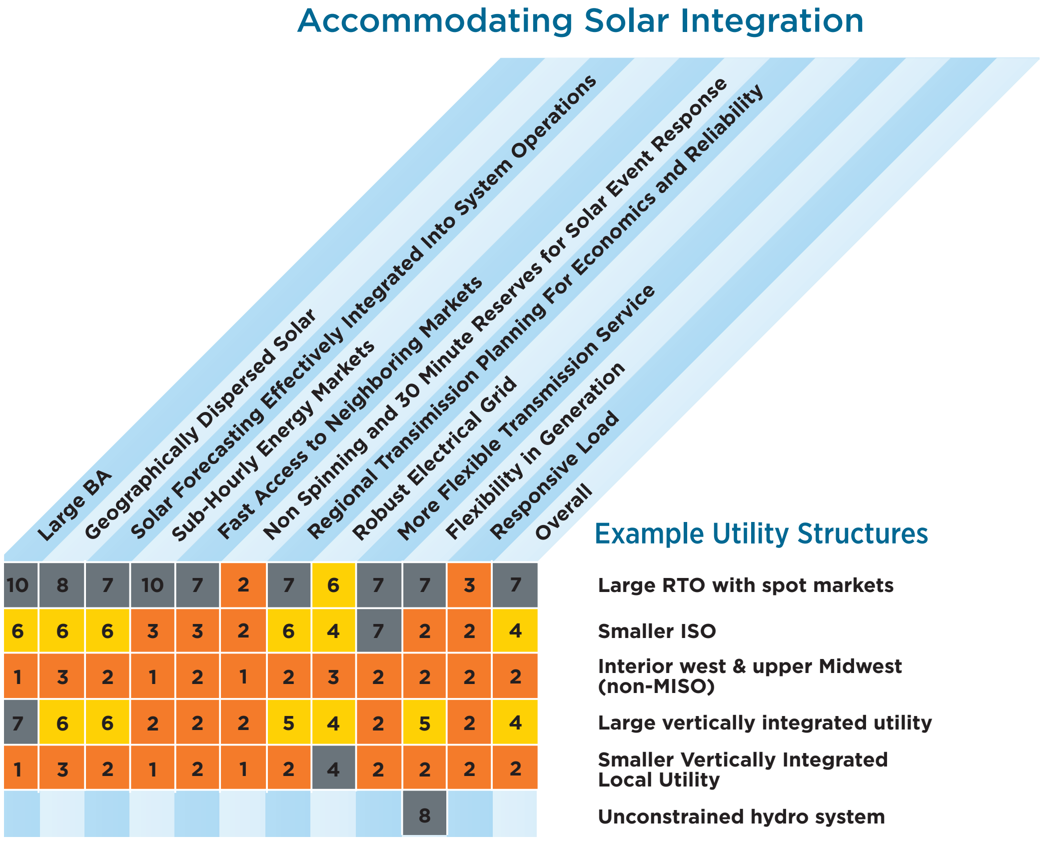


Figure 1. Potential benefits of combined balancing area operations

Figure 1 is adapted from Milligan & Kirby (2007), and shows the potential for eliminating ramping requirements when two or more BAAs consolidate or when they share variability through other means. The symmetrical nature of the graph illustrates that a 400 MW up-ramp in one area can be eliminated at the same time as a 400 MW down-ramp occurs in a neighboring BAA. This represents an opportunity for greater efficiency through various means of actual or virtual consolidation.



Accommodating Solar Integration

Example Utility Structures	Large BA	Geographically Dispersed Solar	Solar Forecasting Effectively Integrated Into System Operations	Sub-Hourly Energy Markets	Fast Access to Neighboring Markets	Non Spinning and 30 Minute Reserves for Solar Event Response	Regional Transimission Planning For Economics and Reliability	Robust Electrical Grid	More Flexible Transmission Service	Flexibility in Generation	Responsive Load	Overall
Large RTO with spot markets	10	8	7	10	7	2	7	6	7	7	3	7
Smaller ISO	6	6	6	3	3	2	6	4	7	2	2	4
Interior west & upper Midwest (non-MISO)	1	3	2	1	2	1	2	3	2	2	2	2
Large vertically integrated utility	7	6	6	2	2	2	5	4	2	5	2	4
Smaller Vertically Integrated Local Utility	1	3	2	1	2	1	2	4	2	2	2	2
Unconstrained hydro system										8		

Figure 2. Sample solar integration assessment

Figure 2 has been adapted from Milligan and Kirby (2010). The figure is based on a simple spreadsheet tool developed to provide a basic assessment of the characteristics of a BAA that can help with large-scale solar integration. Using a scale of 1 to 10, where 1 indicates least capable, the tool assesses each utility structure's ability to satisfy each of the criteria. These ratings are aggregated using a weighted algorithm to provide an overall assessment of the ability of the BA to integrate high levels of solar energy, also represented as a number between 1 and 10, where 10 indicates most capable.

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