The Importance of Flexible Electricity Supply

Solar Integration Series. 1 of 3

Background

Electricity demand is constantly changing, making variability and uncertainty inherent characteristics of electric systems. Control mechanisms have been developed to manage variability and uncertainty and maintain reliable operation. To understand the need for **flexibility** in the generation fleet, it is useful to examine the different grid operating timeframes, which can be divided into **regulation**, **load following**, and **unit commitment**. Figure 1 below provides a graphical depiction of the three general timeframes and the control mechanisms applicable to each.

- *Regulation* typically ranges from several seconds to 5 minutes, and covers the variability that occurs between subsequent economic dispatches. Using automatic generation control (AGC), generation automatically responds to minute-by-minute load deviations in response to signals from grid operators. Changes in load during the regulation time are typically not predicted or scheduled in advance and must be met through generation that is on-line, grid-synchronized, and under automated control by the grid operator.
- *Load following* typically ranges from 5–15 minutes to a few hours. Generating units that have been previously committed, or can be started quickly, can provide this service, subject to operating constraints on the generator.
- *Unit commitment* typically covers several hours to several days. Unit commitment involves the starting and synchronizing of thermal generation so that it is available when needed to meet expected electricity demand.

Ramp rate is essentially the speed at which a generator can increase (ramp up) or decrease (ramp down) generation. Generating units have different characteristics, making some more suited to supplying certain needed functions.

Baseload units—typically large nuclear and coal-fired facilities—often supply the same amount of energy around the clock, although many coal units follow the diurnal load cycle, running at minimum generation levels at night and increasing during the day. These units have slow ramp rates and relatively high minimum generation levels, referred to as **turn-down capability**. They also can take a long time (days in some cases) to start back up once they have been cycled off. Large baseload units also tend to have lower operating costs relative to other fossil-fueled facilities.

Intermediate and **peaking units**, which are generally natural gas or oil-fired facilities, have faster ramp rates, relatively lower minimum generation levels, and can be shut down and started up relatively quickly—however, they also have

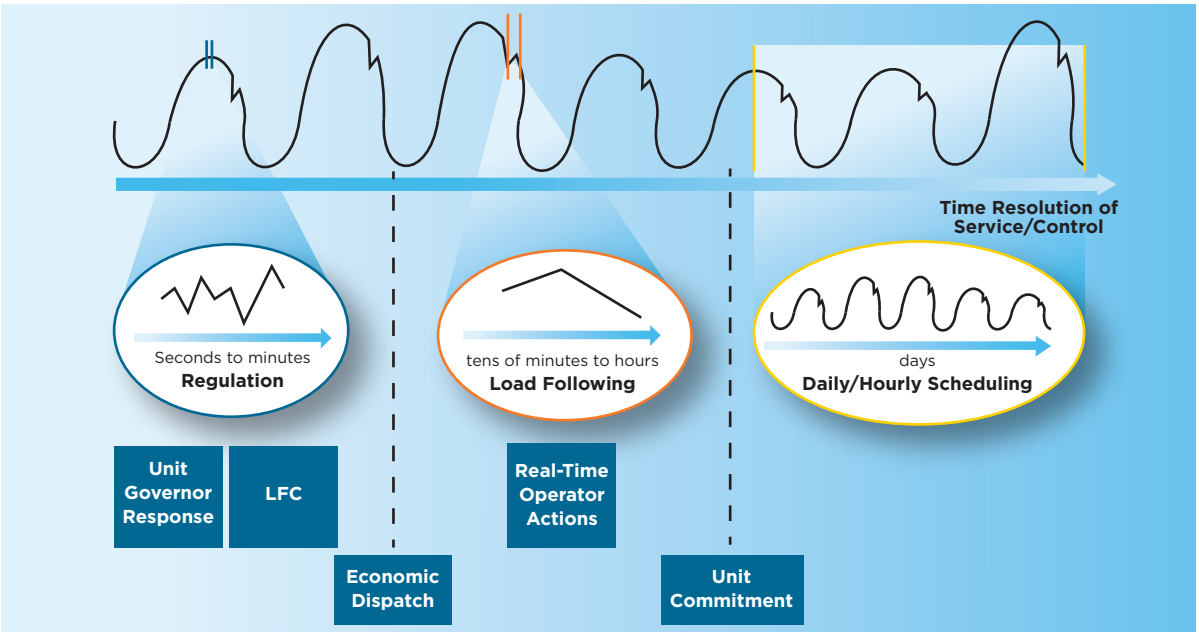

Figure 1. System operating timeframes and control mechanisms

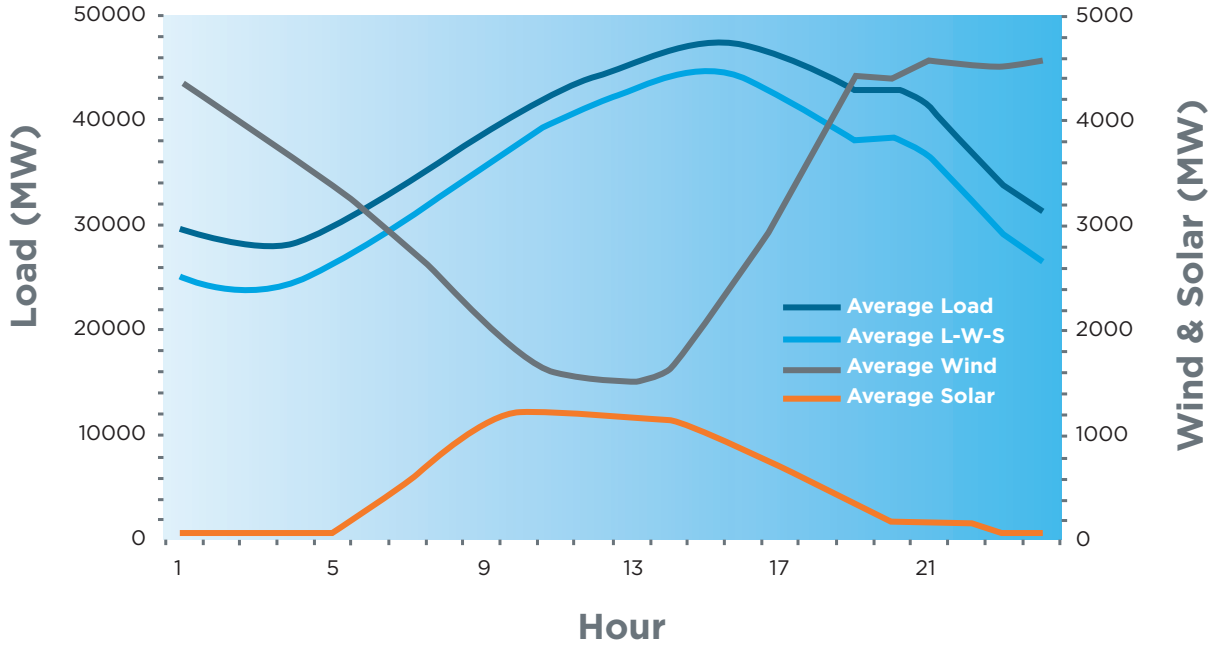

Figure 2. Aggregate solar power variability is similar in time scale to load variability, occurring in the minutes-to-hours time frame associated with load following services (NERC 2009)

relatively higher operating costs. Intermediate and peaking units are most often used to provide load following generation service due to their ability to ramp up and down quickly. Hydro generation has fast response, but can be restricted by environmental constraints (such as erosion control, accommodating salmon, etc.), scheduling practice, and market characteristics. In addition to intermediate and peaking units, there are many additional potential sources of flexibility, ranging from advanced thermal generators, institutional factors, demand response, fuel storage, and electricity storage. In general, the desired mix of flexibility is determined by the need to maintain reliability in the most economical way possible.

The Importance of Flexibility

Large solar and wind generation ramps happen over several minutes to hours. Using regulation **units** to compensate for solar ramps is both costly and unnecessary because regulation is more expensive than other services. To integrate higher levels of variable generation (VG) technologies such as solar and wind, electricity systems need to ensure that grid operators have access to adequate, flexible sources of generation that can provide the additional load following required by VG resources.

There are two primary components to this flexibility: (1) there must be sufficient physical flexibility in the generation fleet and demand response to balance the system with high levels of VG; and (2) the institutional framework, which includes market and operational practices, must allow access to this physical flexibility. Sub-hourly electricity markets provide access, as do large balancing areas. These large balancing footprints and sub-hourly markets (or **dispatch**) allow the grid operator to tap into the inherent flexibility that arises from having a large number of generators available for economic dispatch that can alter aggregate output quickly. This provides significant amounts of load following at little or no additional cost, as generators respond to price and/or dispatch signals. However, if the generation fleet does not have the physical capability to respond quickly enough, there may be a need for supplemental markets to provide for additional flexibility.

While additional flexibility can be gained from existing generators, it can impose significant costs to, and revenue reductions for, those generators. Conventional generation technologies are sometimes designed to run at specific levels and may not be designed for significant ramping duty. The additional cycling can lead to extra wear and tear on the generating equipment. Flexibility, thus, needs market valuation so that generators receive compensation for this service. This can be achieved through expanding and/or modifying ancillary service markets, creating incentives, or imposing new requirements on generators (with built-in compensation mechanisms). It could include creating new types of reserve products. Currently, grid operators usually obtain regulation, **spinning**, and **non-spinning** reserves. The non-spinning reserves are generally 30-minute reserves, meaning they must be able to come on-line within 30 minutes. An interim 10–15 minute non-spinning reserve product would be able to respond within the time frames needed to match average aggregate solar ramps. It would also be more cost-effective than using regulation energy or spinning reserve to compensate for VG ramps.

Generation flexibility needs to be considered in resource adequacy planning. Currently, resource planning focuses on obtaining an adequate level of overall generating capacity without taking into account the different characteristics of generating technologies, such as ramping and turn-down capabilities. The essential goal of resource planning is to ensure that adequate resources are available to meet demand and to maintain reliability through the expected range of system operating conditions. This involves planning in advance to maintain a certain percentage of planning capacity reserve margin (typically 5–15%) above the demand requirements to account for unexpected system events, such as a baseload unit tripping off-line. The reserve margin is calculated by estimating the capacity of supply resources while taking into account the potential unavailability of those resources at times of high risk.[1]

Resource assessments focused on integrating higher penetrations of VG need to evaluate the appropriate levels of system flexibility required to meet electricity demand. They should also account for expected system ramps and reserve requirements. Some flexibility can be gained from the variable generation itself, as modern wind and solar plants are capable of controlling their ramp rates. Additionally, generation resource assessments need to take into account each generator type's ramp rate, minimum generation level, and the amount of time it takes the generator to start-up. System planners must ensure that suitable system flexibility is included in resource planning to account for the planned levels of variable generation.

VG imposes a need for more flexibility but does not require additional capacity to serve load.[2] The traditional focus on capacity must be supplemented by also valuing energy. Accommodating increasing penetrations of variable generation involves accepting energy from variable generation sources when and where it is available. Therefore, consideration should be given to both the physical attributes of all generation resources and the institutional support and incentives needed to maintain reliability. Adding variable generation to an existing power system does not increase the need for installed capacity but will likely change the type of capacity required: more flexible generation resources may eventually replace traditional baseload generation that is not as flexible.

Emerging Sources of Flexibility

Some current and emerging technologies, such as demand response, energy storage, and plug-in hybrid electric vehicles, can help facilitate the integration of larger amounts of VG.

Demand Response

Demand response is defined as an end user's ability to reduce their electric load in response to price signals or other grid management incentives and regulations. FERC reported that, as of 2008, approximately 8% of energy consumers in the United States are participating in some form of demand response program. The potential demand response resource contribution from all such U.S. programs is close to 41,000 MW, or about 5.8% of U.S. peak demand (FERC 2008).

Demand response has been used in the power industry for decades, but recently, advances in communications and control technologies are greatly expanding demand response capabilities,

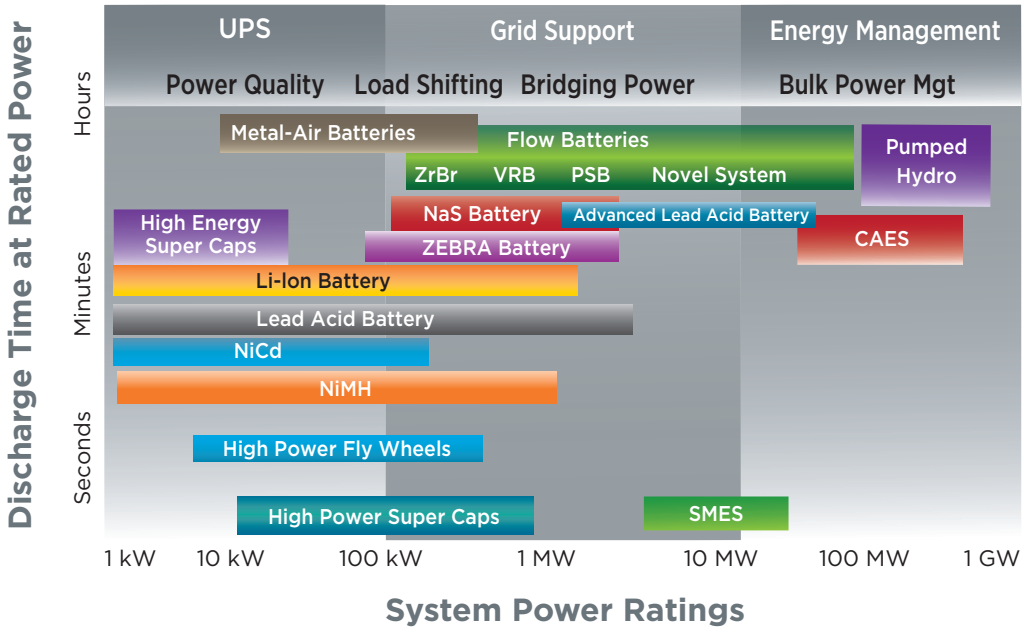

Figure 3. Different storage technologies are best suited for operating over different time frames, providing a variety of flexible grid services (NERC 2010)

[1] As VG penetrations increase, the percentage reserve margin loses its meaning. Rigorous methods for calculating adequacy are based on loss of load probability models, which apply reliability analysis to the adequacy calculations. [2] Exceptions can occur if the VG is exported from the host balancing area with hourly, or longer, schedules.

allowing it to be used as a capacity and energy resource. Demand response provides much-needed flexibility to the power system. Automated dispatchable load resources are capable of responding within seconds and can be used for regulation service and contingency reserves. Slower-responding load control programs can provide sub-hourly and hourly load following services.

Energy Storage

Energy storage has been utilized for many years, particularly in the form of pumped-hydro facilities. Other types of energy storage include batteries, flywheels, compressed air, and thermal storage. Pumped-hydro facilities have existed for more than a century and have been utilized to provide some bulk power storage for peak load management. Water is pumped to an upper reservoir during off-peak hours and then released to provide energy during peak hours. Compressed air storage is similar to pumped-hydro in that air is compressed into a storage reservoir during off-peak hours and then released to power a turbine and provide energy during peak hours. Both pumped-hydro and compressed air storage applications are well-suited for reducing VG curtailments by utilizing the excess energy to fill the reservoirs.

Advances in battery technologies are making battery storage more economical and scalable to both transmission and distribution-level applications. Battery storage can complement VG resources and can be sited anywhere: at the variable generation facility site, at a substation, or on-site at the load.

Other types of energy storage resources with very fast response times are also emerging. A prime example is flywheel storage, which stores electricity for very short periods as mechanical inertia and re-delivers it within a few seconds or minutes to the power system. The quick response time of flywheels makes them ideal for providing regulation service.

Markets are adapting to account for technological advancements that make storage options increasingly economical. For example, NYISO and the Midwest ISO recently modified their tariffs to allow energy storage facilities to participate in their wholesale markets as regulation energy providers.

Plug-In Hybrid Electric Vehicles

Plug-in hybrid electric vehicles (PHEVs) may provide new opportunities for improved system operational management and electric grid efficiency. Through an innovative technology called Vehicle-to-Grid (V2G), PHEV batteries may be able to provide reserves, automatic generation control, or energy. While PHEV battery technology may not yet be ready to withstand constant recharge/discharge as required by regulation service, the charging rate can be safely adjusted. A system operator with access to numerous PHEV batteries could potentially adjust the battery charging rates, thereby providing system ramping services.

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