ENERGY STORAGE

1 ASSISTING THE INTEGRATION OF RENEWABLE GENERATION

The most successful forms of renewable generation tend to have a consistent problem; they are intermittent. To ensure reliability, utilities must carry reserve generation that can be applied very quickly to maintain power when the wind stops blowing or clouds block the sun. As renewable generation like wind and solar become more prevalent, it has become increasingly costly to maintain a high level of reliability. Policy makers, utility planners, and scientists are all looking for a part of the solution to come from energy storage systems.

Until recently, the only effective way to store electricity was through hydropower. By pumping water from lower regulating ponds to storage reservoirs at elevation, the facility can use power to operate pumps. The storage reservoir holds the kinetic energy of the water until it is needed to be converted to electricity. There are many parts of the country that do not have the topology or water supply to support the expansion of storage reservoirs.

2 TYPES OF ENERGY STORAGE AND THEIR APPLICATIONS

Energy storage technologies are currently undergoing renewed research and development in response to the demand. Most of these technologies are evolving and there is not a lot of utility scale operational data to support their viability. The commercially available technologies for utility scale applications fall into the following categories; electrochemical, flywheel, thermal, compressed air, and pumped hydro.

- Electrochemical – There are three main types of battery technologies; lithium ion, sodium sulfur, and flow based which uses a liquid electrolyte and an electrochemical cell.
- Flywheel – Is a mechanical device which stores rotational energy. It is charged by using a motor to increase the speed of a rotating mass which can then be called upon to power a turbine to generate electricity.
- Thermal – This technology can be divided into ice storage and heat storage. Ice storage supplements HVAC by creating ice during an off-peak period which can then be used to provide cooling during the next on-peak cycle. Heat storage can use energy from solar output to heat a medium such as oil or molten salt which is then extracted to power a turbine.
- Compressed Air – Stores energy by injecting compressed air into an underground cavern or an above ground tank. The pressured air is heated and expanded in a turbine to generate electricity.

- Super-Capacitors – Stores electrical charge on a charged plate which is then drawn upon by the electrical grid as needed. These devices store energy on a sub-hour basis to be used to support power quality.
- Pumped Hydro – This is the most established utility scale energy storage available and has been used since the 1920s. It works by running a pump to transfer water from a lower reservoir to an upper reservoir which is then cycled back down to the lower reservoir through a generator.

3 Energy Storage Applications & Efficiencies

Storage is used in a variety of ways to support grid reliability and efficiency. It can help regulate frequency and demand, balance system loads, compliment generator operations, and arbitrage the energy markets.

A device is selected according to the application that is needed such as; balancing VERs, providing system reliability, or managing bulk power supply. Storage can be classified by capacity and the amount of stored energy or hours that can be called upon.

Technology	**Capacity - MW**	**Hours of Storage**
Battery – Li-ion	.001-1	4+
Battery – Sodium/sulfur	1-10	4+
Battery – Lead-acid	.001-10	4+
Flywheel	.01-1	.25-1
Compressed Air	1-350	42-50
Super-Capacitors	.01-1	.25-1
Pumped Hydro	1-1500+	4+

Other prime considerations for selection of storage devices are efficiency, duty life, and cost. Costs are subject to multiple assumptions and are continuing to trend down as this technology develops.

Technology	**Round-trip Efficiency**	**Cycles**
Battery – Li-ion	85	4000
Battery – Sodium/sulfur	75	3000
Battery – Lead-acid	80	2000
Flywheel	70-80	175,000
Compressed Air	42-50*	Operating for 18+

		years
Super-Capacitors	95	25,000
Pumped Hydro	75-85	25,000

* There are currently only two utility scale compressed air storage systems in operation. The efficiency could increase to as much as 70% with future development.

4 California Leads the Way

In response to the addition of renewable resources needed to satisfy its State mandated Renewable Portfolio Standard, Most renewable energy generators, such as wind and solar, are not dispatchable and so other generators or storage devices need to be available to balance the output of these variable energy resources (VERs)

The region has struggled to integrate the large increase of wind generation onto the electrical grid and now the problem has been compounded with the recent large increase of solar generation. California currently has over 6000 MW of utility scale photovoltaic and thermal solar capacity and another 2.1 GW of solar capacity installed behind the meter. Solar is projected to create times of the day when there is an oversupply of generation on the grid and then other times of the day when there is not enough available generation to ramp up and cover the loss of solar generation as the sun goes down. California's three Investor Owned Utilities (IOUs) have been required to build 1,325 MW of storage capacity by 2020.[Please reference] Energy storage will help balance renewable resources by absorbing surplus generation during times of oversupply and then releasing energy back into the grid when VER output decreases.

Modeling future hourly electric supply and demand in California is a challenge because of uncertainty in future policy. The amount of storage that will ultimately be needed in California is a function of their future Renewable Portfolio Standard (RPS), which will determine how much additional solar will need to be balanced by the grid. The electrical grid is projected to have an oversupply of energy during some hours of the day ranging from 190-12,000 GWh/yr. dependent upon the RPS range which California adopts which could vary between 33-50%.

5 Potential Solutions – energy storage & evolving technology

There are a number of ways that California could implement new energy storage capacity. Additional storage capacity at the utility scale might include; hydro pump storage, batteries, compressed air, kinetic energy, super capacitors, or thermal storage. In addition new technology may make dispatchable storage available at the micro level if small customer devices can be aggregated together to help balance power on the grid. The CAISO may allow rooftop solar, energy storage, electric vehicles, and demand response to participate in the wholesale power market by aggregating facilities to meet the 500 kW minimum size. Small storage devices could be significant in the future with the recent development of Tesla Motor's 10 KWh home battery system as an example.

The demand for storage will also depend upon the evolving technology for demand response (DG). There is a growing market for home automation that can control appliances, heating, and cooling via control by wireless networks. This control could potentially be aggregated for participation into the wholesale power market which could then be dispatched to help balance the load on the grid.

6 IRP MODELING OF FUTURE STORAGE BUILDOUT

This IRP analysis assumed that California's future energy storage requirement of 1325 MW would be met but not exceeded owing to the high ratio of cost vs. benefit. California Assembly Bill 2514 requires public owned utilities to consider cost-effective energy storage systems. Current analysis by some public utilities shows that the benefits do not outweigh the costs though this could change in the future as technology evolves. Except for pumped storage, there is not a lot of operational history for utility scale storage systems and hence uncertainty about how well these systems would perform over an extended period of time. The Plexos model used the characteristics of battery storage as a proxy for storage technology since it is currently a front runner under consideration for future storage build out.