

## **Appendix J. Integration of Intermittent Energy From Renewable Resources**

### **J.1 General Integration Principles**

One of the main responsibilities of power system operators is to maintain the balance between the total aggregate electrical demand of the system's customers and the amount of energy generated to meet that demand on an instantaneous basis. Conventional electrical generation technologies, such as nuclear, coal, natural gas and large hydro are controlled and dispatched by the power system operators throughout the day to maintain this instantaneous balance between demand and generation.

However, some renewable resources generate energy according to nature, and the energy from these renewable resources is generally neither controllable nor dispatchable by power system operators. For example, solar resources generally only produce energy when the sun is up, and wind resources generally only produce energy when the wind is blowing. Such renewable resources are often referred to as intermittent renewable generation technologies.

It is anticipated that the amounts of energy generated from solar and wind resources will be substantial. The percentage of solar and wind resources compared to the total capability of a utility's power system may also be defined as "percent penetration." Percent penetration can be measured either by a capacity or energy method. Either measurement method is important, since a utility may use this information to determine the maximum amount of intermittent resources that a power system can absorb without impairing the utility's ability to reliably maintain the instantaneous balance between demand and generation.

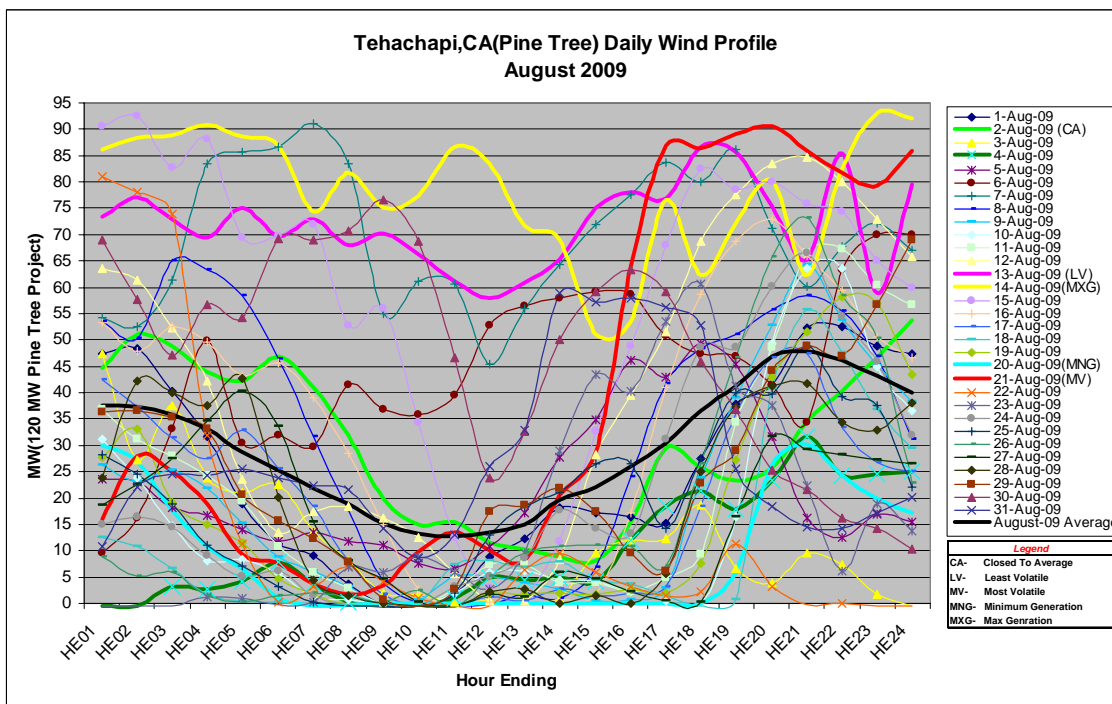
Because power system operators cannot control or dispatch the production of energy from most renewable resources, the remainder of the power system must be managed to accommodate both the changes in renewable energy production and the changes in customer demand. In general, with the addition of increasing amounts of renewable resources, the conventional resources of a power system must become more flexible in their ability to increase and decrease the amount of energy generated to successfully and reliably integrate new renewable generation.

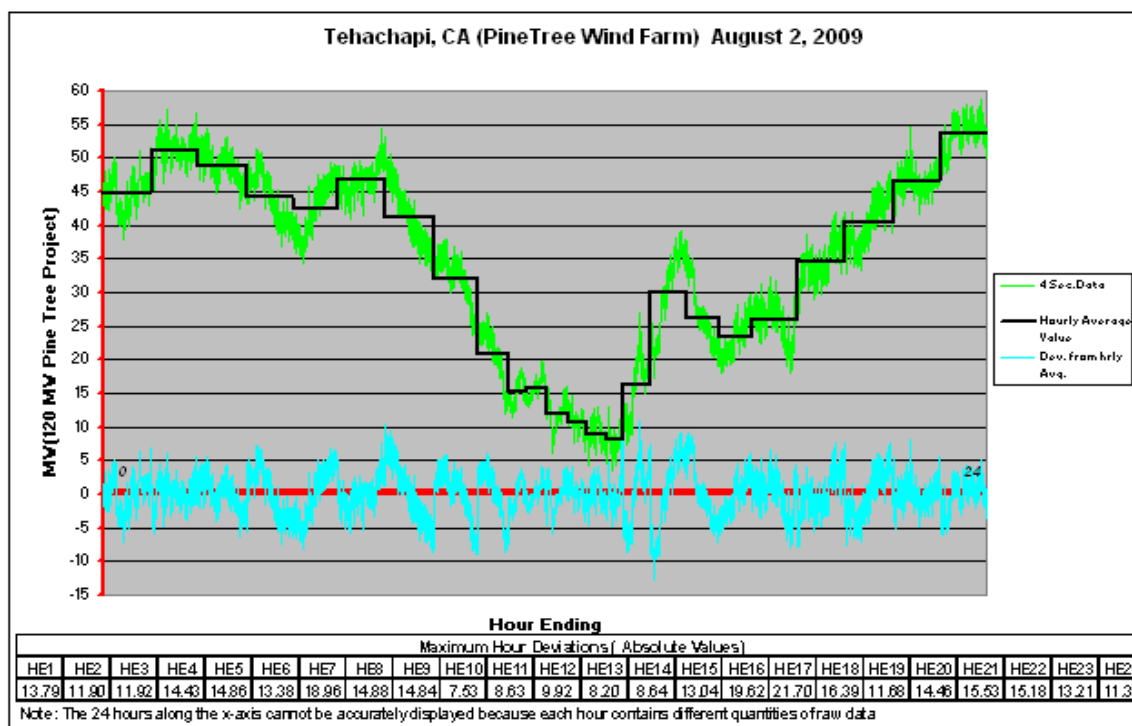
### **J.2 Findings of System Integration Studies**

In the last several years, LADWP has been increasing its efforts to acquire renewable resources. In 2009, 14 percent of energy sold to its customers was generated from renewable energy resources, and 20 percent is expected in 2010. With the much higher percentage of renewables coming on line, a variety of modifications will need to be made to the Power System to successfully and reliably integrate these higher penetrations of renewable resources. In preparation, LADWP has conducted preliminary studies on integrating renewable resources, and has also reviewed many renewable resource integration studies published over the last several years.

These studies have some common observations and recommendations regarding the integration of intermittent renewable resources into power system generation portfolios. Some common observations of these studies include the following:

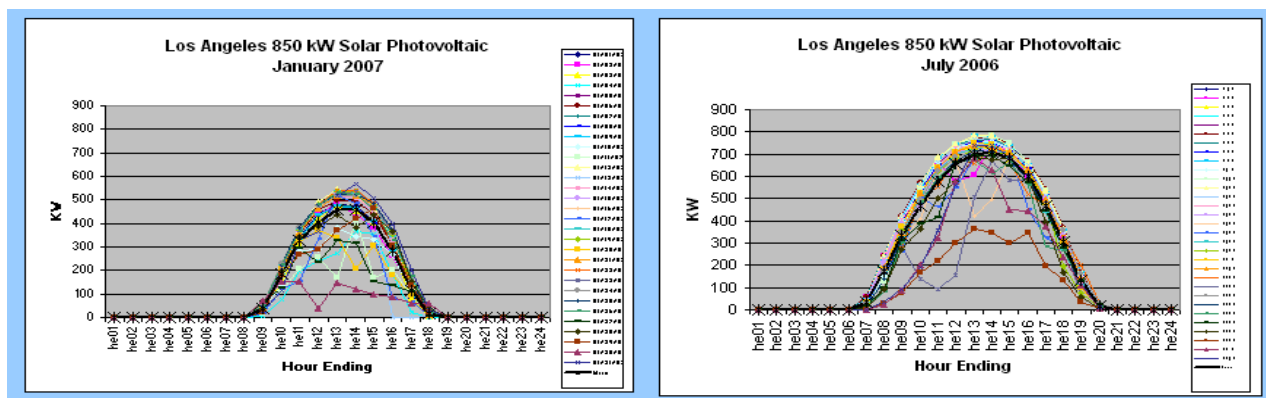
- 1) Larger power systems with robust transmission systems have a greater ability to integrate intermittent wind and solar resources.
- 2) Individual wind farms tend to have a high variability in the amount of energy produced (see Figure J-1).
- 3) Wind energy production impacts regulation (minute to minute variability), load following (hourly variability), and unit commitment decisions (day ahead flexibility). See Figure J-2.
- 4) Wind is usually categorized primarily as an energy resource. The dependable capacity value of a wind farm to the power system is much lower than the rated capacity of the wind turbines.
- 5) There is a financial cost to integrate intermittent wind and solar renewable projects into existing power systems, and this cost increases with increasing amounts of intermittent renewable resources.
- 6) Wind energy production patterns are not usually aligned with daily load patterns. Wind production tends to be greatest in the evenings when the daily load is at its minimum.





**Figure J-2: Wind Farm Impart on Load Following Capability**

- 7) High wind energy production during low power system energy demand hours in many cases represents the greatest challenges for power system operations.
- 8) Average daily and monthly wind energy production profiles are not representative of actual hourly production, due to the high variability in hourly energy production (see Figure J-1).
- 9) Solar energy production patterns are more closely aligned with daily load patterns than with wind energy production patterns (see Figure J-3).
- 10) Energy generated from Solar PV technology is highly sensitive to cloud cover. These PV systems can experience variations in output of  $\pm 50$  percent in 30 to 90 seconds, and  $\pm 70$  percent in five to 10 minutes. When a single large sized PV facility experiences these rapid changes in output, the Power System must also be able to react just as quickly with other generation resources to accommodate such rapid changes. The capabilities of a power system's dispatchable resources will limit the size of a single PV facility.
- 11) In the current energy market, the energy from renewable resource generation will tend to displace the marginal resource, which is typically natural gas. However, if future constraints are applied to carbon fuels such as coal, and coal becomes the marginal resource, then coal energy will be displaced by renewable resources.



**Figure J-3: Solar Photovoltaic Comparisons**

Some common recommendations from these studies include the following:

- 1) Successful integration of intermittent renewable resources requires an investment in transmission and generation resources, changes in power system operations and practices, and cooperation among power system operators and energy providers.
- 2) New generation should be able to operate flexibly, meaning it should be able to start and stop quickly and to cycle on and off many times throughout the year. It should also be able to ramp (change the amount of energy it produces) quickly, and operate at low generation levels.
- 3) State-of-the-art forecasting, particularly for wind resources, needs to be made available to power system operators.
- 4) Wind production equipment needs to have “grid friendly” features, including low voltage ride through, voltage control, and reactive power control.
- 5) Wind energy production must be curtailable by power system operators if wind production negatively affects power system reliability. The power system operators also must have the ability to set power ramp rates for wind projects if needed to ensure power system reliability.
- 6) Natural gas fired combustion turbines and pump-storage hydro plants are good complements to integrating intermittent renewable resources into existing power systems. Additionally, pump-storage hydro plants with variable speed pumping capability provide even more flexibility to a power system. Other energy storage devices described in Appendix K may also assist in integrating intermittent renewable resources.
- 7) Customer load shifting programs work well in integrating intermittent renewable resources.

Further studies, planning and system modeling will be needed as additional renewable resources come on-line to assure system reliability.