Day-long Power Flow Simulations

The Western Interconnection\(^4\) is modeled as a power flow system, where each transmission line has a known admittance, \(Y\), and connects two busbars at unknown voltages, \(V_i\) and \(V_j\). Busbars connected to a generator or a load also have a specified injected power, \(S_i\) and \(S_j\), respectively. The state of the system is determined by solving the power flow equations below, where \(P\) is a matrix constructed from the line admittances. This non-linear system is solved using the Newton-Raphson method with the PowerWorld Simulator.

\[
I = \sum_{k=1}^{n} Y_{ij} S_j = V_j I_j
\]

Optimization Scheme: Wind and solar plant sizes are determined by maximizing the installed capacity subject to the constraint that on a summer day, the additional renewable power in the vicinity of each bus never exceeds the local natural gas generation in the case. The resulting installed capacities are shown in Table 1.

Day-long simulations consist of scaling the California load, proportional to the seasonal variation in the demand. This allows for the determination of the renewable energy used over the course of the day. This discrepancy may also reduce the summertime renewable power output.

Even in this non-optimal case, renewable power still accounts for 40% of California generation during the winter day.

References


Winter Simulations

Day-long hourly simulations were performed for a January day in 2007 assuming the same installed capacities as the July 2016 simulations. Results are shown in Figures 7 and 8.

Since the installed capacities are optimized for the summer daily load profile, the percentage of renewable energy used over the course of the day is significantly reduced compared to the summer 2016 case. Optimization with the annual load, wind, and insulation profiles is required to reduce this discrepancy. Since this is an approximate model, the summertime renewable energy output may be limited.

In this non-optimal case, renewable power still accounts for over 40% of California generation during the winter day.

Conclusions

In this study, we have established a methodology for exploring aggressive wind and solar penetration scenarios. Based on an optimization scheme that accounts for fluctuations in both the renewable resources and load, we can determine the load profile for the summer day in 2016. The optimal power flow strategy is constrained by the necessary power electronics, generation from renewables in California, and the available transmission capacity. The results of these optimizations are shown in Figure 3.

Future Work

- Increase calculations with wind and insolation point data to remove smoothing due to averaging.
- Expand optimization to account for seasonal load fluctuations – this may increase the proportion of renewable power utilized in winter months, but may also decrease the renewable power used in summer months.
- Extend simulations to include sub-hourly fluctuations and real-time resource data to provide more information regarding the dispatchable generation capacity necessary to accommodate intermittency.
- Consider grid stability, worst-case power flow calculations and fault calculations.