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SC C1 – POWER SYSTEM DEVELOPMENT AND ECONOMICS
PS2. Energy sector integration and tackling the complexity of multi-faceted network projects

Question 2.1.1Which criteria can be defined to qualify a stable operation concept in highly decarbonized electrical power systems or subsystems? Are there examples available which define a suitable generation to grid coupling to load ratio?

Power Systems require to balance generation and load on a continuous basis to maintain a stable frequency under normal and different disturbances, in addition to keep voltage within its tolerances. Traditionally, many thermal generators are committed and dispatched to meet load continuously to maintain frequency and provide reactive power and inertia to the system to maintain voltage and stability. Ancillary services (regulation and contingency reserves) are provided by online thermal plants as well to accommodates uncertainties from loads and any contingencies.

(1) Sufficient flexible resources

However, highly decarbonized power systems may push fossil fuel thermal plants retired due to either public policy or revenue requirements. On the other hands, wind and solar can be dispatch down but cannot dispatch up. They are also weather sensitive variable resources with higher uncertainty and variability. The net load, load – wind – solar, could swing widely in a day. To balance with load continuously, dispatchable resources are needed to fill the gaps. Energy storage units can charge / discharge if renewable is greater / less than load. Power to Hydrogen could help to address the seasonal renewable deficiency as well. Demand response and Electric Vehicle (EV) smart charging could effectively reduce the gaps from demand side. Battery or renewable natural gas dispatchable are needed to displace the traditional thermal plants' contributions.

(2) Sufficient inertia and voltage support

In a highly decarbonized power system, FACTS (Flexible Alternating Current Transmission Systems) provides more stability and quality in existing and new power networks with minimal environmental impact. Synchronized Condensers can provide voltage support and inertia to maintain system stability as well. It is also essential to require synthetic inertia and primary frequency response from inverter-based resources – wind, solar, and battery. Hydro, Pumped storage plants, and nuclear plants can provide much needed inertia and voltage supports to the system. Grid-forming invertors can set frequency and voltage for the weak grid, microgrid, or island. As renewable generation changes up and down, power systems require fast response voltage supports and sufficient inertia to maintain voltage and stability.

(3) Sufficient ancillary services to maintain system reliable operation

Due to uncertainty and variability of wind and solar, addition regulation up, regulation down, load following up, and load following down reserves are required to maintain system operation reliable and economic. Wind and utility scale solar can provide downward reserve; Pre curtailed wind and solar can provide upward reserves. Battery, hydro, and pumped storage hydro can provide different reserve services to maintain system reliable, resilience, and economics. Improved renewable forecast will reduce ancillary service amounts and production cost to serve loads.

The New York's Climate Leadership and Community Protection Act (CLCPA) [1], enacted in July 2019, requires an unprecedented transformation of the State's electricity grid to achieve 70% renewable generation by 2030, 100% zero emission electricity by 2040, and an at least 85% economy-wide greenhouse gas (GHG) emissions below 1990 levels by 2050.

The New York Independent Systems Operator (NYISO) in its Climate Change Impact and Resilience Study [2] developed a renewable resource expansion plan to meet 100% emission free electricity in 2040. With the given transmission limitation as of 2025, this plan suggests that 23 GW land-based wind (LBW), 25 GW off-shore wind (OSW), 6 GW behind-the-meter (BTM) solar, 32 GW utility solar, and 14 GW battery storage capacities are needed, in addition to clean energy capacity 14 GW from hydro, Hydro Quebec imports, pumped storage, demand response program, and nuclear plants. 34 GW Renewable Natural Gas Dispatchable (RNGD) capacity will be the backbone for balancing the large variations when wind and solar plants are not producing electricity. Additional 6 GW RNGD resources are needed to maintain system resilience. Total installed capacity is about 154 GW. Comparing with peaking load at 59GW, the installed capacity to peak load ratio is 2.6.

Since solar and wind has much lower capacity factor and limited contribution to system peak hours, the installed capacity to peak load ratio is from roughly 1.15 for traditional power system to 2.6 for emission free power system in NY.

The following observations in the study

- Renewable energy development do not match with needs from load. Upstate has much more renewable resources while downstate has 60% of load
- Renewable generation does not match with load profiles, even though renewable energy is enough to meet annual total loads, but only 6 months have surplus renewable energy. It requires long duration energy storage to mitigate the seasonal renewable deficiency.
- Renewable Natural Gas Dispatchable are required to meet load when wind and solar generation are not sufficient
- Renewable curtailment is inevitable due to limited energy storage capacity
- FACTS and synchronized condensers can help maintain system voltage and stability
- Transmission network expansion are required to unbottle wind and solar
- Transmission flow bandwidth increase significantly
- Significant Transmission congestion occurred between Upstate and downstate NY
- EV unmanaged charging increase system peak demand with evening charging pattern
- EV smart charging will move charging to high renewable generation hours