NEW MARKET INTERACTIONS IN THE CHILEAN ELECTRICITY SYSTEM WITH HIGH INTEGRATION OF VARIABLE RENEWABLE ENERGY

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Overview

The Chilean National Electricity System (NES) has integrated Variable Renewable Energy (VRE) generation capacity at one of the fastest rates in the world. As of 2017, Chile is the only Latin American country to have joined the group of fewer than 15 countries worldwide that generate at least 10% of their electricity from wind and solar resources. Auctions carried out by the National Energy Commission to supply regulated clients, as well as commercial opportunities to renew Power Purchase Agreements with non-regulated clients, will drive the future integration of even greater amounts of VRE in a market where technologies compete without subsidies.

The variability and short-term forecast uncertainty for solar PV and wind generation units is coupled to other sources of uncertainty that are increasingly affecting the electricity market and the economic dispatch. In the short-term, demand forecast errors in the day-ahead dispatch plan of the Independent System Operator (ISO) and frequent unscheduled outages of large generation units are triggering the dispatch of backup units with higher production costs. Further, recently established environmental regulation on local emissions constrains real-time operations of thermoelectric units in unplanned manners. In the medium-term, increased uncertainty in the availability of water inflows to reservoirs due to climate change poses a challenge for water use planning in hydroelectric facilities, a large source of storage capacity in the system. The structure of the Chilean NES, such as its long and radial transmission grid, the concentration of demand in some metropolitan and mining areas, and the widely varying production profiles of VRE resources that depend on their location regionalize the challenges created by uncertainty.

These new trends are raising important questions surrounding existing regulation, such as: Does the current regulation that define the energy, capacity, and ancillary service markets in Chile adequately incentivize the development of new assets which can address the emerging and future flexibility needs of the system? Does the current regulation remunerate enough flexibility to achieve economically efficient, reliable, secure, and environmentally sustainable system operations?

In this paper, the new challenges arising in the energy and ancillary service markets in the Chilean NES are presented. First, a historical analysis of 2017 conducted to assess how the integration of VRE resources has driven the need for flexibility in the Chilean NES is presented. Second, flexibility needs are projected in an analysis for 2021 and 2026. Third, computational simulations of system operations for multiple scenarios in 2021 and 2026 are conducted and reported. The simulation results are used to characterize the operations of conventional and new generation units, thus enabling an assessment of their competitiveness in the energy and ancillary service markets. Additionally, the systemic benefits created by a new flexible generation facility are estimated. An analisis is conducted to determine if flexible units have the capacity to capture the value they produce for the system based on the current definitions of the energy, capacity, and ancillary service markets. Finally, recommendations are made to improve some of the current definitions in the Chilean energy, capacity, and ancilliary service markets.

Methods

The methodology used in this case study has two parts. First, a historical analysis of the operations of the Chilean NES is performed by studying day-ahead programs and real-time operational logs published by the ISO for 2017. The dispatch of generation units, the use of the transmission grid, energy locational marginal prices, and allocation of reserves are characterized. In addition, deviations between day-ahead programs and real-time operations are statistically characterized.

Second, simulations to evaluate system operations in multiple scenarios for 2021 and 2026 are carried out using the Plexos® Integrated Energy Model. Minimum generation levels, ramp rates, minimum up/down times, startup costs and times, heat rate at partial loads, and other generator parameters were included in the energy and reserves co-optimization model. The bulk transmission system is modeled as a DC power flow with losses, and the hydroelectric network connectivity, cascading hydro, and irrigation constraints are fully represented. Simulations are carried out in two stages to represent possible deviations from the day-ahead plan. In the first stage, the unit commitment schedule is obtained using expected demand and VRE production profiles. In the next stage, real-time dispatch is simulated by fixing the unit commitments of slow generators previously obtained and using 14 synthetic VRE profiles and 1 synthetic load profile constructed by replicating historical forecast errors made by the ISO.

A total of 66 scenarios are modelled which consider different water inflow availabilities (low, medium, and high), carbon price policies (5, 30, and 45 USD/ton CO_2 included in the variable cost of generation), balancing area definitions (current and modified definitions), balancing requirements (medium and high reserve requirements), and with or without the presence of a flexible generation asset in the northern region of the NES. Scenario results are evaluated and analysed using various types of metrics.

Results

Interactions in the Chilean electricity market become more complex with higher integration of VRE. Maximum net load 1-hour ramp requirements in the NES are projected to increase from 900 MW as of 2017 to over 2800 MW by 2026. These net load ramp needs were mostly met by reservoir hydro generation located in the south of Chile during 2017. However, transmission limitations between the south and the northern region, where most solar PV capacity is installed, is found to create regional electricity sub-markets and local needs for flexibility. In addition, environmental constraints, such as effluent temperature limits, atmospheric emission limits, and water level requirements in reservoirs, are found to reduce the flexibility of conventional generation units at times when the system is stressed.

Simulations show that baseload coal plants located in the center-south region of the NES are gradually shut down in scenarios with more VRE integration and higher carbon price. In such scenarios, VRE and hydro generation may even completely satisfy demand in the center-south load centers by 2026 on days with lower demand. In contrast, several coal plants in the northern region are kept on. The local need for upward spinning reserves during daylight hours forces these units to cycle between their minimum and maximum generation levels on a daily basis.

The combination of flexible hydro units and increased spinning reserves from coal units dispatched at a minimum level is found to be more competitive to supply the flexible generation market and cover forecast deviations than Combined Cycle Gas Turbine (CCGT) units, even with high VRE integration levels. Only with carbon prices of 30 USD/ton CO_2 or higher do CCGT units effectively replace generation from coal sources. However, in these scenarios, CCGT units go into a cycling mode and experience up to 300 startups per year, which would increase their operations and maintenance (O&M) costs due to greater wear and tear, making them less competitive than coal. If increased O&M costs are accounted for, coal plants replace CCGT units in the generation mix again.

The dispatch of generation units is found to be sensitive to regional reserve markets. The provision of spinning reserves in the northern region by a new flexible asset with low minimum generation level, relatively constant heat rate, and high ramp rate can effectively drive the shutdown of coal plants that are kept on solely to provide reserves, producing significant reductions in system costs, emissions, and VRE curtailment. Nevertheless, remuneration of this flexible unit through current regulation of the energy and reserve markets is found to be significantly lower than the actual benefits the asset produces in the system.

Conclusions

The rapid integration of VRE in Chile is increasing the need for flexible generation units to replace baseload plants in providing ramps, generation at partial load, and fast startups. A historical analysis and computational simulations show that this market is mostly supplied by existing hydroelectric generators, though transmission limitations create sub-systems and local needs for flexibility. These regional needs are met by either coal or CCGT units in different regions and scenarios, and are highly influenced by an intrincate interaction between the energy and reserve markets. Additionally, revenues under current energy and reserve market regulation are found to be significantly lower than actual benefits produced by a proposed flexible generation unit located in the northern part of Chile.