NAME : Maria Alzira Noli Silveira
COUNTRY : Brazil
REGISTRATION NUMBER : 5160

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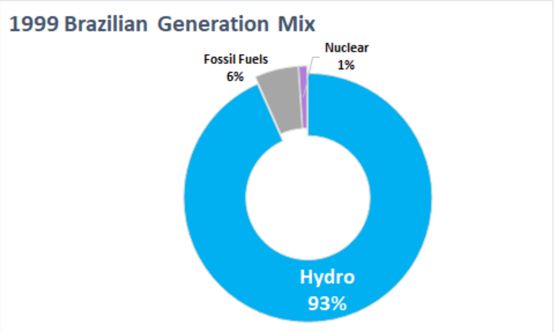
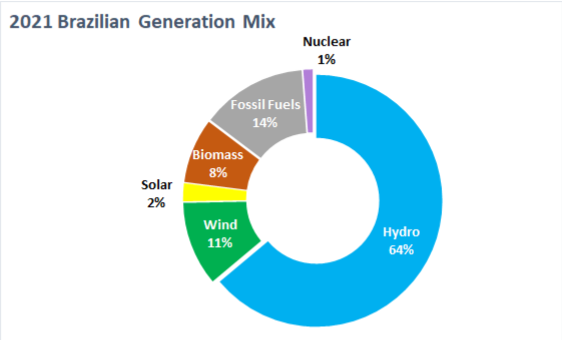
Question 2.4: Building understanding of the new forms of correlation between the different inputs to the year ahead operational plans is essential. For example, low demand associated with overnight conditions will be correlated with a lack of solar PV generation. How can power system operators adjust their operational planning to reflect these new and changing circumstances?

The purpose of this contribution is to illustrate how the solar PV generation is considered in operation planning studies in Brazil.

Over the last 20 years, the Brazilian electricity industry is undergoing significant changes as it transitions from a primarily hydro-based generation mix at the end of the twentieth century (more than 90%) to greater levels of intermittent renewable generation. Besides, the system storage capacity has gradually been reduced because the recent hydro plants were conceived as run-of-river ones. Up to a few years ago, the operation planning studies used the hydro basins' inflow patterns combined with load levels to establish the scenarios to be assessed. Nowadays, the Brazilian system is turning to a hydro-thermal-wind-solar system, so the scenarios to be assessed must consider a convolution of the wind seasonal pattern throughout the year and the solar radiation pattern throughout the day combined with hydro basins' inflow patterns as well as the load pattern.





With high shares of intermittent generation (>10 to 15%), the uncertainty exceeds the range that can be accommodated through operational adjustments. Additional measures are needed to avoid negative impacts on grid performance. With a large share of inflexible generation, comes the need for system flexibility. There are four different flexible resources: grid infrastructure, dispatchable generation, flexible demand response, and storage.

Grid infrastructure mitigates variability by the inherent smoothing benefit of aggregating intemittent renewable plants over large geographical areas. This makes the contribution of a strong grid somewhat unique. Depending on the demand and the generation mix, system flexibility can be increased through options that act on the supply side, on the demand side or on both supply and demand using storage technologies. Flexible generators, such as reservoir hydropower plants or modern gas turbines, and flexible demand response programs can quickly adjust power supply and demand, respectively, to compensate for changes in variable renewable generation output. Storage (utility scale batteries or/and the reversible power plants or pumped storage) does a good job to fill the gap between variable renewable generation and demand by shift generation or load as necessary. Those are solutions to be implemented in the long run to cope with the increase intermittence share in the mix.

On the other hand, to represent those situations in power flow cases for operation planning studies, one must increase the number of scenarios to cover all situations along the day and year-round. Operation planning studies are essential in operating a reliable and secure power system. They aim to identify the operating limits within which reliability criteria are satisfied, anticipating some difficult situation to the real time operation. In Brazil, these studies are performed using deterministic criteria based on the worse scenario situation. The operation planning studies must follow not only the grid evolution, but the evolution of the generation mix as well. The generation mix, combined with the load levels, in general, define the scenarios to be assessed. In a power system with a great share of solar PV generation, the net load to be supplied by control dispatchable generation tends to be the so-called "Duck Curve" due to its shape. The daily patterns of solar generation and energy use can lead to excess supply of unused solar energy at mid-day, followed by a rapid increase in demand from the electric grid in late afternoon and early evening. Solving the "duck curve" problem is one of the challenges to integrating high levels of solar energy to the grid.

In a daily basis point of view, one must represent the early hours of the day till dawn with zero PV solar generation combined with a light load. Another situation is the daylight hours combining a great amount of solar generation with a high use of energy by consumers leading, in some cases, to a very light net load to be supplied by the control dispatchable generation. Finally, the last situation is the one with no PV Solar generation and an even higher energy consumers leading to a very high net load to be supplied by the control dispatchable generation. Besides these three levels there are two steep ramps connecting those levels. The first one is during dawn and second and steepest one which is the evening ramp-up during sunset.

In operation planning studies we represent the full load and not the net load. And we also represent the PV solar generation as well as MMDG separately from the load. We consider 85% of the installed solar capacity for the daylight peak load, 25% for the dawn hours and zero elsewhere. All these situations will generate a great deal of scenarios when convoluted with the wet and dry seasons of the hydro system and the windy and less windy season to cover a year-round scenario.

For the wind farms, the importance of adopting different capacity factors to capture the diversity of wind generation between the coastline and the inland farms of Northeastern Brazil was noticed. Besides, the seasonality throughout the year, there is the need to use different capacity factors of wind generation for peak and light load conditions. The windy season is the second semester, and we use 60% of the installed capacity for the coast farms and 80% for the inland ones during light load studies. For peak load studies, we use 70% and 75% respectively for the coastline and inland wind farms. The Statistical Package for Social Sciences – SPSS software to identify the average generation profiles of each region and load profile was used. For the less windy season we use 30% of the installed capacity.