SJNC – Consultoria e Engenharia de Energia

Study Committee C5

Paper ID 10171-2022

Evolution and Changes of the Electricity Market to Integrate DER in the Brazilian Power System

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Motivation

The scenario of the power system with predominant Distributed Energy Resources and large amounts of variable generation, leads to the following transitions in terms of the market design and regulation to integrate DER, considering market rules and regulatory models applied in the world:

- **evolution and changes of the market rules with the objective to avoid disturbances in the electricity market;**
- **evolution and changes of the regulation with the objective to avoid disturbances in the power system planning and operation;**
- **implementation of energy storage resources to reach both evolutions mentioned above.**

Objectives and Considerations

Analyze, describe and present conclusions about the increasing complexity and challenges caused by:

- **the growing mix of the Distributed Energy Resources;**
- **the massive integration of storage resources;**
- **the impacts on expansion and operation of the Brazilian Power System at the levels of Distribution and Transmission Grids.**

Considering the following points:

- **all the aspects and challenges mentioned above;**
- **the evolution and changes of the market rules to avoid disturbances in the electricity market;**
- **the evolution and changes of the regulation to avoid disturbances in the power system planning and operation.**

Objects of investigation

- **Description and analyses of the increasing complexity and challenges caused by the wide integration of Distributed Energy Resources, as well as technical and economic impacts on the interconnected power system;**
- **Measures to mitigate the risks for the power system with the wide integration of Distributed Energy Resources, especially the implementation of energy storage resources;**
- **Evolutions and changes of the market rules and the regulation in order to give better conditions to integrate DER considering the features of these sources as well as the Grid Codes.**

Challenges

The growing integration of Renewable Energy Sources (RES) and Distributed Energy Resources (DER) causes the challenges:

- **planning resource adequacy for long and short terms;**
- **providing adequate distribution and transmission facilities to incorporate these sources;**
- **mitigating distribution and transmission constraints due to the rapid loss of a large amount of such generation;**
- **enhancing the flexibility, reliability and security of the distribution and transmission grids;**
- **keeping DER penetration level, system inertia and frequency under control;**
- **defining the minimum amount of generation capacity to observe the minimum inertia resources;**
- **managing increased system reserve and ancillary service requirements;**
- **changing the traditional approach and tools to plan and operate the interconnected power system;**
- **changing the operational procedures and requirements of grid codes in face of deep and fast variations of these sources;**
- **improving the methods and tools to make both the power generation and load forecast;**
- **improving DSO and TSO operational structure in face of these issues;**
- **increasing DSO and TSO interaction; and**
- **changing business and regulatory models and market rules.**

Transitions

The growing integration of RES and DER causes the transitions:

- **from a predominant AC grid to a hybrid AC/DC grid;**
- **implementation of special protection schemes;**
- **implementation of mixed overhead lines and underground cables;**
- **implementation of substations with GIS technology;**
- **from a conventional distribution grid to a smart grid;**
- **implementation of energy storage resources;**
- **providing grid services through aggregators;**
- **evolution of regulatory models and market rules.**

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Basic Features of Wind Generation

- it is variable and seasonal and presents high uncertainty and variability at any time;
- the maximum and minimum amount of generation may happen at any time of the day;
- there are fast and deep variations, which depend on the meteorological conditions.
- it should be considered as two basic sources: power and energy:
  - as a power source, there is a great variability at any time of the day;
  - as an energy source, it is seasonal, with monthly generation varying during the year.

It is important to implement the following measures to give security for the power system operation with a high penetration of wind energy:

- Reinforce the interconnections with other areas;
- Improve technical requirements to give robustness to the wind turbines in order to resist impacts from the power system;
- Observe a mandatory minimum amount of inertia from other sources of generation to guarantee transient and dynamic stability.

Basic Features of Solar Generation

- There are two main technologies used for Solar Generation: Heliothermic or Thermal Solar and Photovoltaic;
- Heliothermic technology is expensive, but it presents the following advantages: it is possible to store enough energy to be used up to 12 hours after sundown;
- Photovoltaic technology has reduced its costs consistently, with widespread use, but it presents the following disadvantages: it depends effectively on the presence of solar radiation;
- Solar Radiation and Temperature are the main factors for PV efficiency;
- Solar radiation is the most important positive factor, but the increasing of temperature reduces the generated power;
- It is important to say that in the Northeast region of Brazil there is high incidence of solar radiation and constant wind during the whole year, which means good conditions to increase the power produced by Solar PV plants.

Challenges Caused by Variable Generation

The operation of wind plants can cause impacts related to power quality and harmonic penetration at the connection point and over voltages caused by the electromagnetic transient (EMT) phenomenon. The deep and fast loss of wind power can also cause the following operational impacts on the power system:

- Surpassing the operational limits of transmission lines and equipment;
- Surpassing the power system limits in an area;
- Decreasing the performance of voltage stability and control;
- Decreasing the performance of dynamic stability and of frequency control of the power system.

The solutions for the problems caused by Variable Generation

- Use of additional generation reserves from other sources, especially if the loss of wind generation happens in the period just before or during the peak load;
- Defining additional requirements for frequency and voltage control of the power system, including System Protection Schemes (SPS);
- Defining new requirements in the grid code in order to guarantee power system security;
- Defining preventive measures to be carried out rapidly in real time;
- Reinforcement of the transmission grid and implementation of SPS in critical areas.

Challenges Caused by Distributed Energy Resources (DER)

- The integration of DER, connected directly to the end consumers or into the distribution grid in large scale, will require a reformulation of the regulation rules and grid code of the electricity sector as well in the business model and modus operandi of the Distribution Companies.
- In this scenario, Distribution Companies should be responsible for the expansion and operation of the whole distribution system considering all the generators and consumers connected to the grid.
- Today, these companies are responsible only for the expansion and operation of the installations of the grid. This new model is similar to the DSO (Distribution System Operator) implemented in Europe years ago, substituting the previous DISCO (Distribution Company).
- Distributed Generation has a tremendous advantage, which is production in the same place where it is consumed.

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Challenges Caused by Distributed Energy Resources (DER) (continuation)

- This fact reduces investments and costs of expansion of the power system grid. However, it requires changes in the regulation rules of the electric sector and it causes challenges for the operation of both transmission and distribution systems.
- However, if Distributed Generation is produced away from the place of the load, the benefit can disappear, because the greater the generation surplus the greater the losses in the distribution grid.

Implementation of Storage in the Power System

Initially it is important to make some considerations about the special role of Storage to improve power system operation considering the high penetration of variable generation:

- The power must be consumed at the same moment it is produced. This is why Storage has a special role to accommodate the energy surplus which cannot be consumed immediately;
- Hydro plants run of river and variable sources requires Storage means to accommodate generation surplus to be used at other times when the surplus disappears;
- Power Systems need flexibility from the generation plants in order to make the balance between "generation and load";
- Storage means make possible the control of delivered power by variable sources and the power flow in the distribution and transmission grid.

Benefits of Implementation of Energy Storage Resources in the Power System

- reduction of the needs of reinforcements in the distribution and transmission systems;
- reduction of the distribution and transmission congestions;
- reduction of the amount of additional generation reserve, and reduction of losses in the grid;
- reduction the losses of generation, which cannot be accommodated in the interconnected power system.

Places to install Energy Storage Resources

- in the same site with wind and solar plants to control the power delivered by these plants;
- in the distribution grids to control the power flow and to reduce the investment to reinforce these grids;
- in the transmission grids to control the power flow and to reduce the investment to reinforce these systems; ESR would be installed at the following levels of the network:
  - at 230 kV to control the power flow in some areas;
  - at 500 kV to control the power flow in the inter-regional interconnections.

Evolution and Changes of the Electricity Market to Integrate DER

The integration of Distributed Energy Resources (DER), connected directly to the end consumers or into the distribution grid in large scale, will require:

- reformulation of the regulation rules and grid code of the electricity sector;
- reformulation of the business model and modus operandi of the Distribution Companies.

With large integration of the DER, the Distribution Companies should be responsible for the expansion and operation of the whole distribution system, through the following alternatives:

- Incorporation of these new functions into the current DISCOs;
- Transformation of the current DISCOs into the DSO (Distribution System Operator); or
- Creation of the IDSO (Independent Distribution System Operator), similar to the ISO for the transmission system, responsible for coordinating the whole operation in each area of distribution, which would include one or more DISCOs.

It is important to emphasize the following points:

- the integration of DER cause impacts in the expansion of the transmission and distribution systems which is necessary to be evaluated especially because the uncertainties that they aggregate in this process;
- there is no need to change system reliability criteria such as n-1 with DER, generally from renewable energy sources;
- it is necessary to implement some important operational measures caused by the presence of variable generation in RES and DER.