Study Committee C2

System Operation and Control

Paper 10160_2022

Brazilian Interconnected Power System - Implementation of Wind Power Farm in Restoration Process: Practices and Experience

Antonio P. Guarini — Independent Consultant

Natália de C. Maciel **Luiz G. S. Duda** — ONS

Motivation

- The C2-C6-302 Report from Biennial Cigre 2020 “Brazilian Interconnected Power System - The Use of Wind Power Farm in the Restoration Process” proposed a methodology to anticipate Wind Power Farm (WPF) connection and defined a minimum grid configuration that allows to speed-up the load restoration in the Northeastern Region when the system experiences a total or partial disturbance by using WPF technologies implemented in the BIPS. In this context, this paper aims to continue the previous work presenting some additional dynamic evaluations, a WPFs statistical analysis, proposing modifications in the technical requirements for the Brazilian Grid Code and more. It is relevant to state that, currently, all WPFs in the Brazilian grid are grid-following converter interfaced.

Fluent Restoration Areas Implemented in BIPS’ Northeastern Region

- The BIPS’ restoration philosophy is based on a two-stage process: (i) fluent and (ii) coordinated restoration. Its main objective is to restore all 230 kV and above transmission lines within 2 to 3 hours.
- The BIPS’s restoration process implemented includes 44 fluent restoration areas distributed among the country’s regions. Considering the current fluent restoration paths, it is possible to restore approximately 22% of BIPS’s total load.
- There are 5 geoelectric fluent restoration areas implemented in the Brazilian Northeastern Region (Figure 1). This region has significant wind power penetration, with almost 15,5 GW (August 2021) of WPFs installed capacity and its capacity factor reached 44,4% in the last 12 months.

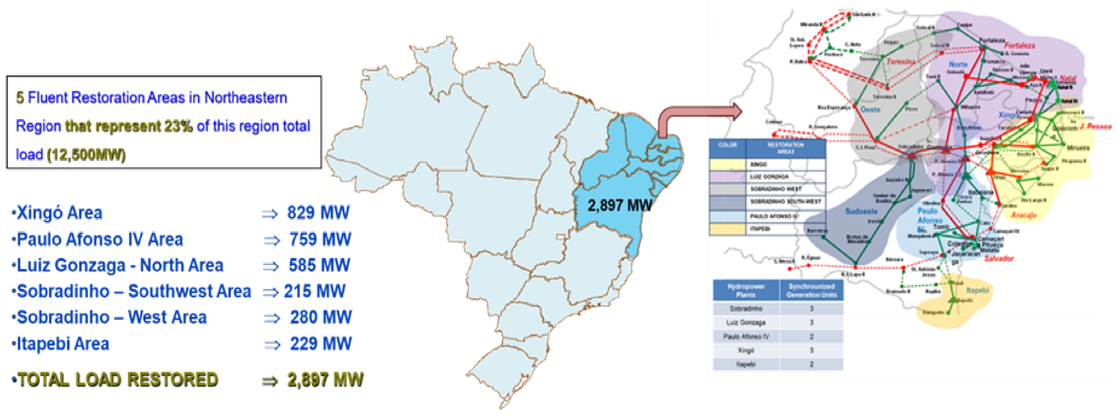

Figure 1 – Fluent Restoration Areas at Brazil’s Northeastern Region

Fluent Restoration of Luiz Gonzaga Area

- The fluent restoration procedure of Luiz Gonzaga Area and its associated grid configuration require that Luiz Gonzaga HPP operates with a minimum of three (3) synchronized GUs to supply the priority load of Fortaleza and Natal metropolitan areas. Luiz Gonzaga fluent restoration area re-establishes 585 MW according to Figure 2.

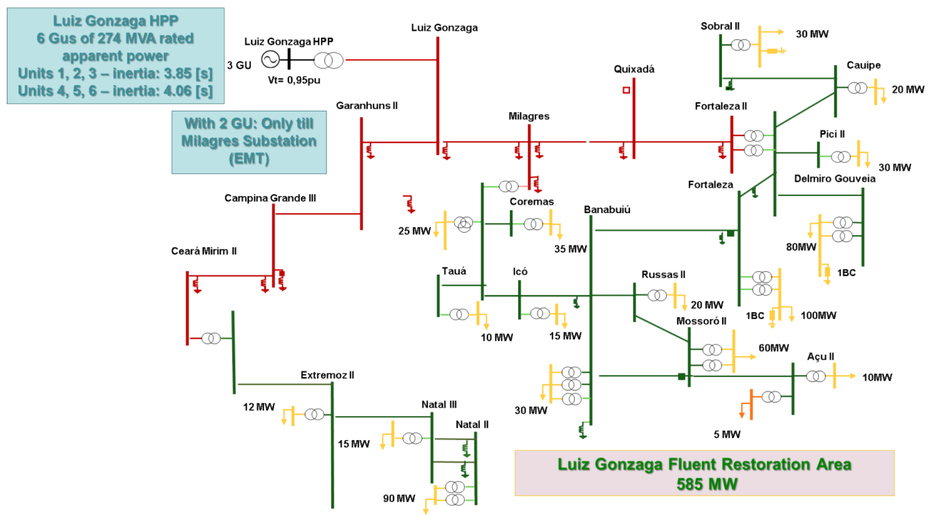

Figure 2 - Fluent Restoration of Luiz Gonzaga Area

Fluent Restoration of Xingó Area

- The fluent restoration procedure of Xingó Area and its associated grid configuration requires that Xingó HPP starts with a minimum of three (3) synchronized generation units to meet the priority load of Recife, João Pessoa, Maceió and Aracajú metropolitan areas. The Xingó fluent restoration area re-establishes 829 MW (Figure 3).

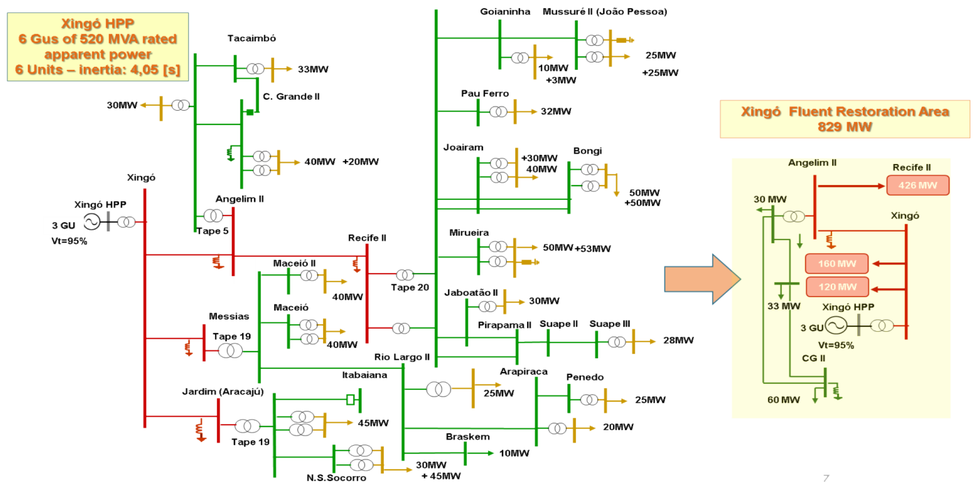

Figure 3 - Fluent Restoration of Xingó Area

Minimum Grid Configuration for WPFs Connection in Restoration Process at Northeastern Region

- The C2-C6-302 paper defined the most robust minimum grid configuration that allows secure and reliable additional load pickup and load rejection, generation unit rejection and any other contingencies that may occur during the restoration process (Figure 4).

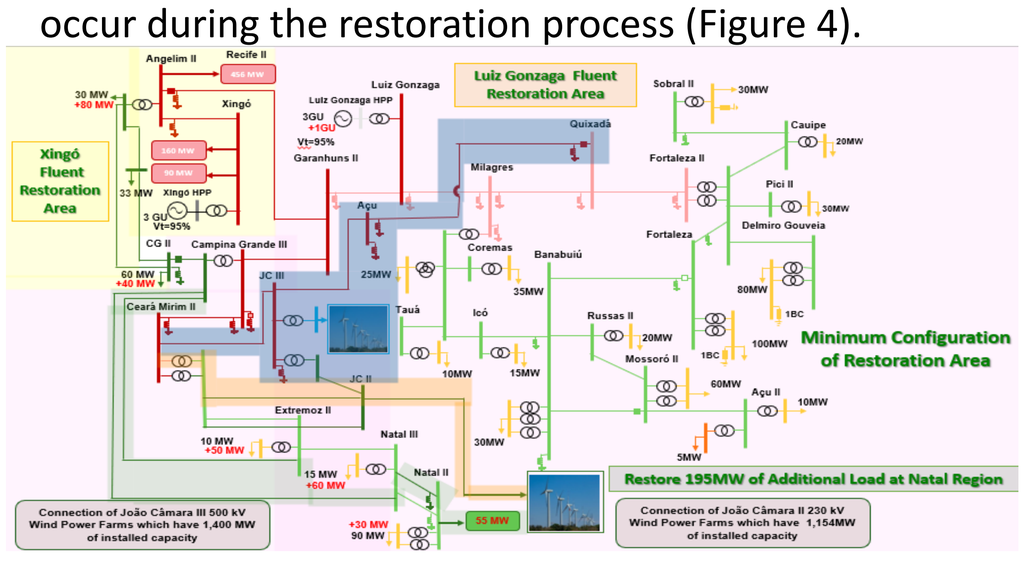

Figure 4 - Minimum Grid Configuration for WPF Connection

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- In most Brazil's current restoration corridors implemented, hydro generation is used as a blackstart resource. That said, when including the WPF earlier in the restoration process, the hydro generation is important to guarantee the grid's stability and account for the seasonality and wind availability.

Criteria to Choose the Common Coupling Point (CCP) Substations

- An important point is to choose which WPF should be connected at first in the restoration process, depending on the additional load amount to be restored, the wind generation capacity and its capacity factors, the types of control available and the possibility of using WPF with synthetic inertia.
- The criteria to choose the CCP at the 230 kV João Câmara II and the 500 kV João Câmara III substations was that they both are near fluent restoration areas. The total capacity installed at João Câmara III and João Câmara II substations is approximately 1,400MW and 1,154MW, respectively, and detailed information (Figure 5).

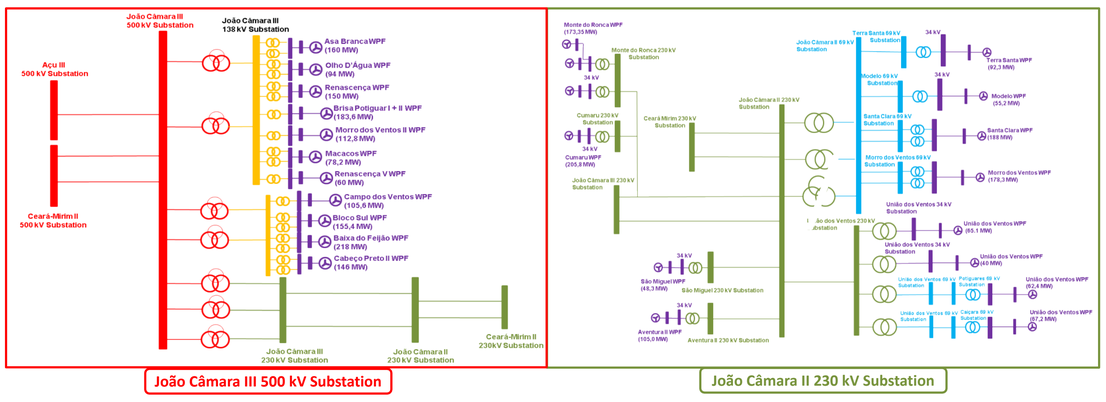


Figure 5 - Connections of WPF at the 500 kV João Câmara III and at the 230 kV João Câmara II Substations

Intermittent Characteristic of the WPFs

- Focusing on wind power generation, the intermittent characteristic of those power plants allied to the difficulties at predicting the generation amount at a short-term basis are the main challenges faced by all operation process: from planning to programming and real-time operation. Figure 6 shows the verified generation, for a year, from one WPF at João Câmara III and another at the João Câmara II substations, presenting the intermittency and difficulty when predicting wind power generation.
- From September 2020 until August 2021, the average wind generation in the Northeastern Region of the Brazilian state called Rio Grande do Norte, where João Câmara II and III substations are located, was 2,092 MWmed, and its capacity factor reached 44,49%.
- The generation ramp up can be controlled once there is wind available, and the operator can act limiting the wind generation at steps.

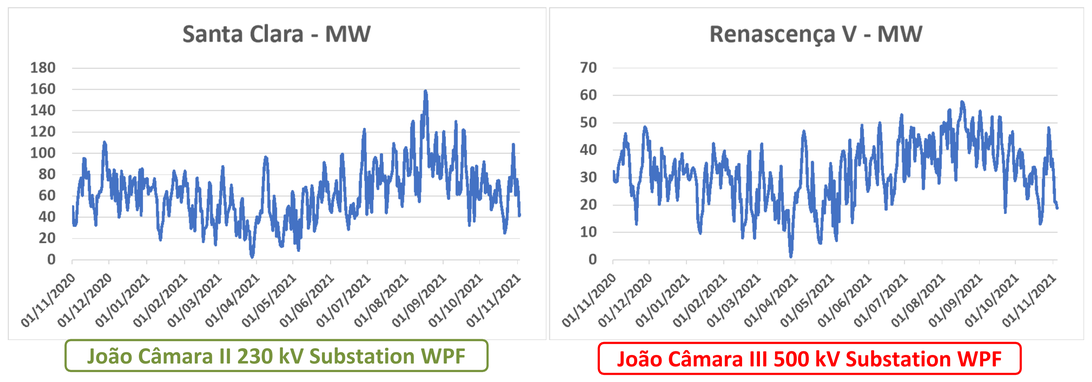


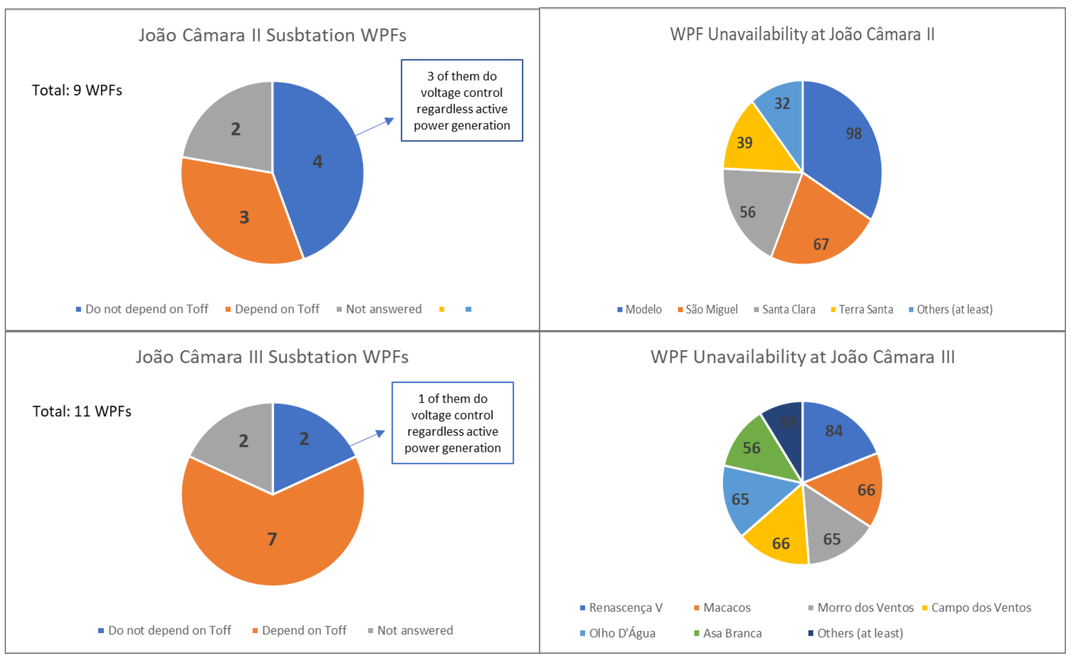
Figure 6 - One year measurements from a WPF at the 500 kV João Câmara III and other at the 230 kV João Câmara II substations

The Need of Installing Synchronous Condensers for BIPS' Restoration

- Once the WPF does not contribute to the operation reserve, the grid must be prepared to deal with a great amount of generation loss, using, for example, virtual inertia or backup from other sources known as base generation.
- Therefore, it will be expected that during the midterm electrical planning analysis, before the grid expansion bidding process, there might occur an evaluation of synchronous condensers (SC) installation in the grid to guarantee a better short circuit power and equivalent inertia at the CCP.

Statistical Analysis for the Wind Power Generation and Its Availability

- Considering a real time operation analysis, WPFs owners were consulted relying on some topics of their operation, such as: shutdown duration (Toff), turn on time (Ton), ramp time after a shutdown and voltage control. The availability concept used considered the number of times the WPF generation was under 10 MW for 1 hour during the period between January 1st, 2020 and May 31th, 2022. The graphics summarizes the results of that survey.



- Telecommunication resources of the WPF (mostly at total shutdown) might be affected and the plant's local operation might be required, possibly retarding the connection of those resources to the grid.

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Evaluating the WPF Response at the Restoration Process

Minimum Grid Configuration with or without the 500kV Trunk

- It was analysed the WPF behaviour for all WPF used at João Câmara II substation disconnection followed by their reconnection at three different moments, without and with the 500 kV trunk. After that, all load (175 MW) from Natal II substation was completely disconnected (Figure 7).

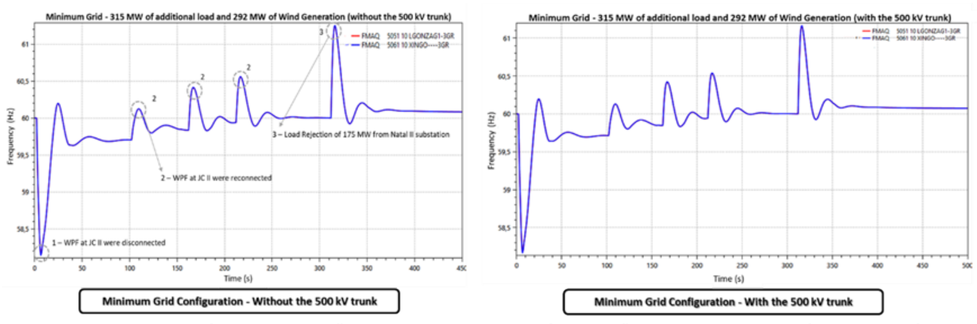

Figure 7 – Evaluation of Minimum Grid Configuration with or without the 500 kV between Ceará Mirim II and Quixadá Trunk energization

- The maximum frequency reached during when comparing both situations was slightly smaller, so the energization of the 500 kV trunk is not necessary.

Minimum Grid Configuration and the Synthetic Inertia

- It was analysed the behaviour of synthetic inertia at the response of the WPF when one GU is rejected and how it might affect the choice of which parks should be considered in the restoration process, considering other additional load scenarios (Figure 8).

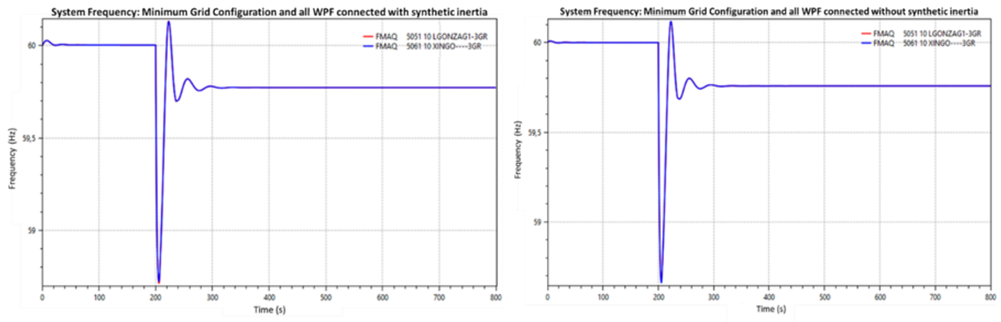

Figure 8 – Synthetic Inertia at 230kV João Câmara II substation WPFs

- The lowest frequency reached when there is a rejection of one hydro unit was 58.73 Hz and, when the synthetic inertia was disabled, the frequency reached 58.66 Hz.

Minimum Grid Configuration with Less Generating Units at Luiz Gonzaga or Xingó HPPs

- It was analysed the loss of one GU at Xingó and Luiz Gonzaga HPPs, considering the following configuration: a) seven GUs; b) six GUs (Figure 9).

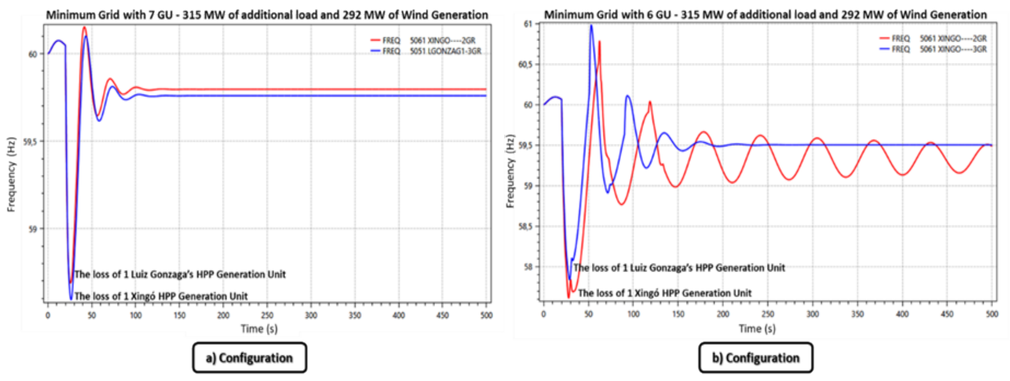

Figure 9 – Evaluation of the reduced GUs available after the parallel closure of Xingó and Luiz Gonzaga Restoration Areas

The Technical Requirements for Grid Procedures

- Nowadays the Brazilian Grid Code does not consider WPFs as part of the restoration process and there is no frequency and voltage parameters to evaluate their behaviour during the restoration coordinated phase. After the results obtained in this paper, it is proposed modifications in Brazilian Grid Code under the restoration studies criteria at dynamic response considering WPFs, according to Table 1.

Table 1 – Acceptable frequency variation for restoration studies

Electrical Measures		Fluent Phase		Coordinated Phase	
		Minimum	Maximum	Minimum	Maximum
Frequency (Hz)	Hydro	56	66	57	63
	Thermal	-	-		
	Wind	-	-	56[1]	63[1]

[1] Frequency value that the WPF disconnects instantaneously

Integration of WPF in the BIPS' Restoration Process

- The minimum grid configuration required for earlier connection of the WPFs in the restoration process in the Northeastern Region should be, at coordinated phase, the one after the parallel and closing loop of Luiz Gonzaga and Xingó Areas, needed to make the final configuration robust enough. Therefore, this paper recommends implementing the proposed procedure presented on topic 8 of it.

Conclusions and Recommendations

- It is important to mention that, in the BIPS, the restoration process proposed depends on synchronous energy resources and does not start with WPF generation.
- The dynamic results show that the most secure and reliable configuration is the one with seven GUs, hence it needs to be the minimum grid configuration to assure a good dynamic response in case of GUs' contingencies.
- The ramp up time of the wind parks can vary a lot between them and so, an evaluation of their real time behaviour is a key point to be explored to choose their grid connection order.
- The synthetic inertia, under the conditions studied (292 MW of WPGs and 7 GUs), did not contribute to improve the frequency profile during contingencies.
- The minimum configuration allows a bigger amount of load restoration, and the wind generation will contribute with active and reactive power dynamically and at steady state, potentially accelerating the load restoration.