EMT Practices in ONS

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Summary

ONS and BIPS

EMT models in ONS today

August 15th: A turning point for EMT in ONS

Future of EMT models in ONS

ONS and BIPS

What is ONS?

Brazilian Interconnected Power System (BIPS)
System Operator (SO)

ONS Operador Nacional do Sistema Elétrico

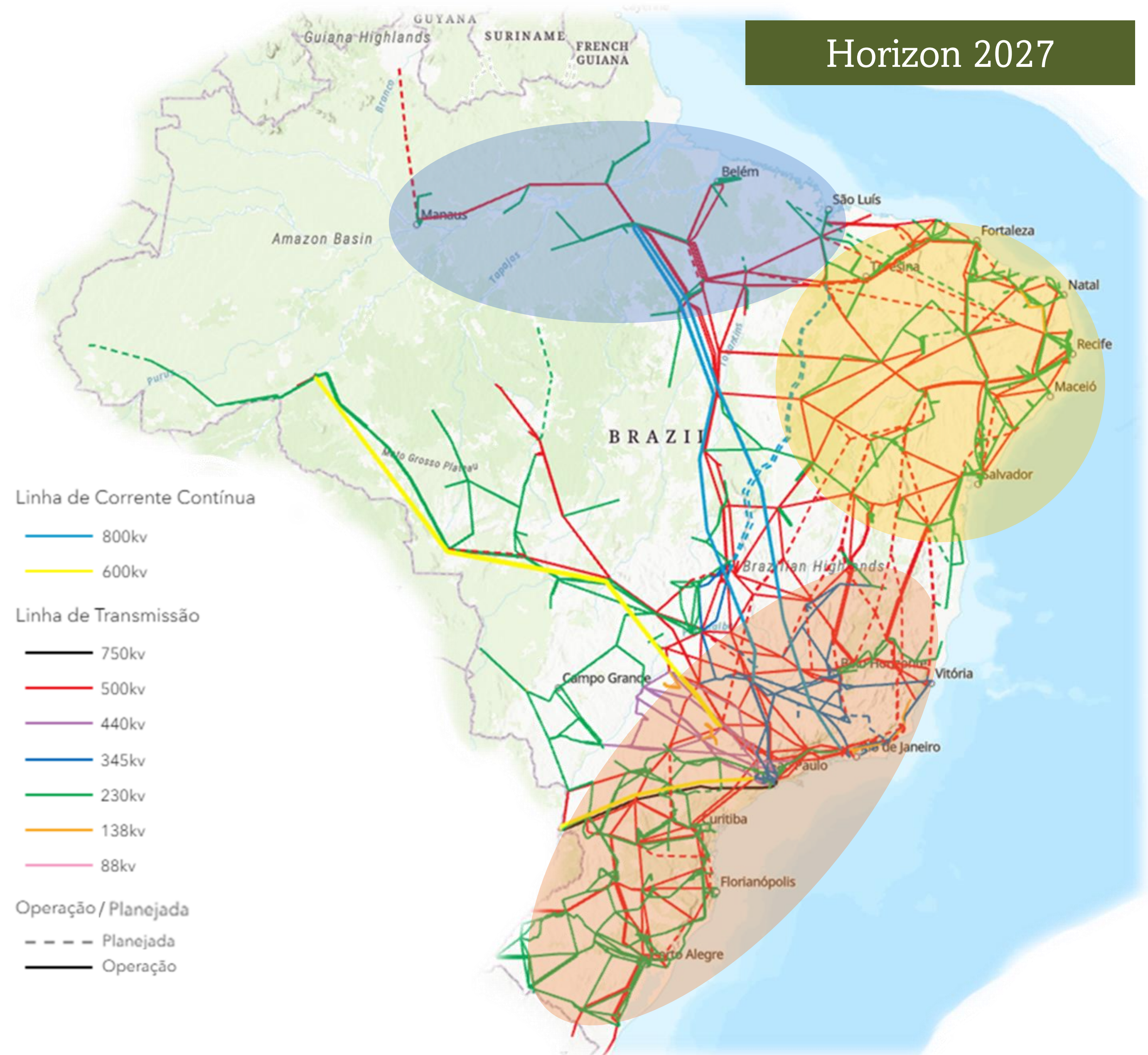
> 225 GW
Installed Capacity over more than
1500
power plants

> 180,000 km
Transmission Lines operated by ONS with voltages
≥ 230 kV

75 GW
average load in 2023

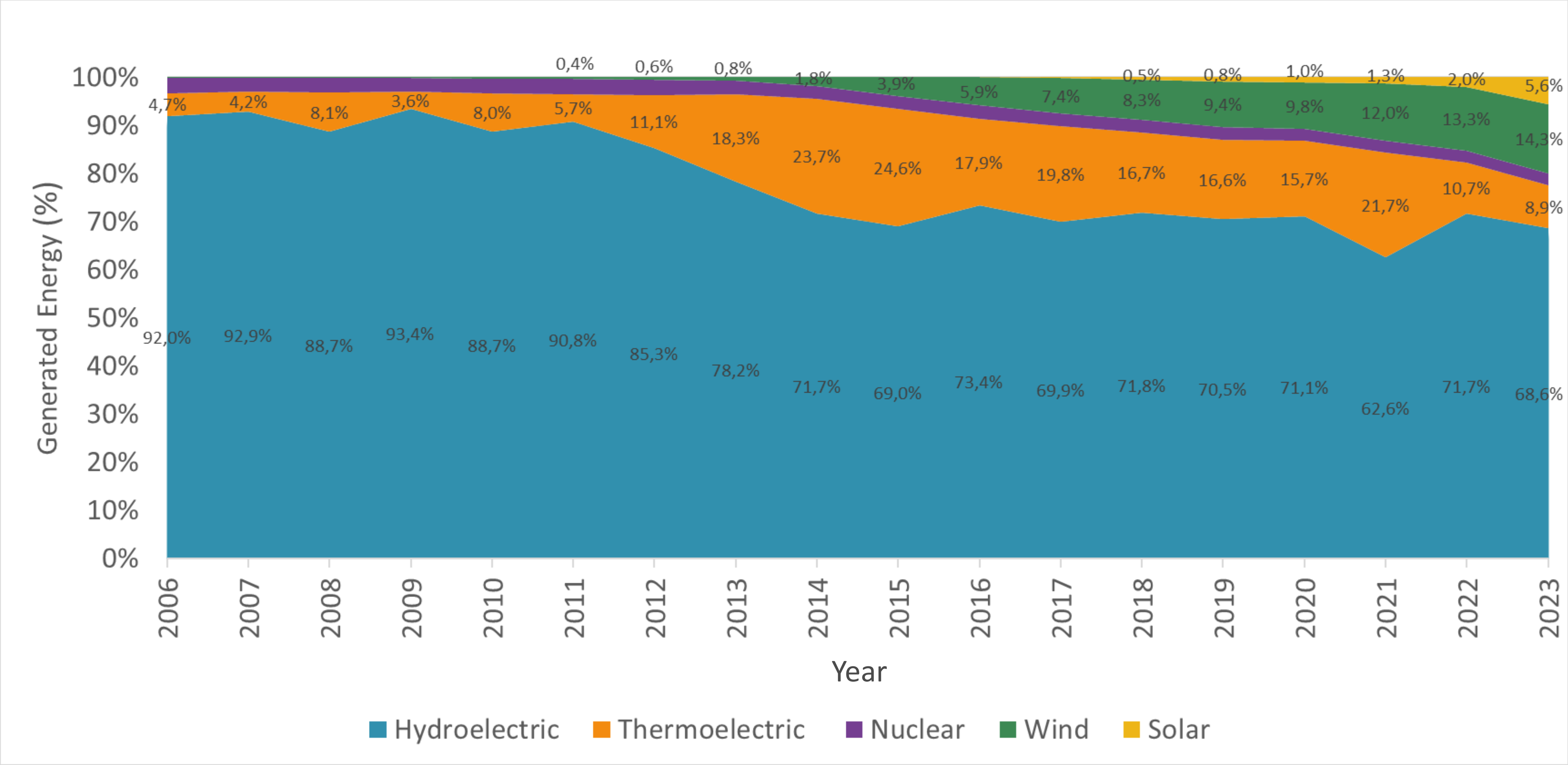
102 GW
peak demand 02/07/2024

Brazilian Interconnected Power System (BIPS)



- One of the world's largest synchronous networks
- One system operator → ONS
- Main load center in South/Southeastern Brazil
- Large hydropower plants far from load centers at the North
- Rapid increase of wind and solar generation at the Northeast

BIPS Electricity Mix



EMT Models in ONS today

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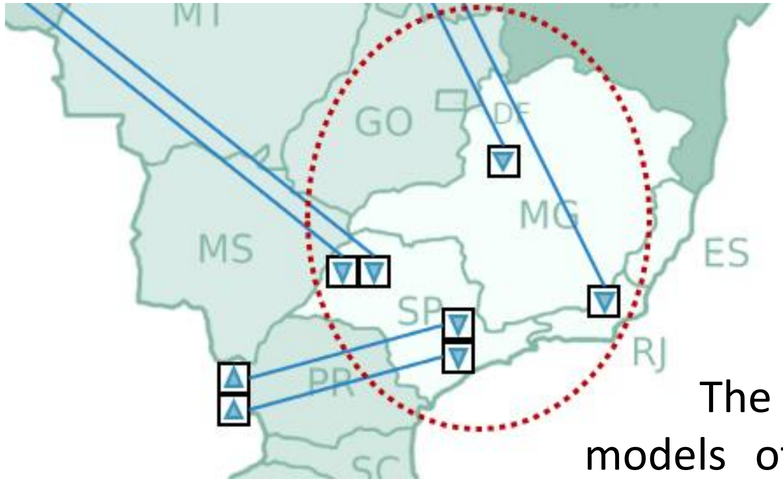
- Multi-infeed Performance
- Transformer Energization
- Other ad-hoc studies

EMT Models in ONS today

Multi-infeed Performance



Multi-Infeed configuration with **20.6 GW** capacity HVDC LCC links in close electrical proximity.

This setup can lead to simultaneous commutation failures across different HVDC links, which pose a risk to the system's stability, especially during faults or disturbances near the inverter stations.

The use of the PSCAD software with detailed electromagnetic transient models of the HVDC systems is essential in analyzing this phenomenon, allowing precise simulation of the interactions between HVDC converters and the AC network equivalent, and determination of commutation failures expected duration based on main contingencies. These commutation failure duration times are then used at the transient stability simulations to ensure safe operating conditions under the multi-infeed configuration.

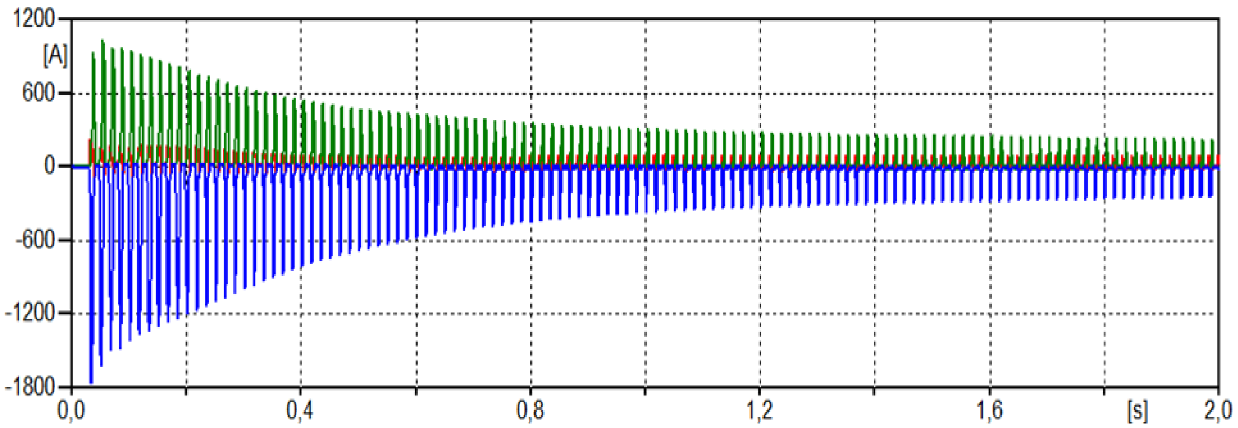
Transformer Energization

Other ad-hoc studies

EMT Models in ONS today

Multi-infeed Performance

Transformer Energization



ATP network model up to the second electrical neighborhood from the substation of connection. Both normal operation and simple outages in the first neighborhood of the connection substation are evaluated.

Simulations include 200 random energizations, using a statistical breaker model without pre-insertion resistors or point on wave switching. If RPI or POW controllers are present, simulations are also done considering their functionality in mitigating inrush currents.

The most severe conditions identified statistically should be reproduced deterministically to assess inrush current damping, temporary overvoltages, and arrester energy dissipation.

Other ad-hoc studies

EMT Models in ONS today

Multi-infeed Performance

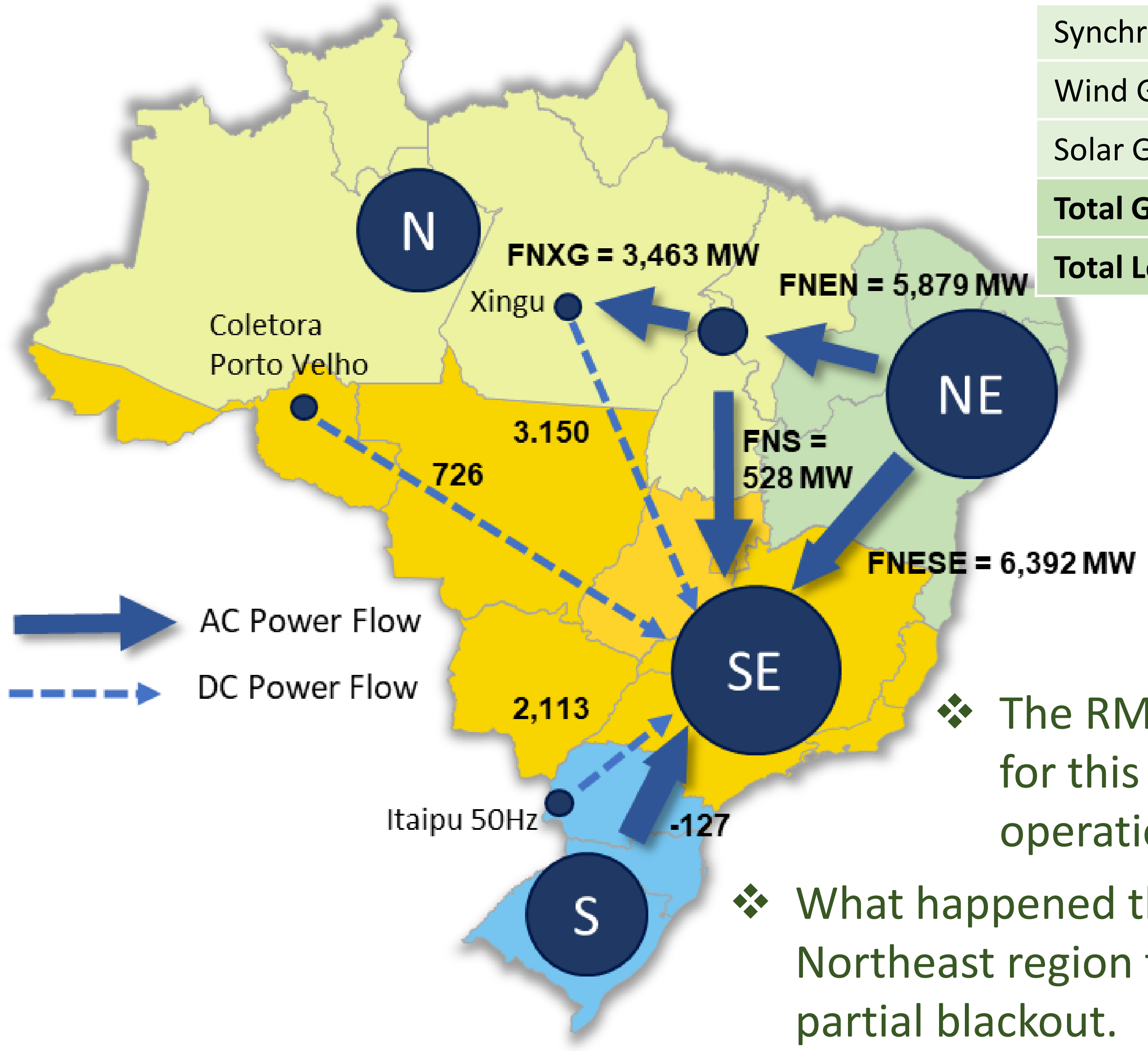
Transformer Energization

Other ad-hoc studies

- Load rejection
- Single-Pole/Triple-Pole Auto-Reclosing
- Transmission Line Energization
- Transient Recovery Voltage (TRV)
- SVC Hunting

August 15th:
A turning point for EMT in ONS

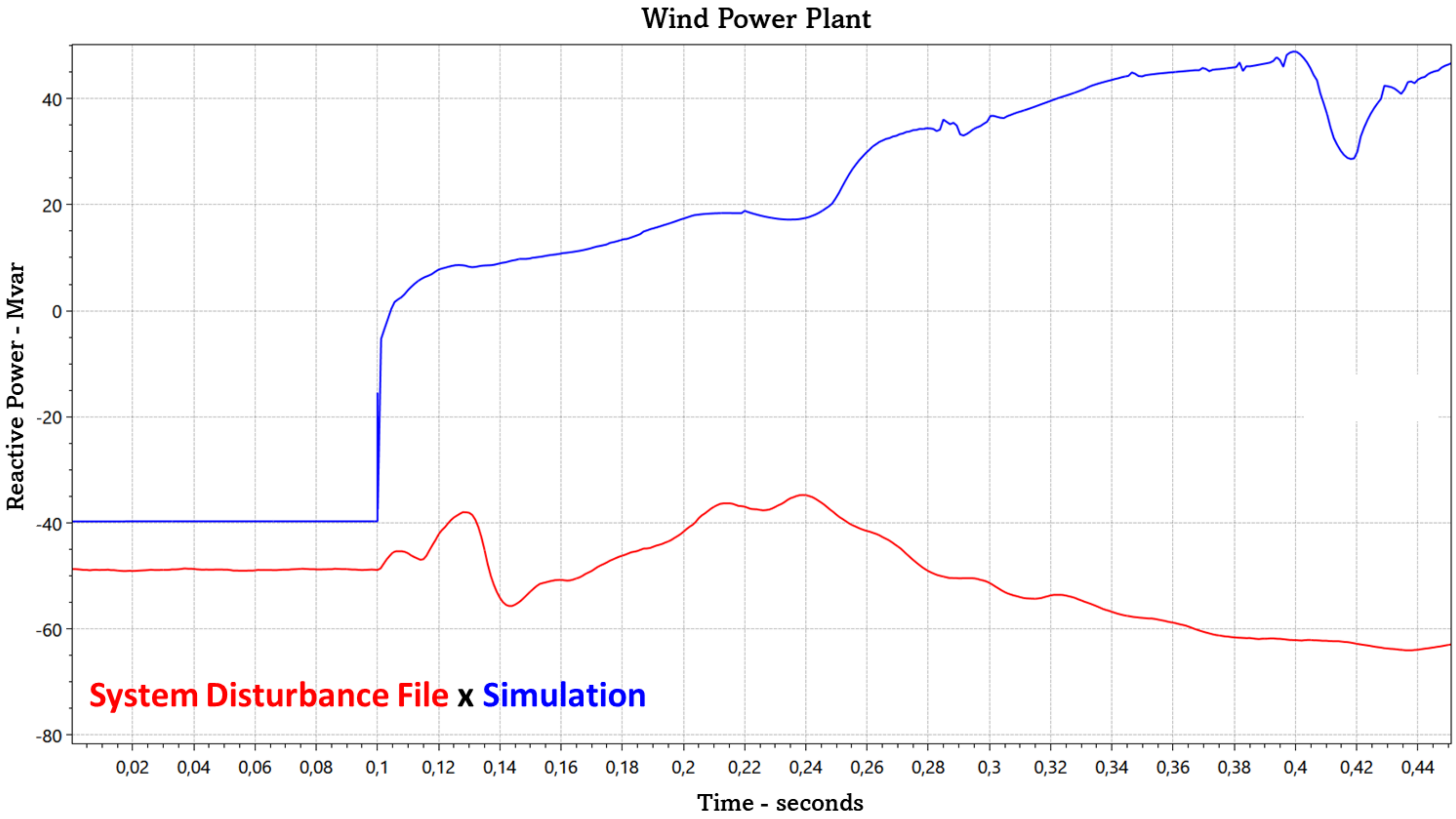
Event Overview



Northeastern Brazil	
Synchronous Generation	2,926 MW
Wind Generation	16,317 MW
Solar Generation	3,211 MW
Total Generation	**22,454 MW**
Total Load	**10,151 MW**

- NE power exporting around 12 GW with 90% IBR internal generation
- Event started with the outage of 500 kV Fortaleza II – Quixadá transmission line, which was transmiting 2 GW
- The RMS simulations showed that the system was stable for this outage, with all voltages within normal range of operation
- What happened though, was a voltage collapse across most of the Northeast region that led to cascading outages culminating in the partial blackout.

System Disturbance File x Simulation



Future of EMT models in ONS

Operador Nacional
do Sistema Elétrico

New Model Requirements

- Before August 15th, RMS models provided by the plant owner were validated only during the commissioning phase, against field tests. In this phase, several limitations can arise when testing complex functionalities, such as the logic for reactive current injection during faults.

1 **Viability Analysis**

2 **Pre-Operational Studies**

3 **Plant Commissioning**

- Validation of RMS model against field tests

New Model Requirements

- Before August 15th, RMS models provided by the plant owner were validated only during the commissioning phase, against field tests. In this phase, several limitations can arise when testing complex functionalities, such as the logic for reactive current injection during faults.
- To address this limitation, it will now be necessary to provide, during the pre-operational study phase, a PSCAD model of the real equipment accompanied by a validation report based on laboratory tests and/or HIL simulations. The real equipment RMS model, in turn, must be validated against this PSCAD model. During commissioning, only fine-tuning of parameters will be required, along with confirmation of performance against field tests.

1 Viability Analysis

2 Pre-Operational Studies

- Validation of PSCAD model against field/HIL tests
- Validation of RMS model against PSCAD model

3 Plant Commissioning

- Confirmation of performance of RMS model against field tests

New Model Requirements

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- To address this limitation, it will now be necessary to provide, during the pre-operational study phase, a PSCAD model of the real equipment accompanied by a validation report based on laboratory tests and/or HIL simulations. The real equipment RMS model, in turn, must be validated against this PSCAD model. During commissioning, only fine-tuning of parameters will be required, along with confirmation of performance against field tests.
- We believe this approach ensures that most system behaviors are accurately modeled and validated before commissioning, reducing risks and uncertainties during the actual implementation phase, and ensuring that the RMS models used in ONS simulations are truly representative of the real-world performance of the equipment installed in the field.

EMT Model Validation

- Currently, we do not yet have a defined routine for validating EMT models. This approach has been intentional, allowing manufacturers the flexibility to leverage validation processes they have already conducted to meet the requirements of other operators in different countries. We do, however, have some minimum requirements:
  - It must be the manufacturer's official three-phase electromagnetic transient model for studies
  - All protection, control, and measurement logic must be represented, as well as the different control sampling rates, communication delays, and measurement sampling inherent to the equipment installed in the field
  - The validation should include fault conditions (under and overvoltages) and be representative of various operational conditions of the actual equipment (different SCR levels, active power generation, etc.)
  - The validation must have been performed on equipment that is identical or equivalent to that implemented in the field. Equivalent equipment is understood to be those that can be fully represented by the same control topology, differing only in parameterization

EMT Model Validation

- We are actively engaging with manufacturers to better understand the specific details and characteristics of their models. Once this initial phase is complete, we will work toward establishing formal guidelines for the validation process.
- This phased approach ensures that the validation framework we eventually implement is both robust and aligned with industry practices, while also ensuring a rapid initial submission of validated EMT models to quickly establish the representativeness of our RMS models. This allows us to maintain momentum in developing a reliable model database as we work towards more formalized validation standards.

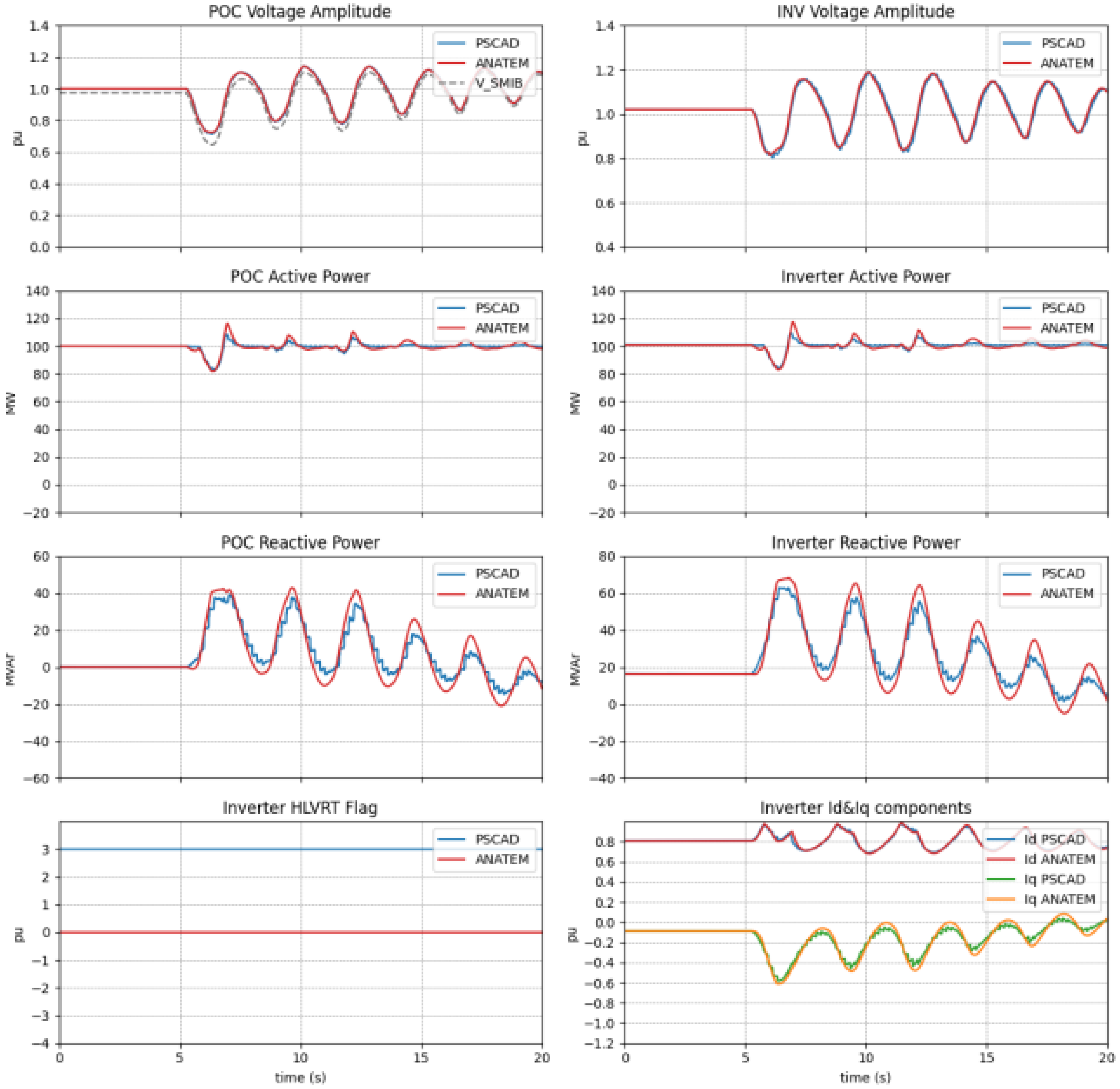
Short-term Objectives

❖ Benchmark for RMS model validation

Complete the validation of PSCAD and RMS models based on laboratory and/or HIL tests, ensuring consistency between different levels of modeling.

For the EMT x RMS validation, there is a specific guide with requirements regarding:

- Simulation time window, sampling rate, format and grid structure
- List of variables to collect
- Test scenarios: voltage and power steps, frequency excursions, shunt switching, faults, oscillation events, LVRT/HVRT tests

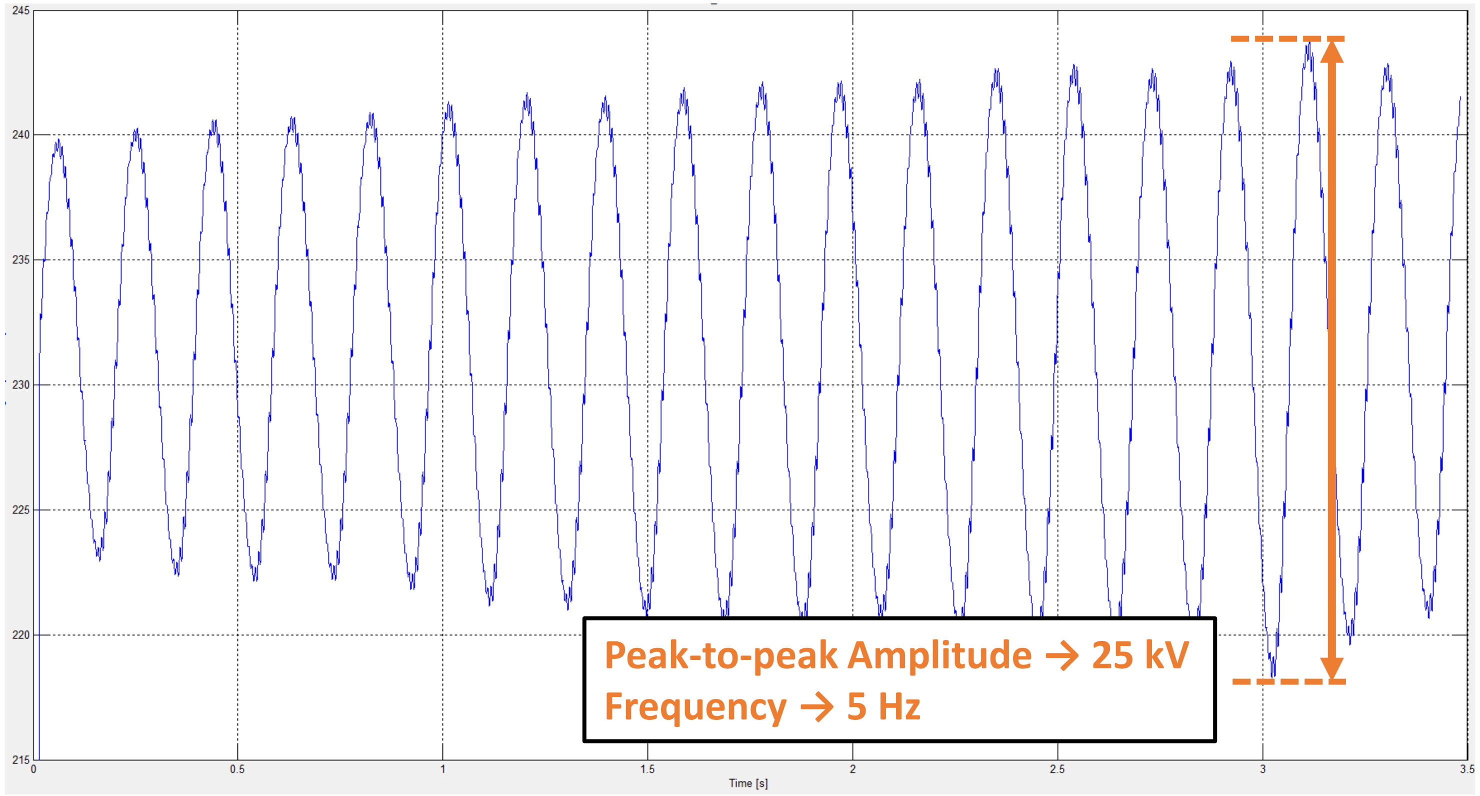


Long-term Objectives

❖ Evaluation of Oscillation Events in IBR Controllers

Use of the PSCAD models to improve the evaluation of oscillation events in Inverter-Based Resource (IBR) controllers. Currently, this assessment heavily relies on PMU (Phasor Measurement Unit) data and support from the equipment manufacturer.

The integration of these detailed models into ONS's study framework will allow for independent and more thorough analysis of IBR controller performance during oscillatory events.

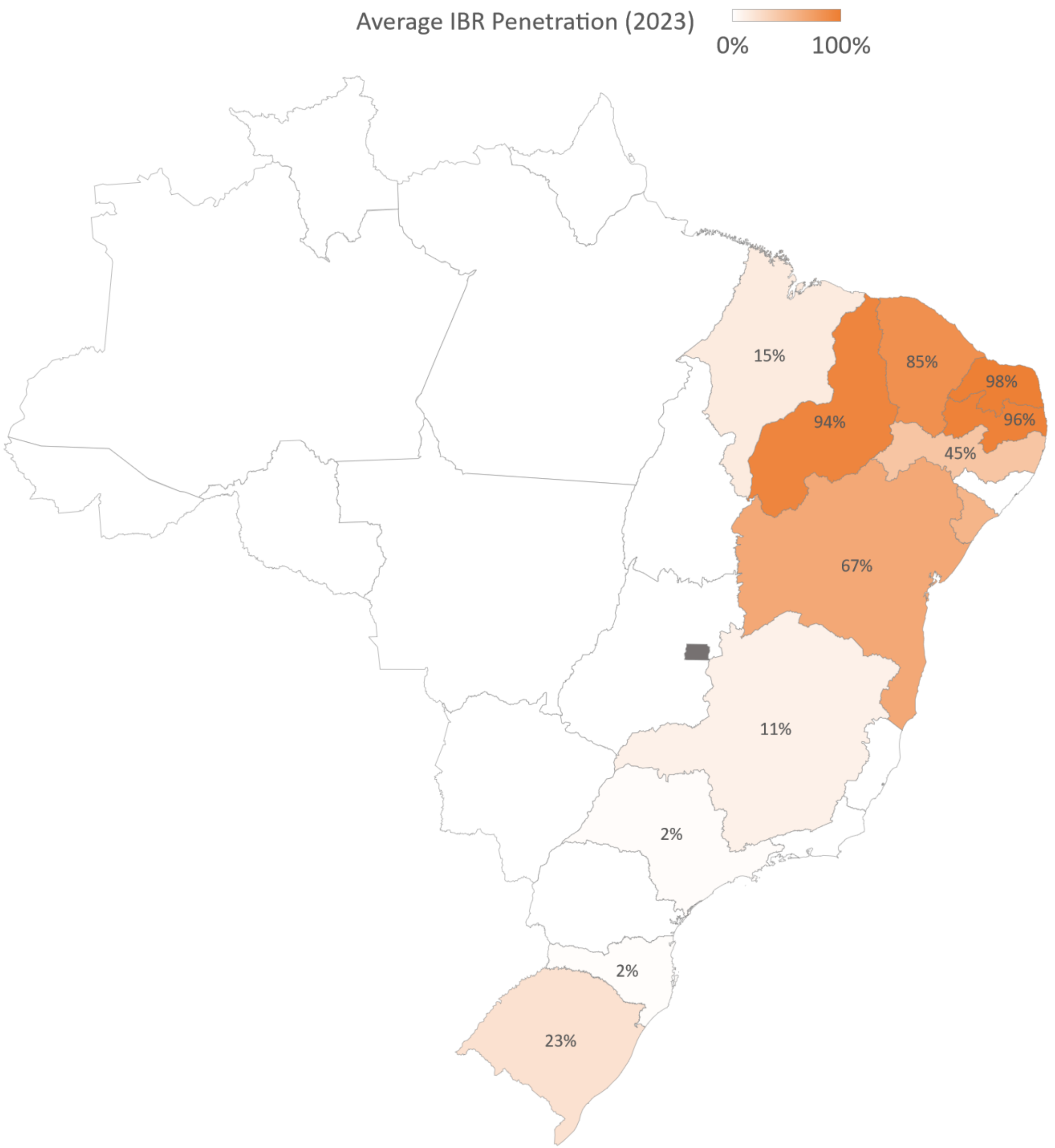


Long-term Objectives

❖ New Studies Focused on High IBR Penetration / Low SCR Areas

Leverage these models for advanced studies in areas with high penetration of IBRs or regions characterized by low Short-Circuit Ratios (SCR). These regions are particularly susceptible to stability issues, such as voltage and frequency oscillations, due to the lower levels of inertia and SCR.

With a comprehensive database of EMT models in place, ONS can conduct focused studies that explore new mitigation strategies, enhance system planning, and ensure more robust integration of IBRs. The ability to simulate complex interactions in these scenarios can provide valuable insights into system behavior, enabling more precise planning and operational decisions.



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Thank you!