



2014 CIGRÉ Session

Workshop on Large Disturbances



System Security – Improvements in Brazil

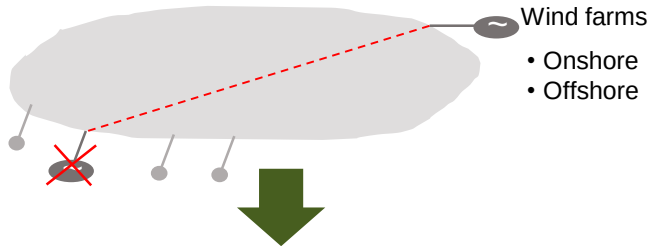
Paulo Gomes – ONS

Paris, August 25th, 2014.

Lessons learnt from Recent Blackouts in Large Interconnections

- No power systems are immune to large blackouts.
- Power systems are usually designed considering the N-1 criterion, but are subjected to low-probability multiple contingencies:
 - Extreme: impacts can be mitigated through P&C actions;
 - Catastrophic: blackout cannot be avoided (straight to restoration).
- Power interconnections are getting larger, more complex and face increasing sustainability demands, all of which impact system security (Cigré Large Disturbances Workshops).
- The new communication protocols ensure higher efficiency and simpler processes at the risk of turning power systems more vulnerable to malicious acts.

Power Systems are Changing: Trends and Consequences

Trends	Consequences
Society claims for green energy (wind, biomass and solar) Increase of environmental constraints/reduction of CO₂ emissions	✓ Replacement of old thermal (oil/coal) and nuclear plants by renewables ✓ Move generation location in relation to load ✓ Difficulties to build transmission facilities and hydro plants, mainly with reservoirs  • Increase of large energy blocks transfers & bottlenecks • Systems are operating closer to their limits • Reduction of power system controllability, affecting reliability and security
Increase of weather adverse conditions (winds, tornadoes, electric discharges and bushfires), malicious acts and cyber attacks	✓ Occurrence of multiple contingencies with the possibility of increasing the number of severe disturbances ✓ Besides technical aspects, blackouts bring social and political pressures
Use of new technologies (HVDC and HVAC links)	✓ System operation becomes more complex
Society claims for a more reliable and secure energy supply	✓ More investments

System reinforcements to prevent blackouts following multiple contingencies are usually not cost-effective, due to their low probability of occurrence. Weather and climate changes were the culprits of some large disturbances, and higher public awareness coupled with the large digital load, contributed to higher social and economical distress, so no wonder large blackouts may nowadays easily develop into minor political crises. Large investments, without careful cost-effective analysis, have been made in the aftermath of large blackouts as a result of the uncomfortable societal pressures.



Minimizing the occurrence of blackouts (Improvements to the Brazilian Grid)

- Existing system installations – Retrofits

- Grid codes and improved designs for new installations

- Higher observability and controllability at control centers

- Operation criteria are now a function of the weather conditions

- Drills and other operator training tools

Improvements already implemented or ongoing

Identification and upgrading of existing strategic installations:

Out of a total of 115 strategic HVSSs, 69 are currently being upgraded

The ongoing HVSSs improvements focus on 4 issues

- ❖ Bus arrangements
- ❖ Protection and Control
- ❖ More Equipment
- ❖ Electromagnetic compatibility

❖ Electromagnetic compatibility

This improvement process will be extended to all the 436 HVSSs of the main grid

ARRANGEMENTS

Bus configuration improvements:

Main Bus and Transfer Bus → Double Bus

Ring Bus → Breaker and a Half

Sectionalized Bus

Additional equipment into Bays:

Circuit Breaker

Switches

EQUIPMENT

Switching Equipment

Reserve Phases Availability

AC-DC Auxiliary Services

Backup Generators

Compressed Air Systems

**PROTECTION
AND CONTROL**

Bus protection – installation or upgrade

SB Full Digitalization

Replacement of obsolete protection and control systems

Update alarm and local supervisory systems

More disturbance recording devices, PMUs included

SIPS - System Integrity Protection Schemes: review/updating

**ELECTROMAGNETIC
COMPATIBILITY**

Insulation coordination - Review

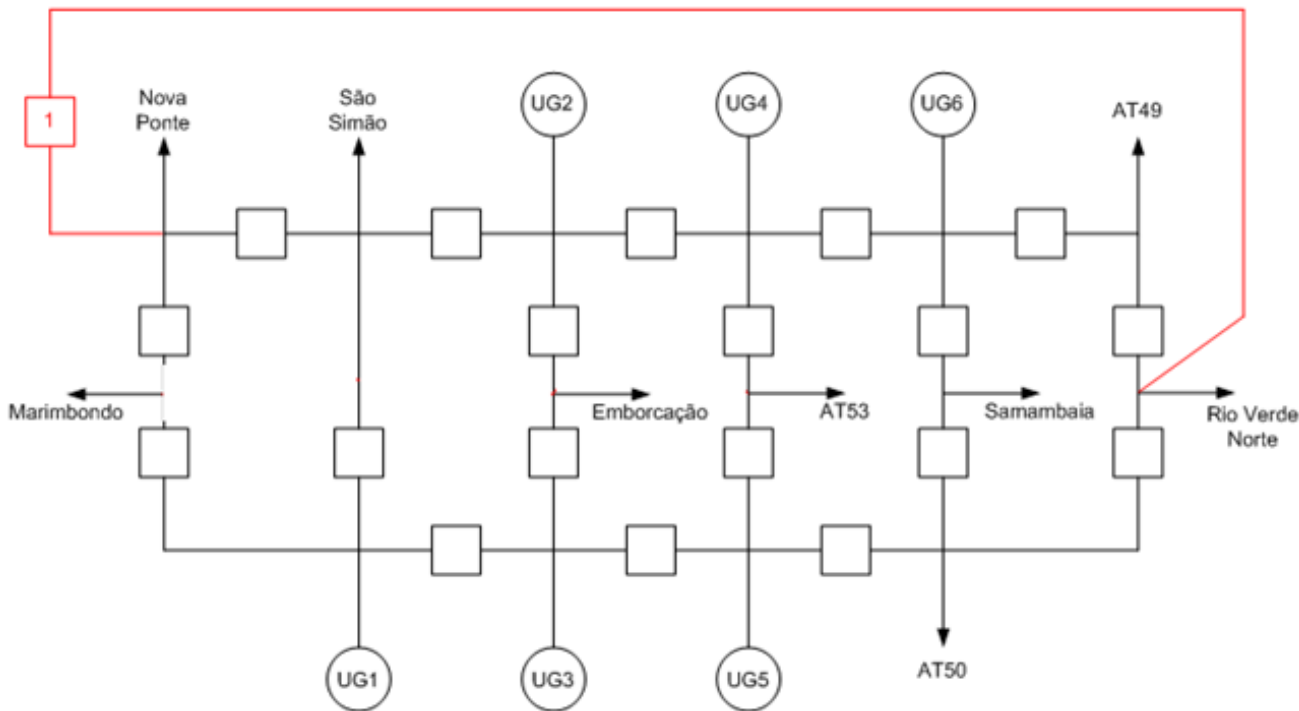
Upgrading the HVSs grounding (due to grid topology changes and increased short circuit levels)

Replacement of control, current and voltage measurement devices (aging or lack of equipment)

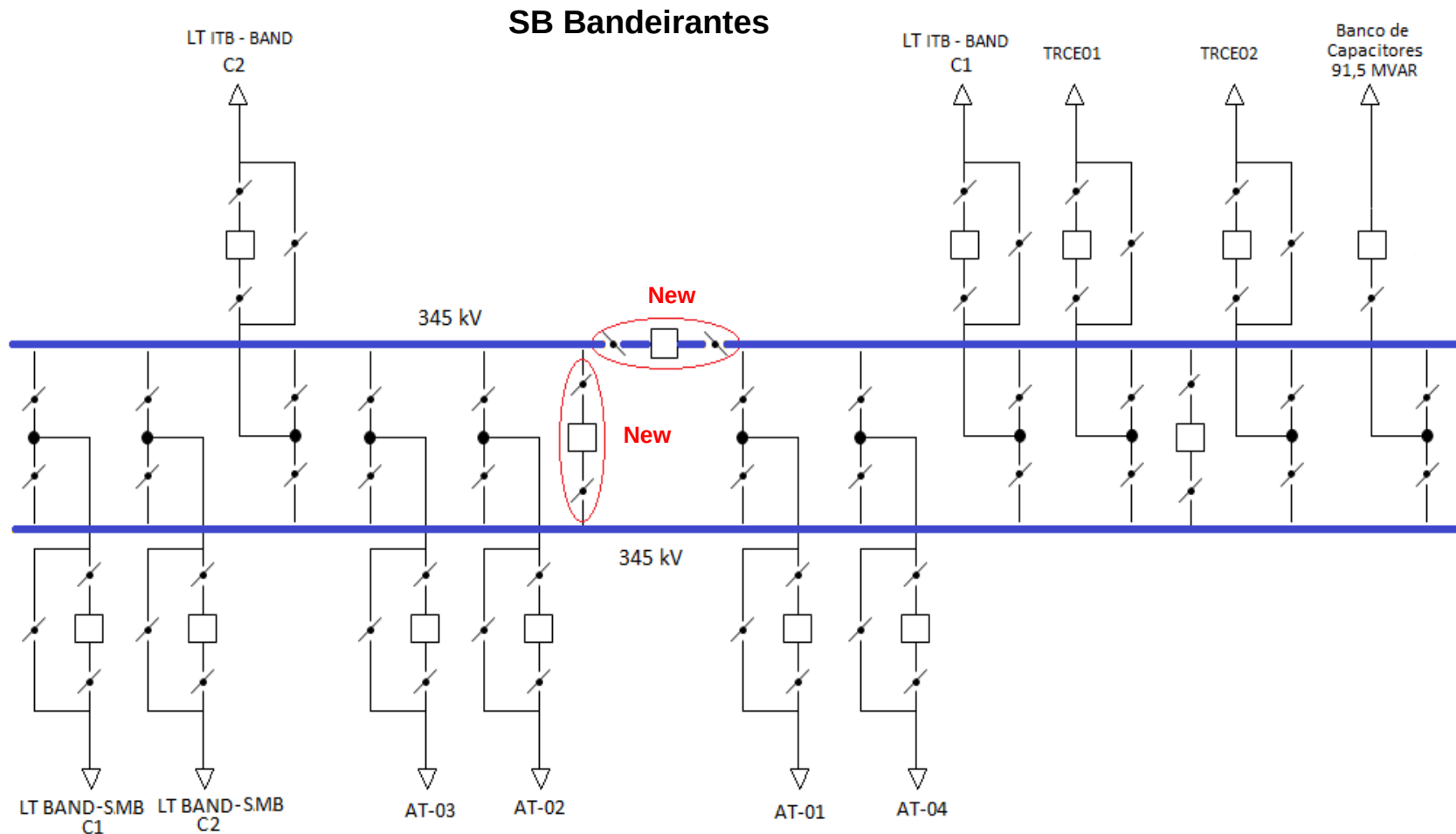
Raising surge protection levels

SB Itumbiara – Avoid System Separation

- 500 kV bus has a modified ring configuration
- Contingencies involving TL S.Simao and the circuit breaker between UG1 and UG3 generating units cause the opening of the 500 kV ring bus, splitting the SE/NE interconnection
- Risk of large load energy blocks disconnections and even blackouts



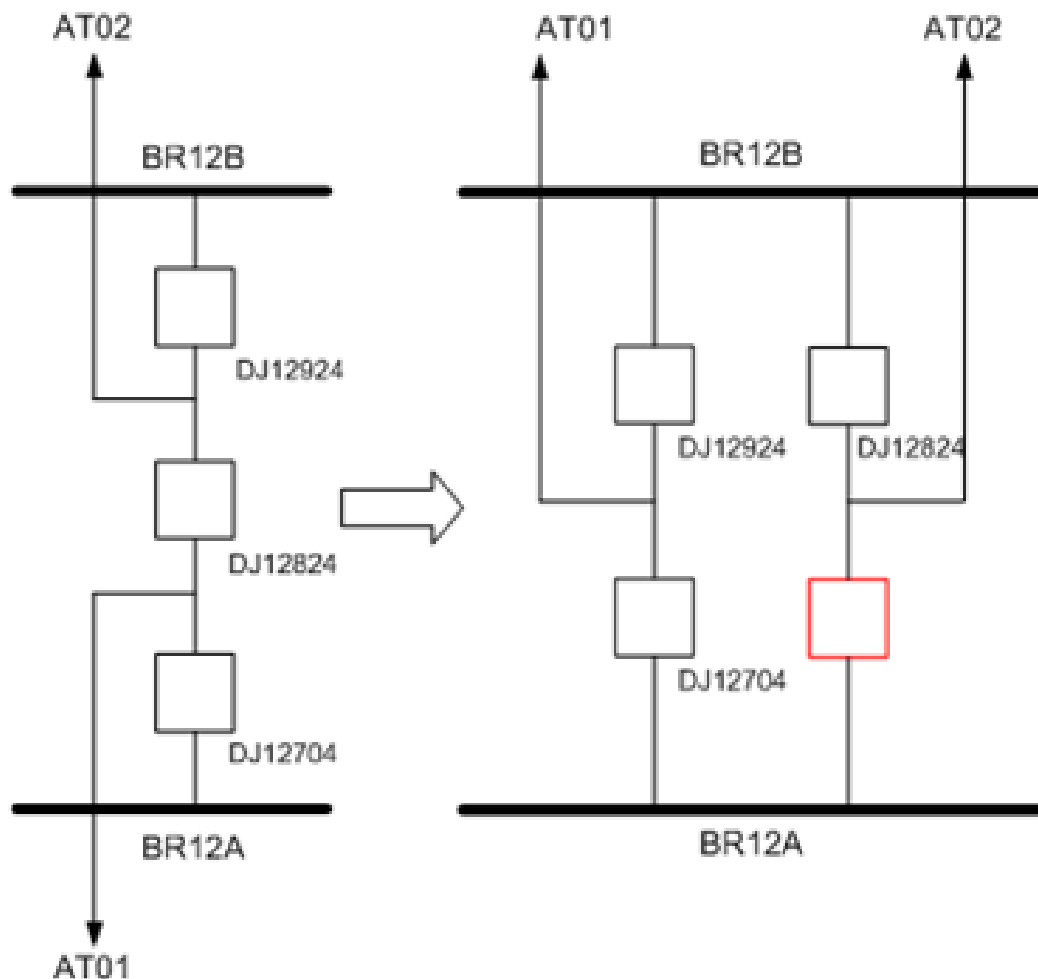
Proposed Solution: avoid openings of the 500 kV ring



For this 345 kV HVS, it was proposed the addition of a split bus breaker plus the installation of a new bay with a circuit breaker interconnector and associated switches.

Tijuco Preto SB – 2X 765/500 kV – 1,500 MVA

Transformers in the same bay



Problem: 2 transformers sharing the same bay - double contingency risk



- Simultaneous loss of the 2 transformers leads to Itaipu SPS incorrect operation, causing:
 - ✓ S/SE interconnection outage
 - ✓ UFLS operation

Proposed Solution:
Only 1 transformer per bay

Reinforcing towers in TL segments crossing critical areas



A Collapsed 765 kV Tower



Measures related to Protection & Control

- New SIPS
- PSS tuning
- Testing TL protection

Out of step protection – used in inter-regional interconnections

Measures related to Control Centers

- Continuously updated operator instructions
- Higher interaction between real time operation and operation planning personnel
- More intensive use of Drills
- Tools for higher observability and controllability at control centers
 - New software: DSA
 - Weather conditions monitoring
 - Monitoring bushfires
- Operate the transmission system below its physical limits

Other preventive measures

- Interact with environmental agencies to ensure continuous cleaning of right-of-ways in order to minimize the occurrence of TL outages caused by vegetation/bushfires;
- Assess, together with security agencies and transmission agents, the feasible alternatives for protecting the crossings of major existing transmission circuits, which are critical to the security of the interconnected energy system;
- Implement agreements involving State Departments of Energy and Transmission Agents with Federal and State Polices to ensure the facilities with high systemic risk are secure from acts of vandalism;
- Promote, in conjunction with State Departments of Energy and Transmission Agents, public awareness campaigns to reduce the occurrence of bushfires in areas that are crossed by main transmission corridors;
- Implement a communication process with communities located near areas considered more critical, so that any strange movement is communicated to the transmission company.

Actions implemented to reduce restoration time

The impact of a blackout increases with the duration of the supply interruption. The actions implemented to reduce the average load restoration time include:

- Increase the number of power plants with black-start capability
- Implement a special testing procedure for black-start devices
- In the case of long transmission systems, install shunt reactors considering restoration (such reactors would not be necessary for steady state operation)
- Keep replacement transmission components distributed in strategically located HVSS along the system
- Adopt trip to house-load operation in thermal and nuclear power plants
- Build dedicated transmission lines to provide cranking power (“blackstart”) for thermal and nuclear power plants from some specific hydro plants
- Detailed studies to determine restoration alternatives to face different system configurations after disturbances
- Resources to enable operators to perform the restoration process
- Operators’ training considering the use of simulators, drills and simulation of real time situations (under pressure)

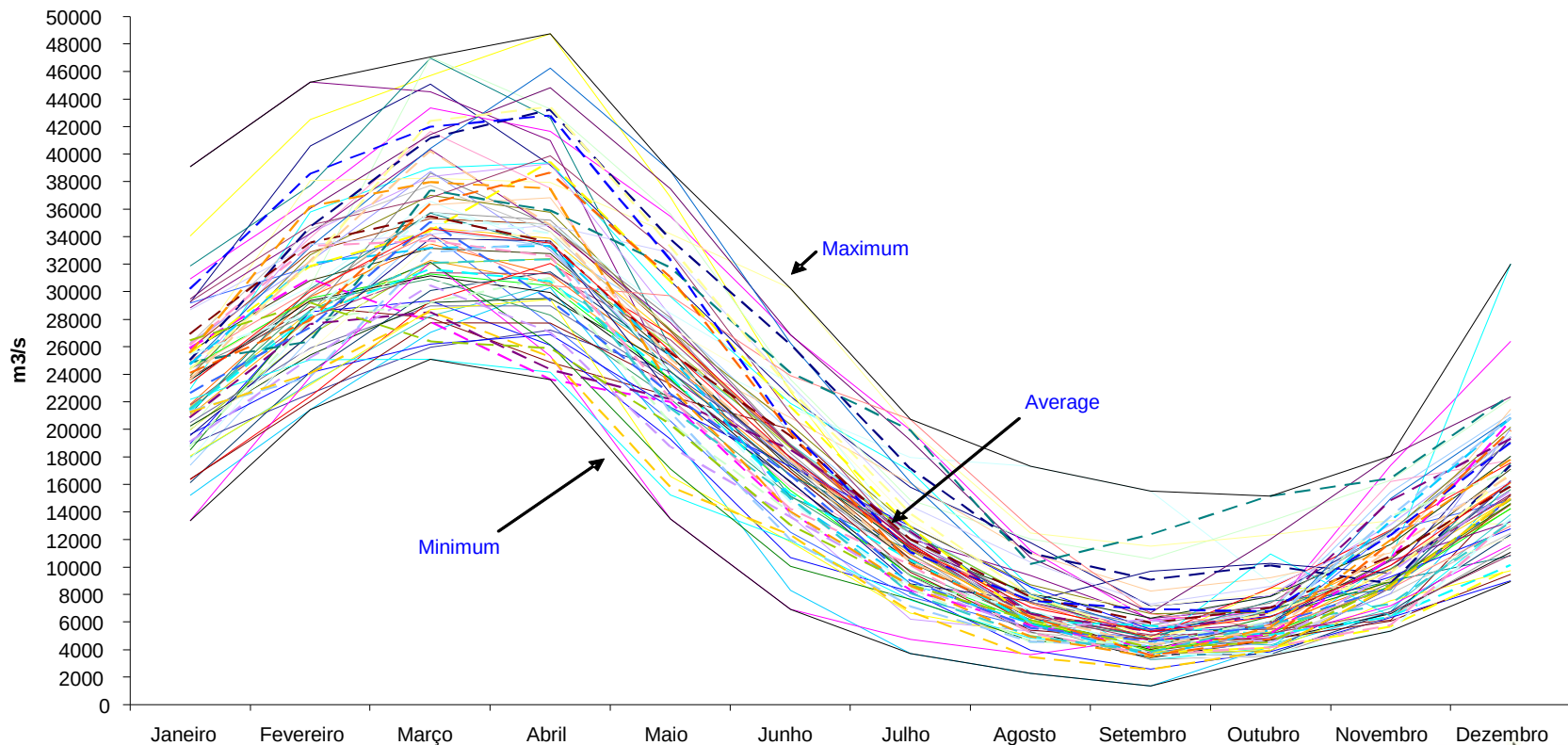
New Scenario - Integration of huge run-of-river plants through long transmission trunks into the BIPS*

*Brazilian Interconnected Power System

Amazon River plants – remotely located from big load centers and requiring very long HVDC and HVAC transmission systems (design based on the N-1 criterion)

The Madeira River hydrogram

Hidrograma de Vazões
UHE Jirau
Período 1931 a 2007



- Potential adverse interactions due to HVDC multi-infeed from “new, large generation sources”;
- Higher probability of transmission systems outages due to:
 - Higher exposure to line failures (TLs are up to 2,500 Km long);
 - Transmission system routes (circuits in the same right of way) crossing areas having adverse weather conditions / bellicose indians / high keraunic levels;
 - Cables lie above the preserved jungle. “No right of way corridors”;
 - Increased repair time in case of permanent TL problems;
 - Large flooded areas during the Amazonian wet season;
- Large seasonal changes in power transfer levels through the new corridors due to run-of-the-river operation;
- Multiple owners sharing transmission installations;
- Difficulties in controlling voltage profile and ensuring minimum short circuit levels at receiving end areas.

- Ensure minimum short-circuit levels at the receiving-end area and voltage profile control during disturbances, to minimize the risk of HVDC bipoles commutation failures;
- Increase power system security by deploying online computational tools to ensure that stability limits are not violated during operation;
- Conduct detailed studies for the overall optimization of the HVDC link controllers;
- Better interaction between expansion and operation planning personnel during the project design of new large projects of generation and transmission;
- Provide control centers with new resources and technologies to allow the detection of online power system security level (situational awareness);
- Implementation of WAMS, now, and WACS, in the future – effective use of PMUs;
- New restoration process considering power system evolution and specific resources such as PMUs, new Black-Start devices, higher automation levels, and local and remote feedback controls to achieve better frequency control of islanded areas and dynamic voltage profile control along the restoration corridors.

**Thank you for your
attention!**

Questions?

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