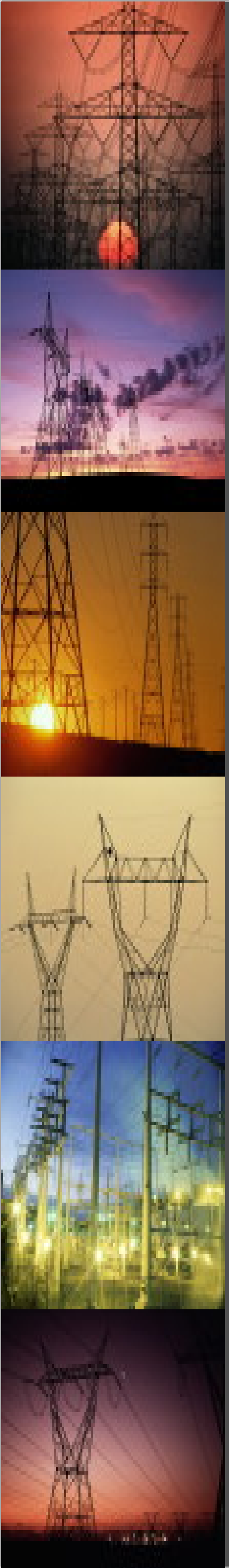

Operador Nacional do Sistema Elétrico

Brazilian Strategies for Blackout Prevention

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Huntington Beach - CA
February, 2013

A little bit of geography

A little bit of geography

Where is ONS?

Northeast Control Center
Location: Recife

National Control Center
And North-Midwest Control Center
Location: Brasília

Southeast Control Center
(and backup to National)
Location: Rio de Janeiro

South Control Center
Location: Florianópolis

The National Interconnected System (NIPS)

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765 kV

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765 kV
± 600 kV

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500 kV

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765 kV

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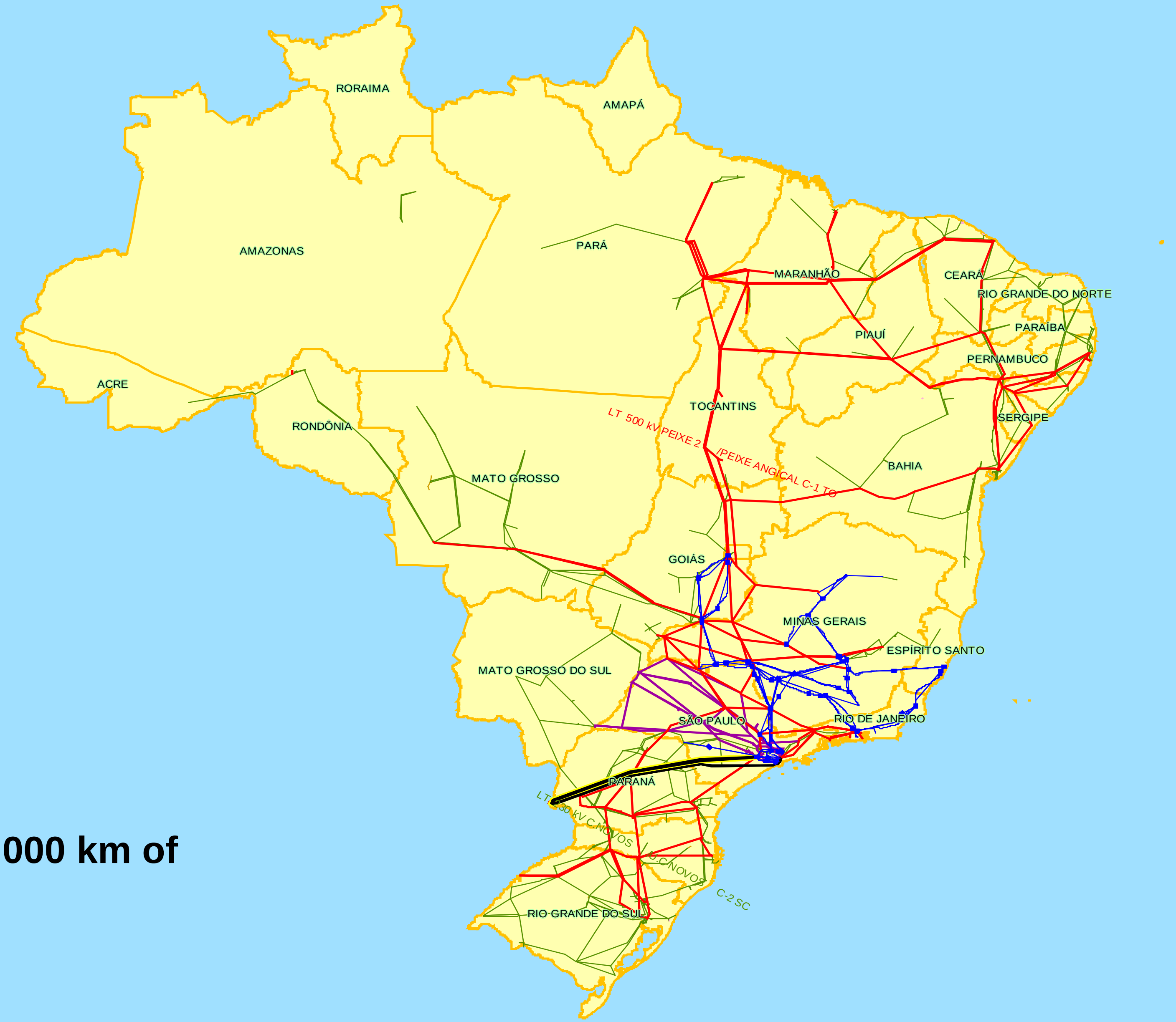
500 kV

440 kV

The National Interconnected System (NIPS)

765 kV
± 600 kV
500 kV
440 kV
345 kV

The National Interconnected System (NIPS)



765 kV
± 600 kV
500 kV
440 kV
345 kV
230 kV

Approximately 100,000 km of transmission lines

The National Interconnected System (NIPS)

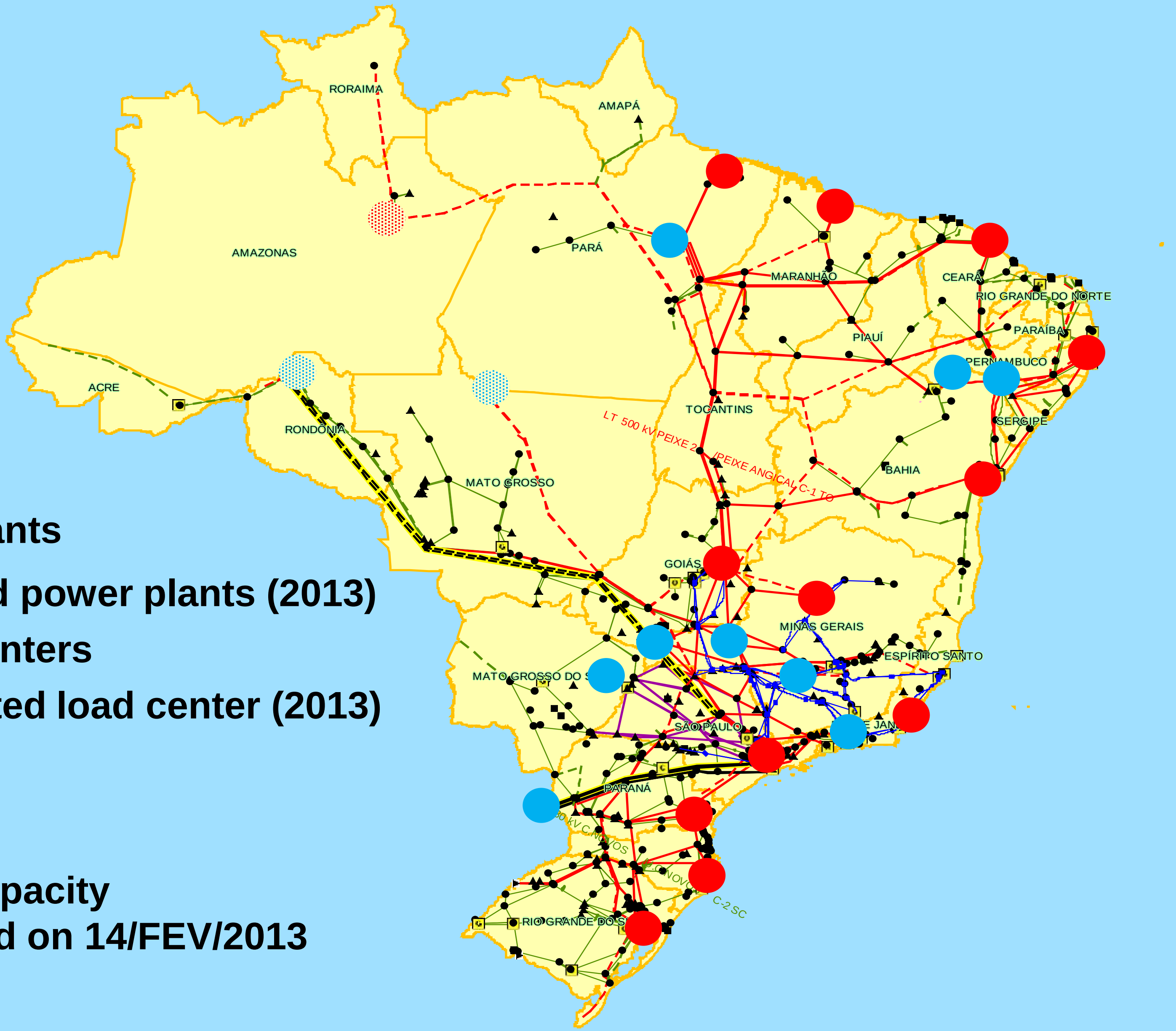
700 Substations

~ 200 Power Plants (≥ 30 MW)

85% of Hydroelectrics

System Expansion

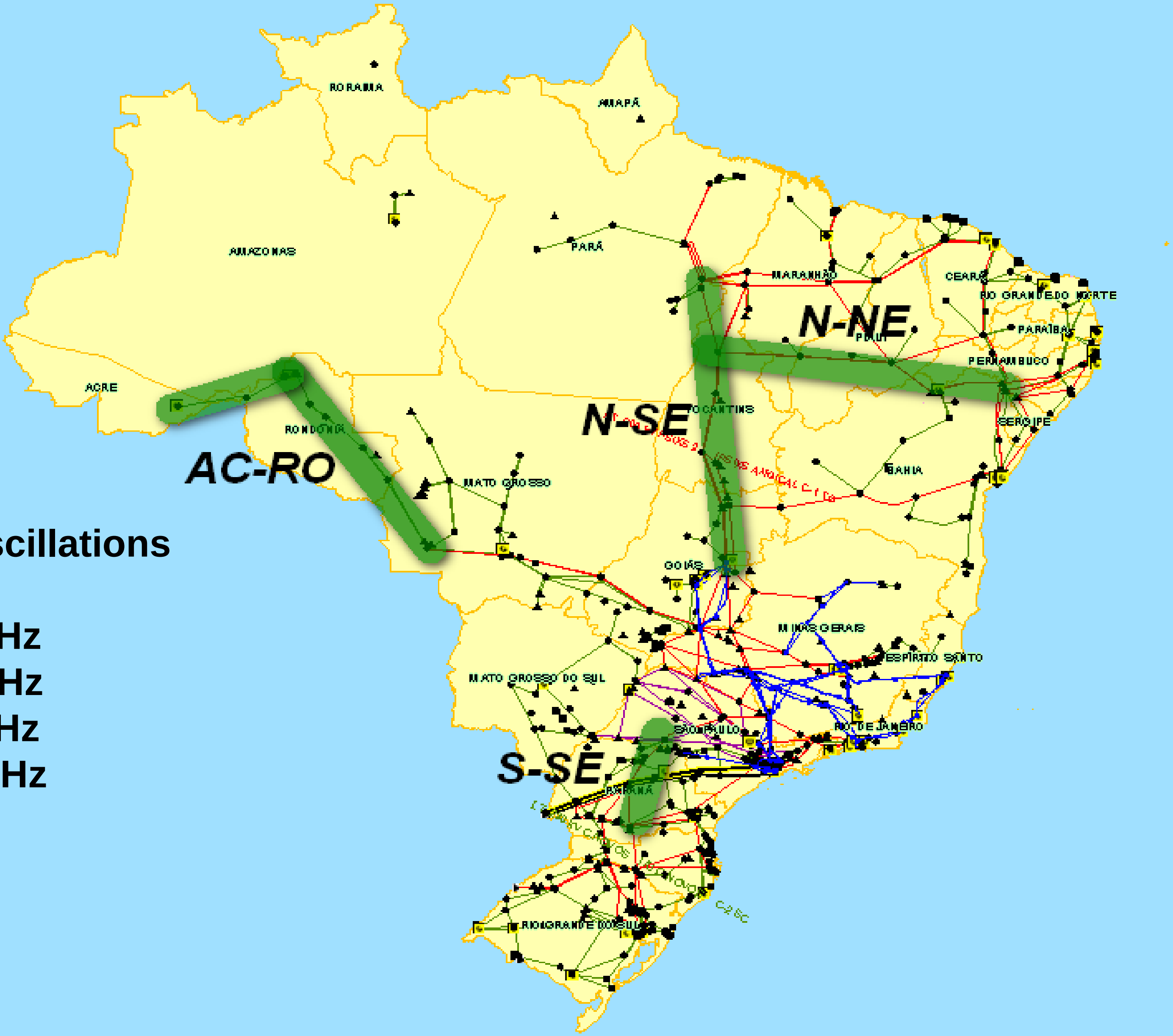
The National Interconnected System (NIPS)



- Biggest power plants
- Important planned power plants (2013)
- Important load centers
- New interconnected load center (2013)

115 GW installed capacity
72 GW peak demand on 14/FEV/2013 (10:35 pm)

The National Interconnected System (NIPS)



Inter-area natural oscillations

N-SE	0.35 Hz
N-NE	0.45 Hz
S-SE	0.65 Hz
AC/RO - NIPS	0.35 Hz

- Under frequency load shedding
  - ✓ S, SE, MW and AC/RO:

Step	Frequency (Hz)	Region			Max Delay (seconds)
		S (% of load)	SE and MW (% of load)	AC-RO (% of load)	
1st	58.5	7.5	7	15	0.35
2nd	58.2	7.5	7	10	0.35
3rd	57.9	10	7	10	0.35
4th	57.7	10	7	10	0.35
5th	57.5	10	7	10	0.35

Strategies for blackout prevention

- Under frequency load shedding
  - ✓ N and NE:

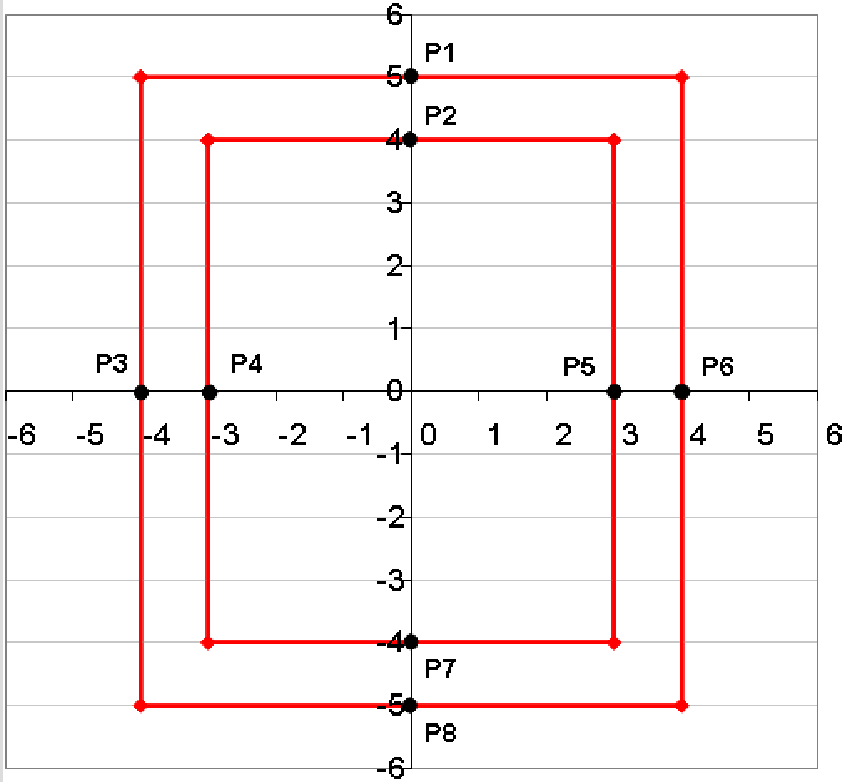
Step	Rate(Hz/s)	Load (%)	Backup (Hz)
1st	0.7	6	57.3
2nd	1.1	7	57.2
3rd	1.5	11	57.1
4th	1.7	8	56.8
5th	1.9	8	56.5

- SIPS
  - ✓ Existence of SIPS for every interconnection
    - AC/RO - NIPS: Out-of-step tripping (OOS)
    - S-SE: OOS and generation shedding
    - N-SE: OOS and generation shedding
    - N-NE: OOS and load shedding

Strategies for blackout prevention

- Use of Out-of-step tripping
  - ✓ Adopted philosophy: Trip on characteristic entrance
  - ✓ Reason: Loss of transitory stability
  - ✓ Advantages: Split the system in 2 stable islands. This is only achieved if the system separation occurs in less than 500 ms after the loss of synchronism.

- Protection characteristics



LT 500 kV Miracema/Colinas C1 e C3, em Miracema

LT 500 kV Gurupi/Miracema C1 e C3, em Gurupi

LT 500 kV S. Mesa/Gurupi C1, em Serra da Mesa

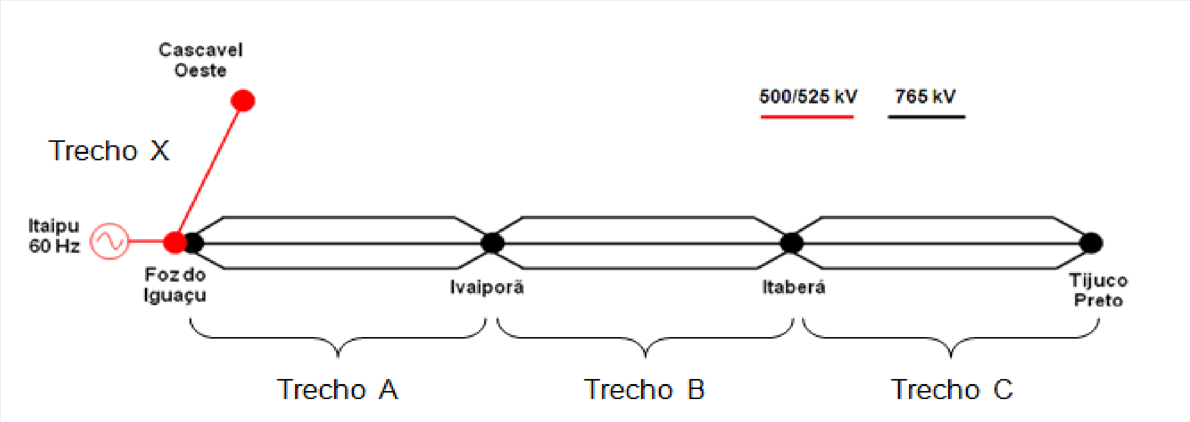
LT 500 kV S. Mesa 2/Peixe 2, em Serra da Mesa 2

- Tempo de discriminação (25 ms)

- Valores em %, na base 100 MVA - 500 kV

Strategies for blackout prevention

S-SE Interconnection



Segments		Number of circuits involved (based on unavailability/contigency)			
		LT 765 kV Foz – Ivaiporã	LT 765 kV Ivaiporã – Itaberá	LT 765 kV Itaberá – Tij.Preto	LT 525 kV Foz – Cascavel
Trecho A	X	–	–	–	1
	AX	1	–	–	1
	A2	2	–	–	–
	A2X	2	–	–	1
	A3	3	–	–	–
	A3X	3	–	–	1
	ABC	1	1	1	–
Trecho B	B2	–	2	–	–
	B3	–	3	–	–
Trecho C	C2	–	–	2	–
	C3	–	–	3	–

10/FEV/2010 N-NE Blackout

NIPS load → 67401 MW
N/SE Flow → 2484 MW
N/NE Flow → 1949 MW

1) Loss of part of N – NE interconnection

2) OOS separated NE from the rest of NIPS

3) OOS separated N from the rest of NIPS

4) Underfrequency scheme shed 2696 MW from NE (30% of total) balancing the generation/load at the island

5) SIPS dropped 4 (out of 23) generation units from Tucurui Power Station (North)

Everything happened in less than 2.5 seconds

S and SE were not affected !

So here comes the question

- Based on what we have seen, would PMUs help to minimize this disturbance consequences?

Maybe so, maybe not

Planned use of PMUs

- Based on previous experience, ONS intends to firstly deploy a synchrophasor measurement system in order to observe system oscillations and to improve its strategies for out-of-step tripping
- PMUs inherently measure angles, but angle differences have not been widely deployed yet for control and protection purposes
- Angle differences have strong relation with the impedance variation between the main power sources during disturbances caused by topology changes - loss of transmission lines

Planned PMU locations