



Furnas

**The FURNAS experience
at Real Time Digital Simulation
after 20 years of RTDS Simulator
Commissioning**

FURNAS Centrais Eletricas S.A.

- **Mix private/state-owned company established on February 28, 1957**
- **65 Substations (120.000MVA - transformation capacity)**
- **17 hydroelectric power plants, 2 conventional thermal power plants and 3 Wind farms (16.000 MW)**
- **24.000 km of transmission lines**
- **40% of Brazil energy pass through FURNAS system**

ITAIPU transmission system:

765kV

- 4 substations
- 3 circuits
- 800 km

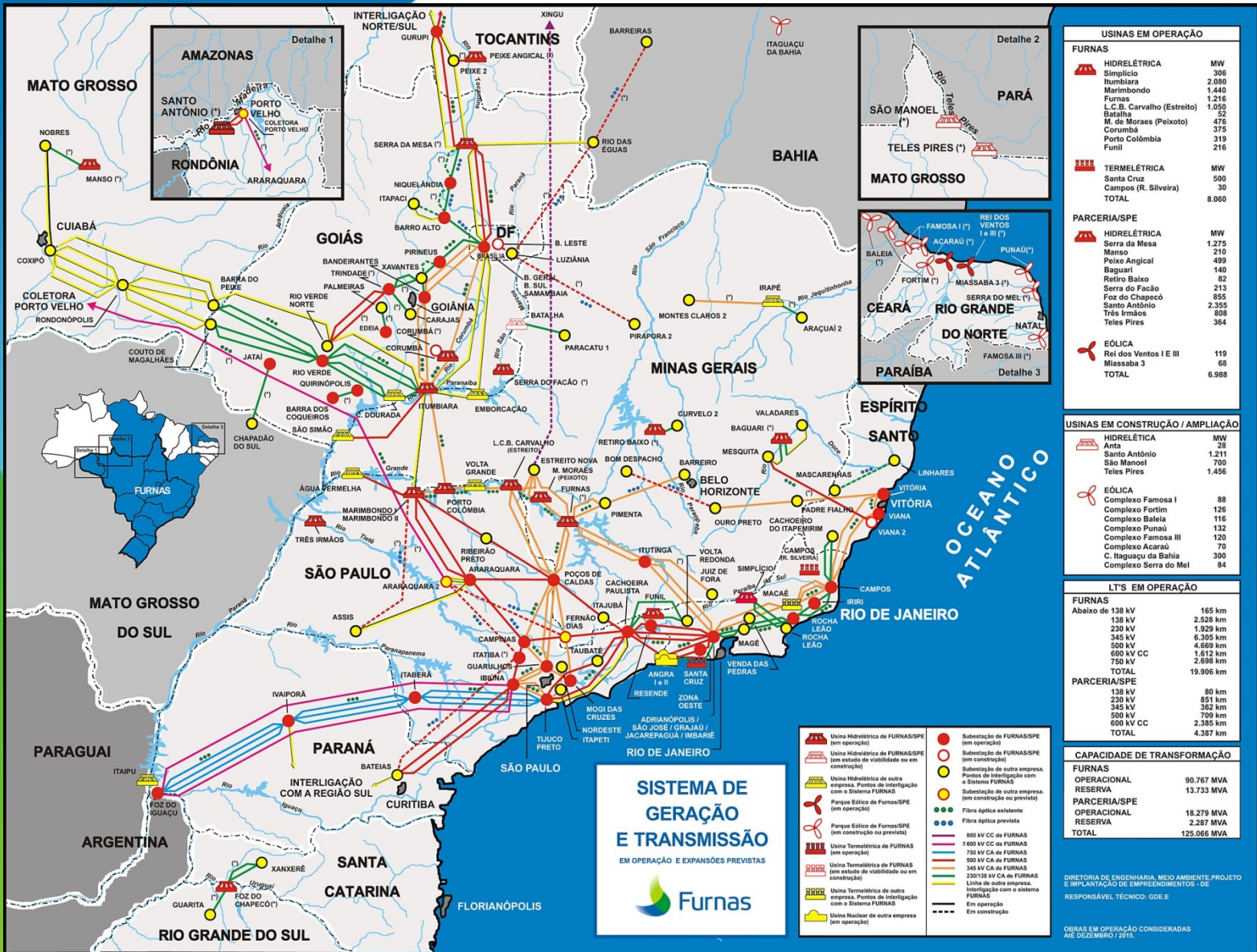
HVDC system

- +/- 600kV
- 2 Bipoles (2 converters per pole)
- 6300MW
 - 800km

FURNAS Centrais Eletricas S.A.

Examples of partnership:

- UHE Santo Antonio (Rio Madeira) – 3150 MW
- Rio Madeira Transmission system:
Bipole 2 of the HVDC link (+/- 600kV, 3150 MW, 2400km)
- Belo Monte Transmission system :
Bipole 1 of the HVDC link (+/- 800kV, 4000MW, 2000km)



SISTEMA DE GERAÇÃO E TRANSMISSÃO

EM OPERAÇÃO E EXPANSÕES PREVISTAS

USINAS EM OPERAÇÃO	
FURNAS	
HIDRELÉTRICA	MW
Simpleício	306
Iumbiara	2.080
Marimbondo	1.440
Furnas	1.216
L.C.B. Carvalho (Estreito)	1.050
Batalha	52
M. de Moraes (Peixoto)	476
Corumbá	375
Porto Colômbia	319
Funil	216
TERMELETRICA	MW
Santa Cruz	500
Campos (R. Silveira)	30
TOTAL	8.060
PARCERIA/SPE	
HIDRELÉTRICA	MW
Serra da Mesa	1.275
Manso	210
Peixe Angical	409
Baguari	140
Retiro Baixo	82
Serra do Fação	213
Foz do Chapeço	855
Santo Antônio	2.355
Três Irmãos	808
Teles Pires	364
EÓLICA	MW
Rei dos Ventos I e III	119
Missaba 3	68
TOTAL	6.988

USINAS EM CONSTRUÇÃO / AMPLIAÇÃO	
HIDRELÉTRICA	
Anta	MW
Santo Antônio	1.211
São Manoel	700
Teles Pires	1.456
EÓLICA	MW
Complexo Famosa I	88
Complexo Fortim	126
Complexo Batalha	116
Complexo Punaó	132
Complexo Famosa III	120
Complexo Acaraú	70
C. Itaguacu da Bahia	300
Complexo Serra do Mel	84

LT'S EM OPERAÇÃO	
FURNAS	
Abaixo de 138 kV	165 km
138 kV	2.528 km
230 kV	1.929 km
345 kV	6.305 km
500 kV	4.669 km
600 kV CC	1.612 km
750 kV	2.698 km
TOTAL	19.906 km
PARCERIA/SPE	
138 kV	80 km
230 kV	851 km
345 kV	362 km
500 kV	709 km
600 kV CC	2.385 km
TOTAL	4.387 km

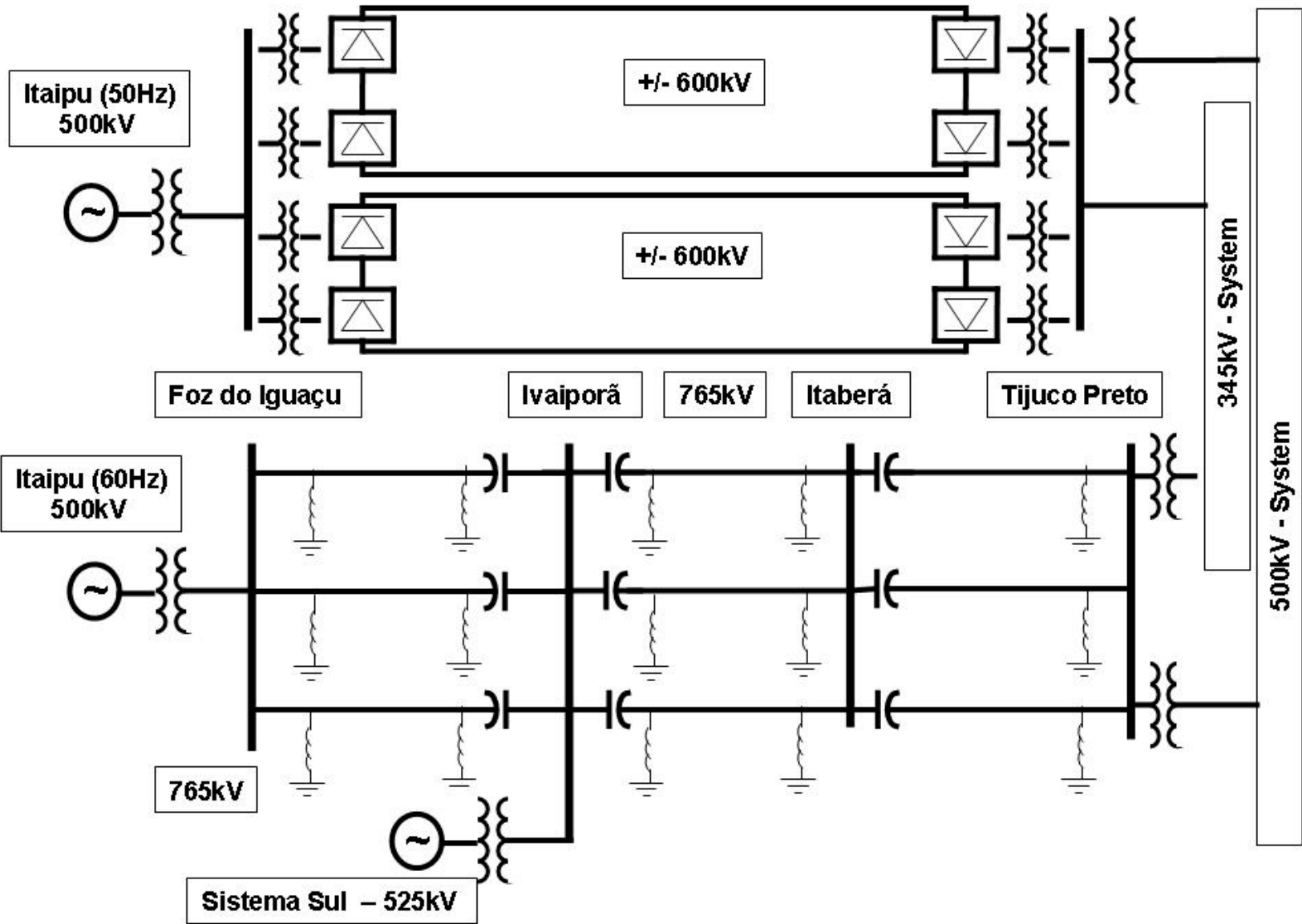
CAPACIDADE DE TRANSFORMAÇÃO	
FURNAS	
OPERACIONAL	90.767 MVA
RESERVA	13.733 MVA
PARCERIA/SPE	
OPERACIONAL	18.279 MVA
RESERVA	2.287 MVA
TOTAL	125.066 MVA

DIRETORIA DE ENGENHARIA, MEIO AMBIENTE, PROSTO E IMPLANTACÃO DE EMPREENDIMENTOS - DE
RESPONSÁVEL TÉCNICO: GDE E

OBRAS EM OPERAÇÃO CONSIDERADAS
A 01 DE DEZEMBRO DE 2015.

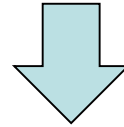


Furnas

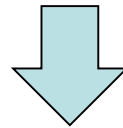


First Contact with Real Time Simulation:

TNA (scale down model of the FURNAS HVDC sytem) conected to real controls



FURNAS has considered the simulator an important tool for support the operation



Latter on FURNAS has realized that the AC representation at the inverter bus should be enhanced



FURNAS

FURNAS

FURNAS



RTDS™
Real-Time Digital Simulator



RTDS™
Real-Time Digital Simulator



RTDS™
Real-Time Digital Simulator



HVDC Studies Supporting System Operation

Hardware & Software Tests:

- Digitalization of Analog functions
- Redundancy scheme for the CCA (Current Control Amplifier)
- New Software versions

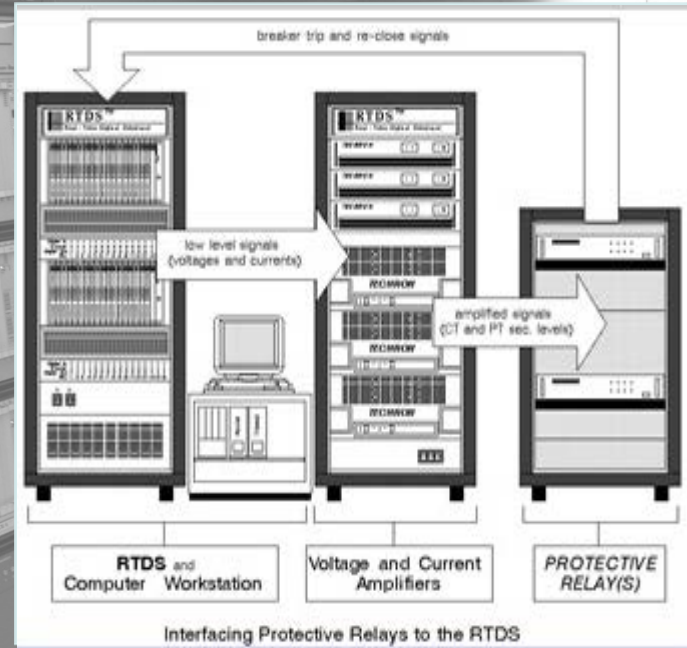
System Performance:

- Event modeling and analysis
- Comutation failure evaluation
- Paraguai 500kV system analysis

Protection System Testing

Real Time Tests:

- Outage Analysis
- Pre and Post FAT Real Time Tests
- New Setup evaluation
- Outsourcing testing (FURNAS hired to perform Real Time Test)
- Protection compatibility and Firmware upgrade analysis



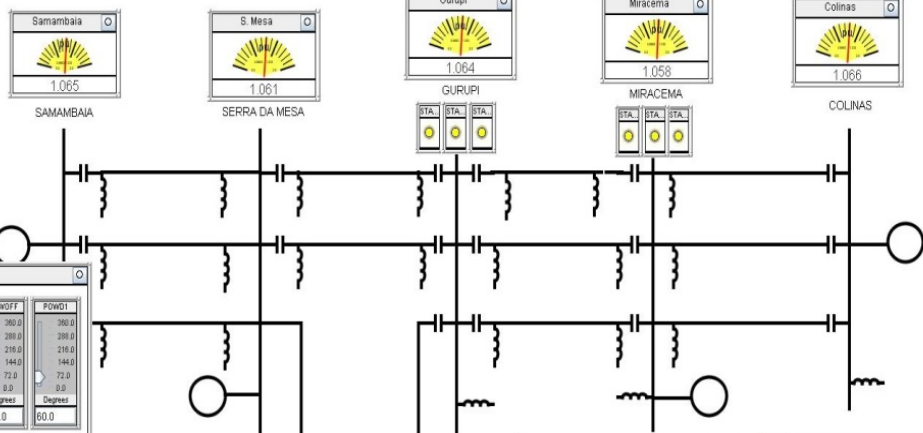
Draft file: C:\RTDS_USER\fileman2011_Norte_Sul\Norte_Sul_2011_GUMI.dft

Forças: Bypass_Cap: Subsystem:

Distâncias: Mic:

RESET: 1

START: 0



Temporização

Frequência	FtTime1	FtDur	POW0F	POW0I
95.01	10.0	10.0	360.0	360.0
76.01	6.0	6.0	200.0	200.0
57.01	6.0	6.0	210.0	210.0
38.01	4.0	4.0	144.0	144.0
19.01	2.0	2.0	72.0	72.0
9.01	0.8	0.8	28.8	28.8
0.0	0.0	0.0	0.0	0.0
60.0	0.1	0.3	328.0	60.0

ExtTime: 10.0

ExtDur: 0.0

ExtTime: 0.0

ExtDur: 0.0

ExtTime: 4.0

ExtDur: 2.0

ExtTime: 0.03

ExtTime: 10.0

ExtDur: 10.0

ExtTime: 0.0

ExtDur: 0.0

ExtTime: 4.0

ExtDur: 2.0

ExtTime: 0.03

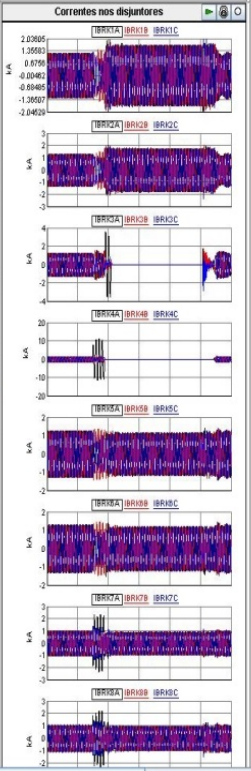
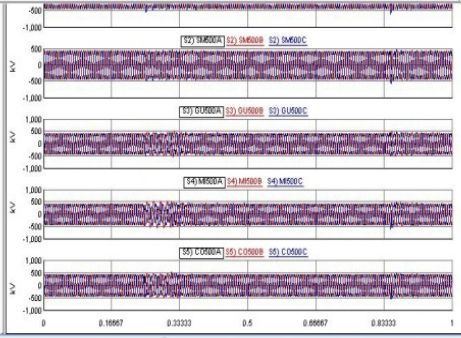
Falhas

AFB	BFB	CFB	ABFB	BCFB	CAFB	F1a	F1b
0	0	0	0	1	0	0	0

AFB	BFB	CFB	ABFB	BCFB	CAFB	F2a	F2b
0	0	0	0	0	0	0	0

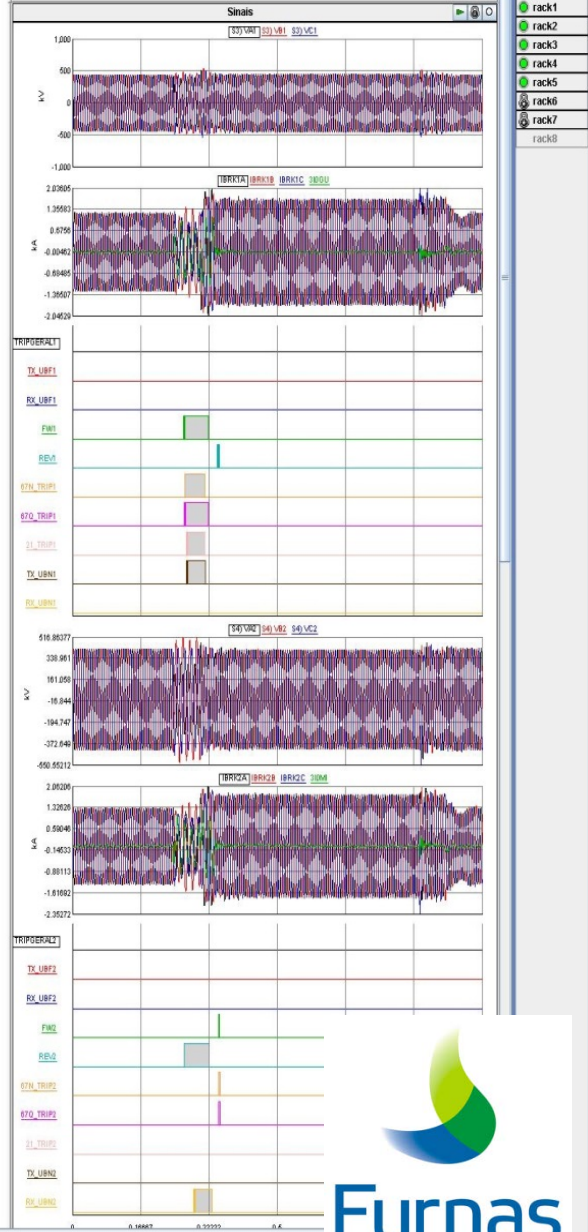
FNS

SMG01P	SMG01Q
-822.2	43.42
SMG02P	SMG02Q
-809.7	41.01
SMP0P	SMP0Q
-1102.0	-151.2

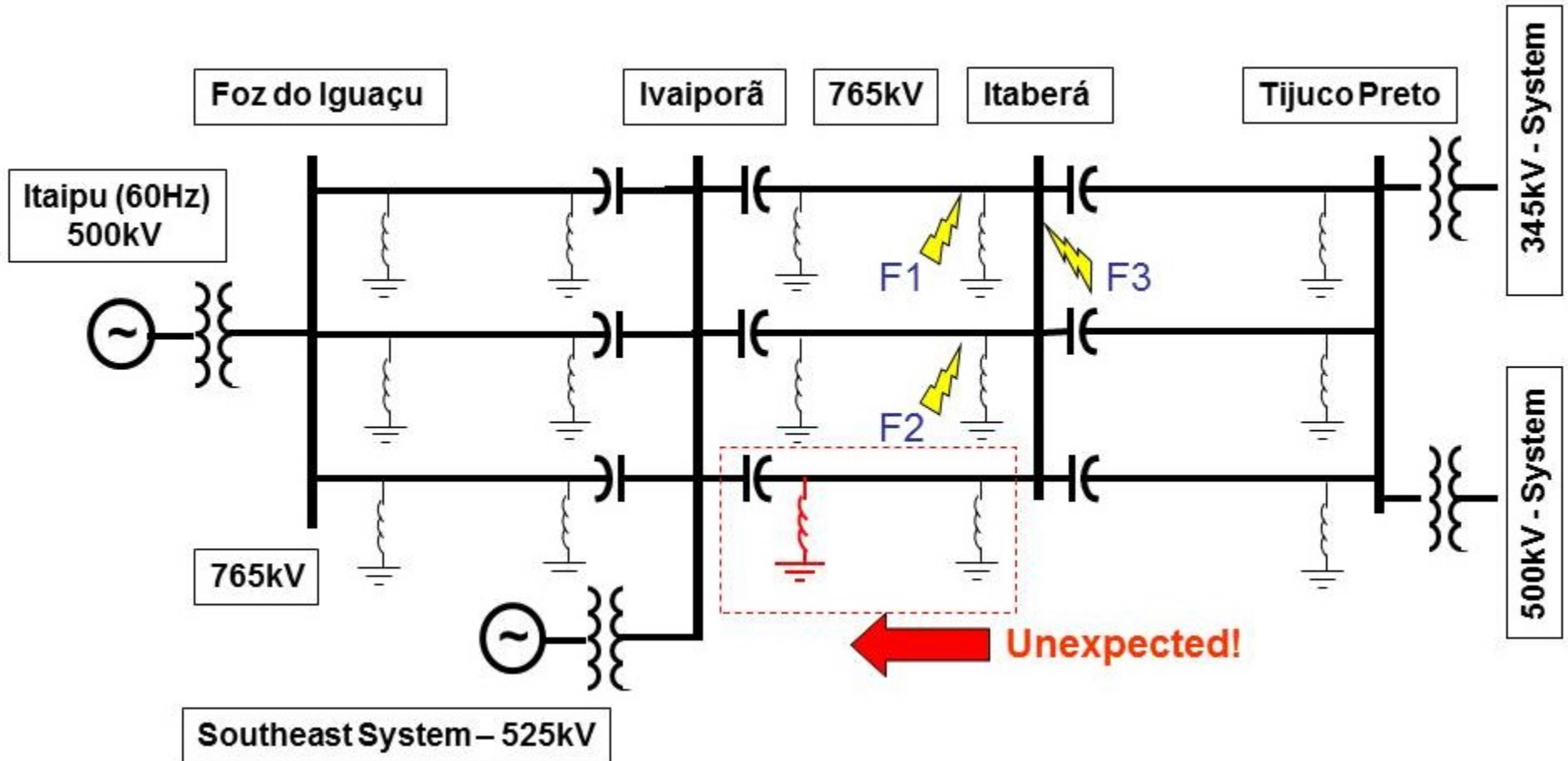


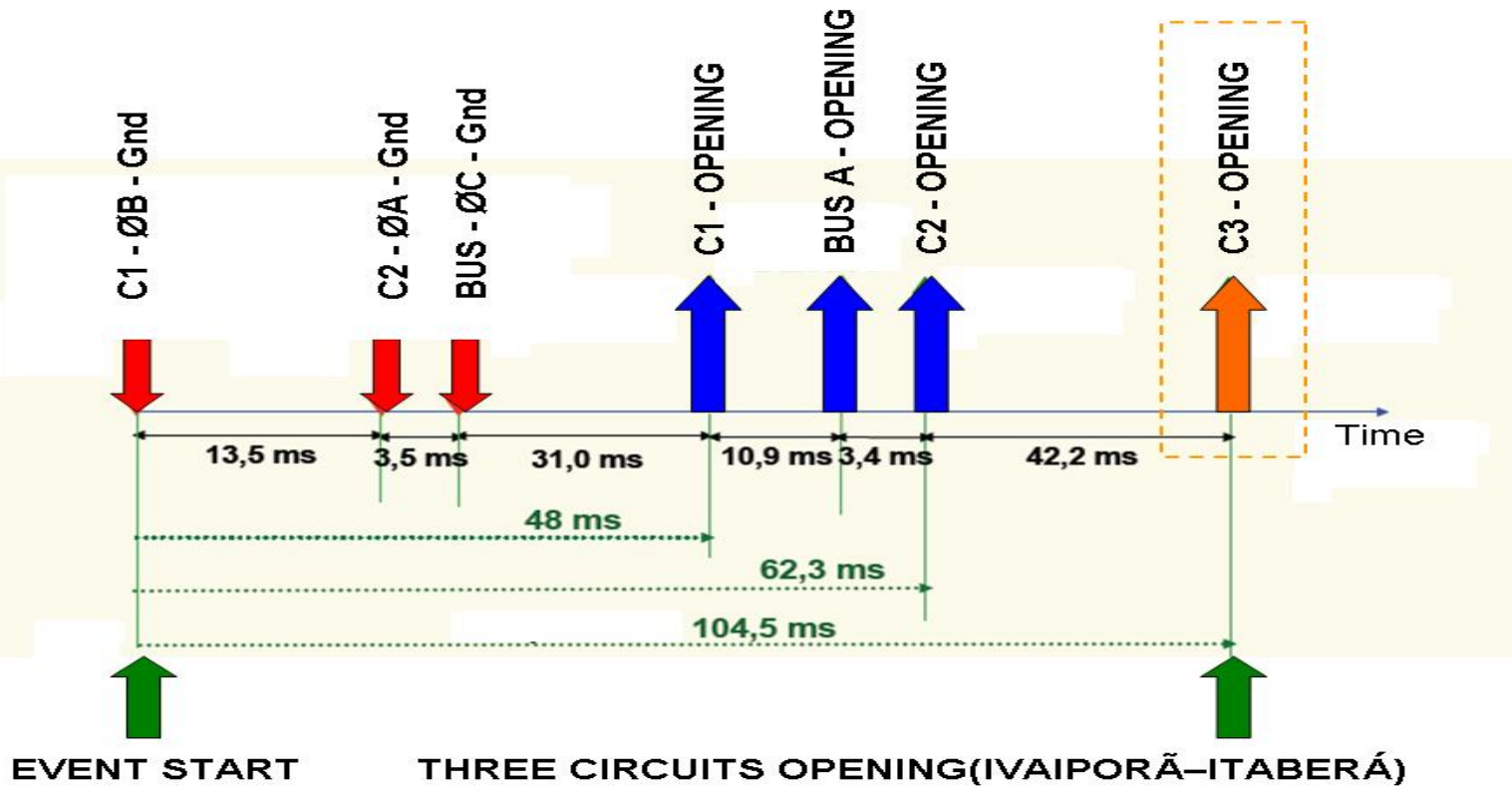
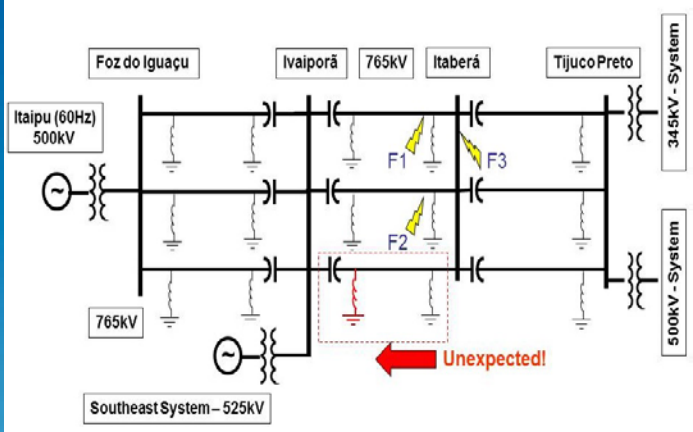
Controle Bypass Capacitores Serie

C00001	C00002	C00003	C00004	C00005	C00006	C00007	C00008	C00009	C00010
0	0	0	0	0	0	0	0	0	0



765kV Outage Analysis:





Power Outage:

- **765kV: 5.564 MW**
- **HVDC System: 5.329 MW (Blocking of 2 Bipoles)**
- **Total Power outage: 24.400MW**
(40% of the Brazilian Transmission System)

Reactor C3 currents (COMTRADE File)

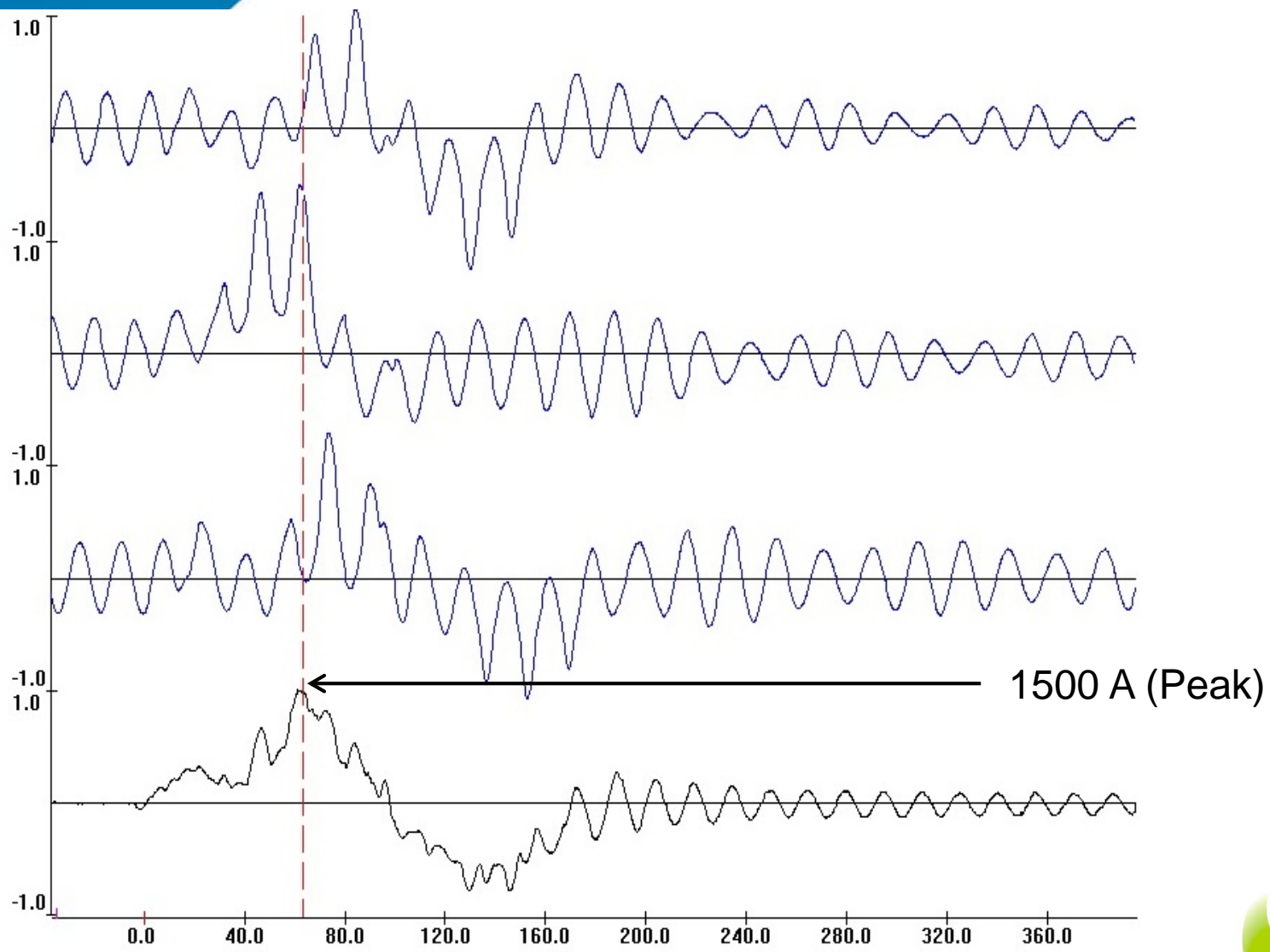
Cx012 Cv012
RT IA IV3 IA
Fs:A Ud:A
Pr:800.00 Se: 5.00
Vnst: 196.3
Vrms: 475.6
Md:Norm. Int:Linear
Int.Usada: LINEAR

Cx013 Cv013
RT IA IV3 IB
Fs:B Ud:A
Pr:800.00 Se: 5.00
Vnst:1594.1
Vrms:1037.9
Md:Norm. Int:Linear
Int.Usada: LINEAR

Cx014 Cv014
RT IA IV3 IC
Fs:C Ud:A
Pr:800.00 Se: 5.00
Vnst: -9.6
Vrms: 461.4
Md:Norm. Int:Linear
Int.Usada: LINEAR

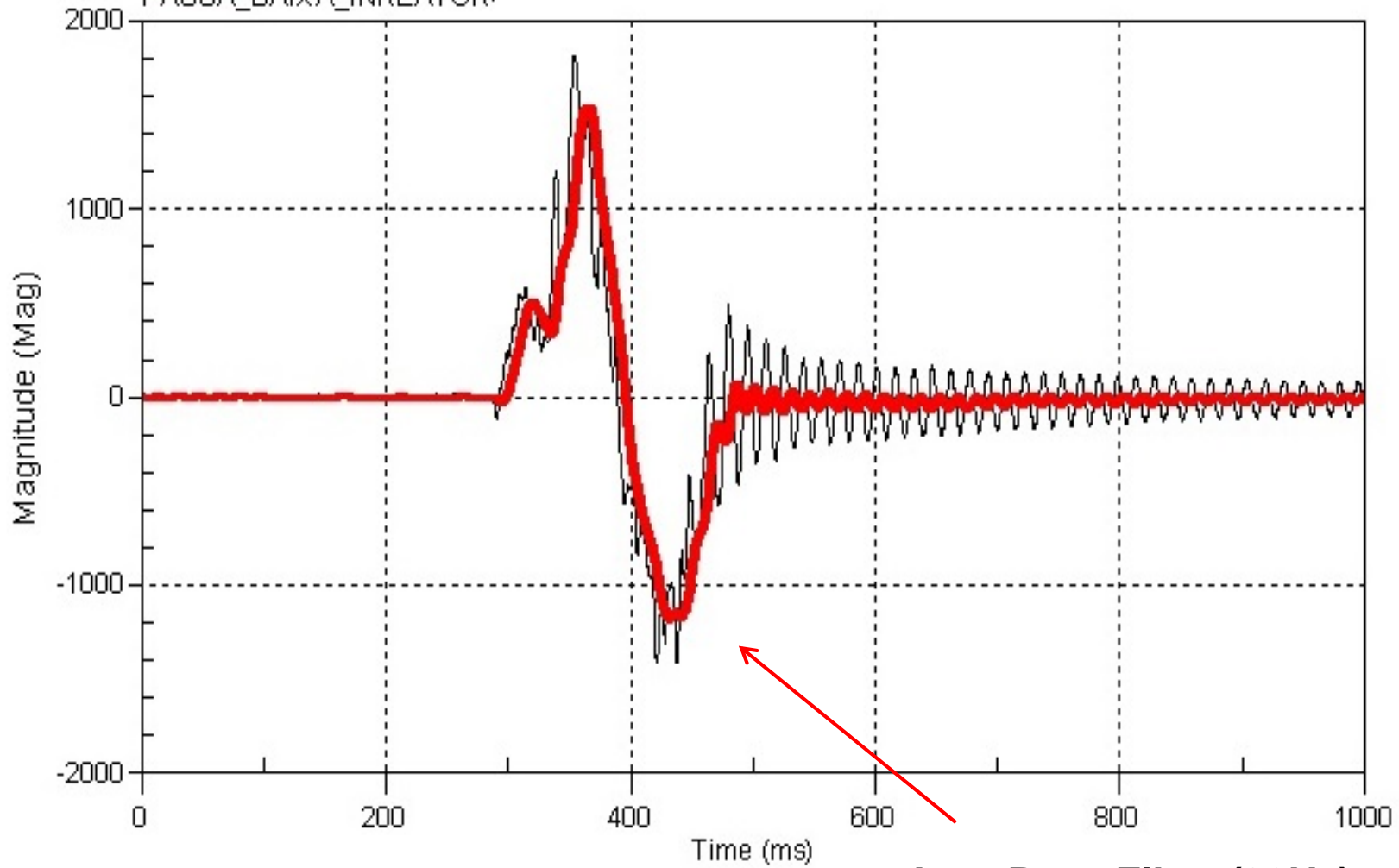
Cx015 Cv033
Soma de 3 canais
Fs:A Ud:A
Pr: 1.00 Se: 1.00
Vnst:1781.1
Vrms:1506.8
Md:Norm. Int:Linear
Int.Usada: LINEAR

Br1:63.990 ms



INREATOR:

PASSA_BAIXA_INREATOR:



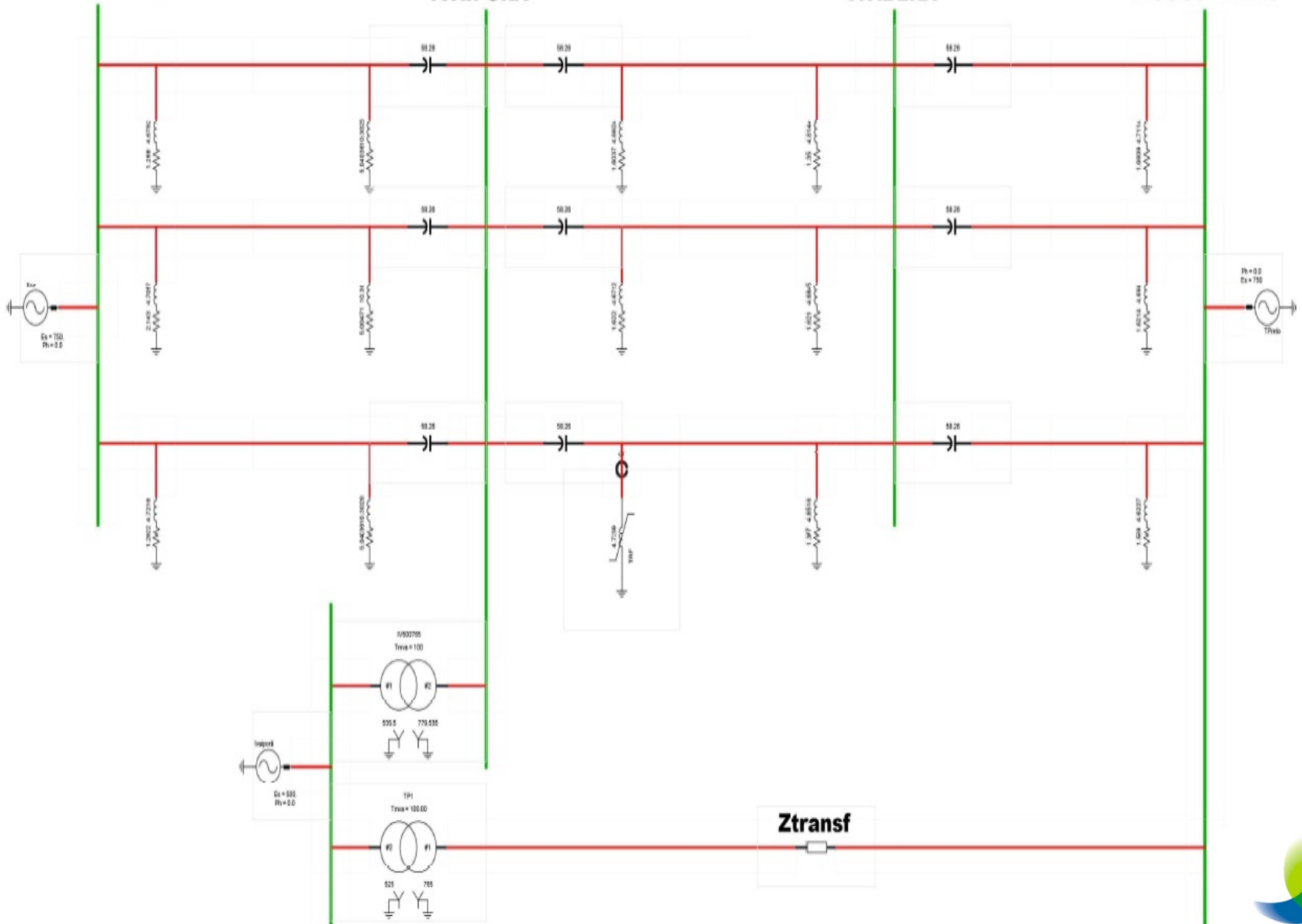
Low Pass Filter (30Hz)

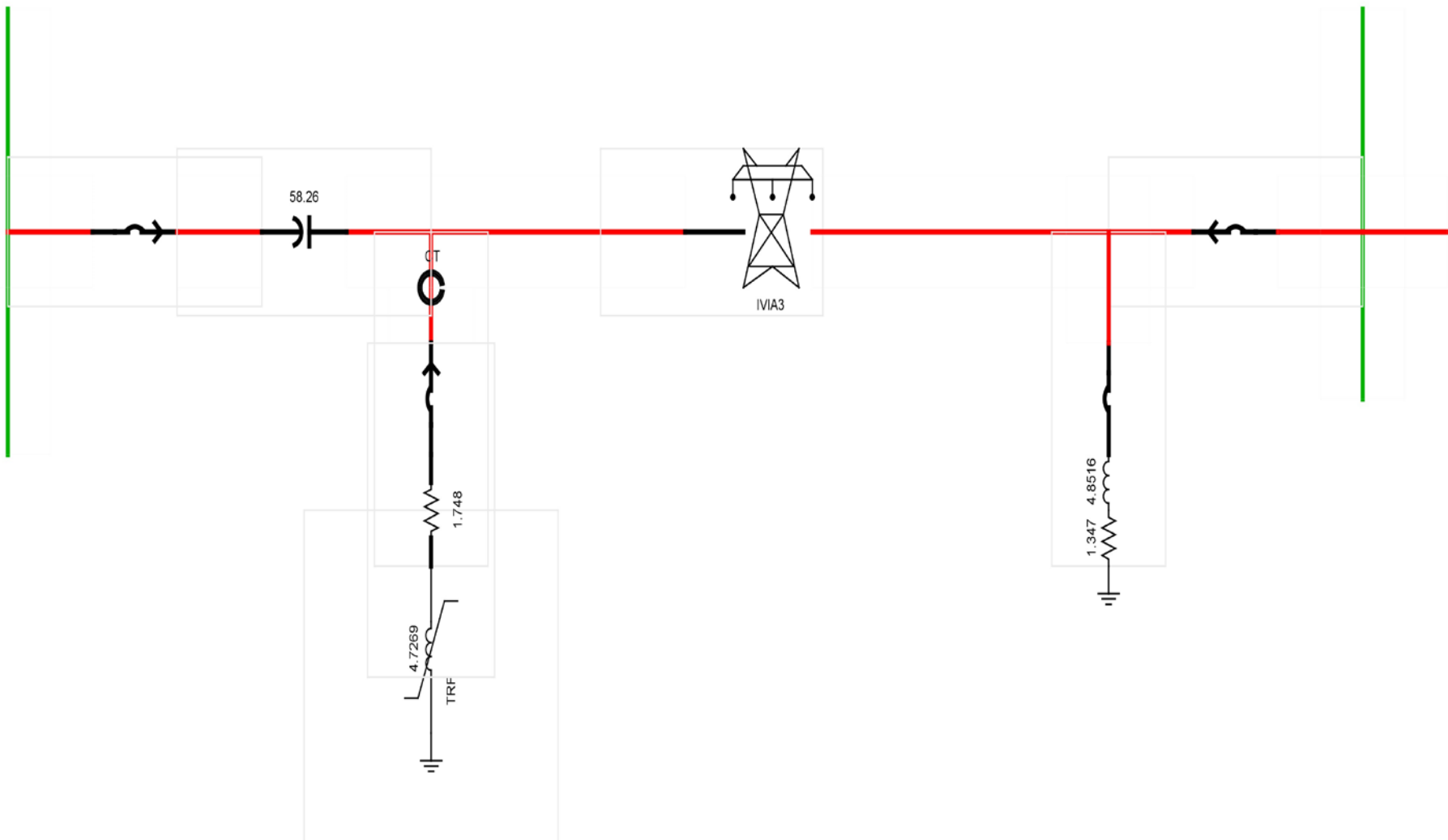
FOZ DO IGUAÇU

IVAIPORÃ

ITABERÁ

TIJUCO PRETO

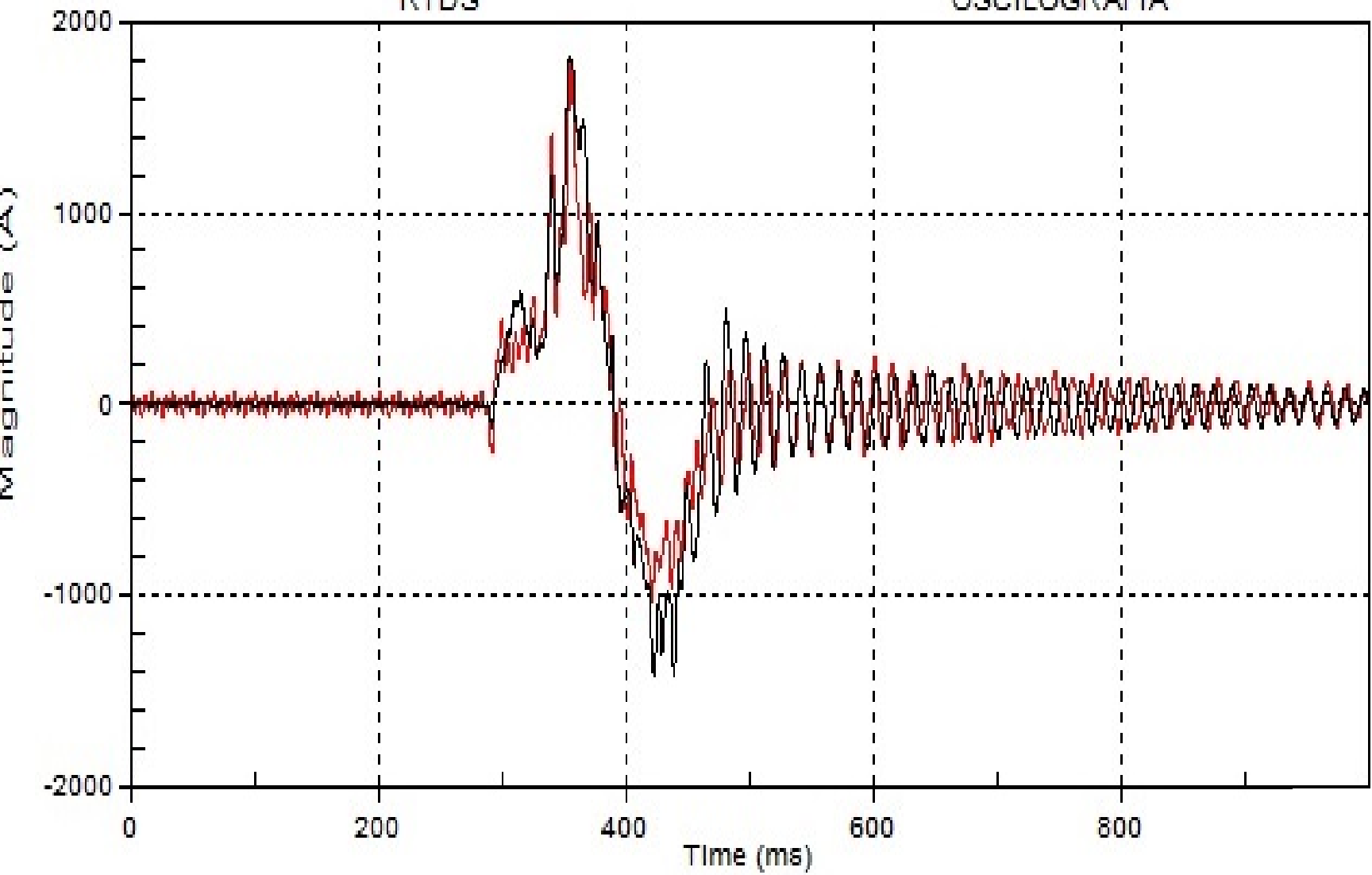




INreator

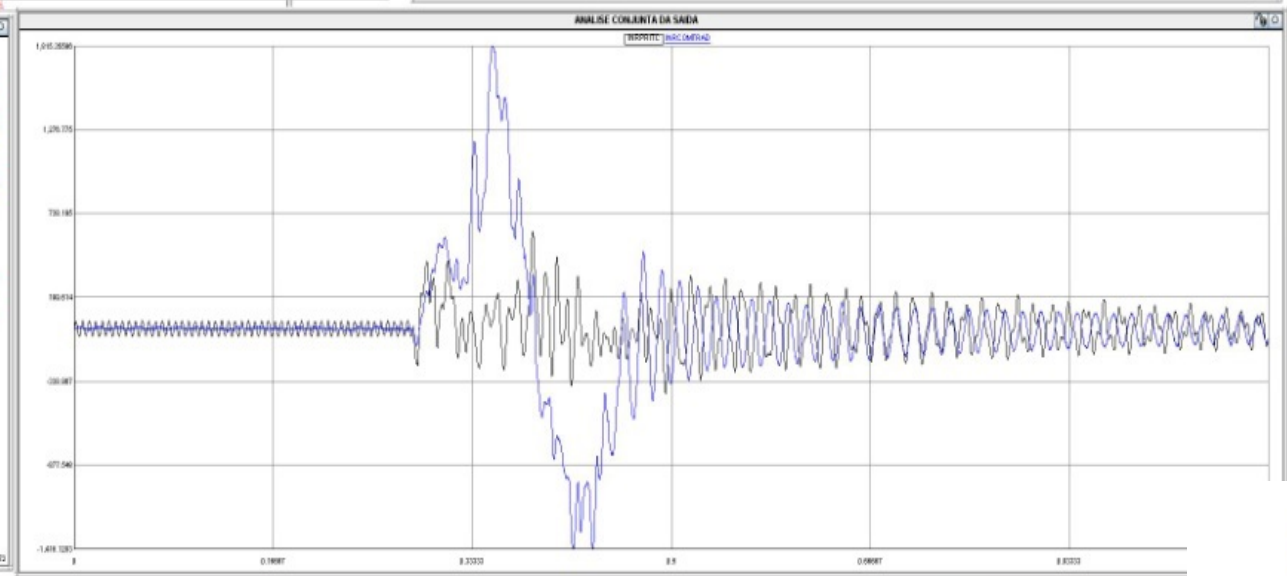
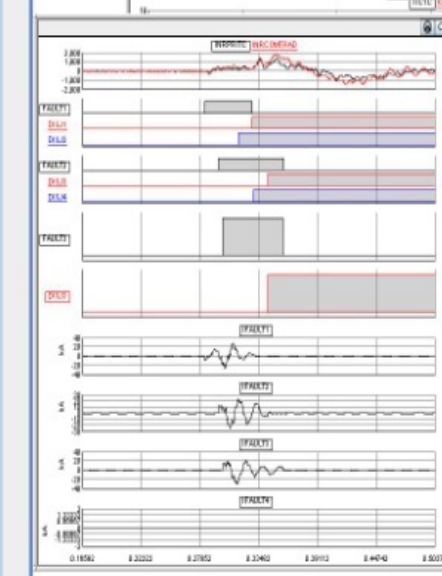
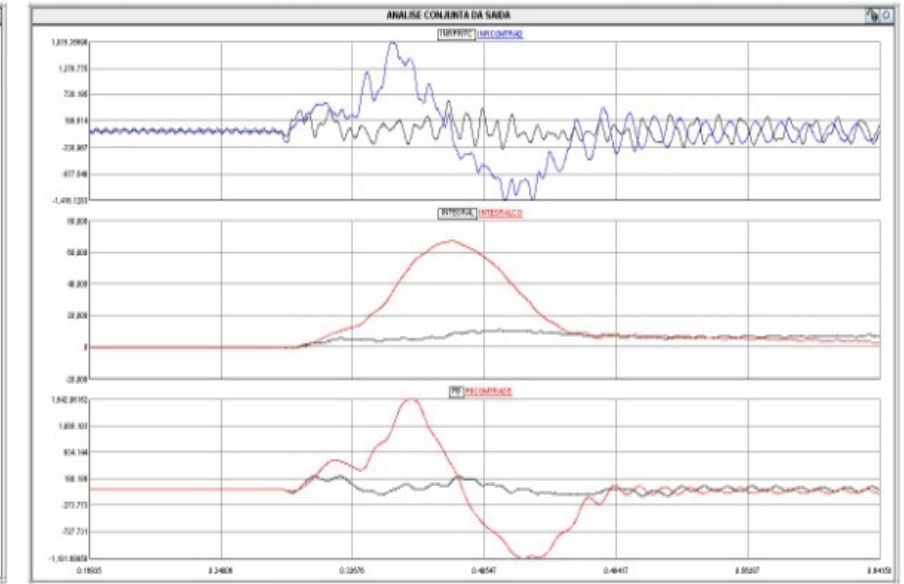
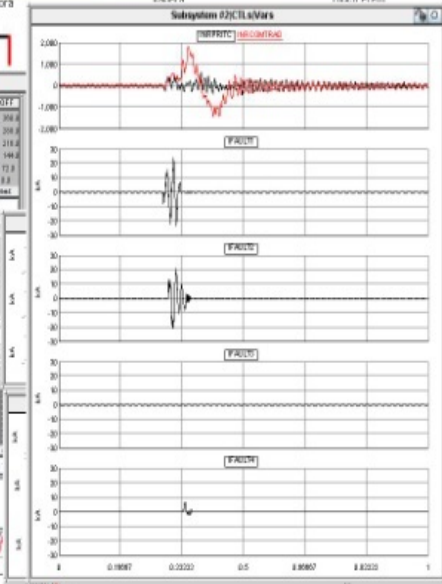
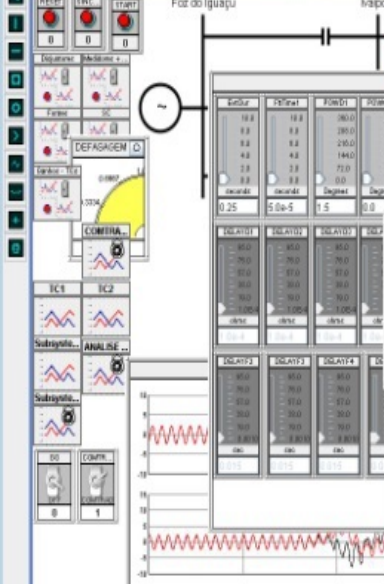
RTDS

OSCILOGRAFIA





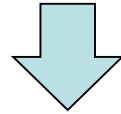
C:\RTDS_USER\Berman\Ocorrencia_10112008\Ocorrencia_Base_PACW.msh Compiled on rack1 to rack4 Started: 10/05/24



- rack0
- rack1
- rack2
- rack3
- rack4
- rack5
- rack6
- rack7
- rack8

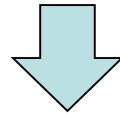
Real Protection Testing using the RTDS

Real Current of the event applied to the protection (COMTRADE)



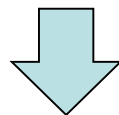
Protection TRIP

RTDS Reactor current applied to the protection



Protection DID NOT TRIP!

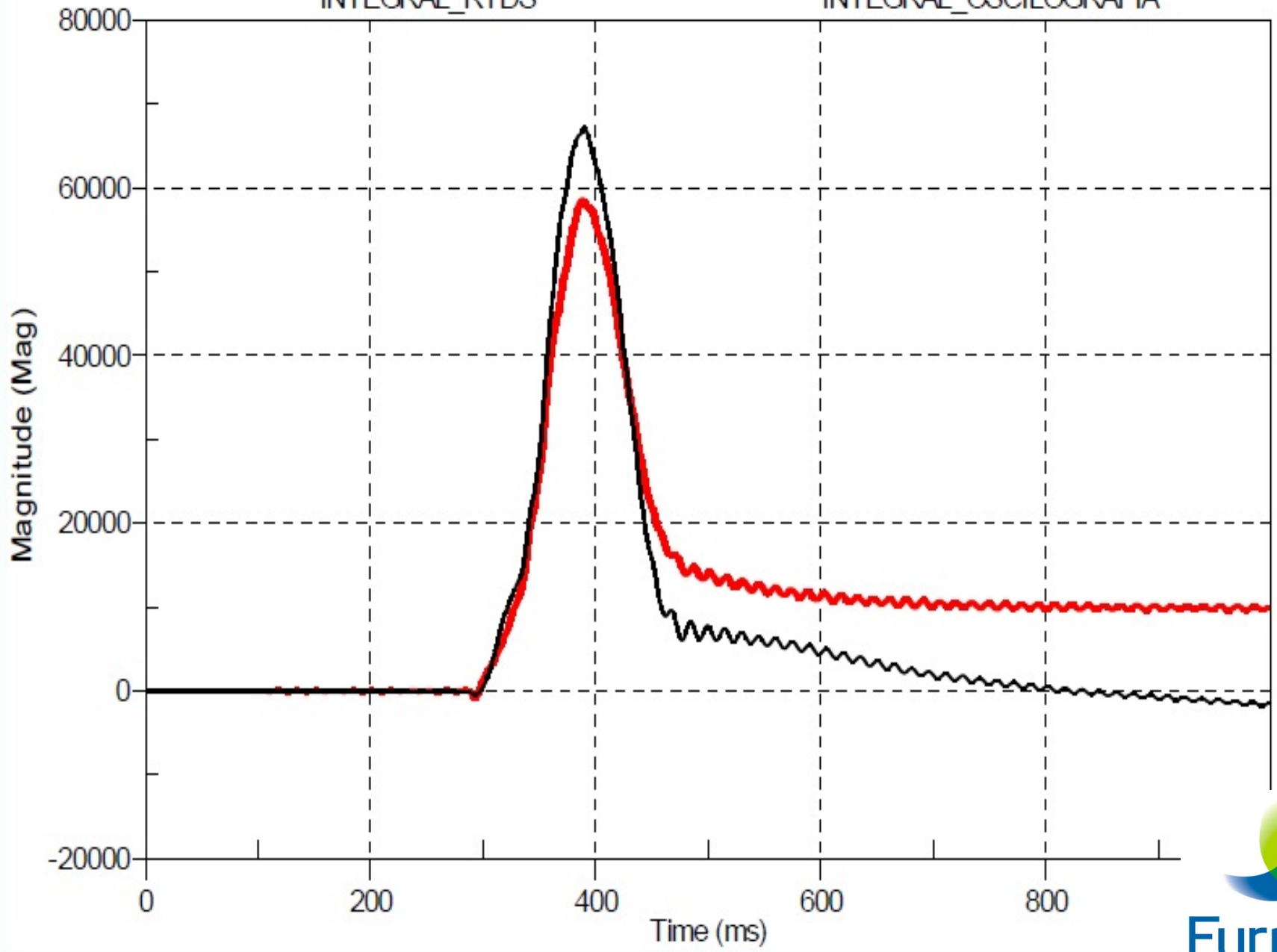
RTDS Reactor current + 3% gain



Protection TRIP!

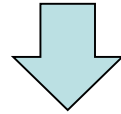
INTEGRAL_RTDS

INTEGRAL_OSCIOLOGRAFIA



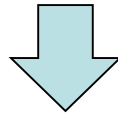
New Digital Protection Testing using the RTDS

COMTRADE current of the event applied to the protection



Protection DID NOT TRIP

RTDS Reactor current applied to the protection



Protection DID NOT TRIP

Protection TRIP only after a 200% gain applied!

Report of the Studies were presented to the National Agency of Electrical Energy

Recommendations of the Agency:

 **Instalation of Booster Shed to enhanced the insulation**

 **The Brazilian ISO must increase the priority
for the upgrade of the 765kV protections**

Conclusion:

- Real Time tests are useful for support system operation
- Hardware Replicas for controllers and Protection Spares has a important role for system operation analysis



More realistic analysis



Operators training on real situations



Additional Spare Set for emergency

- FURNAS Operation Staff realize that is important to include the supply of hardware replicas for FACTS devices (HVDC and SVC)



**Thank you
for your Attention!**