Analysis of Events using Phasor Measurement
(The Experience of Medfasee Project)

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The MedFasee Project
(Main Characteristics)

- Project started in 2003

- Project Characteristics:
  - Development of a prototype
  - Study, dissemination and educational use of the WAMS technology
  - Applications for power system monitoring, control and fault location

- All hardware and software components were developed by the MedFasee team
MedFasee Project
(Structure and Geographical Location)

- Five geographical regions are covered (9 universities)
- Virtual Private Network over Internet for communication
The MedFasee Eletrosul Project

- First installation in a 500kV system in Brazil
- Main transmission utility of south
- 4 PMUs and 1 PDC
- Applications for monitoring tools and fault location
- Power system performance analysis
PMU – RPV Reason

- Multifunctional device
  - PMU
  - Digital Fault Recorder
  - Power Quality Recorder
  - Continuous Recorder
  - Travelling Wave fault locator
  - More…

- IEEE C37.118 compliant
  - ONS testing at NIST: conditionally passed

- Sending 60 phasors per second (3Φ)
- Link Ethernet and UDP/IP protocol
- Configurable to 10, 12, 15, 20, 30 and 60 phasors per second and positive sequence
Selected cases

- 01/09/2006 - Generation dropping in a coal thermal plant
  - Comparison between simulation and measured oscillations

- 07/04/2009 – Special protection schema Itaipu (14000 MW) – Tucurui (8340 MW)
  - Measured oscillations modes and damping

- 10/04/2009 – System splitting in 2 islands
  - Causes not yet identified

- 09/08/2009 – Transmission line tripping
  - Fault location using phasors from both terminals

- Unbalance in 525 kV lines
  - Positive sequence errors
01/09/2006 - Generation Unit Tripping

- Disturbance detection
  - Generator unit tripping from a coal thermal plant
  - Jorge Lacerda – 343 MW;
An oscillation mode of 1.14 Hz was identified and attributed to a local oscillation mode of J. Lacerda
The same mode appears in the event simulation!

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**Table 1 - Oscillation mode damping**

<table>
<thead>
<tr>
<th>Damping (ζ)</th>
<th>Measured (%)</th>
<th>Simulated (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ζ₁</td>
<td>10.1</td>
<td>13.5</td>
</tr>
<tr>
<td>ζ₂</td>
<td>6.2</td>
<td>7.1</td>
</tr>
</tbody>
</table>

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**JLacerda B (Units 5 and 6) Rotor Angle**

Reference: Itaipu 60 Hz

- Frequency = 1.2Hz
- Damping (t₁-t₂) = 13.5%
- Damping (t₂-t₃) = 7.1%

-62,688 degrees; t₁=1,038s
-66,877 degrees; t₂=1,857s
-68,006 degrees; t₃=2,703s
Main oscillation modes of Brazil

- North-South: 0.20 - 0.40 Hz
- South-Southeast: 0.60 - 0.80 Hz
- North-Northeast: 0.55 - 0.65 Hz
- MG state - System: 0.40 - 0.45 Hz
- RIO - System: 1.10 - 1.30 Hz
- Sao Paulo - System: 0.65 - 0.75 Hz
07/04/2009 - Special Protection Schema tripping

◆ Characteristics:
  – Automatic dropping of generation in Itaipu and in Tucurui
  – Maintain integrity of the system after losing 765 kV circuits from Itaipu transmission
  – Power plants are 2200 miles apart
  – 33 milliseconds delay for signal transmission

◆ SPS raised in 900MW the transmission capacity from North-SouthEast

Generation shedding: 576 MW

Generation shedding: 2300MW
07/04/2009 - Special Protection Schema tripping

◆ Characteristics:

- One-phase short circuit followed by the tripping of two circuits C1 and C2 from 765kV Foz do Iguaçu – Ivaiporã.
- Generation dropping of 4 units of Itaipu and 2 units of Tucurui.

◆ Frequency Behavior

![Graph showing frequency behavior]

- Distribution system
- Transmission system
07/04/2009 - Special Protection Schema tripping

- **Inter-area System Oscillations**

![Graph showing Inter-area System Oscillations](image)

**Transmission system**

**Distribution system**

Frequência do SIN - SPMS MedFasee

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>59.65</td>
</tr>
<tr>
<td>135</td>
<td>59.7</td>
</tr>
<tr>
<td>140</td>
<td>59.75</td>
</tr>
<tr>
<td>145</td>
<td>59.8</td>
</tr>
<tr>
<td>150</td>
<td>59.85</td>
</tr>
<tr>
<td>155</td>
<td>59.9</td>
</tr>
</tbody>
</table>

Tempo (s) - Início: 04/07/2009 21:35:00 GMT
07/04/2009 - Special Protection Schema tripping
(Measured electro-mechanical oscillations modes)

- North - South mode:
  - Frequency: 0.36 Hz
  - Damping: 5.99 %

- South-Southeast mode:
  - Frequency: 0.62 Hz
  - Damping: 8.82 %
07/04/2009 - Special Protection Schema tripping

- The special protection scheme actuated again in 22/07/2009 with generation shedding of 3180 MW from Itaipu and 627 MW from Tucurui for a different disturbance (tripping of 3 x 765 kV lines)
10/04/2009 - System islanding

Description

- Started 18:39
- Opening of several interconnections
  - Gurupi-Miracema (LT A)
  - Serra da Mesa – Samambaia (LT B)
  - Serra da Mesa – Rio das Éguas (LT C)
  - Rio das Éguas – Bom Jesus da Lapa (LT D)
- Consequences
  - 2 separate systems: N/NE e S/SE
  - Load shedding in N/NE: 2550 MW
  - Some generation dropping in S/SE
- Restoration:
  - 18:47 – Closing of N/NE - SE
  - 19:21 – Closing of SE - NE
10/04/2009 - System islanding

Frequência do SIN - SPMS MedFasee (com filtro)

Frequência (Hz)

Tempo(s) - Início: 04/10/2009 18:37:00 (local)

UnB
USP-SC
PUC-RS

Inicio da Falha

Frequência do SIN - SPMS MedFasee

Tempo(s) - Início: 04/10/2009 18:37:00 (local)

UNIFEI
UnB
COPPE
USP-SC
UTFPR
UFSC
PUC-RS
Oscillation in S-SE – 0.57Hz
10/04/2009 - System islanding

- Parcial reclosing
10/04/2009 - System islanding

- Oscillation S-SE – 0.63Hz
- Oscillation N-S – 0.3Hz
10/04/2009 - System islanding

- Complete reconnection
10/04/2009 - System islanding

- S-SE – 0.59Hz.
- N-S – 0.36Hz.
- Local Oscillation in South 1Hz.
09/08/2009 - 525 kV Transmission Line Tripping

- Strong winds in the region
09/08/2009 - Transmission Line Tripping (Fault location with syncrophasors)

**1st fault and tentative reclosure**

- Corrente na LT Ivaiporã - Areia
- Corrente LT Areia - Ivaiporã

Eventos:
- Evento 1
- Evento 2
- Evento 3
- Evento 4
09/08/2009 - Transmission Line Tripping (Fault location with synchrophasors)

- Several 2 terminal algorithms were used
- Errors between 6 and 4 miles (5% - 4% of line length)
- Sub cycle protection interrupt the fault before a stable cycle exists
Unbalance in 525 kV line
(Current unbalance measured from both terminals)

- Up to 10% in both sides
- Does positive sequence represent this line?
Thank you!

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