Hydro Québec TransÉnergie

Une division d'Hydro-Québec

Hydro-Québec TransÉnergie Perspective on Phasor Measurement

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System Studies, System Planning

Chattanooga, Tennessee
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Agenda

- **Overview of Hydro-Québec TransÉnergie**
- **Phasor Measurement System**
  - Synchronized monitoring system (Location)
  - Data collection and event validation
  - Geomagnetic activity monitoring
- **Defense Plan for Contingencies**
- **Transient behavior of a series compensated system – Measurements**
- **Future developments and challenges**

Hydro-Québec TransÉnergie Transmission System

- Islanded System **36 000 MW**
- 735 kV Series Compensated
- Transmission Lines **32 227 km**
  Both bulk and Regional Networks
- Substations **512**
- Interconnections **17**
  Import and Export Capability

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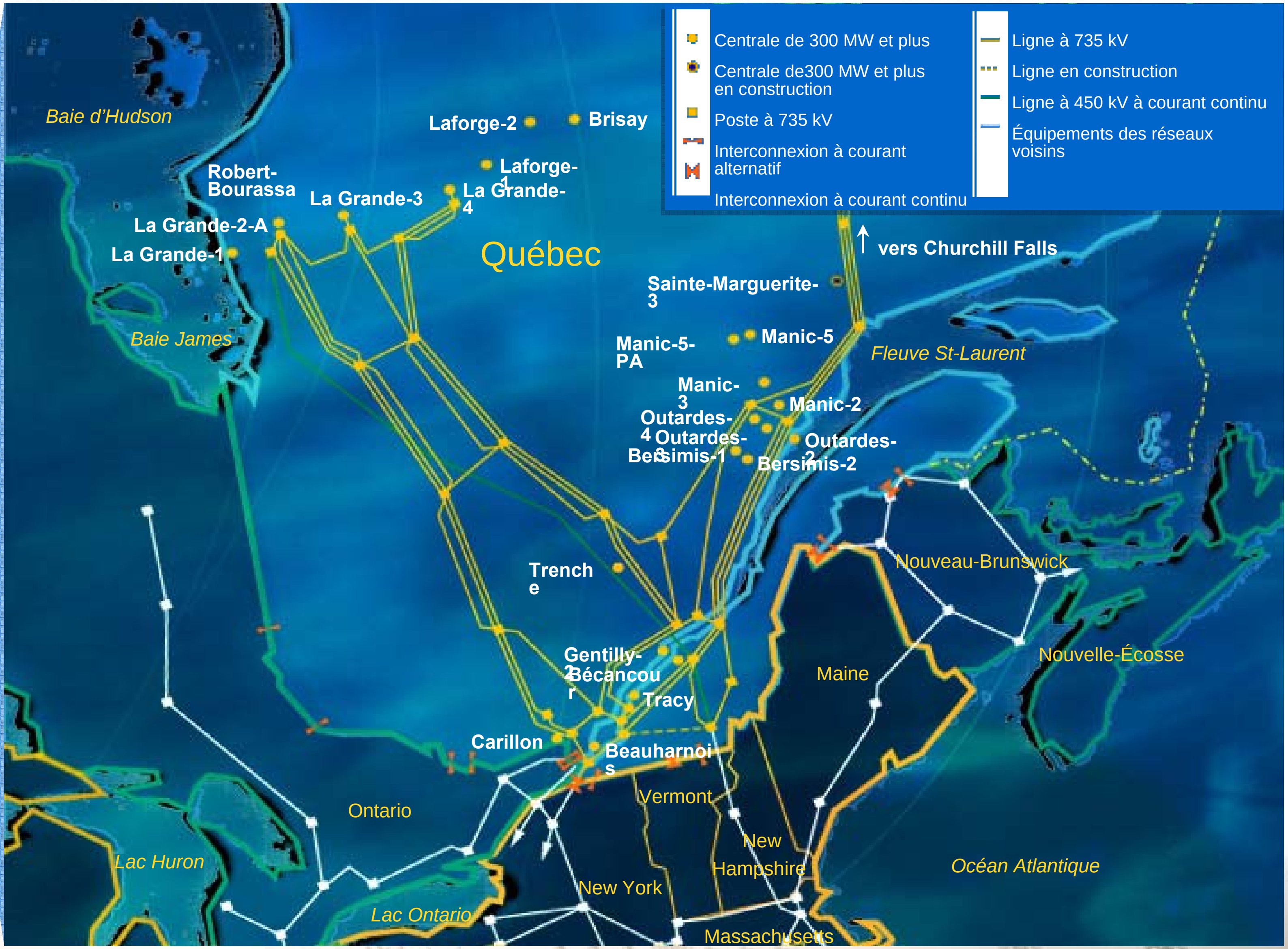
Hydro-Quebec Transmission System



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Interconnections

Users		Transmission Capacity Import mode	Transmission Capacity Export mode
New York	2	1 000 MW	2 125 MW
Ontario	5	550 MW	1 195 MW
New England	3	1 670 MW	2 303 MW
New Brunswick	2	785 MW	1 200 MW
MacLaren	2	213 MW	153 MW
Alcan	2	985 MW	335 MW
Churchill	1	5 200 MW	0 MW

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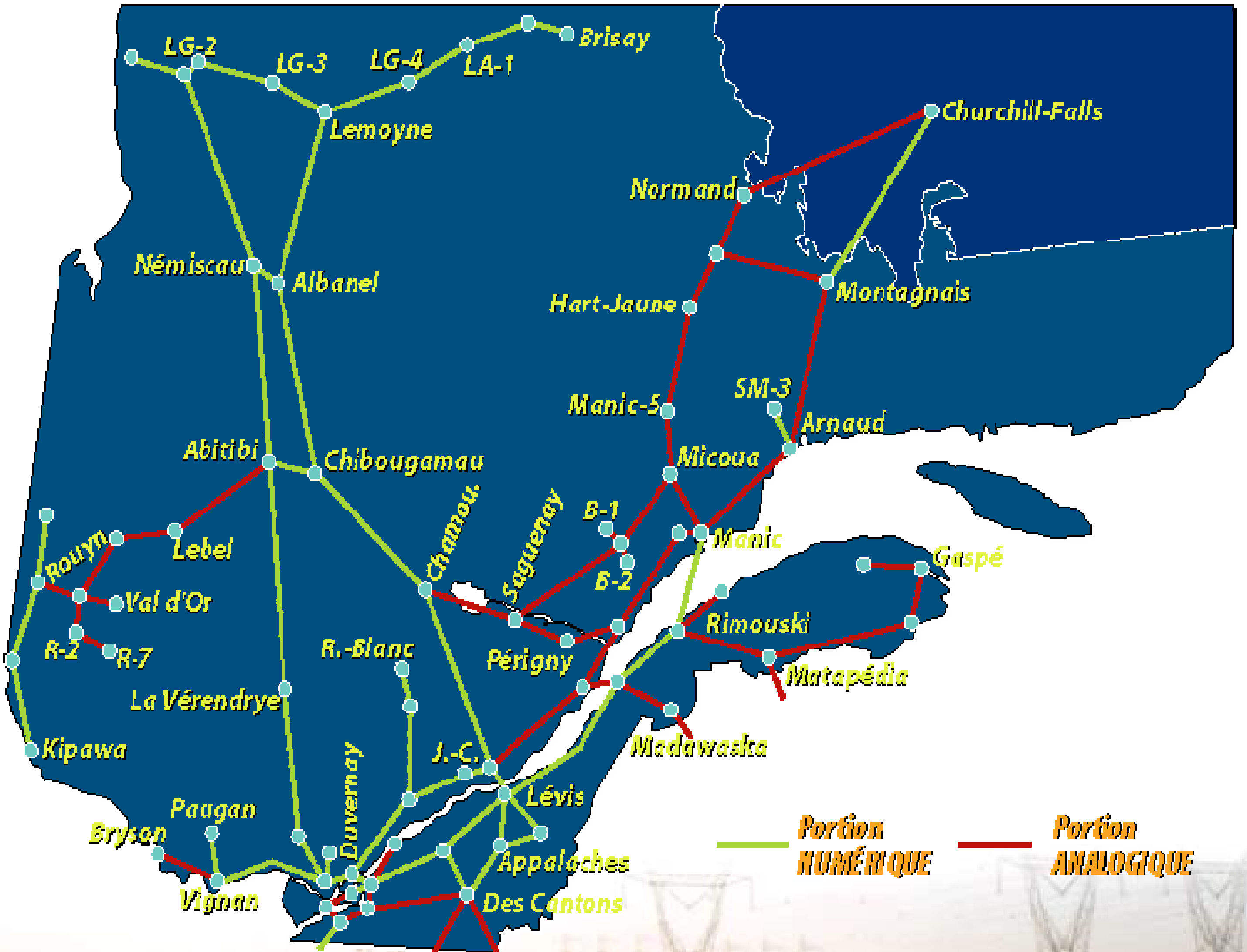
Telecommunication System



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Synchronized phasor measurements

Remote Locations

- PMUs installed in 8 Locations
- Measure Voltage every Cycle (Amplitude and Phase, harmonics)
- Transmitted to 2 master stations

Central Units (2)

A. Calculate phase angle differences between 8 locations;

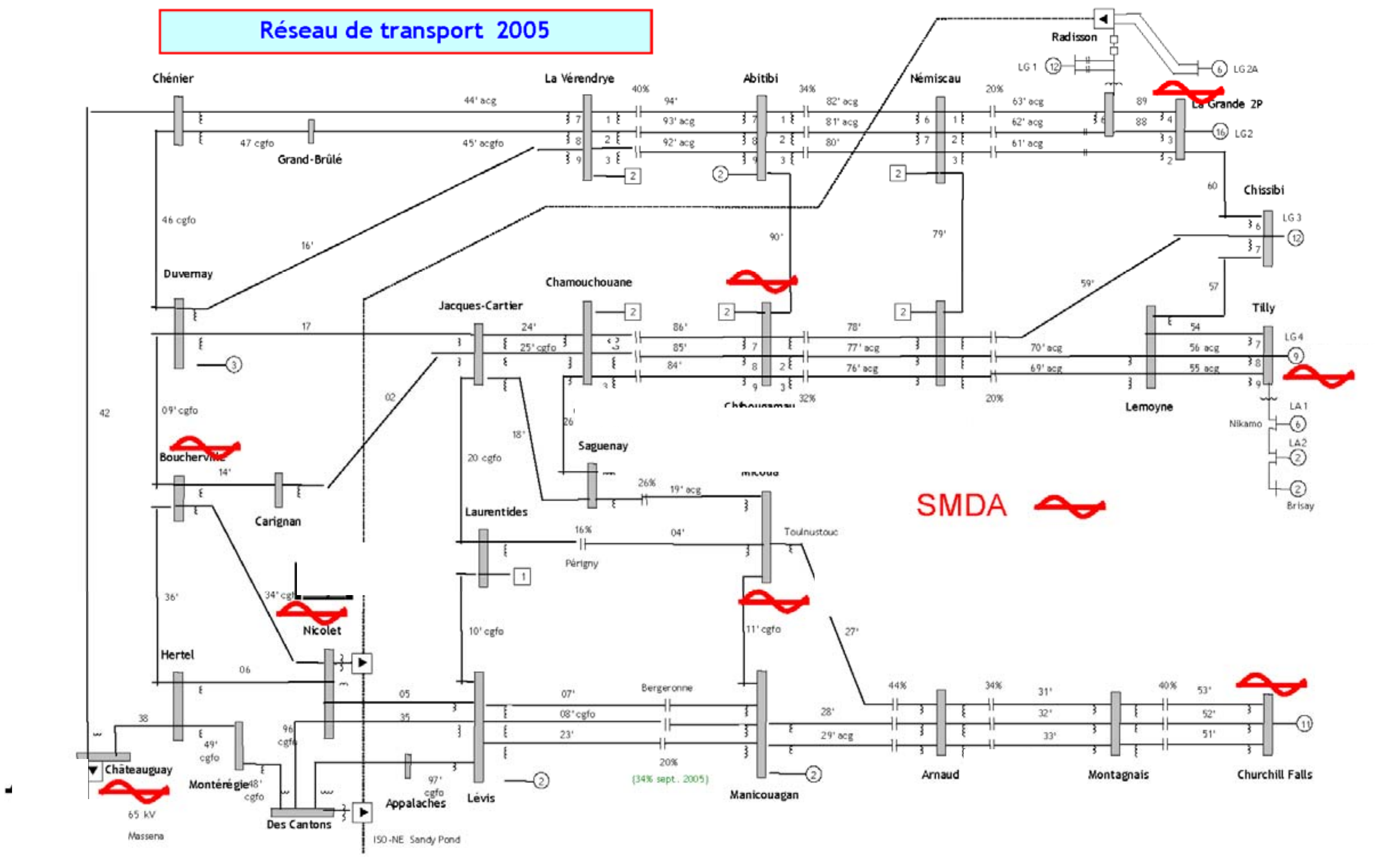
B. High harmonic content and geomagnetic activity ──► Alarm to operator;

C. If variations are detected data is stored every cycle until the end of the event.

System Topology

System load flow data is downloaded every 5 minutes- Transferred into stability data for analysis

The Location of phasor measurement units



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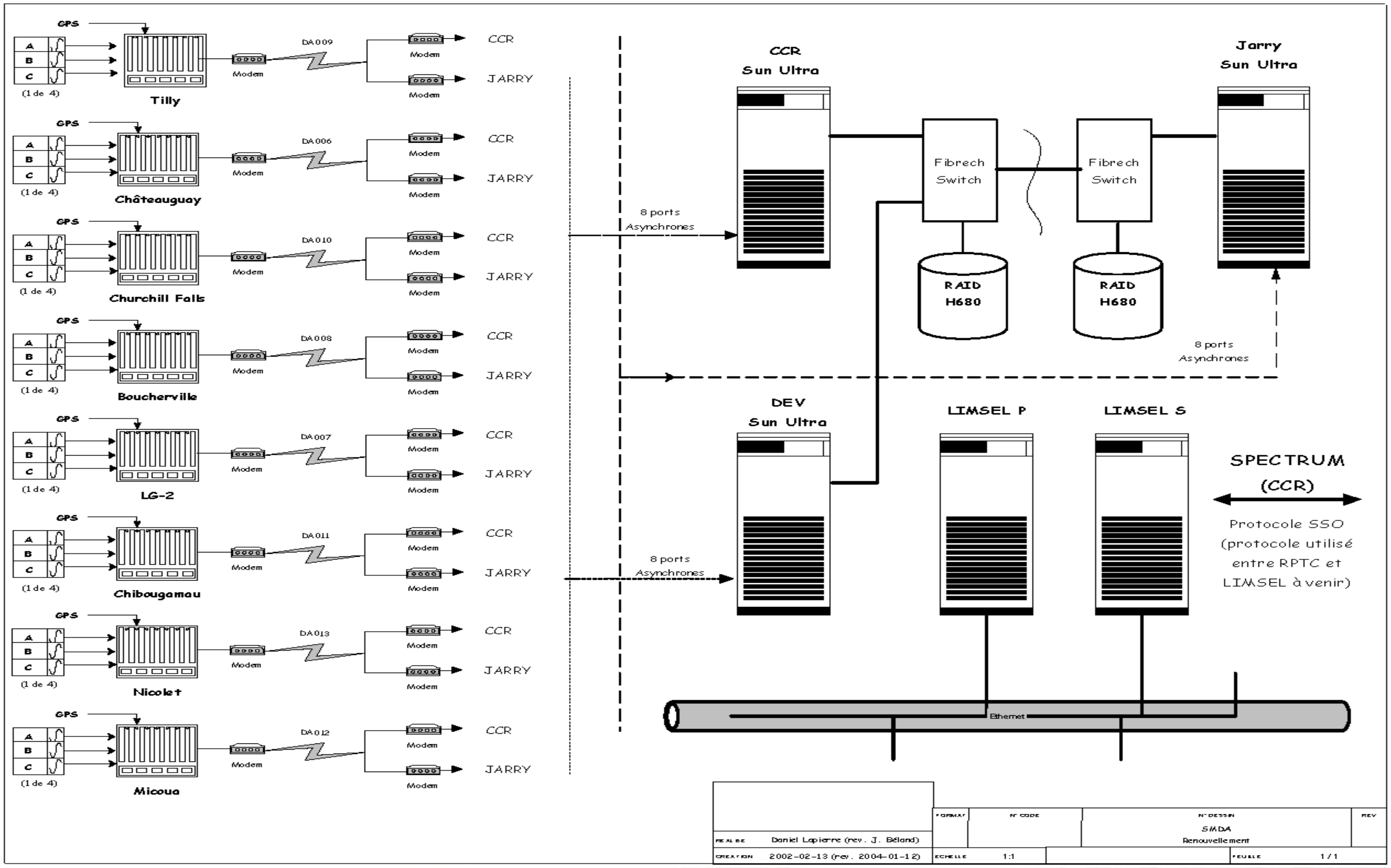
Phasor Angle Difference Measurement System



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Hydro-Quebec - Defense Plan
Main Philosophy

1- Insure service continuity for most probable events

2- Keep system integrity after exceptional event, if possible

3- Insure the security of the equipment if a blackout unfortunately arises

4- Insure restoration of the system within a reasonable time span after catastrophic events

SPS allowed

Decreasing Probability

Increasing Severity

Increasing Consequences

Defense Plan

- ***Insure the reliability and the security of the system following multiple contingencies***
- ***SPS are coordinated together to give best possible coverage for all events and system behaviours***
  - *Power Rejection and Remote Load Shedding (RPTC)*
  - *Automatic Switching of Shunt Reactor (MAIS)*
  - *Under Frequency Load Shedding (DSF)*
  - *Under Voltage Remote Load Shedding (TDST)*
  - *Protection from System Separation (SPSR)*

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RPTC

- Maintain stability after multiple loss of lines and series capacitors
- The system split in different axis
- In each axis, combine events by detecting any loss of line within a time span
- Power rejection and remote load shedding
- Readjust actions and levels depending on the pre-contingency conditions

MAIS

- Control of 765 kV Voltage
- Individual controllers are installed in 735 kV substations
- Rely on precise measurements of direct sequence voltage to supply good coordination
- Automatically trip or close shunt reactors

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DSF

- Restore balance between production and load
- Locally measured frequency and voltage
- Trips pre-selected feeders
- Trips a required amount of capacitors banks

TDST

- Maintain voltage stability after the loss of lines.
- Average direct sequence voltage from MAIS in 5 substations in the load area.
- Remote load shedding.

SPSR

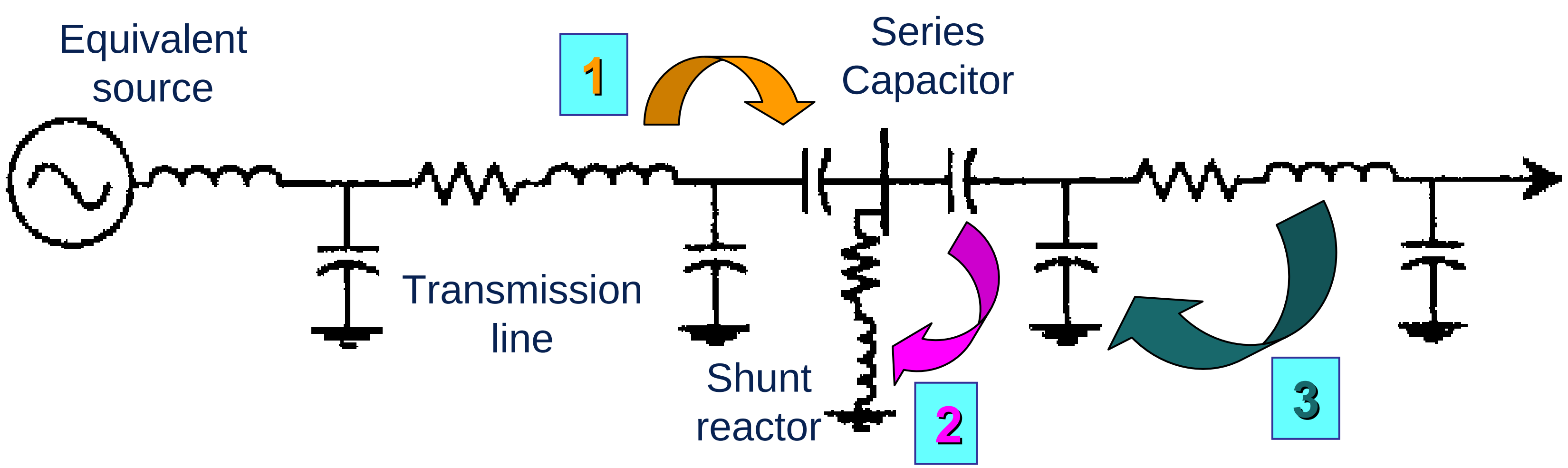
- Limit overvoltages and protect equipment following system separation
- The system is divided in different axis
- In each axis, events are combined by detecting line opening
- Instability detectors close arresters
- Overvoltage and frequency relays trip Lines

Specific Characteristics

- **Rely on precise local phasor measurements**
  - Frequency for load shedding
  - Voltage for shunt switching and load shedding
  - Frequency variations, instability detection and overvoltage for equipment protection
- **Rely on precise identification of system events and loss of lines**
  - Power Rejection and Remote Load Shedding
  - Protection Against Overvoltage
- **Rely on quick application of mitigation actions to maintain stability**
  - Same actions regardless of level of severity (Umbrella coverage)

Precise Measurements

Series Compensated System Transient Behavior

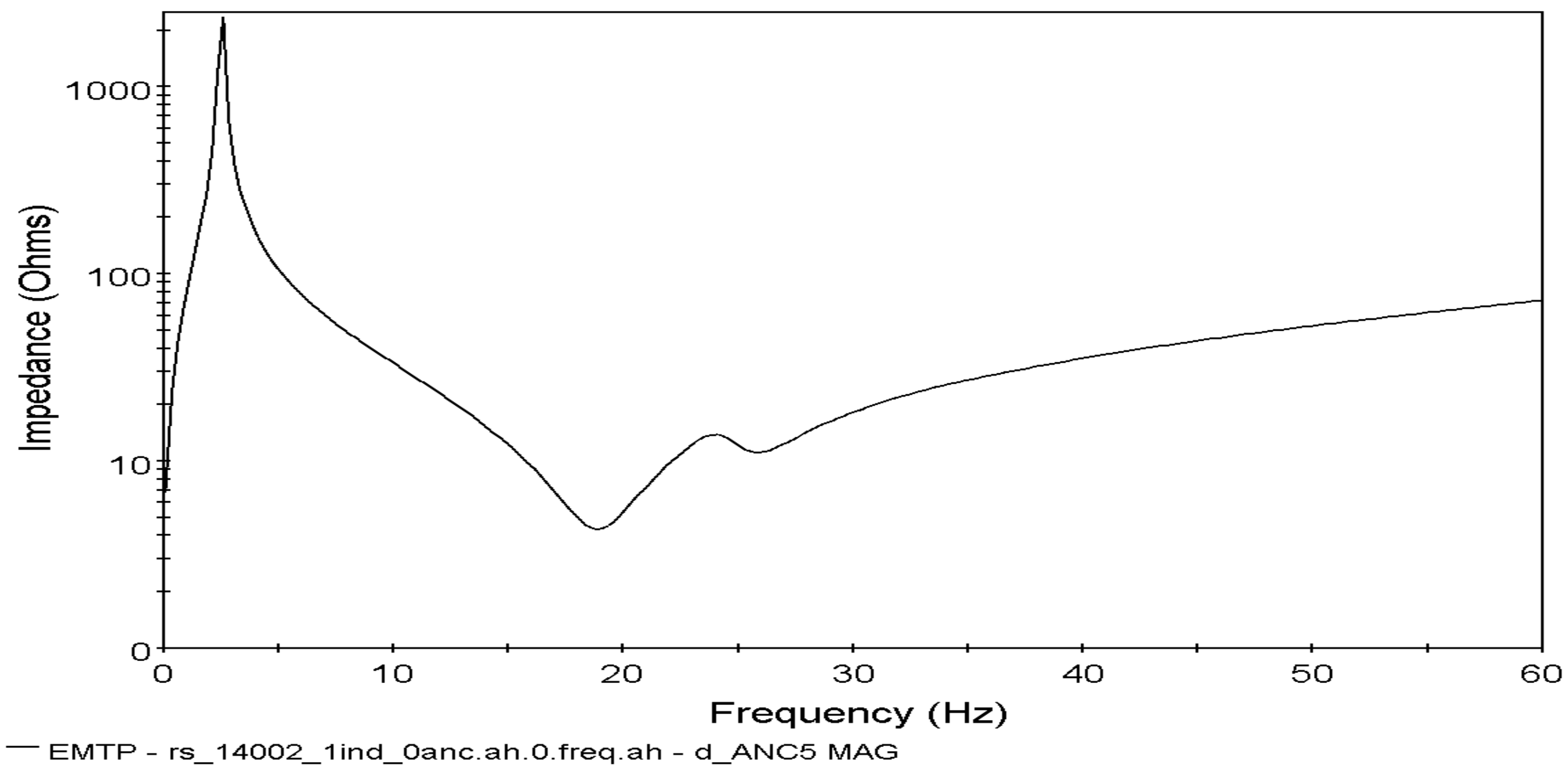


1 **Series line resonance**

2 **Parallel shunt reactor resonance**

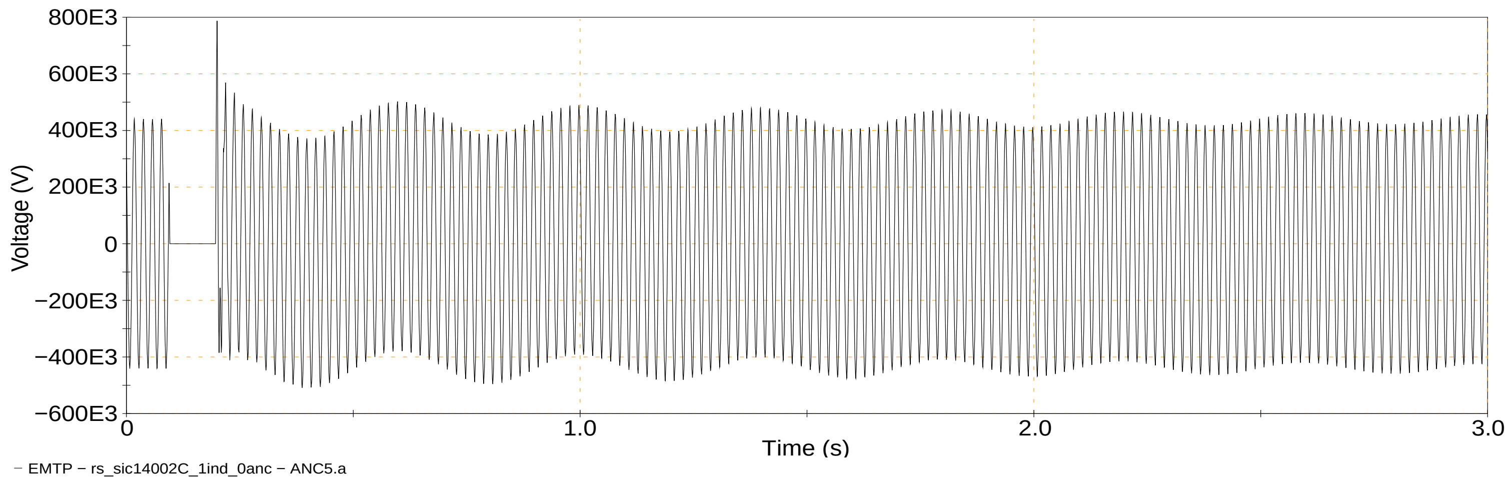
3 **Shunt capacitance resonance**

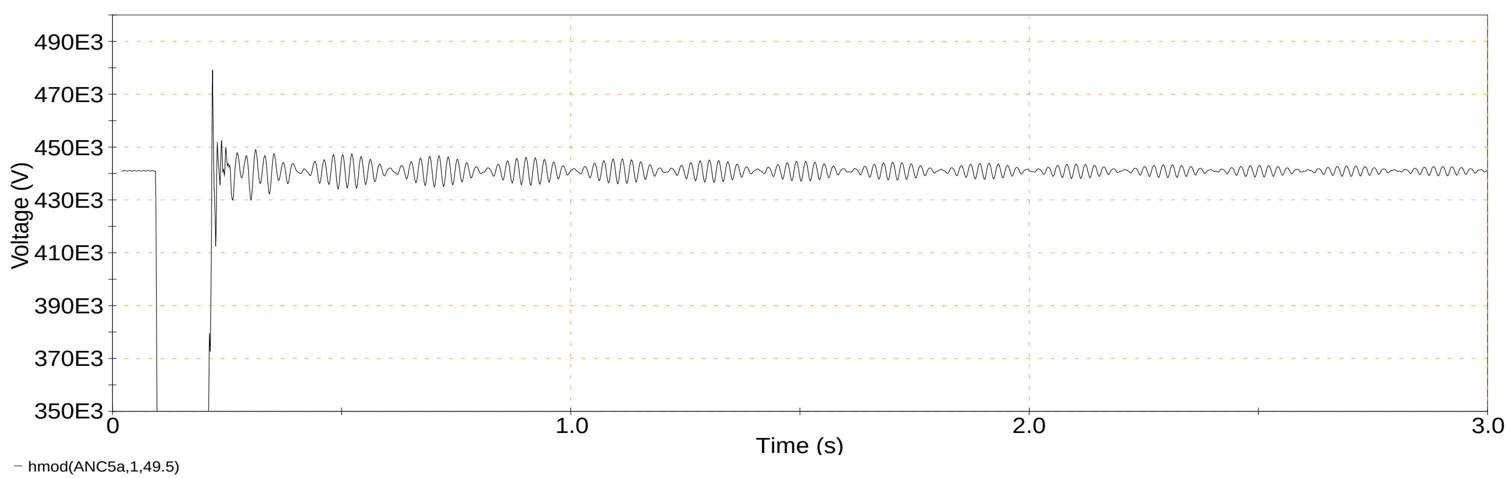
System Behavior



Frequency Response on series compensated Network

Transient voltage – No transformer





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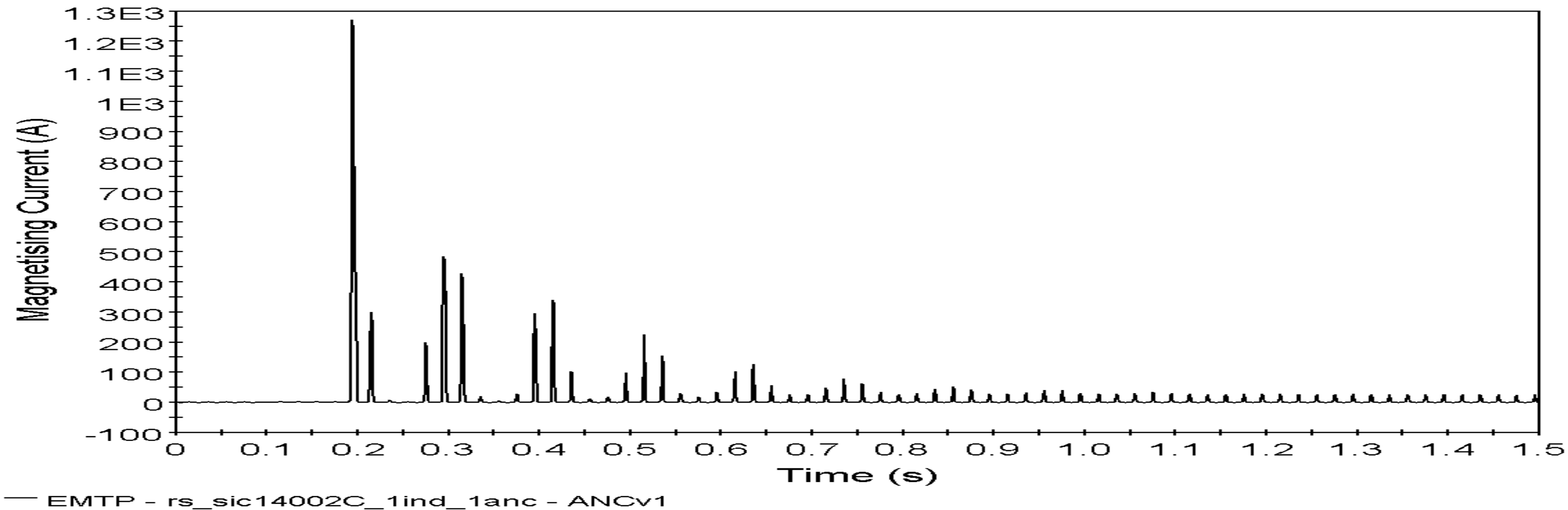
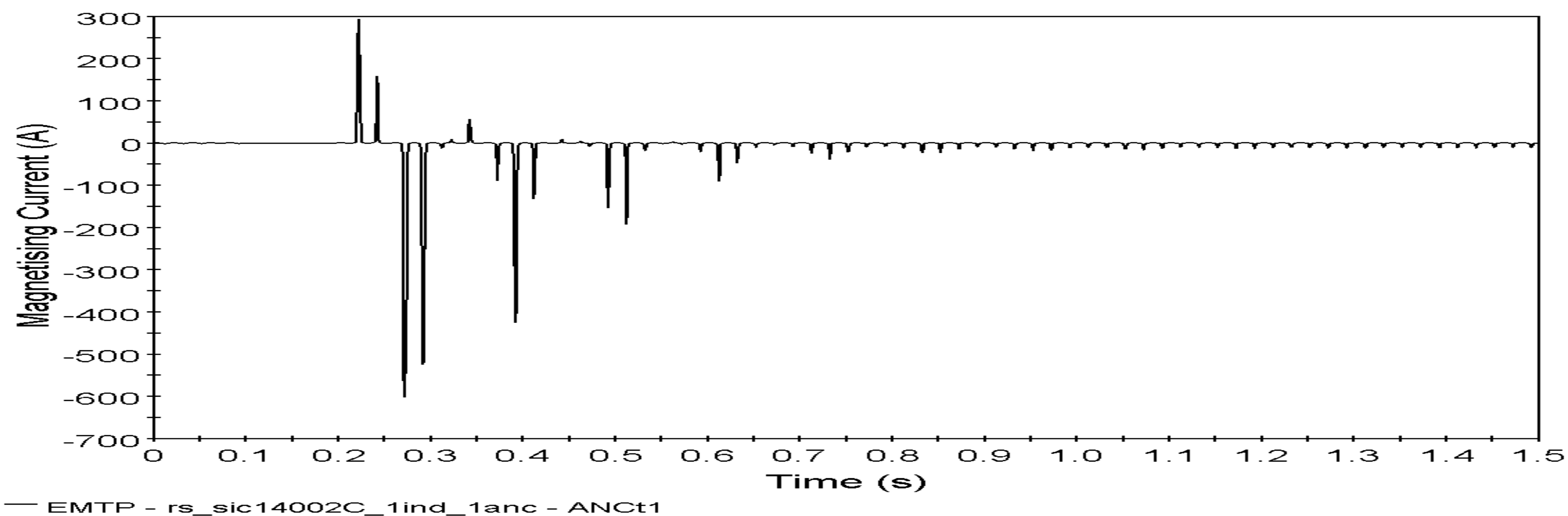
Impact of Transformer saturation





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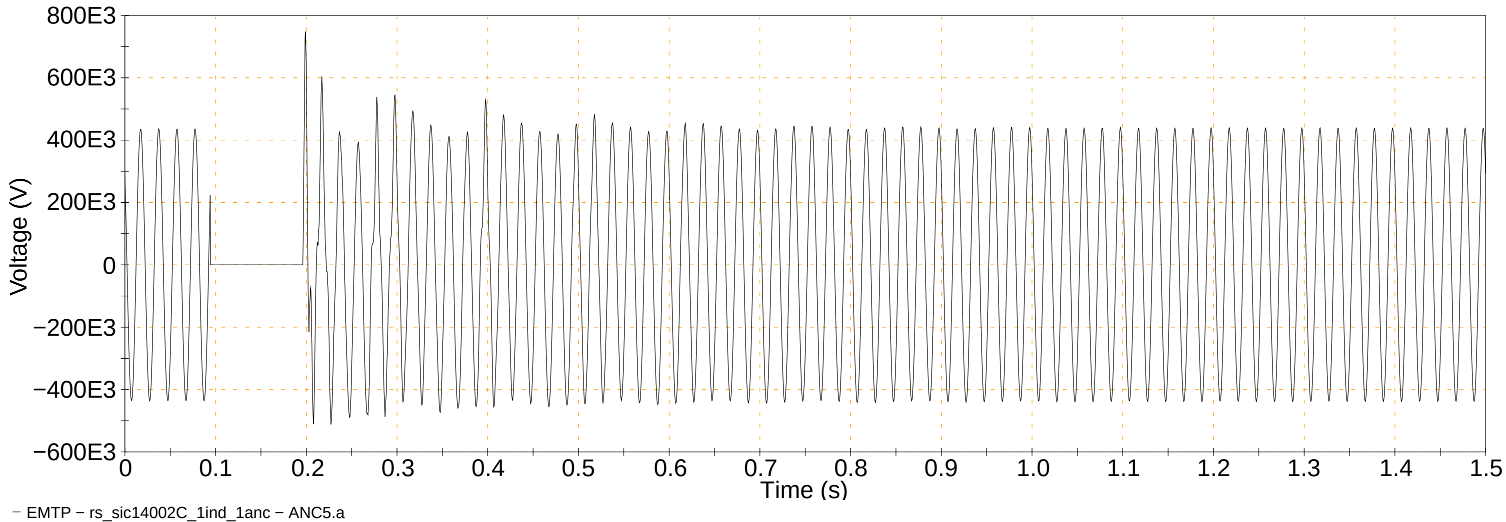
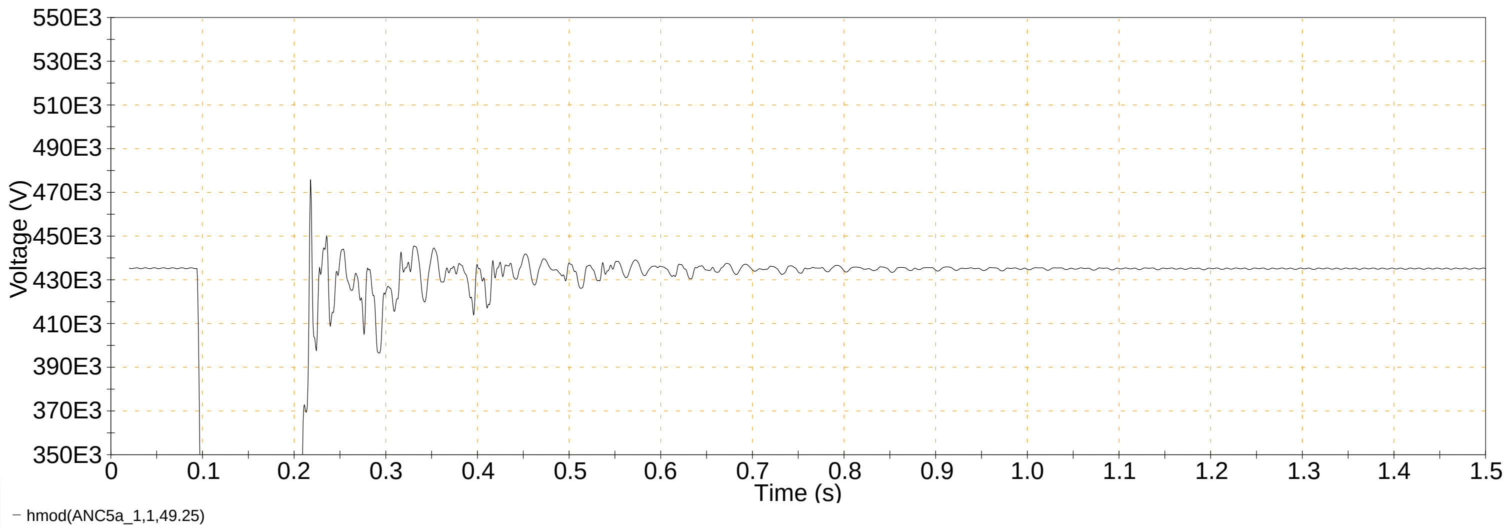
Transient voltage - With transformer saturation





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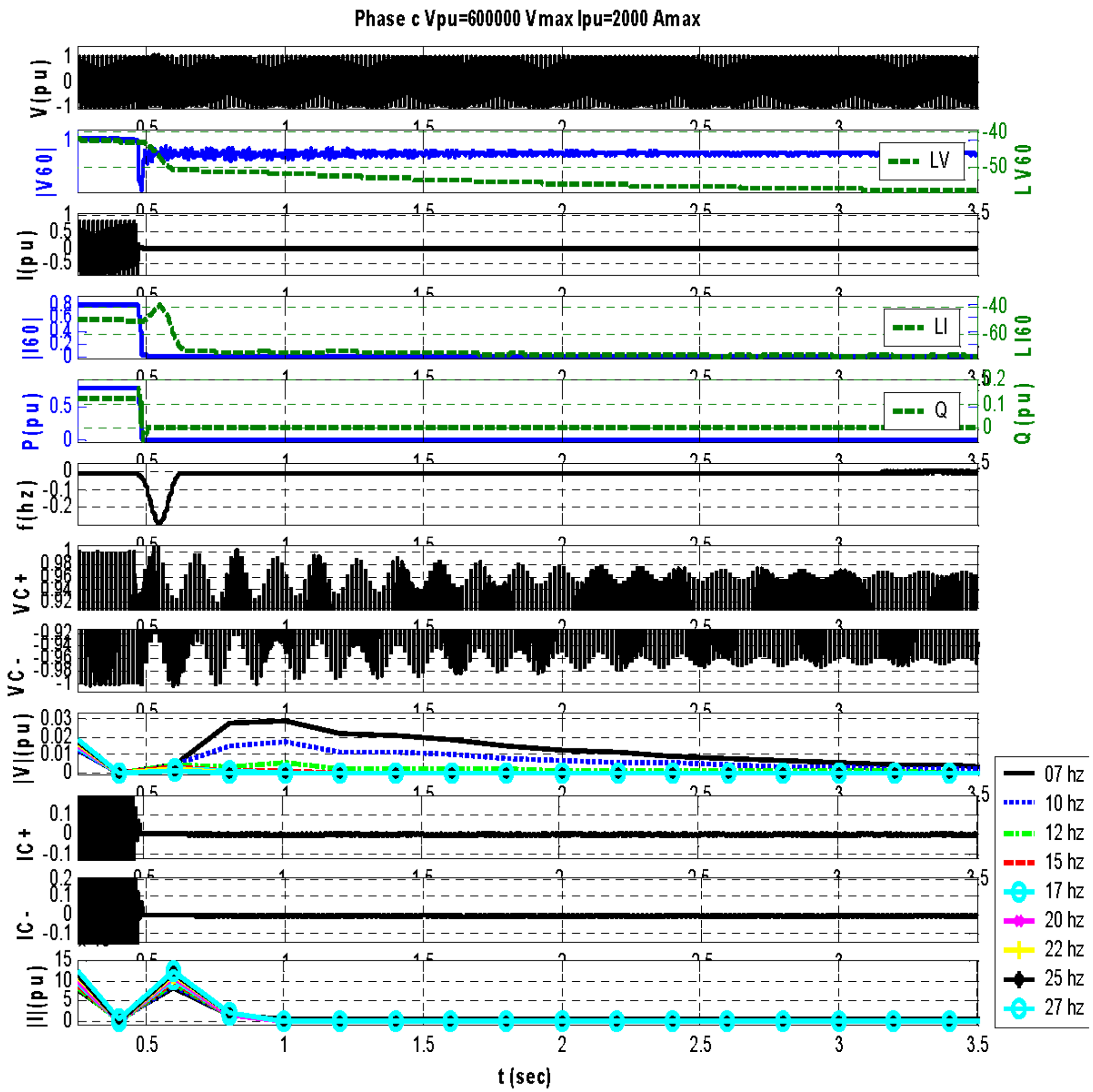

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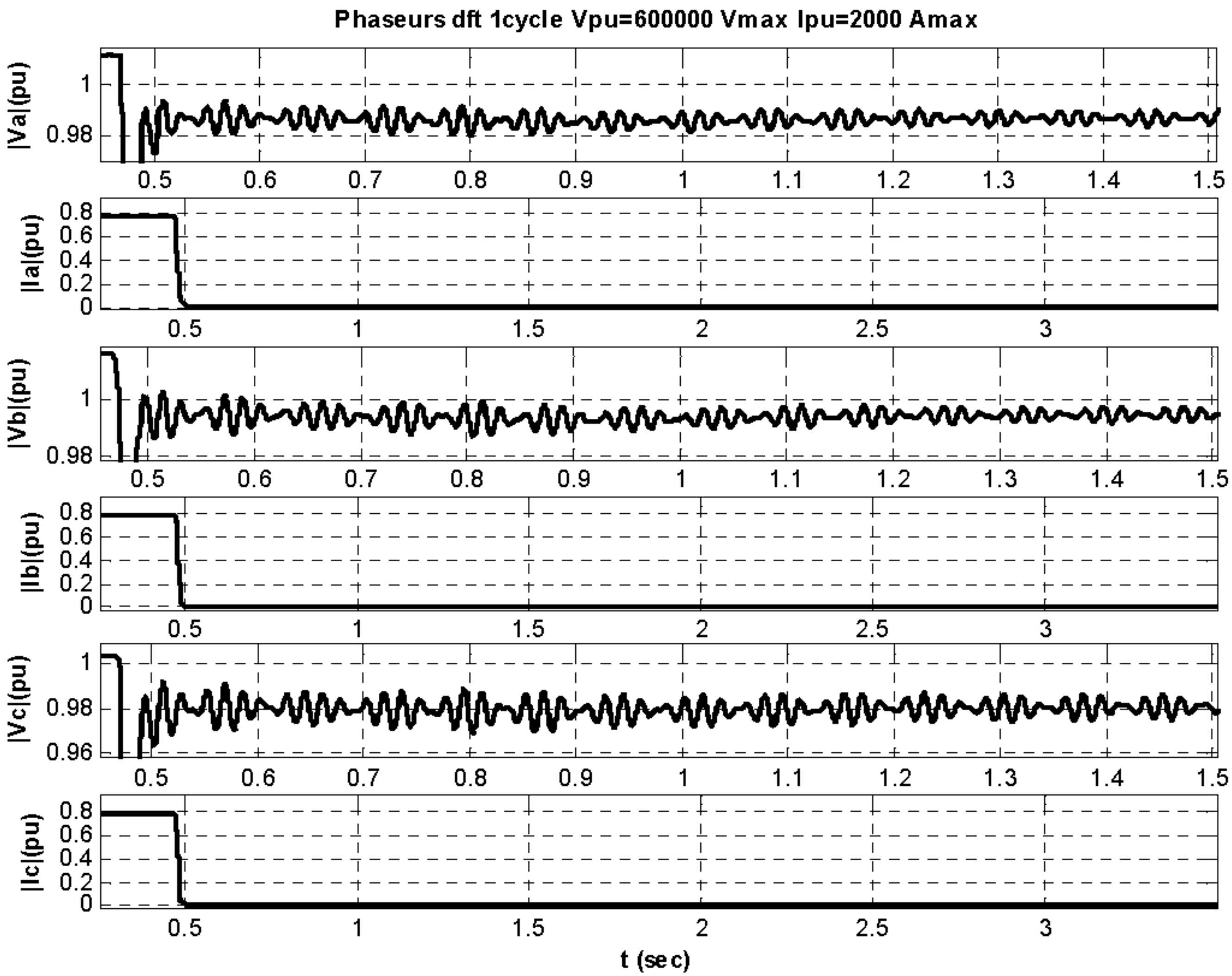

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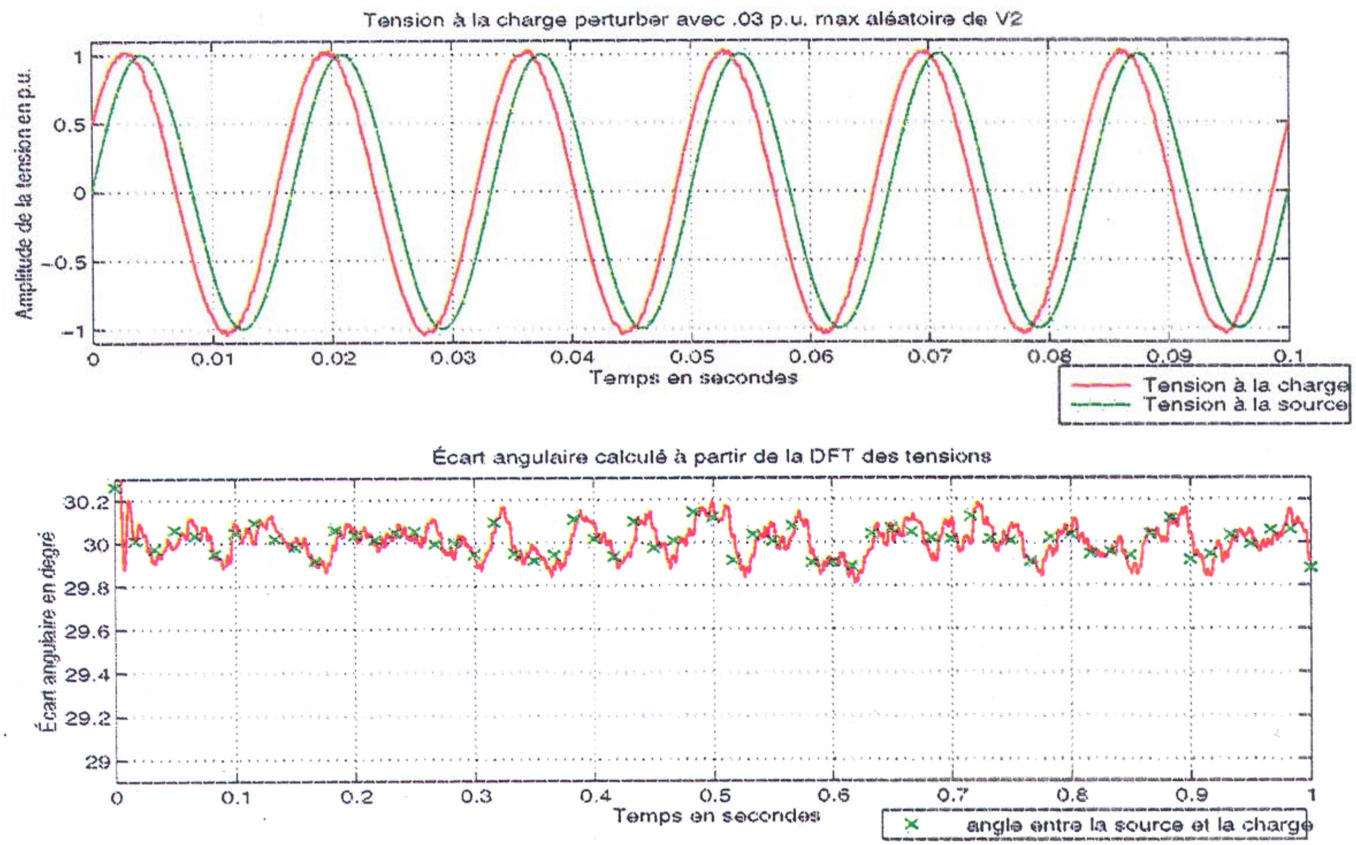
Impact of unbalance on phase angle difference

FIGURE 2: Impact de 3 % de V2 à la charge sur la mesure d'écart angulaire (DFT)



Stability and Real life

FIGURE 1: Écart angulaire entre V à Tilly et Boucherville (ST600)

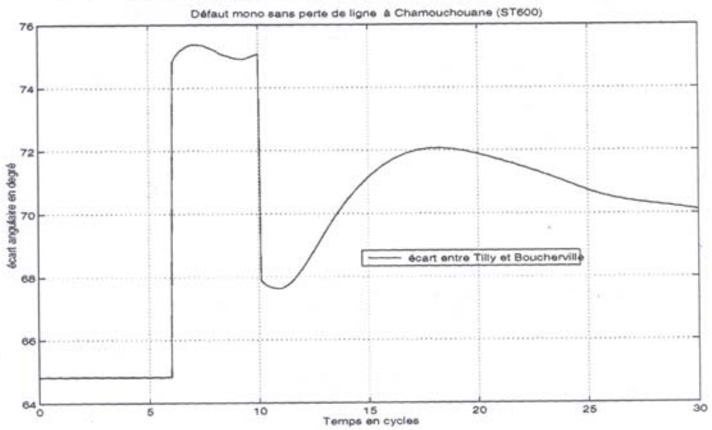


FIGURE 3: Écart angulaire entre V à Micoua et Boucherville (EMTP)

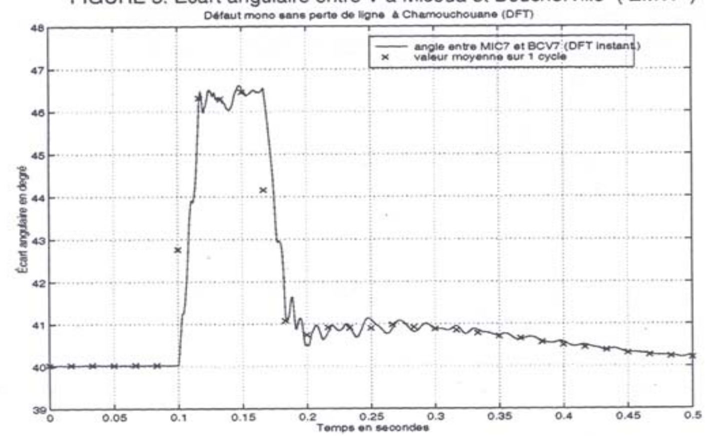


FIGURE 2: Écart angulaire entre V à Micoua et à Boucherville (ST600)

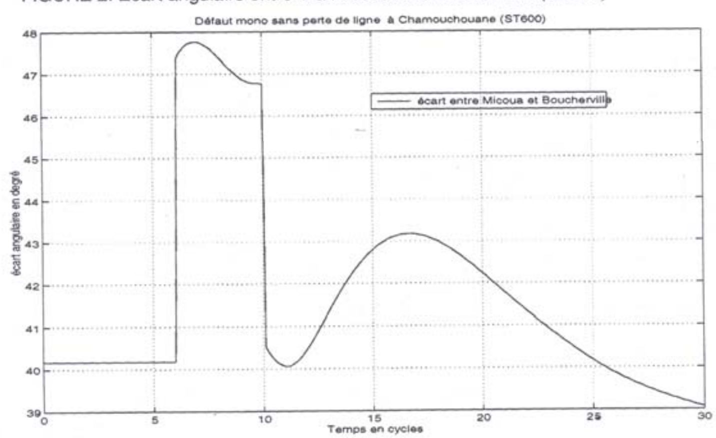
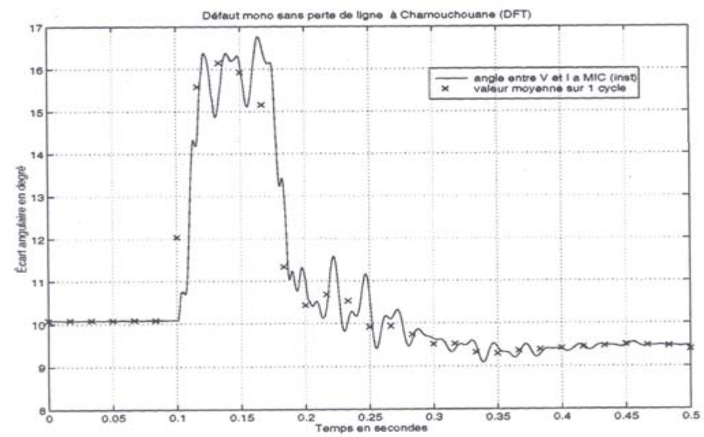


FIGURE 4: Écart angulaire entre V et I à Micoua (EMTP et DFT)



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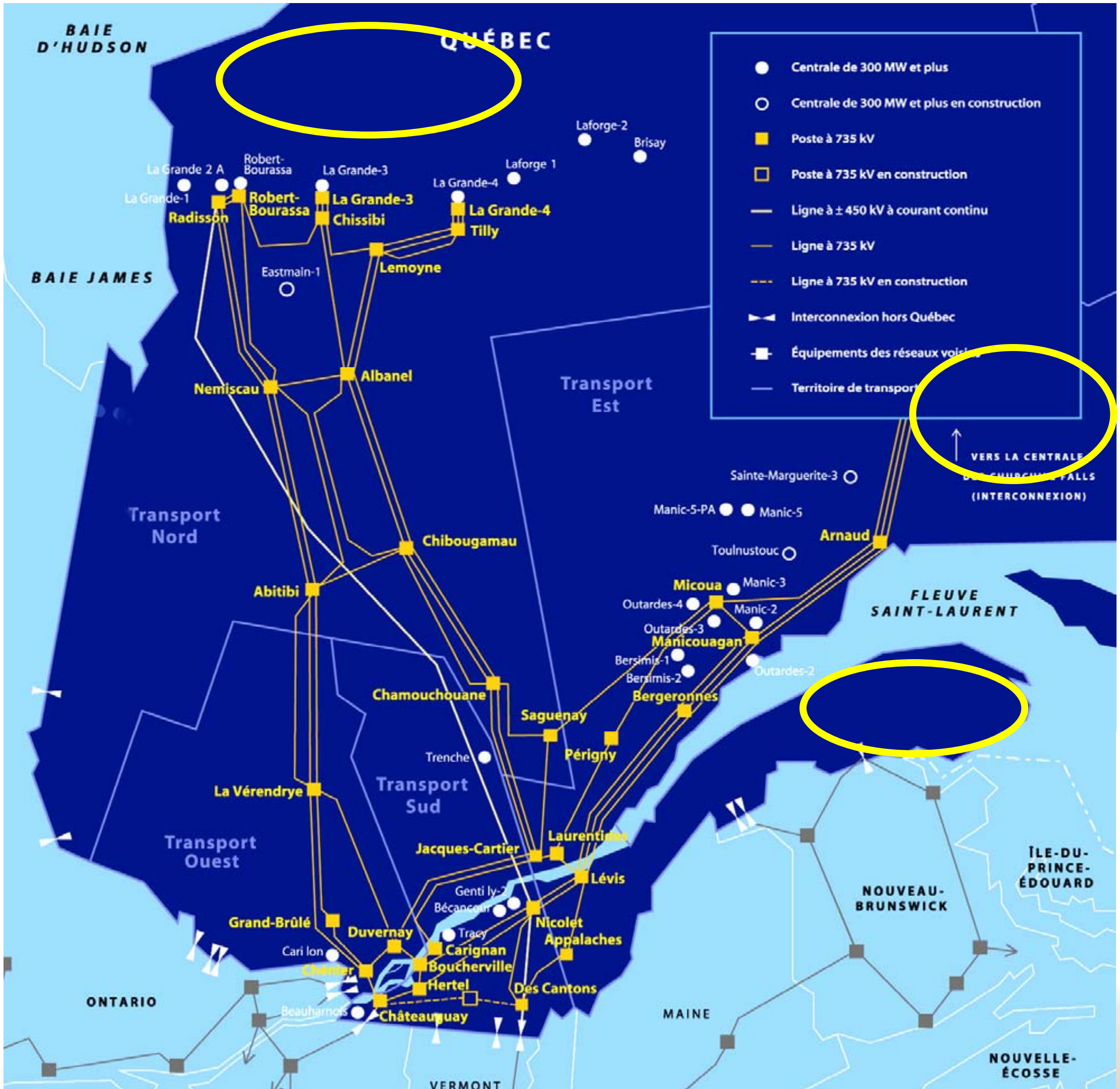
Future Challenges

- **There are many uncertainties with respect to future development of the system; delays can be short.**
- **The defense plan must evolve to follow system developments while maintaining the required efficiency and performance.**
- **Studies indicate that automatic actions will have to consider the severity of events to the system.**
- **Implementing new solutions may take 5 - 6 years or more.**



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ACOR R&D Project

- Goal is to enhance reliability of the system.
- Allows development of new products through a partnership between IREQ, TransÉnergie and manufacturers.
- Use of new techniques (fuzzy logic).
- Building on existing systems to enhance performance and address perennity.
- New products are developed in steps (need to proof of concept, manufacturing, testing and commercialization).

New filtering algorithms

- **Use of adaptive techniques to measure system variables**
- **Obtaining more precise measurements of system variables takes longer**
- **Actions must accommodate for more error when speed is required**

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New Products - SPS

- New method to detect line opening using local measurements (manufactured product to be installed on the network)
- New method to detect loss of synchronism (replacement of an old relay)
- New method to detect instability of a power plant
- New method to detect instability of a network (Instability indices)
- Use of synchronised phasor measurements to analyse severity of events.

New Products - Regulation

- New multi-band power system stabiliser
- New dynamic shunt compensator controls
- Overall regulation of SVCs based on synchronised phasor measurements

Thank You for Your Attention!

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