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Recent Developments in ANATEM A Comprehensive Program for the Analysis of Electromechanical Stability of Large Power Systems

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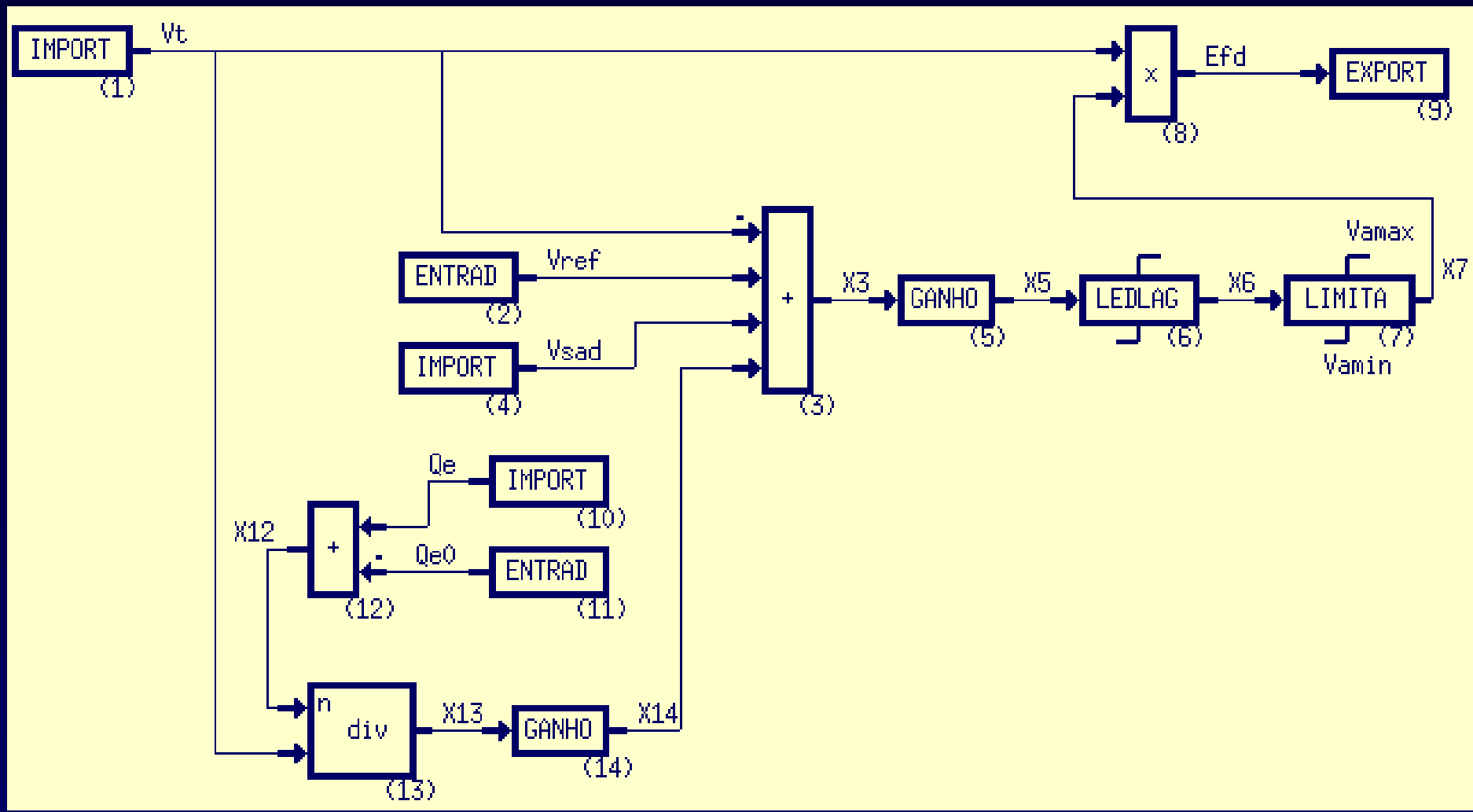
Features of the ANATEM

- Simulation of electromechanical stability of large power systems.
- Several detailed equipment models.
- Flexibility in modeling of controllers: User Defined Controllers
- Graphical Interface for visualization of the simulation results

Equipment Modeling

- Synchronous Machines (AVR, PSS, Governors)
- Induction Motors
- HVDC link including CCC
- On-load tap changers (OLTC)
- FACTS devices
- Static and Dynamic loads
- OLTC
- Relays

User Defined Controllers (UDC)



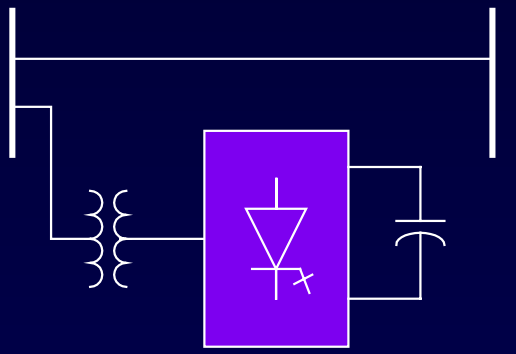
User Defined Controllers (UDC)

- Built-in Models: Computationally more Efficient, but fixed structure
- Flexibility
- 67 different elementary block types
- Allows to model all equipment control system in detail, Dynamic Loads and Special Protection Schemes (under development).

Recent Developments in ANATEM

- New Models
  - Modeling of new FACTS devices
  - Modeling of Special Protection Schemes
- Improving the Speed and Numerical Performance
- Post-processing Tools to Enhance the Productivity of Engineering Studies

New FACTS Device Models (under development)



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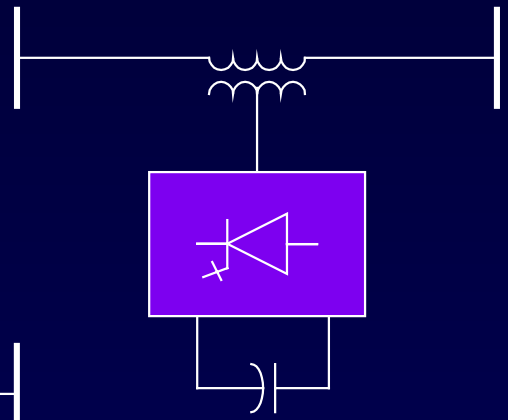
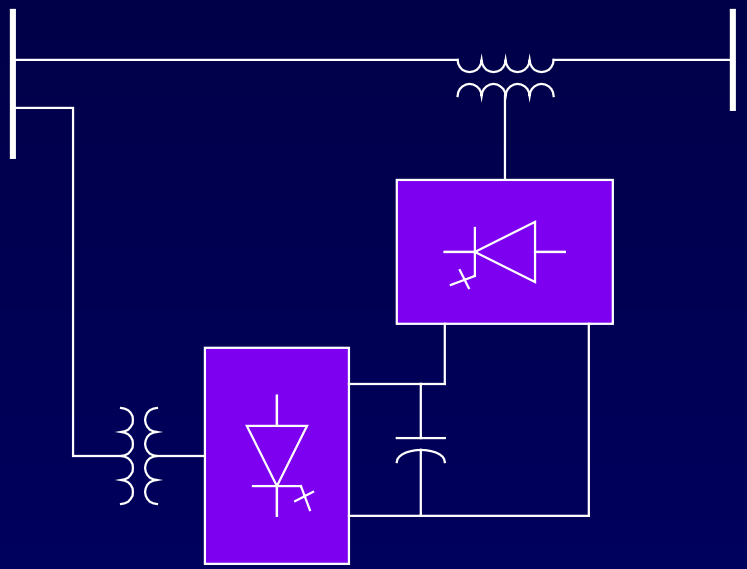


CSC



UPFC

Relay Models

- Underfrequency Relay for Load Shedding
- Undervoltage Relay for Load Shedding
- Overcurrent Relay for Line Tripping
- Impedance Relay for Line Tripping
- Overvoltage relay for Line Tripping
- Overvoltage and Undervoltage relay for shunt reactor/capacitor switching
- Out-of-step relay for detection of loss of synchronism between systems

Modeling of Special Protection Schemes (under development)

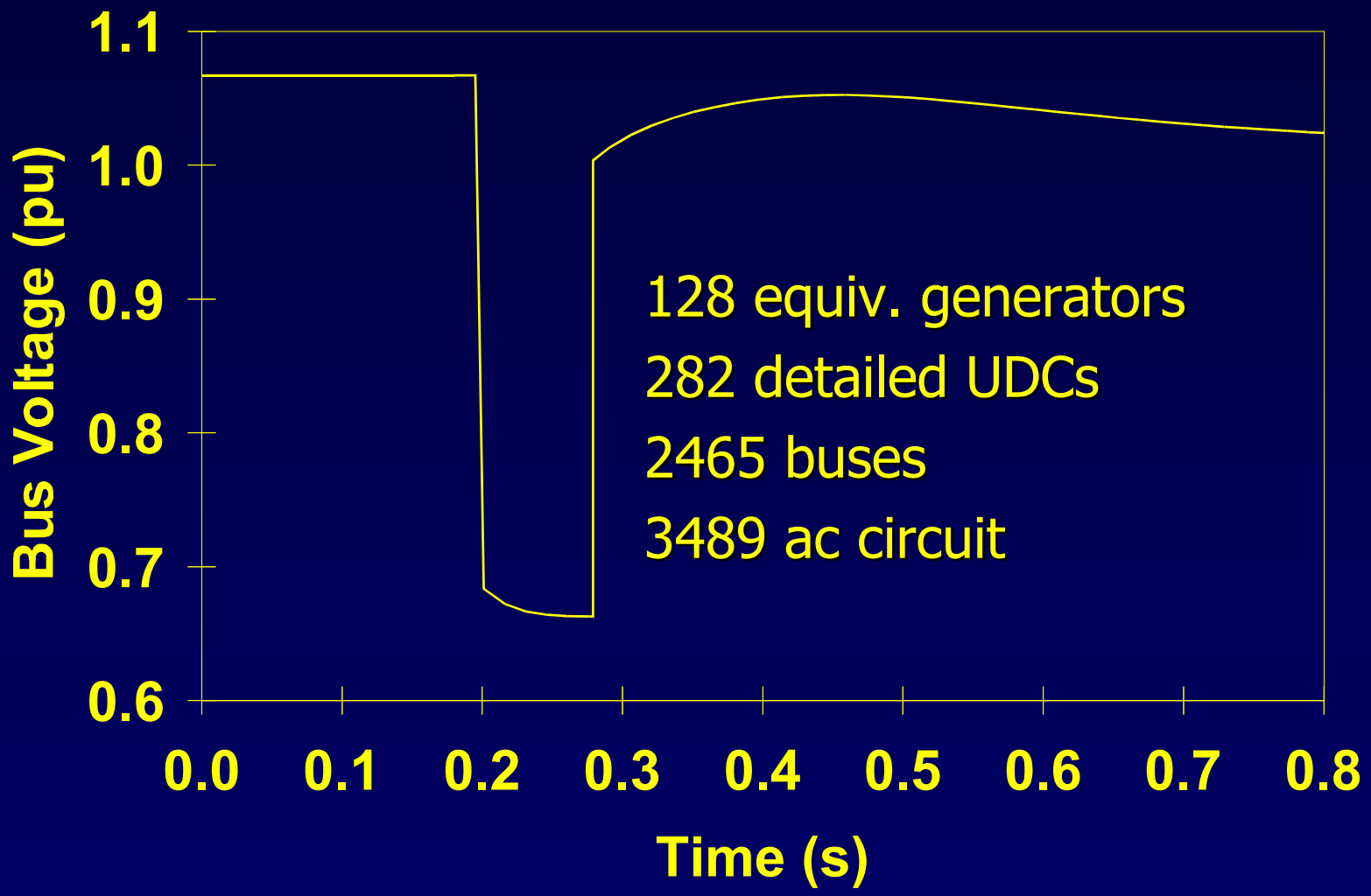
- Set of UDC Relays.
- Each switched element associated with a breaker, triggered by single or multiple relays.
- Interaction among relays.
- Breaker Reclosures are allowed (circuit, load and shunt breakers).

Improving the Solution Methods

- Implicit Alternate Solution Scheme.
- ac network solution
  - External Current Injection Method
  - Newton Method
- Variants of Newton Method
  - "Full" Newton
  - "Dishonest" Newton
  - "Very Dishonest" Newton

Full Brazilian Power System

Short Circuit at Cachoeira Paulista-Adrianopolis 500 kV Line



Comparison of Network Solution Methods

Method	Average Number of Iterations	Time (s)
External Injections	8.35	231
Full Newton	3.01	510
Dishonest Newton	3.02	353
Very Dishonest Newton (after 10 steps)*	3.02	282
Very Dishonest Newton (after 100 steps)*	3.02	274
Very Dishonest Newton (after 500 steps)*	3.06	271

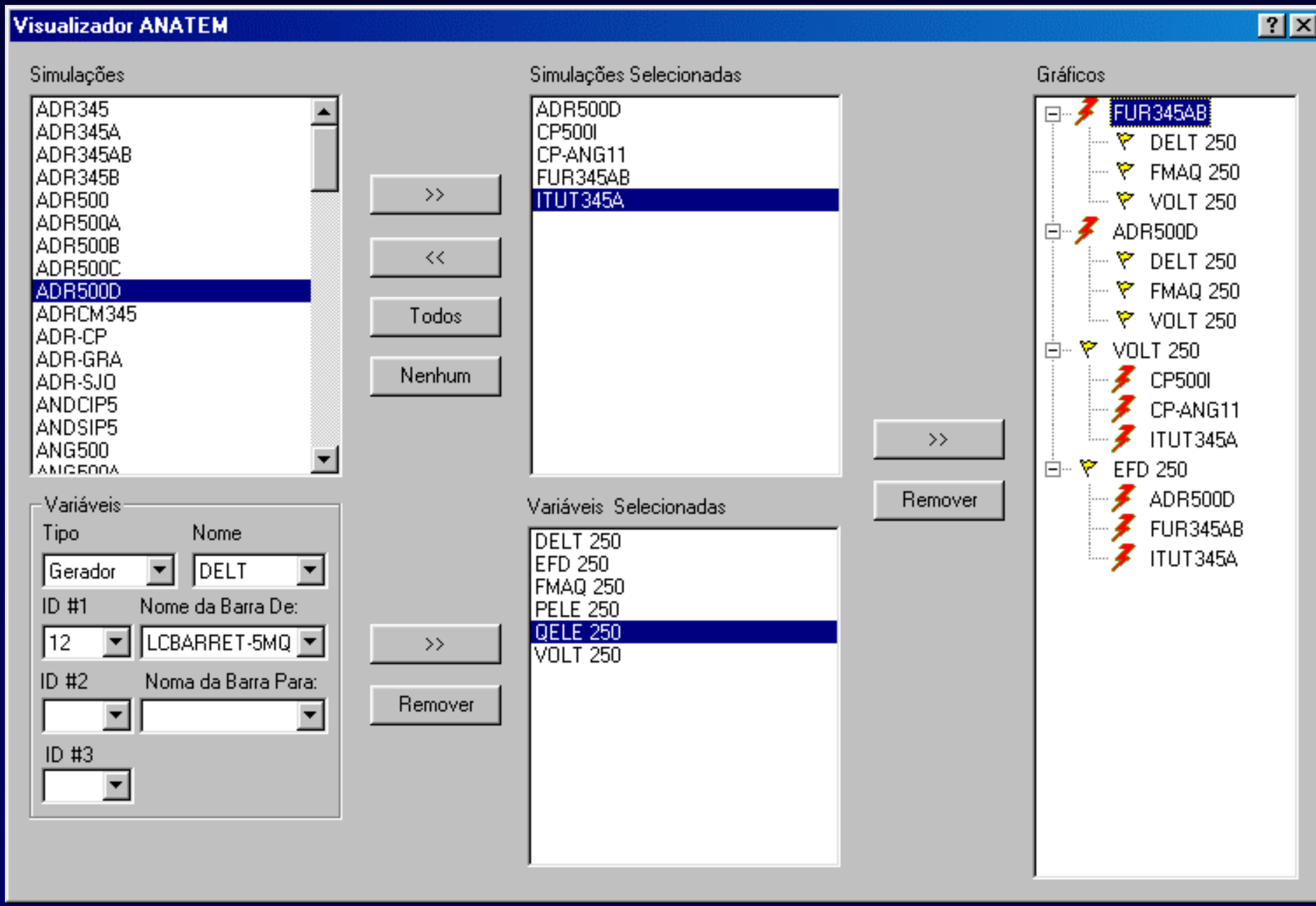
Methods at Discontinuities

Method	Number of Iterations	
	t=0.20s	t=0.28s
External Injections	25	26
Full Newton	6	5
Dishonest Newton	9	18

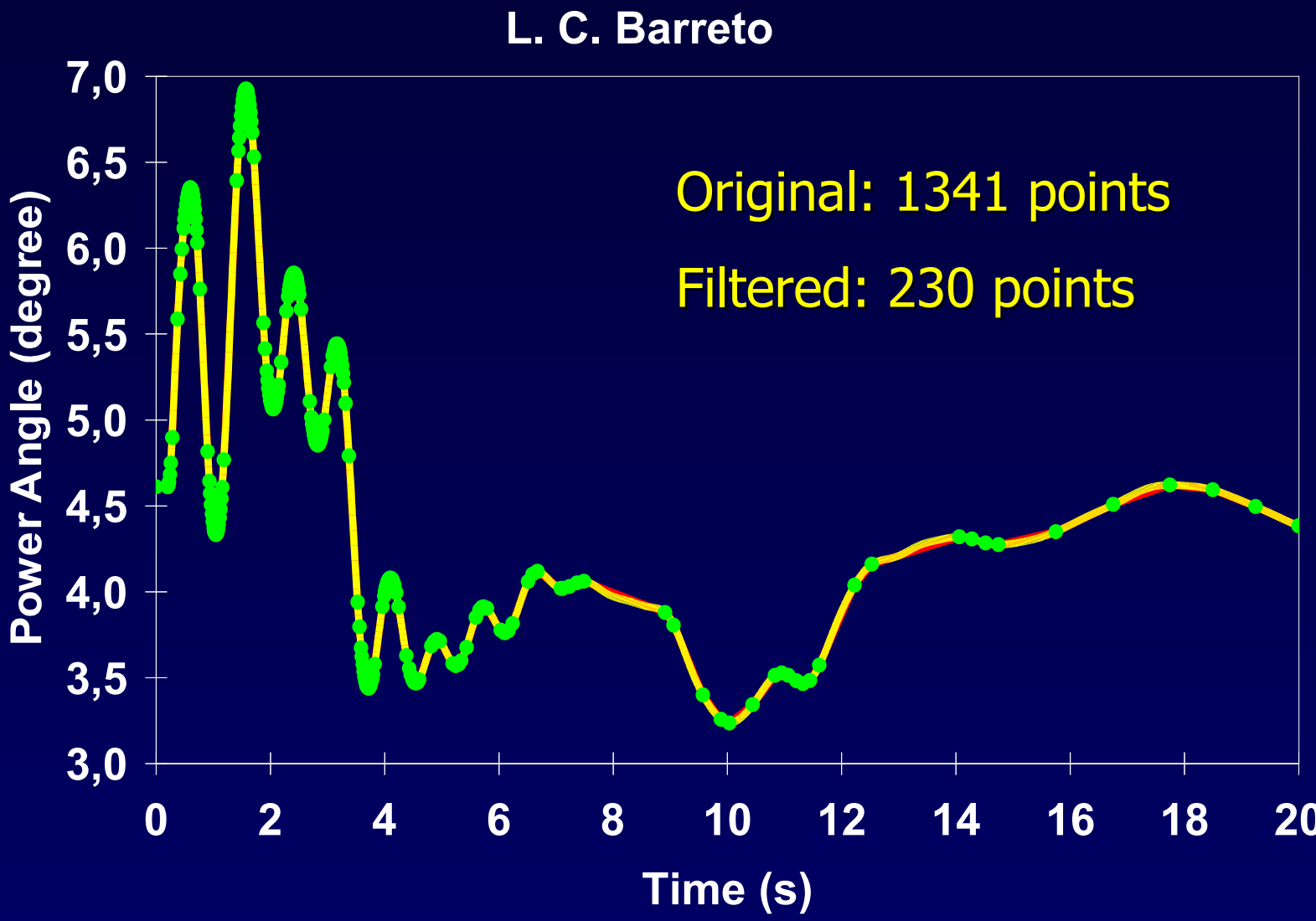
Post-Processing Manager Program

- Large Scale Systems: Large number of cases and monitoring variables.
- Combine Cases and Variables
- All Network variables calculated from bus voltages and network topology
- Large Amount of data storage solved by a filtering algorithm.

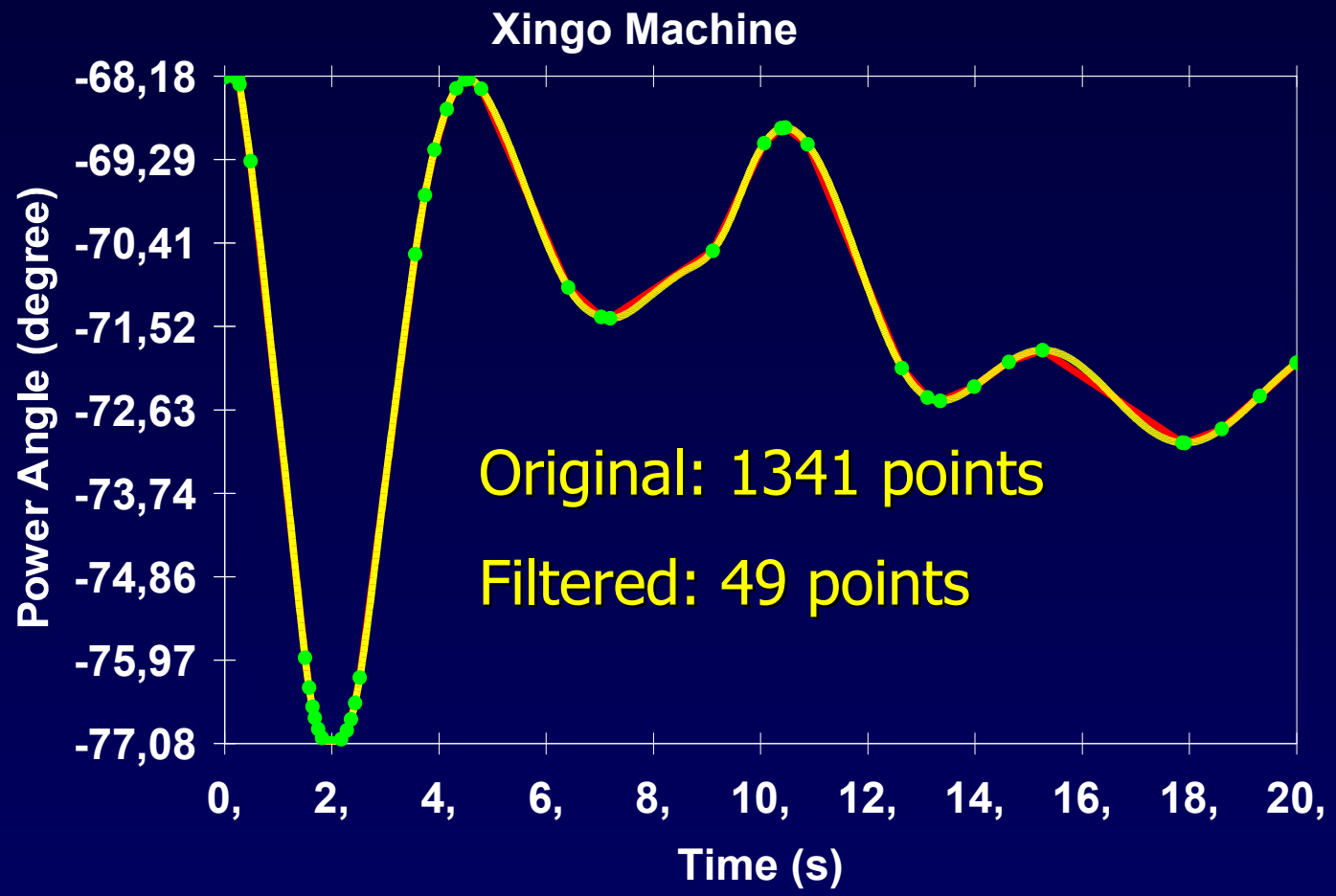
Post-Processing Manager Program



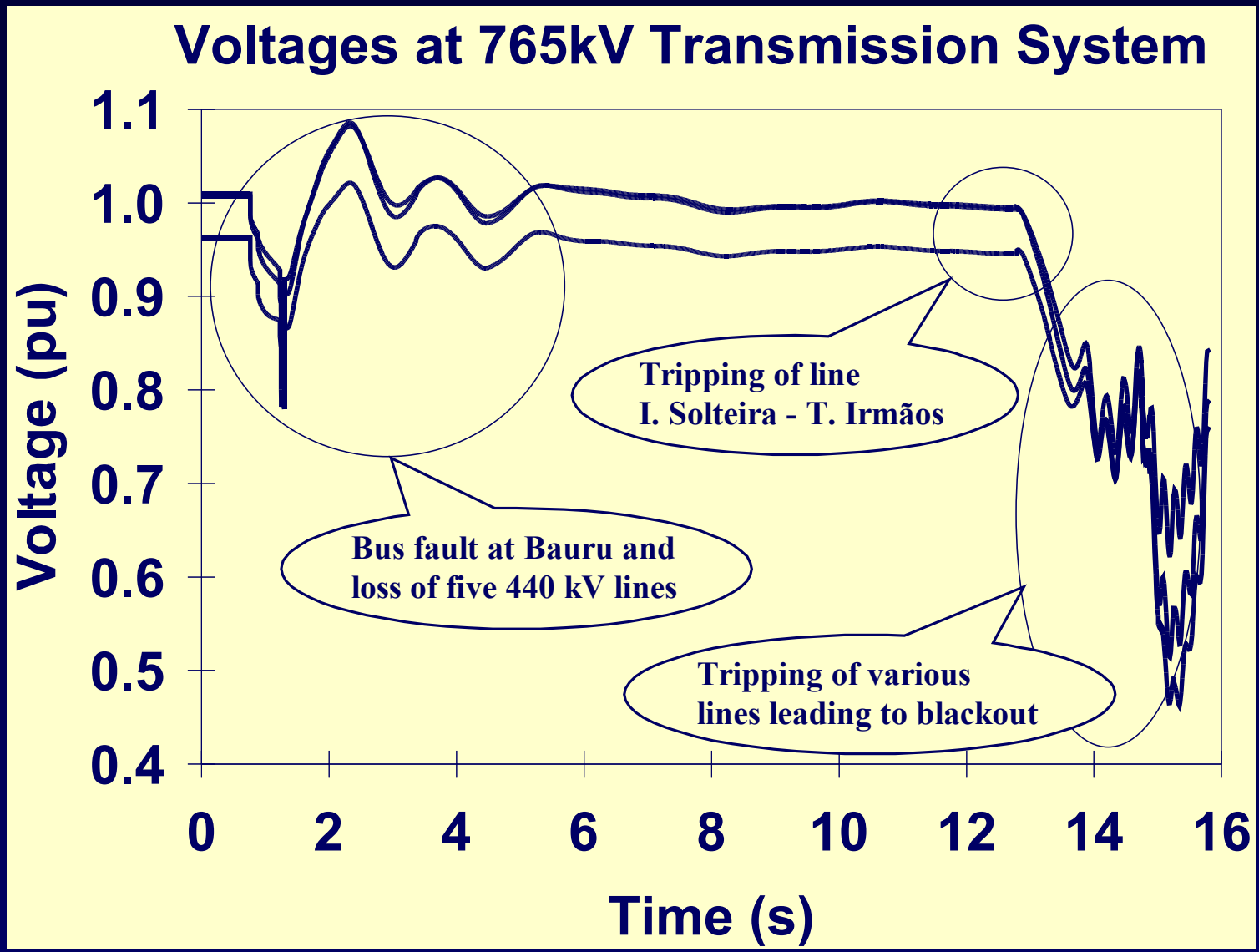
Filtering of Curves



Filtering of Curves



Simulation of March 11th Blackout



Other Developments

- Integration into a power system package, including power flow, small signal analysis, short-circuit calculation, etc., by means of a data base management system.

- Mid-Term Stability Simulations, including Automatic Generation Control (AGC) and Secondary Voltage Control.

Conclusions

- Recent Developments in ANATEM involved improvements in modeling, numerical robustness, flexibility of use and visualization of results.

- The constant feedback from the electrical companies helped making the software suitable to the stringent requirements of the electrical energy sector.