Consistency between off line simulation and real time simulation for large power systems and networks

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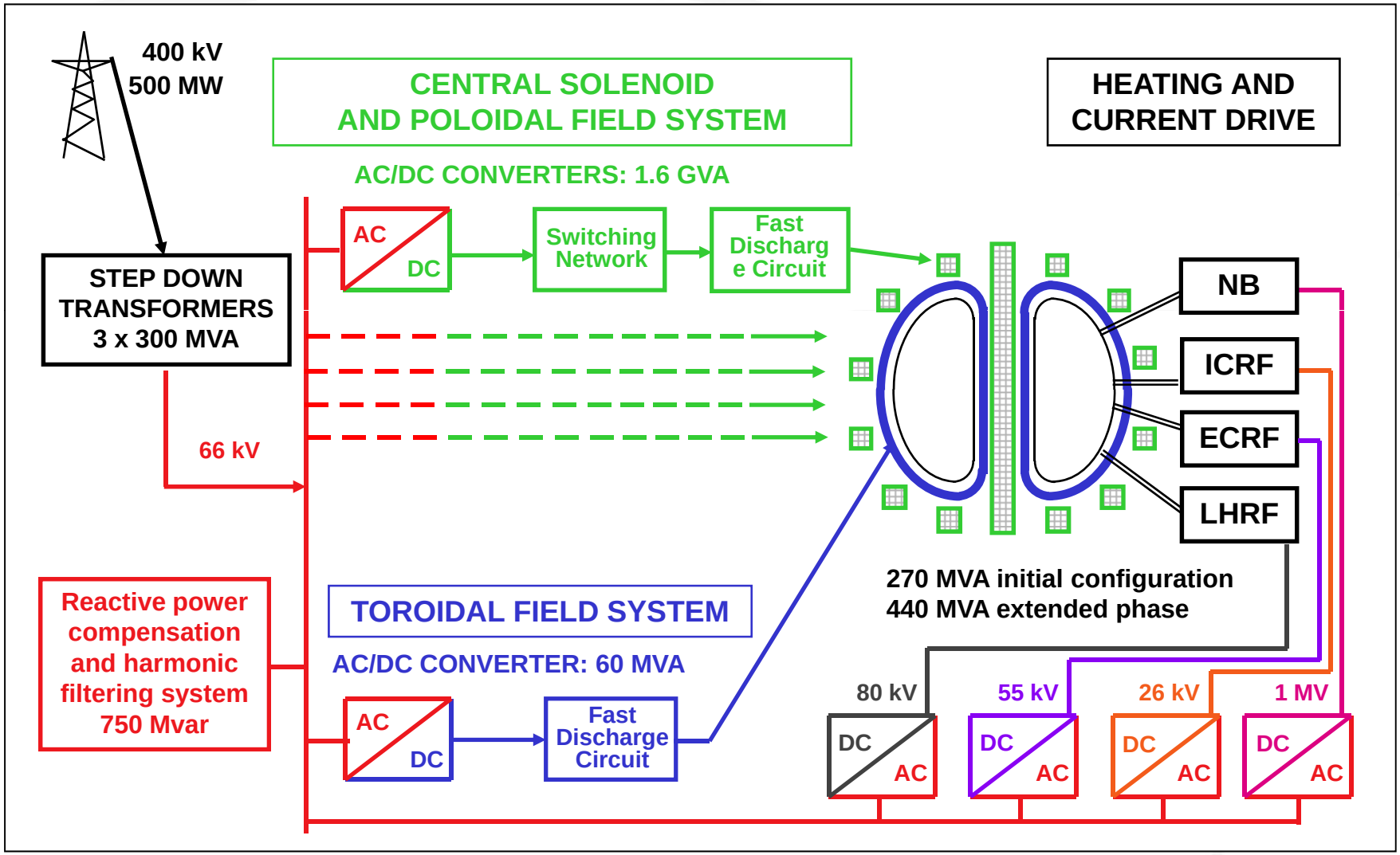
Summary of the presentation

- Large power systems : definition and examples
- Specificities of the simulation of large power systems
- Different approach for accelerated simulation and real time
- Example of ITER PPEN simulator
- Other examples

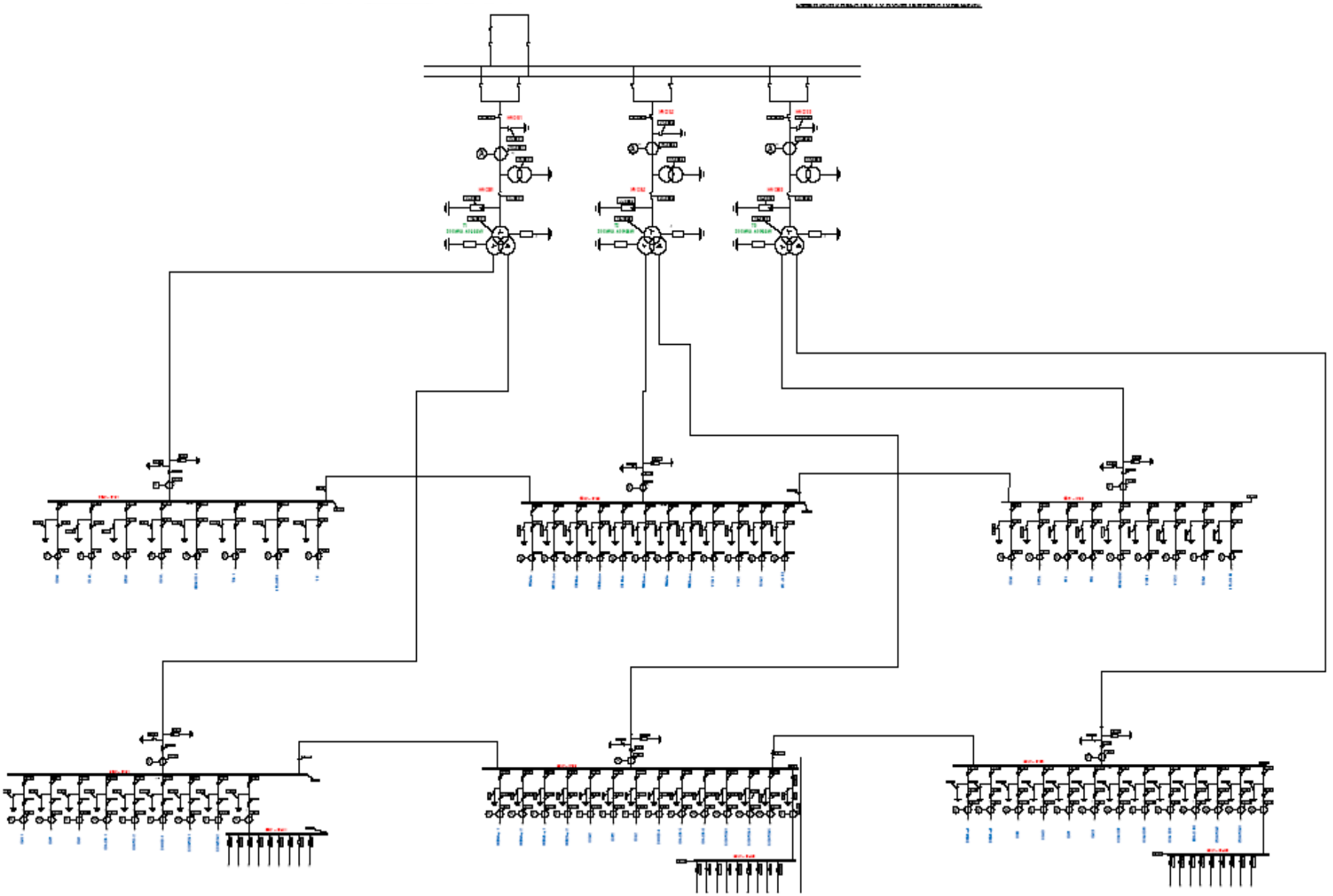
Large power systems and power networks

- Large power systems :
  - Power networks of industrial plants, nuclear plants
  - National or urban grids
  - Railway or tramway power grid
  - Transport systems with insulated grids,…
- Specificities :
  - Large number of nodes and branches,
  - Various type of components and systems
    - Machines (generators, motors,….)
    - Power electronics (FACT, SVC, VSD, …)
    - …
  - Various type of possible scenarios and configurations
    - Connected to the grid / Insulated
    - …

Exemple : ITER power network



Exemple : ITER PPEN power network



Different types of simulations of large power systems

- Off line simulation : feasibility study, base and detailed design, expertise on real systems :
  - Static or quasi-static : load flow calculation, short circuits,
  - Transients : stability analysis, abnormal event,
  - High frequency : harmonics, resonance
- Real time simulation :
  - Training simulators,
  - HIL, protection and control system testing.

Specificities for simulation of large power systems

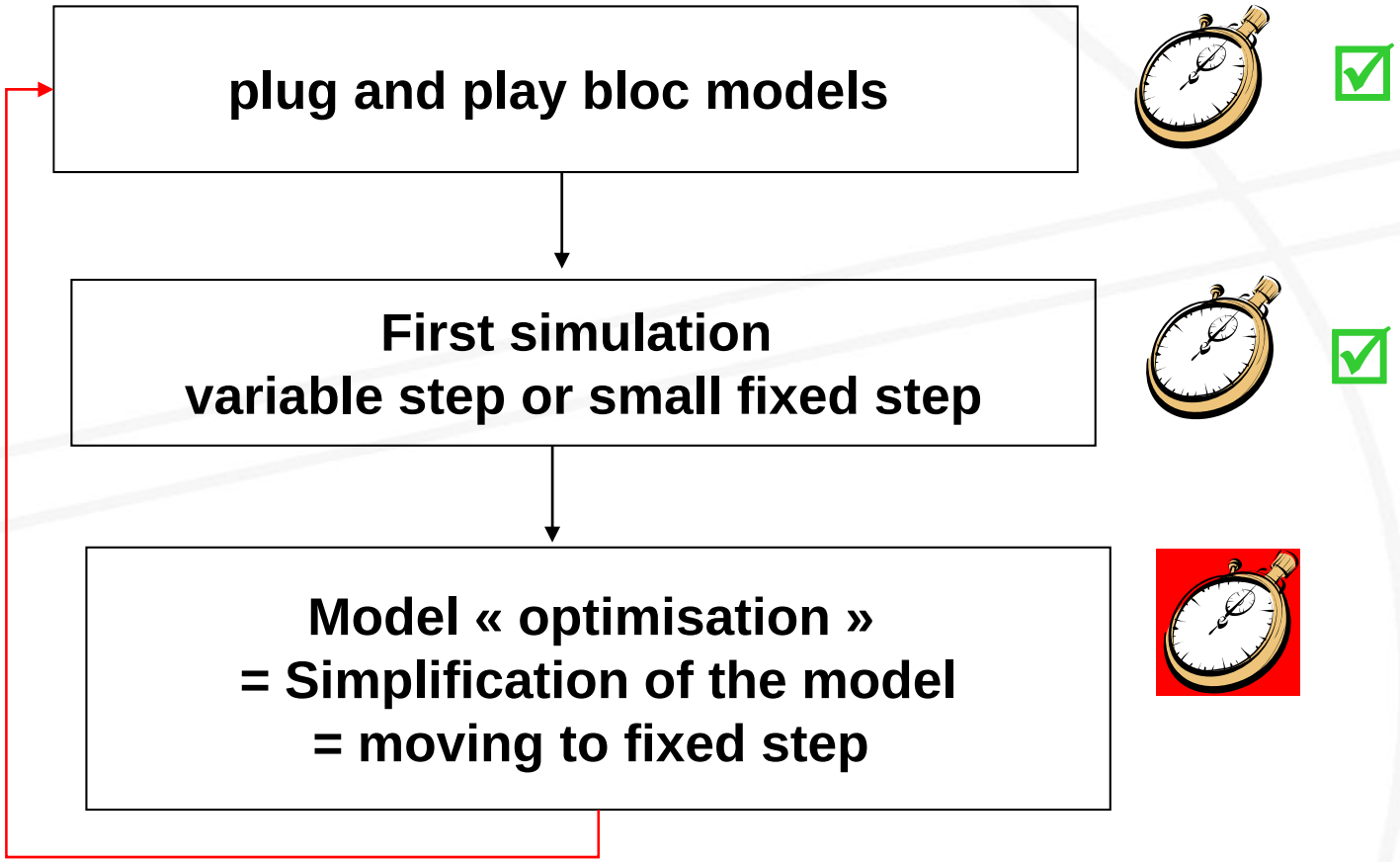
- Large number of nodes, branches, sources and loads
  - ⇒ Large number of state variables and equations
- Various type of components and systems
  - Power electronics (FACT, SVC, VSD, …)
  - Machines (generators, motors,….)
  - ⇒ Various time constants :
    - ⇒ Scenarios from the process (minutes)
    - ⇒ Electromechanical (seconds)
    - ⇒ Electrical (50 Hz => 20 ms)
    - ⇒ Switching (micro seconds) and harmonics

⇒ Problems of calculation time

- ⇒ For off line industrial simulation
- ⇒ For real time simulation

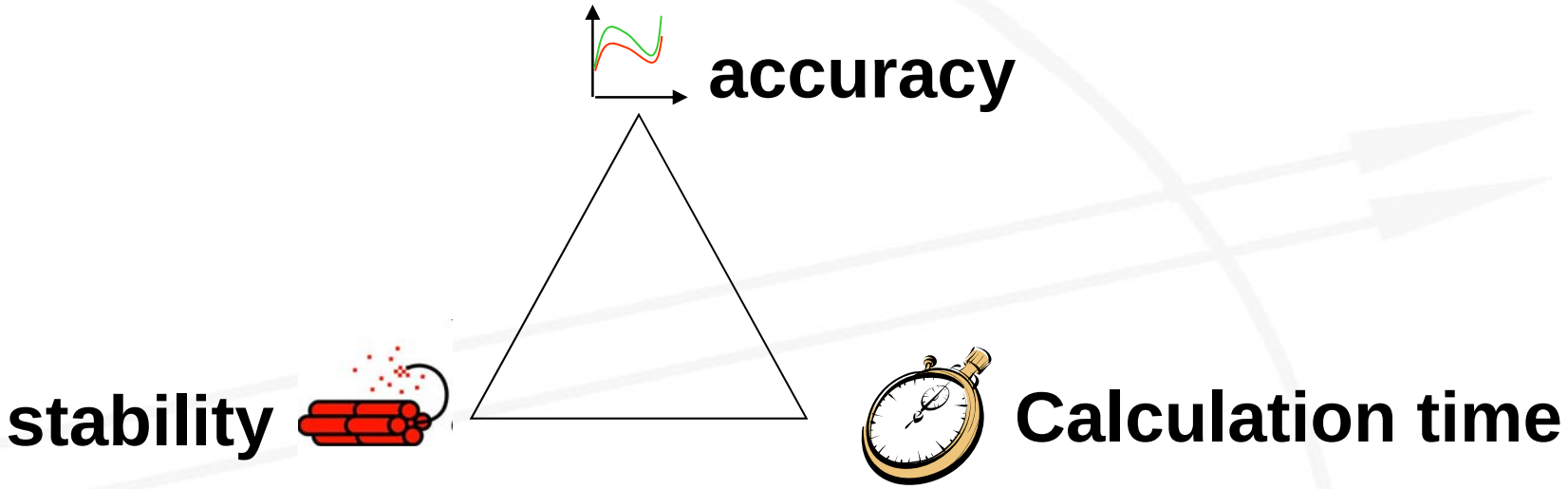
Several methods to accelerate simulation

1. Model « optimisation » a posteriori



Several methods

2 – managing the trade off at the model design phase :



- Step 1 : Identification of physical phenomena to represent and to neglect versus simulation objective
- Step 2 : Identification of the time constants of the power system
- Step 3 : Choice of the adapated software

Step 1 : Identification of physical phenomena

- Typical identification of physical phenomena to represent and to neglect versus objectives
  - For AC network, are RMS value are sufficient or sinwave representation is useful ?
  - Are they converters and are switching operations important ?
  - Are they circuit breakers and are overvoltage due to switching important ?
  - Are they generators and are non linearities important (ex turbocharger effect on the Diesel) ?
  - Are they singificant cable / line length and are parasitic capacitance important ?

Step 2 : Identification of the time constants

- Typical Identification of the time constants of the power systems
  - RC 1st order due to cable impedance
  - Switching frequency of converters
  - Control system time step
  - …

Step 3 : Identification of the adapted software

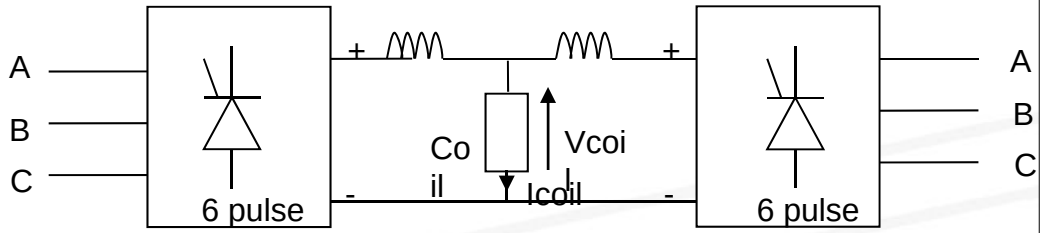
- Phasor simulation software/solver :
  - Only calculate amplitude and phase of the electrical variable,
  - Naturally fixed step (AC period)
  - Well adapted to real time (ex : ETAP + ETAP real time)
- Transient simulation software (ex : PSIM, EMTP, MATLAB + RT LAB)
  - Calculates the sine wave of electrical AC variables based on differential equations

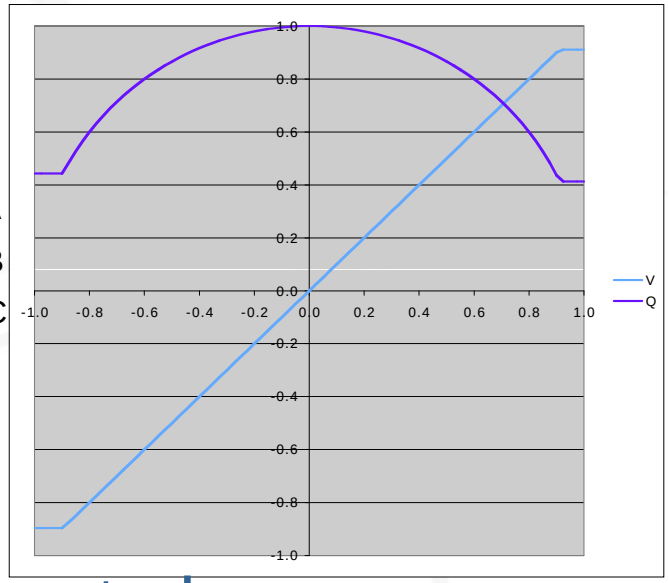
ITER PPEN models and simulations

- Ex : converter representation for the ITER PPEN global simulator :
  - Step 1 : simulation objective
    - simulation objective : check if reactive power and voltage on RTE 400 kV network
    - Inputs :
      - plasma scenario :
        - » 13 coil currents/voltage profile
        - » 5 heating system power profile
      - Components parameters
    - Output : power and voltages at every node

ITER PPEN models and simulations

- Step 1 : analysis of significant phenomena





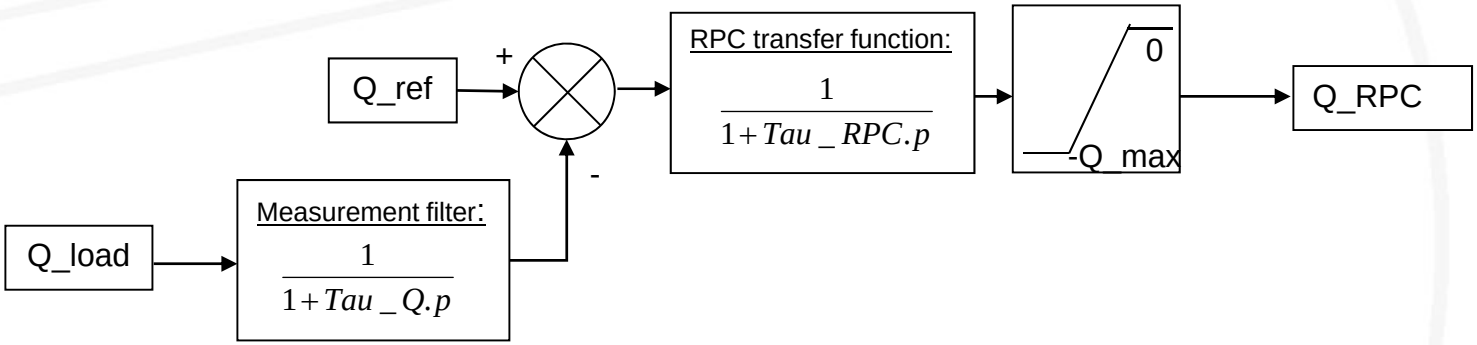
Simplified model without switching to be representative of :

- Active power
- Reactive power
- Alpha angle limits

Depending on coils current/voltage profile

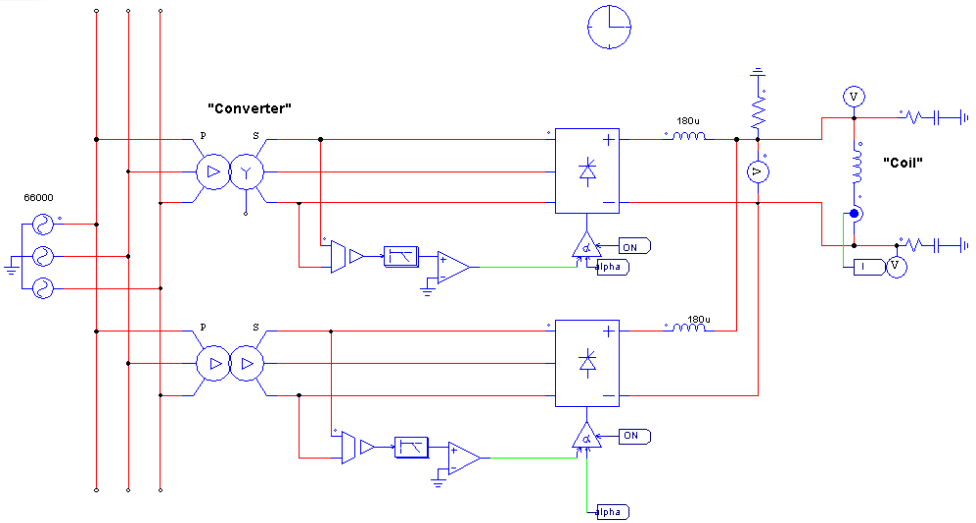
ITER PPEN models and simulations

- Step 2 : minimal time constants analysis :
  - Time step selected : 3 ms because of RPC (Reactive Power Compensator) dynamics



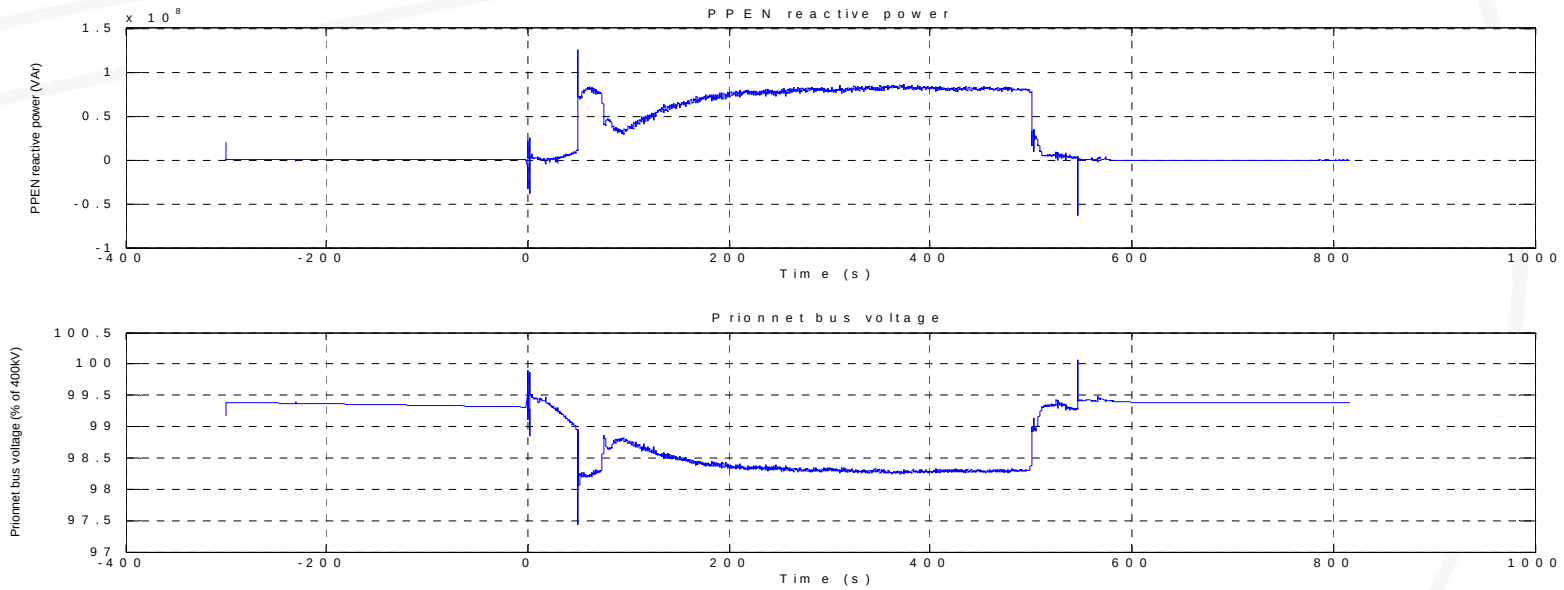
ITER PPEN models and simulations

- Step 3 : software selection
  - Context : Phasor simulation + converters represented without switching but accurate depending on topologies
  - Need for friendly MMI
    - ⇒ Choice of Matlab *.m with phasor solver developement
    - ⇒ Remark : PSIM chosen for converters simulation with component detailed design objective



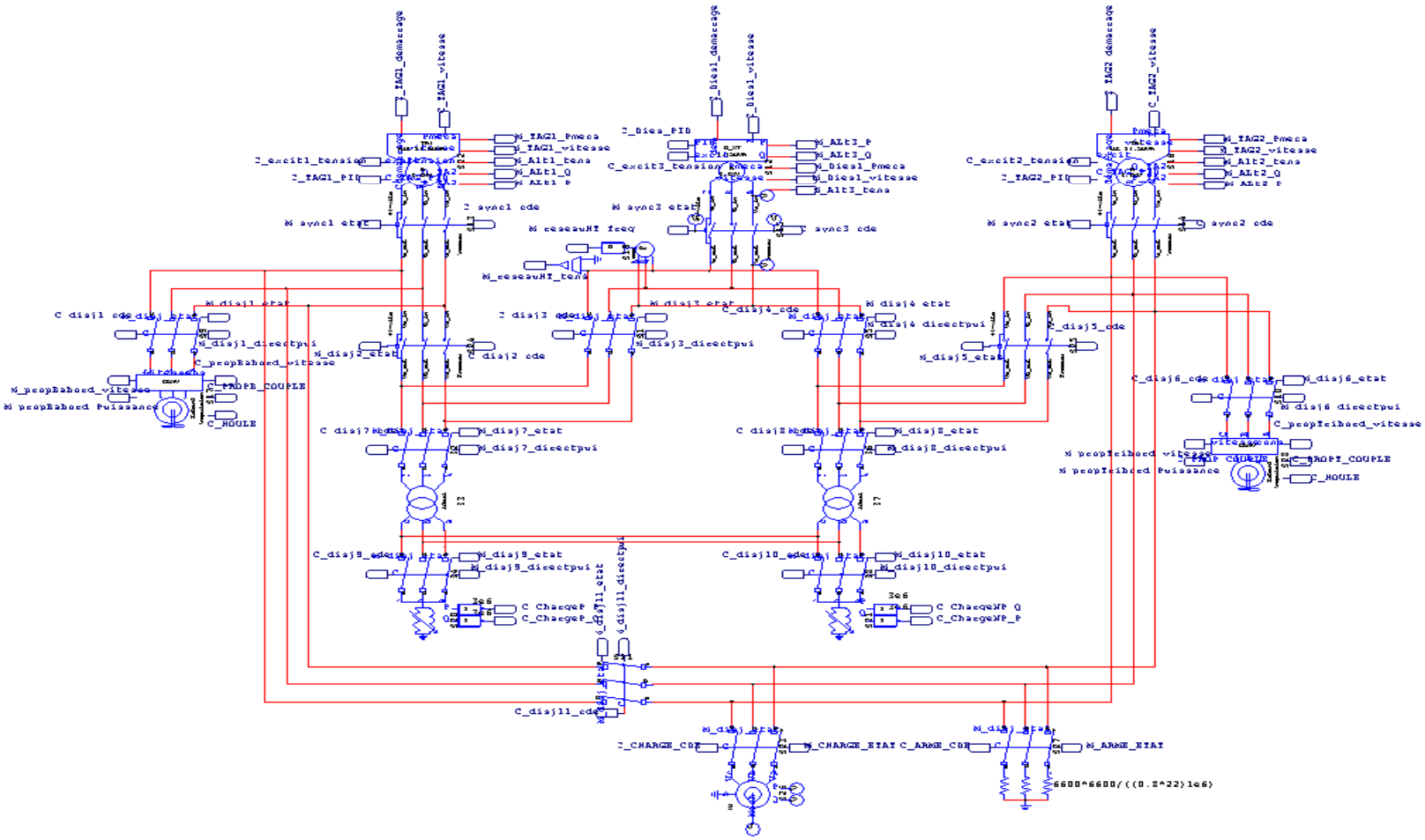
ITER PPEN models and simulations

- Results :
  - Complete PPEN network with :
    - AC distribution with 90 branches
    - More than 30 converters unit (12 pulses)
  - Better than real time on a classical laptop (easy to move to real time)

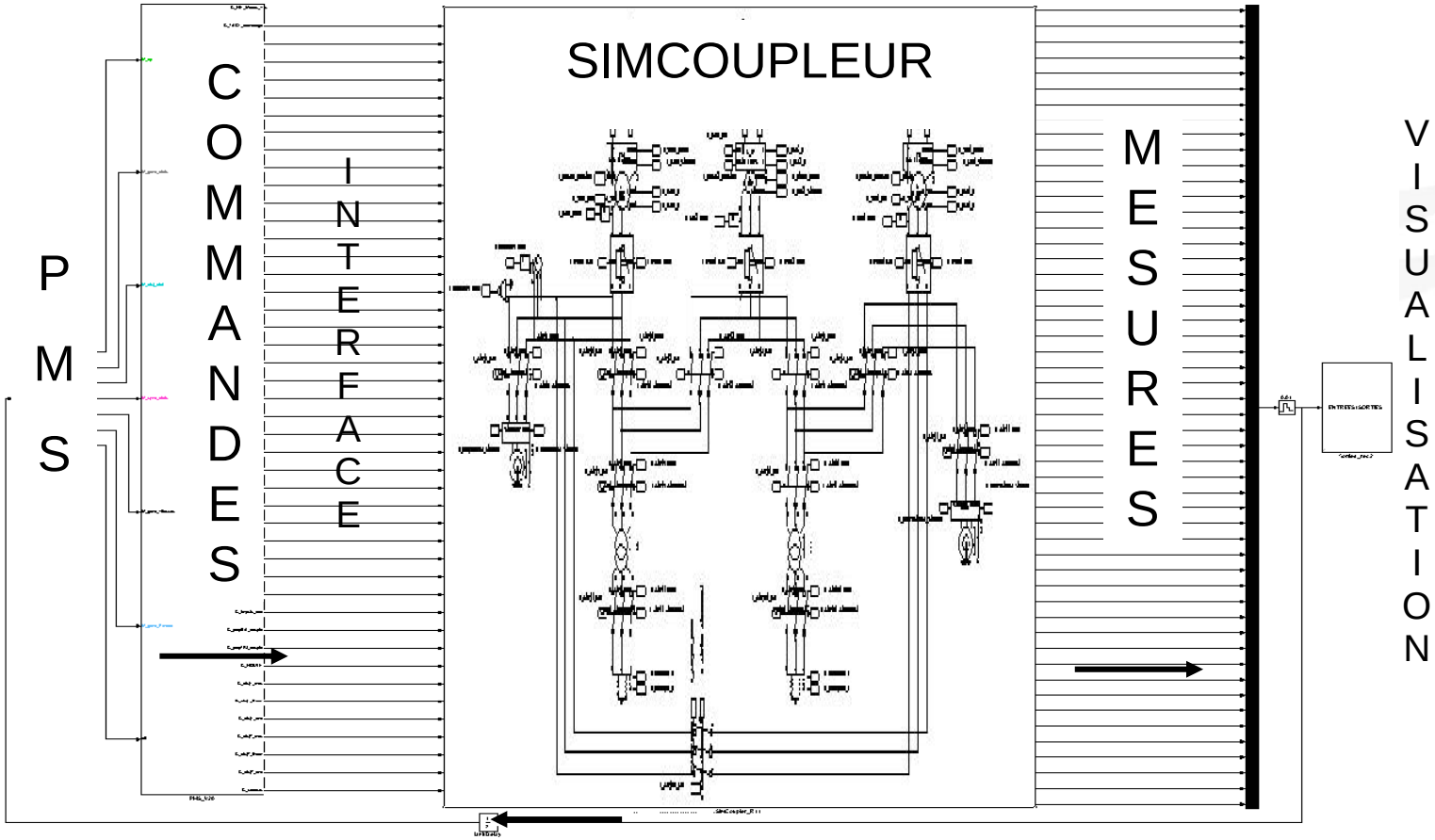


Other examples : MOSARE plateform

- AES (All Electric Ship) simulation for transient stability analysis : MOSARE plateform for French DGA



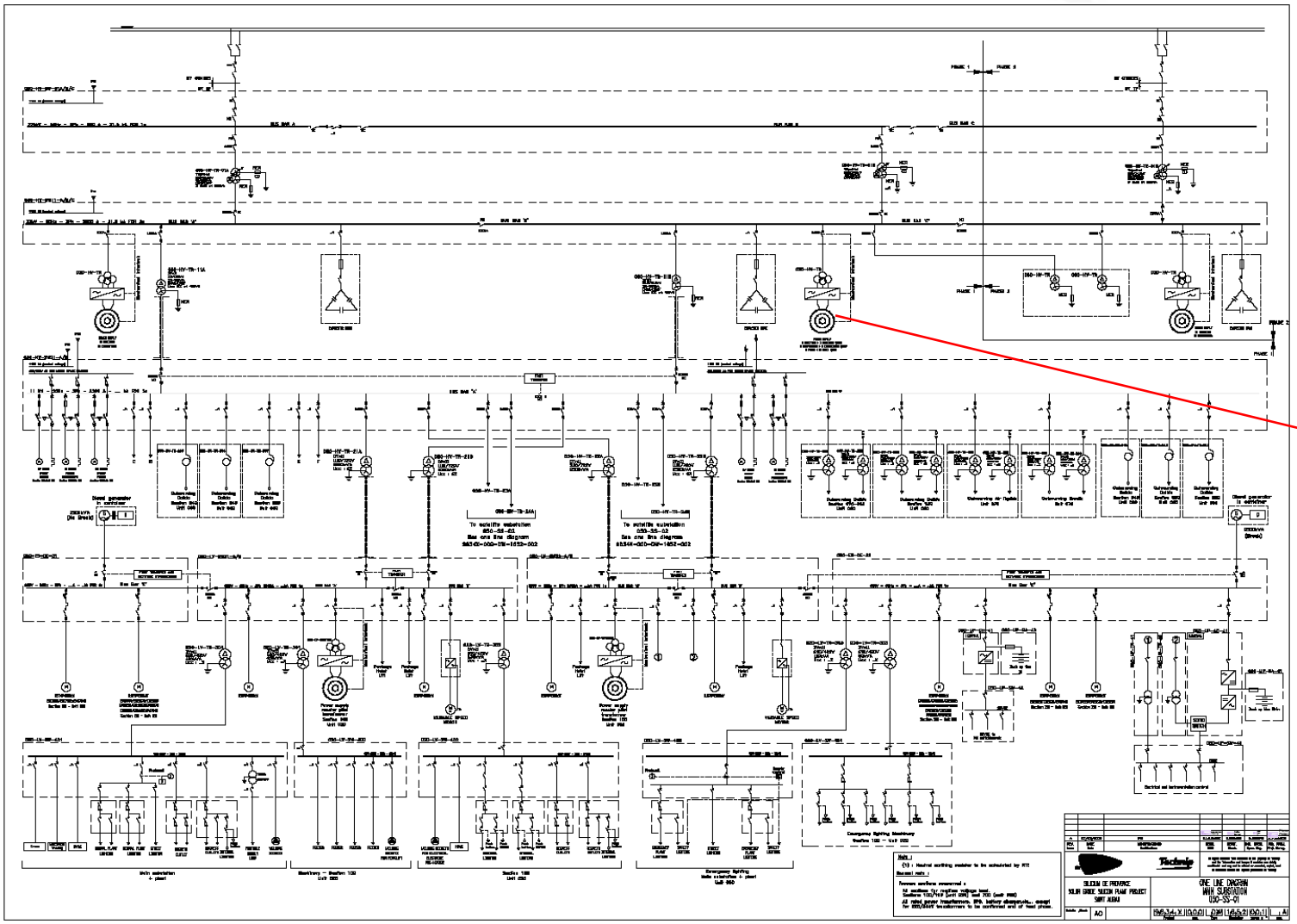
Other examples : MOSARE plateform



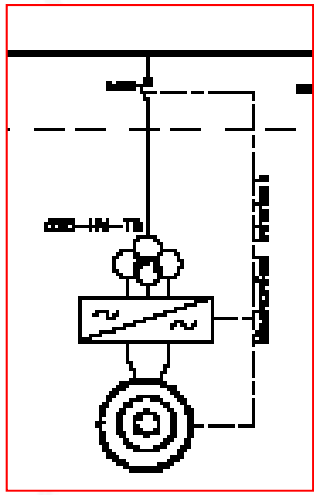
Co simulation between power and control parts

Other examples : SILPRO power network

- Preliminary study of the HV power network for a new plant (FEED : Front End Engineering Design) : TECHNIP

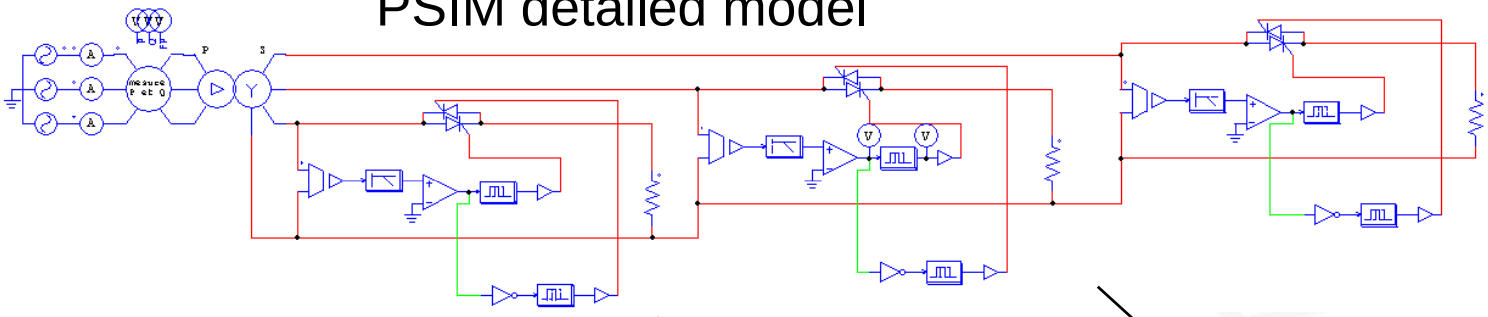


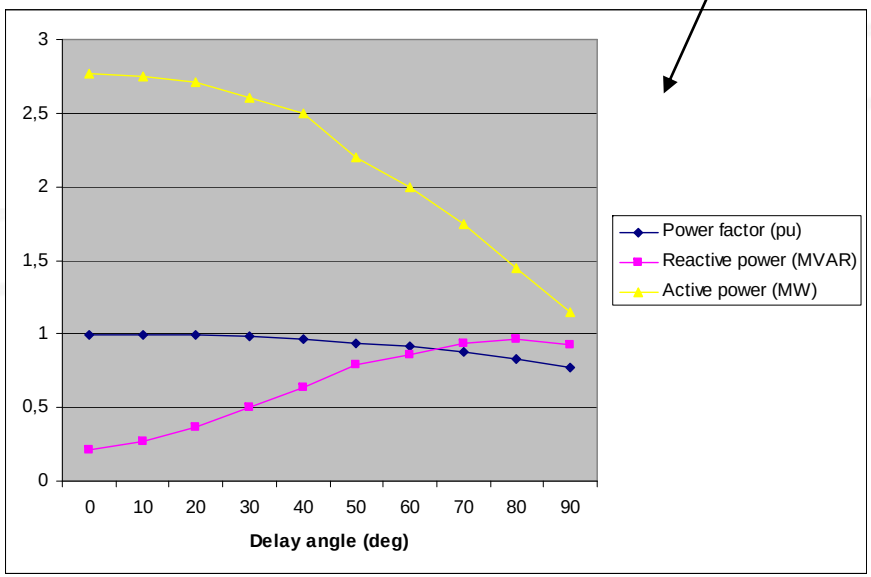
- 2 * 120 MVA Transformers
- 42 reactors (3.8 to 4.6 MVA)



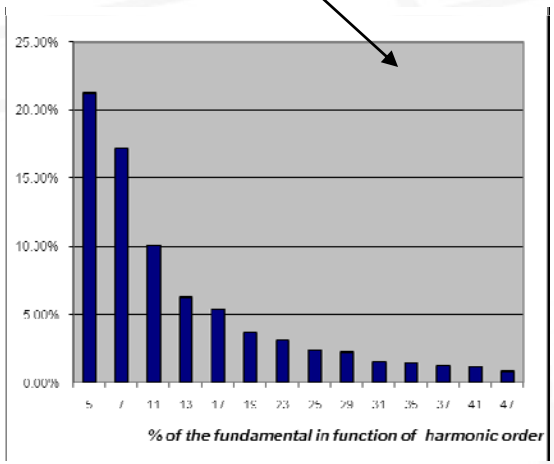
Other examples : SILPRO power network

PSIM detailed model





Reactive power characteristics

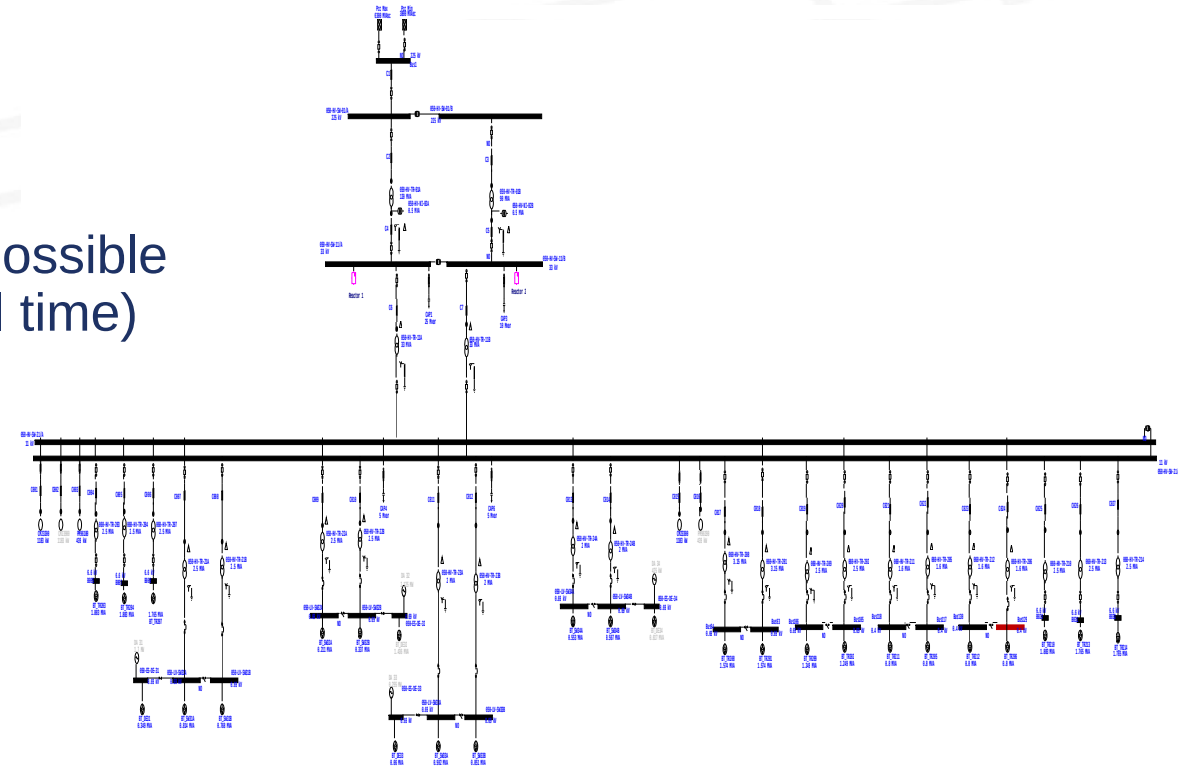


Harmonics characteristics

Other examples : SILPRO power network

- Complete ETAP model of the network
- Validation of SLD :
  - Load flow and reactive compensation
  - Short circuits
  - Harmonics
  - Motor starting
- Very fast model with possible REAL time (ETAP real time)

ETAP model



Conclusions

- The modeling methodology is decisive both for accelerated offline simulation and real time simulation of large power systems
- A good preliminary definition of the detail level is time saving on the whole project