iTesla: Innovative Tools for Electrical System Security within Large Areas

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Panel: Faster than Real-time Dynamics Simulation
Tesla: Main Objectives

To develop a toolbox that will be needed by Transmission System Operators to operate the European power system in the years to come

- This toolbox will provide operators with tools to assess the security of power system situations from 2 days ahead to real time. The outputs will be relevant preventive or curative actions when needed.
- Today TSOs must operate the system with reduced margins. Current contingency analyses are no longer suitable to address phenomena such as high penetration of intermittent energy sources, new power electronic devices, larger power transfer over long distances.

To validate this toolbox at the national and at the pan-European level

- In particular, validation on different European grids in various situations.
- And validation on the whole European continental network.
iTesla: a collaborative R&D project co-funded by the European Commission (7th Framework Programme)

Project costs 19.4 M€ (EC : 13.2 M€)

started in January 2012 and will run until end of 2015.
I/Tesla: An European Platform

Online: permanently running
sliding window: 2 day ahead to few min. ahead

Offline: once a week/month

External data (forecasts and snapshots) provided by individual TSOs

Data acquisition and storage

Management of security rules

Merging module

Contingency and Base cases screening (several stages)

Time domain simulations

Synthesis of recommendations for the operator

Sampling of stochastic variables

Building of realistic initial grid states

Impact Analysis: Time domain simulations

Data mining on the results of simulation

Offline validation of dynamic models

Improvements of defense and restoration plans

IEEE PES Power & Energy Society
Offline: Definition of security rules

• High Performance Computing (HPC)
  ✓ 9.7 \times 10^6 \text{ core.hours} on CURIE: GENCI@CEA (ranked 26), for 12 months

  ✓ Intensive use of **Time domain simulations**

• Data mining and applied mathematics
  ✓ Non-Gaussian variables
  ✓ PCA, Clustering, Copulas
  ✓ Ensemble trees, Decision trees
  ✓ Optimization (MINLP)

• Use of open source solutions
• Investigated dynamic phenomena classified according to their frequency spectrum \((time\, constants)\)
TIME DOMAIN SIMULATION: 3 DIMENSIONS

Simulation tool

Computational performance

Modelling flexibility

Accuracy - Quality

Computational performance:
Look head ➔ Contingency analysis («what if») on large number of base cases

Each time domain simulation must be faster than real time but not executed in real time (too late to make decisions) !!!
• Different Needs for Time Domain Simulation (TDS)
  – On-line Dynamic Security Assessment (DSA) simulating 1 min.
    • Analysis of 5000 contingencies for 1000 base cases in 5 min. ➔ 5 \times 10^6 \text{TDS}
    • Screening techniques: optimistic \text{ratio} 5\% ➔ 250 000 \text{TDS}
    • Parallel processing using a private Data Center: 1000 cores ➔ 250 \text{TDS/core}
    ➔ 1 \text{TDS/core in 1.2 sec. (130 000 State Variables \Rightarrow Challenging )}

  – Off-line Studies (Monte-Carlo approach) simulating 1 min.
    • Analysis on 5000 Contingencies for 5000 base cases in 20 hours ➔ 25 \times 10^6 \text{TDS}
    • Importance sampling possible: average ratio 50\% ➔ 12.5 \times 10^6 \text{TDS}
    • Using external HPC once a week/month: 10 000 Cores ➔ 1250 \text{TDS/core}
    ➔ 1 \text{TDS/core in 58 sec. (feasible)}
    
    \text{Actual cost for one run} = 200 \times 10^3 \text{core.hours (Commercial offer \approx 20 k\€)}
LESSONS LEARNED SO FAR IN THE PROJECT

- Speed up of individual Time Domain Simulation (TDS)
  - Fine grain parallelism: difficult ➔ keep cores for external loops
  - Sparse Linear Solver: most computational intensive part
  - Dedicated Sequential LU (KLU) seems very difficult to beat (http://www.fp7-pegase.com/)
    - Size is only around 100 000 and very sparse (0.01 \% nnz)
    - Stiff system: very large ratio between the largest and the smallest time constants:
      ➔ frequent full LU preconditioning requires for iterative methods (GMRES)
  - Management of Input / Output becomes critical when a large number of TDS are running in //.
    - Conflicts to access the shared file system
    - Minimize the amount of outputs, write in the local file system then copy to the shared file system
THANK YOU FOR YOUR ATTENTION!

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