EMTP Simulation of micro-grids : from 100% conventional synchronous generation to 100% inverter-based generation

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Summary

1. Introduction
2. Simulation of typical hybrid networks with inverters and synchronous machines
3. Simulation of a real industrial case aiming at 100% inverter based generation
4. Conclusion

1. Introduction

- To combat climate change, conventional generators are gradually replaced by renewable energies.
- This can become a challenge, especially for micro-grids because their stability is difficult to preserve because of their low inertia.
- This is one of the reasons why micro-grid is becoming more and more studied
- This presentation will show how EMTP can be used to study the stability of micro-grids with a high percentage of renewable generation, sometimes even without any synchronous generator:
    - On typical networks
    - With a real study-case

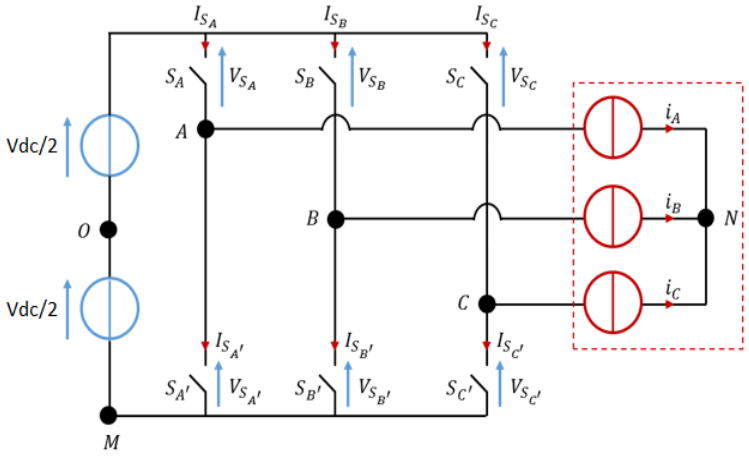
2.A. Models implementation

Inverters

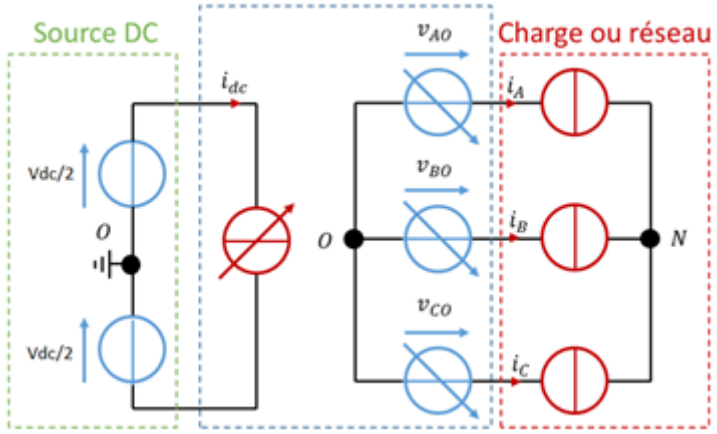
Current-controlled
(« grid-feeding »)

Voltage-controlled
(« grid-forming »)

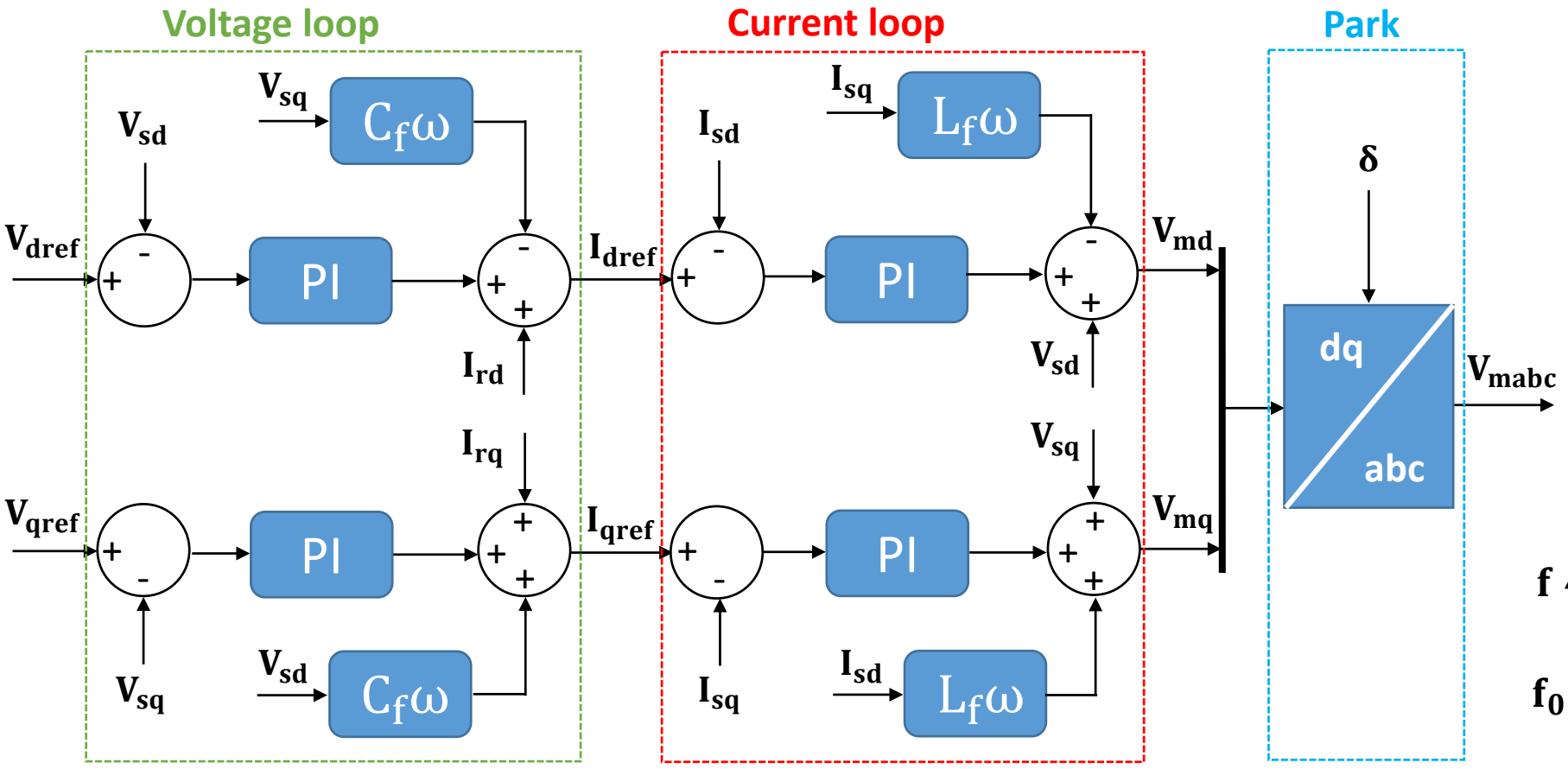
Detailed model



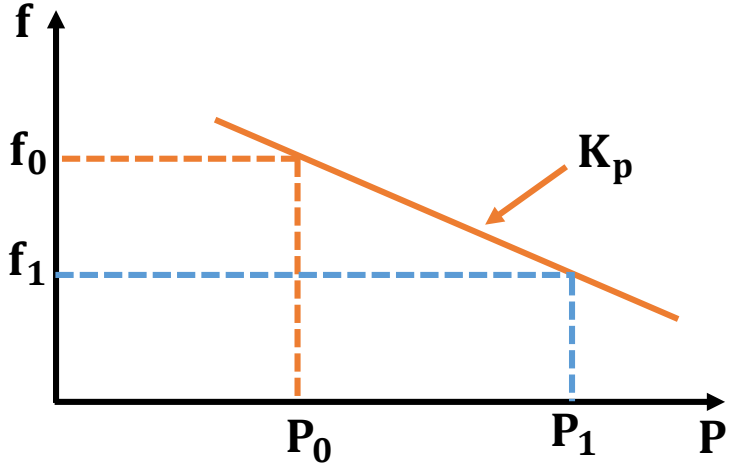
Average model



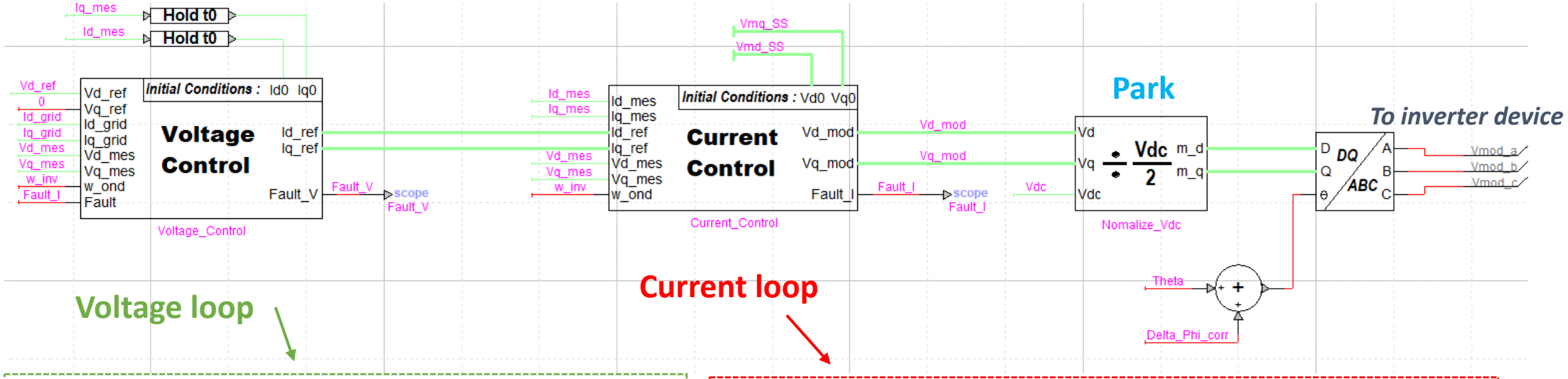
Cascaded voltage loop with droop control

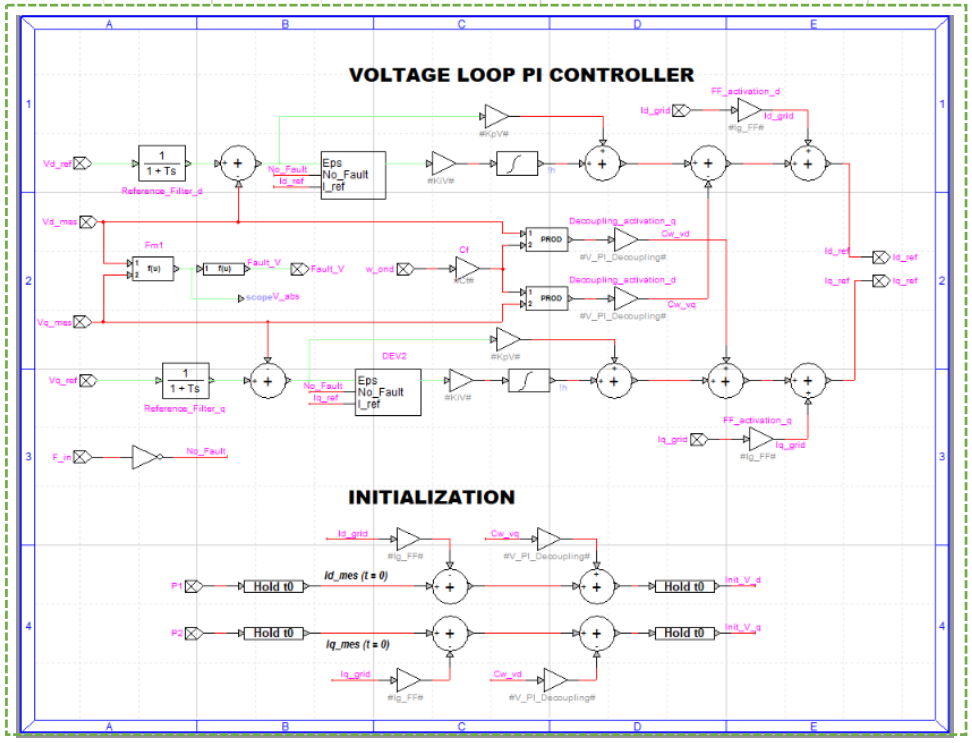


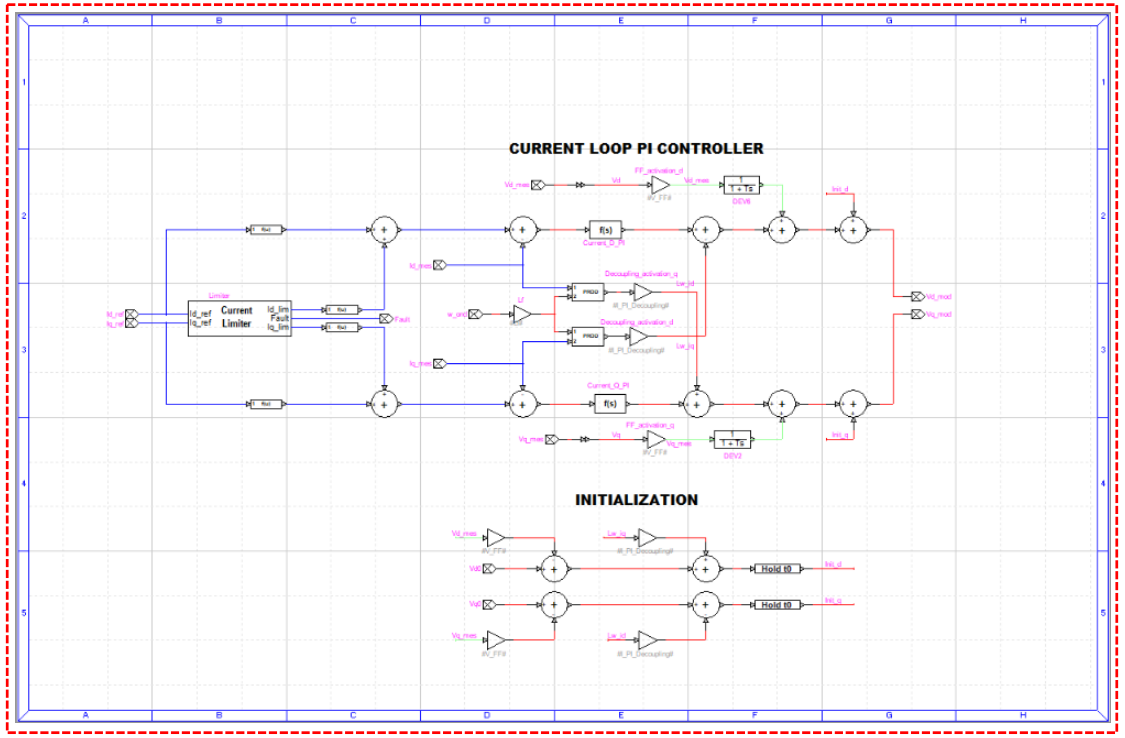
$$f - f_{ref} = -K_p(P - P_{ref})$$



EMTP Implémentation

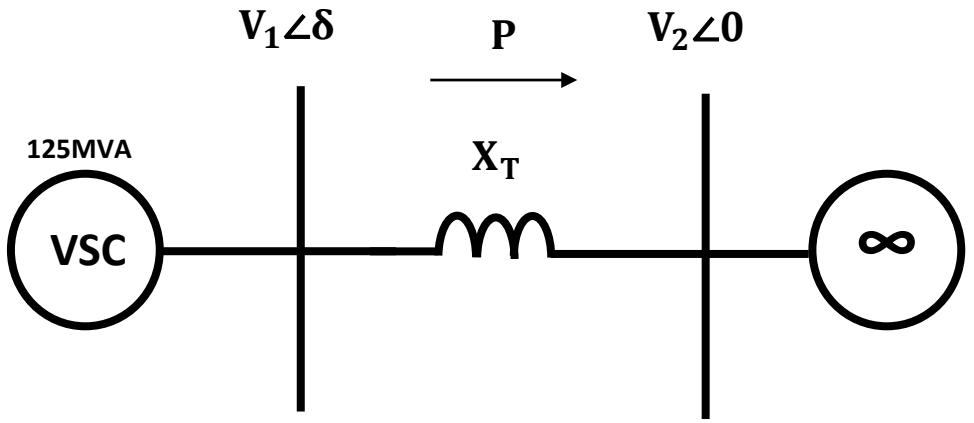


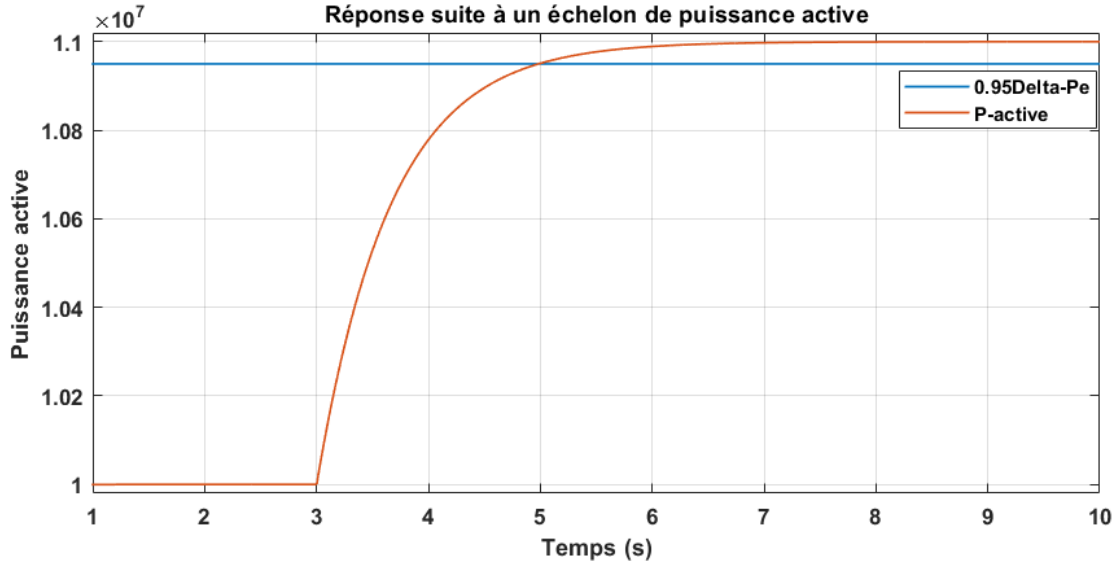




2.B. Testing on benchmarks

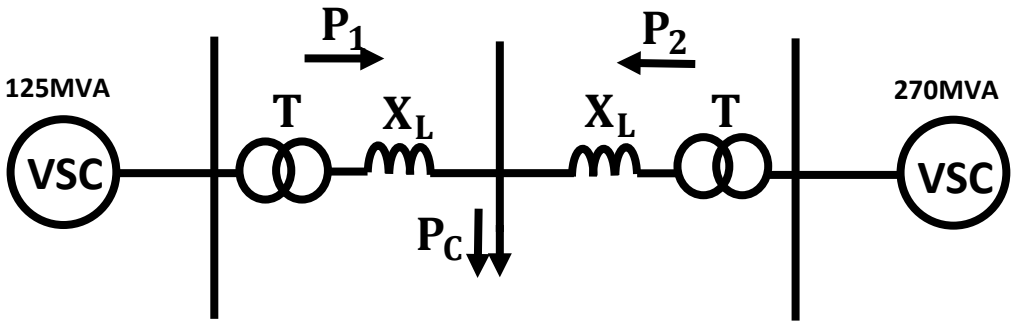
Active Power Step

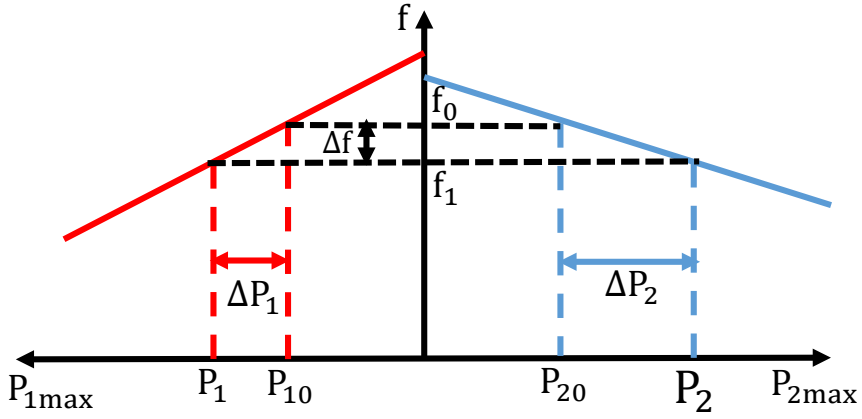




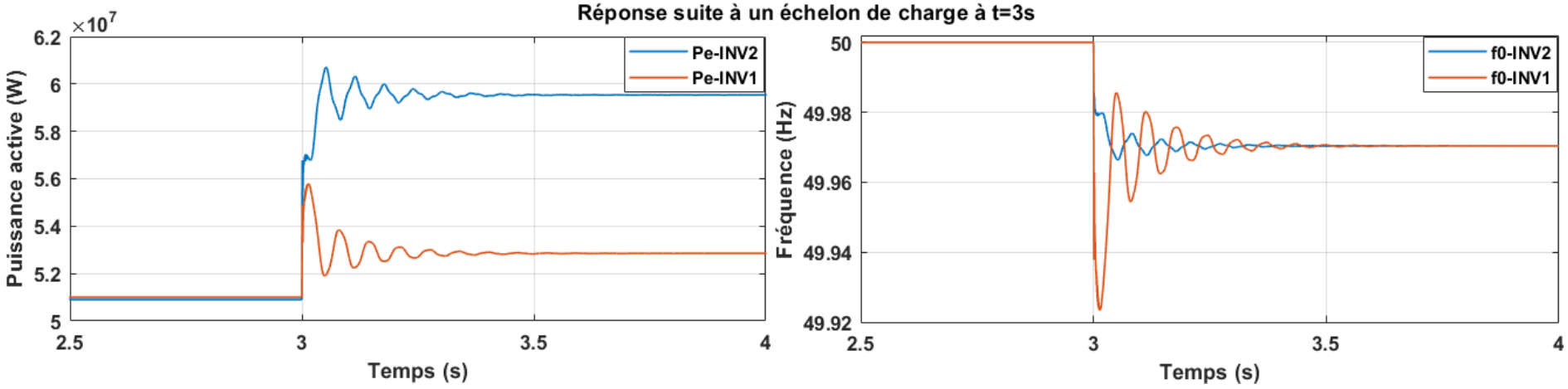
2.B. Testing on benchmarks

Load sharing between two groups





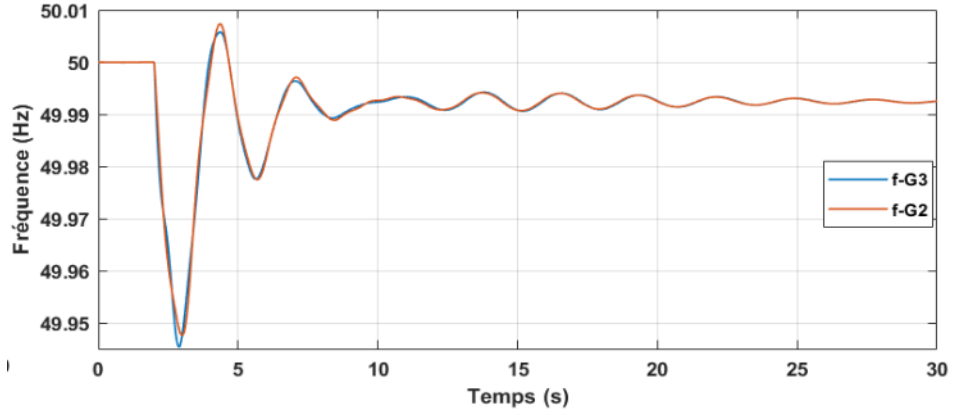
$$\Delta P_1 . s_1 = \Delta P_2 . s_2$$

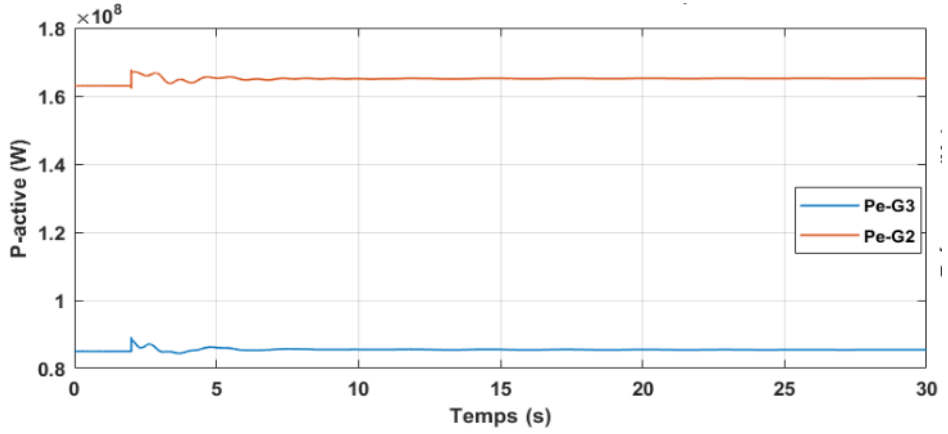


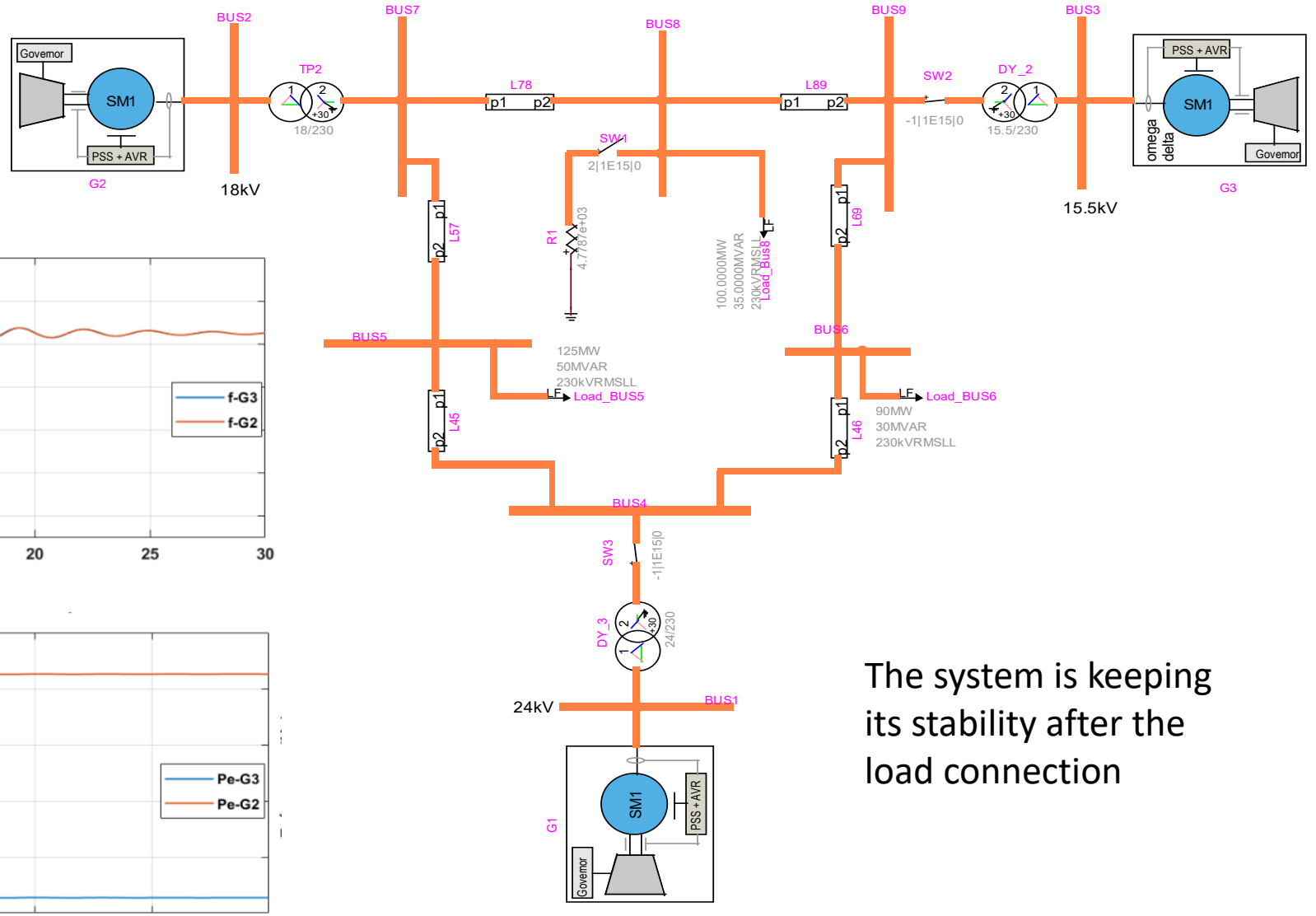
2.B. Testing on benchmarks

Tested on IEEE9 BUS

Step of load



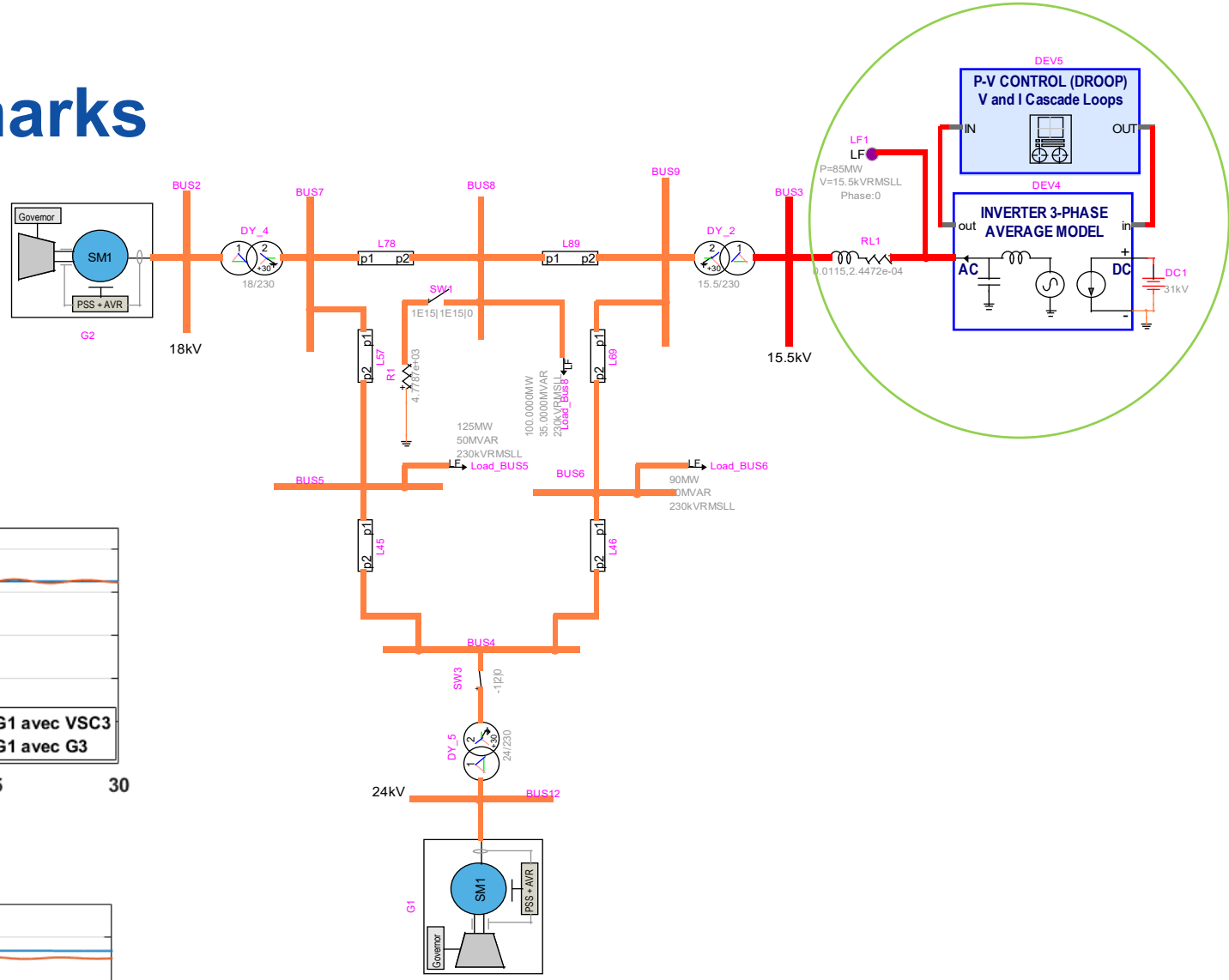


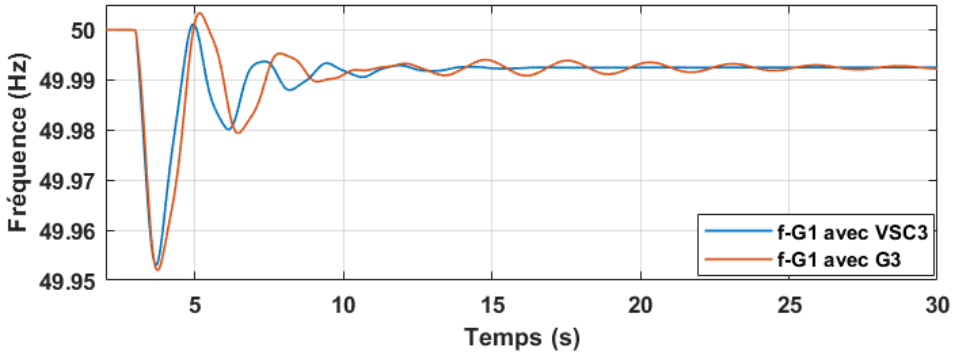


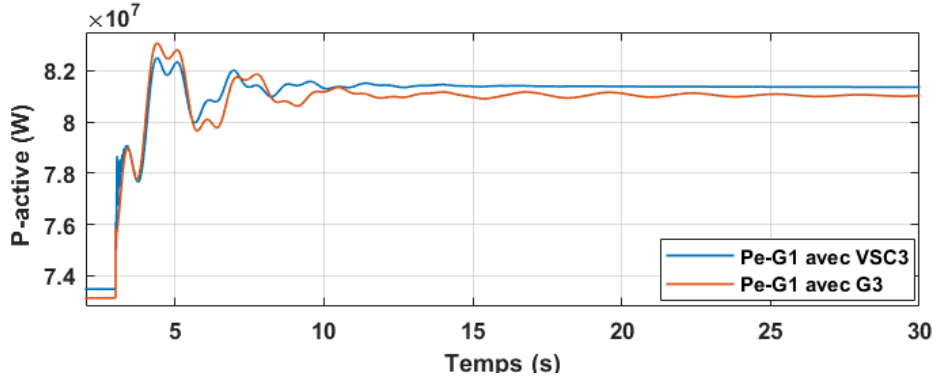
The system is keeping its stability after the load connection

2.B. Testing on benchmarks

Having one inverter instead of a synchronous machine does not influence much the stability (it is even slightlly improved)

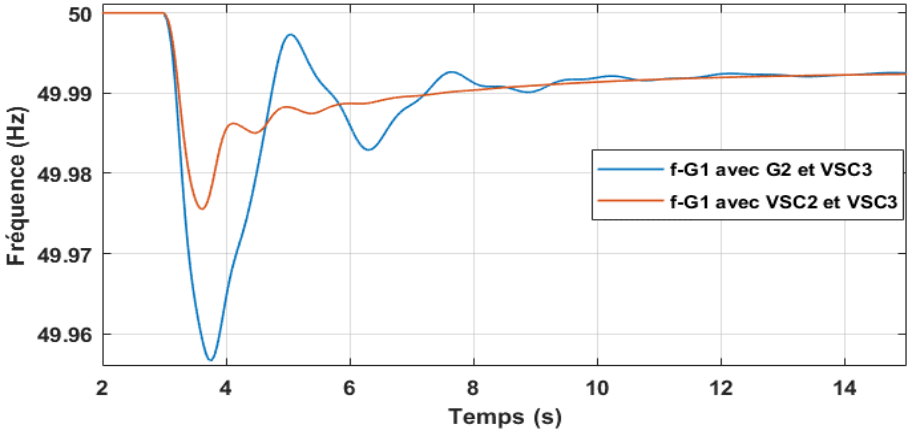


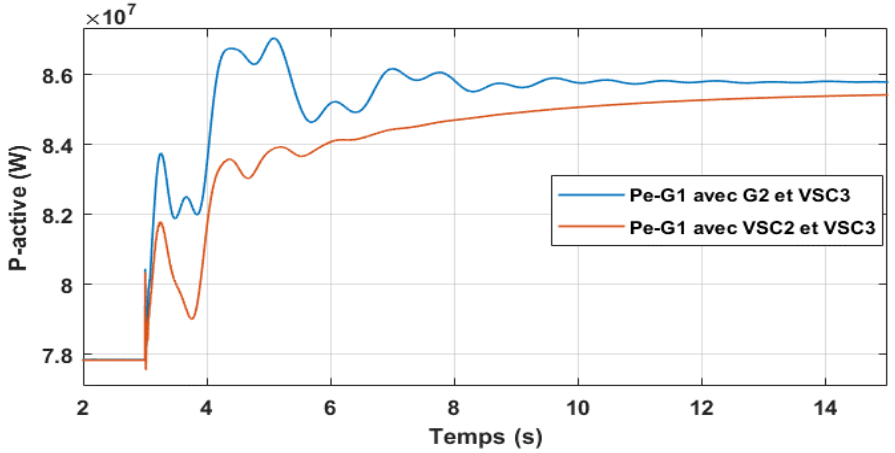


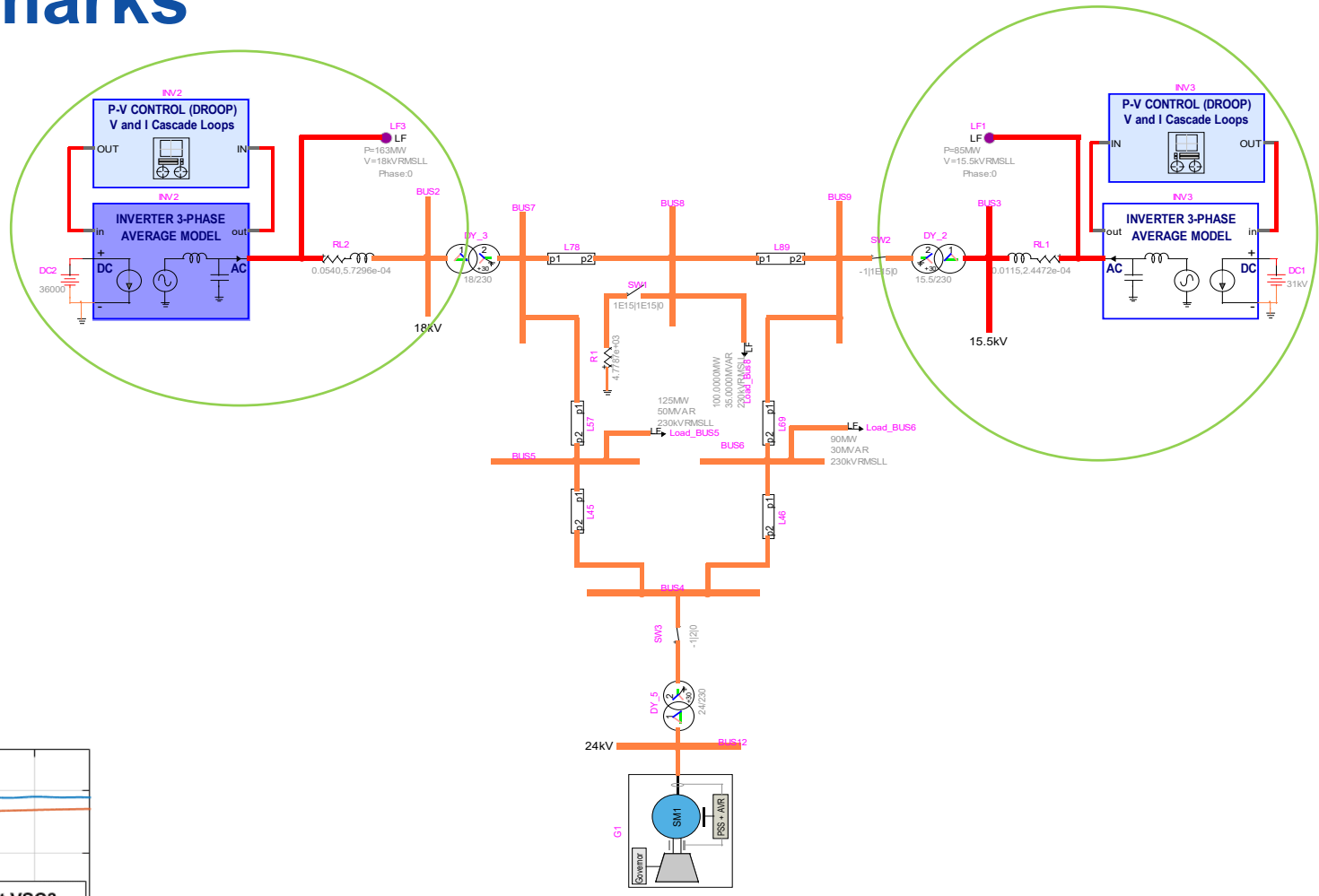


2.B. Testing on benchmarks

Having two inverters significantly improves the frequency stability

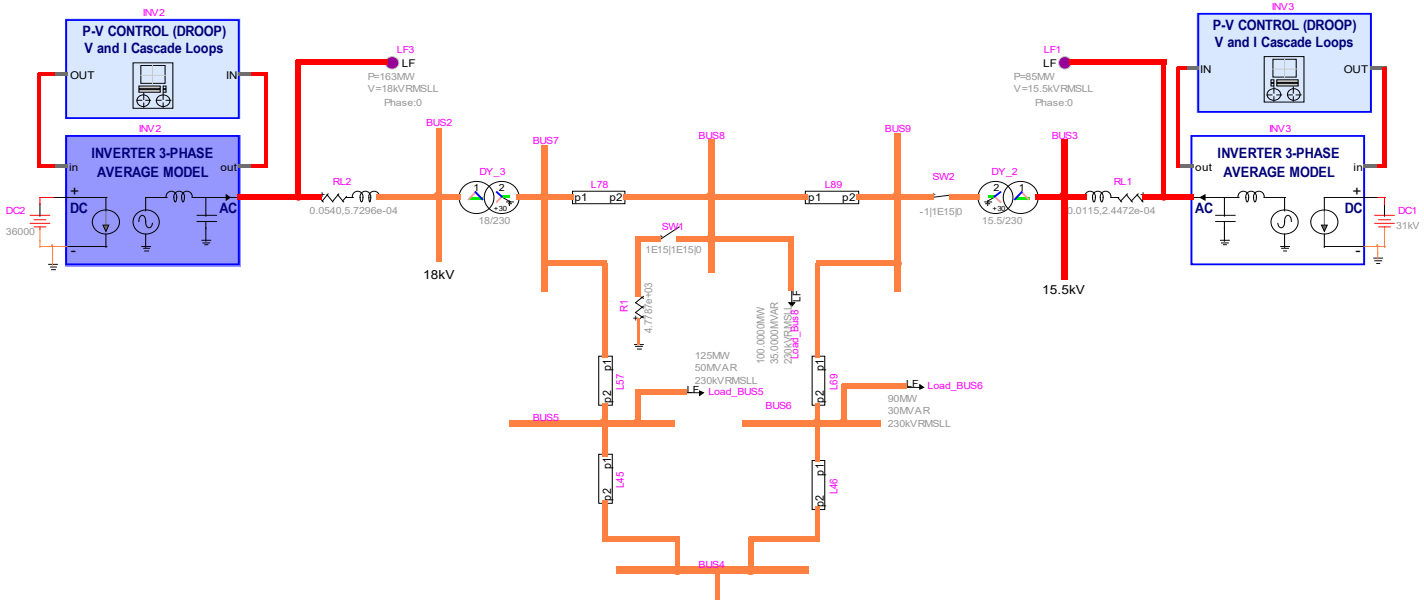


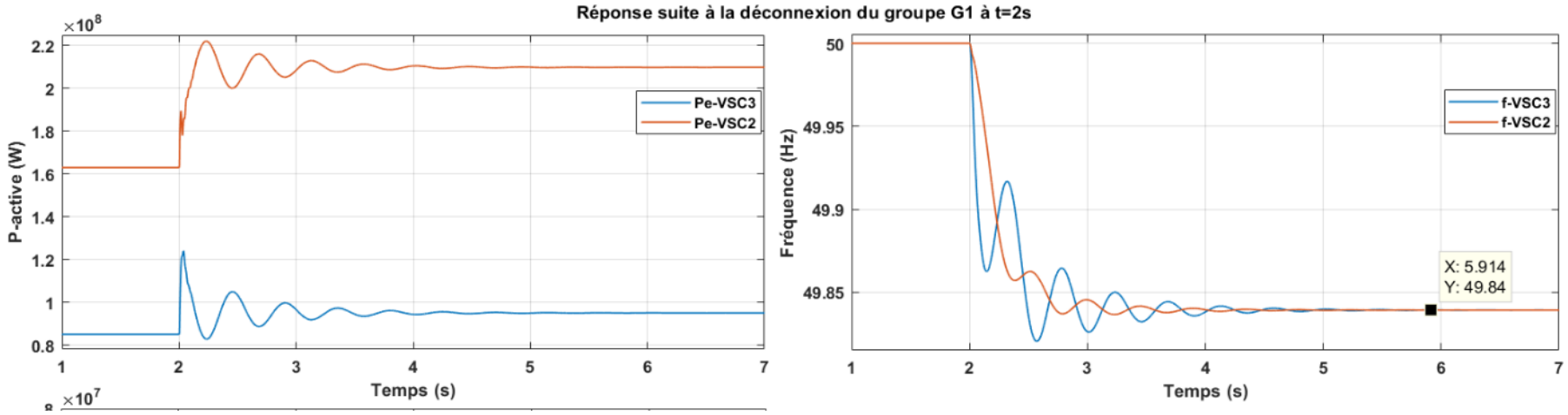




2.B. Testing on benchmarks

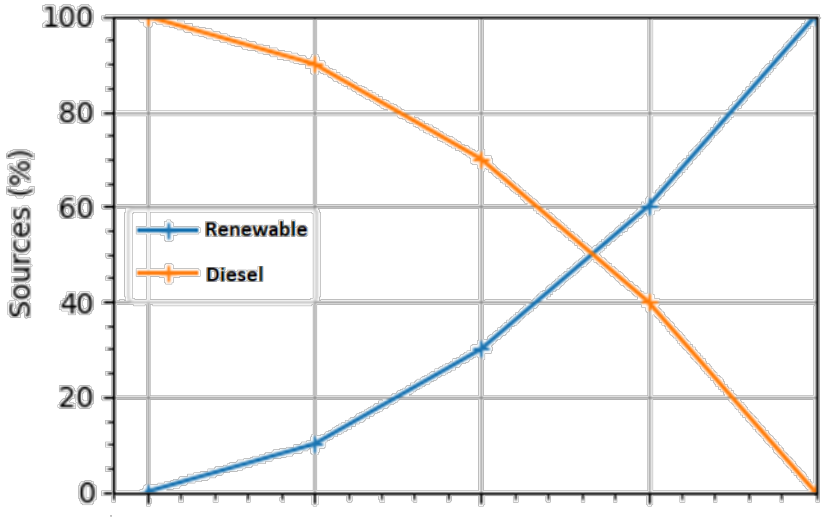
The system keeps its stability even when disconnecting the last synchronous machine.



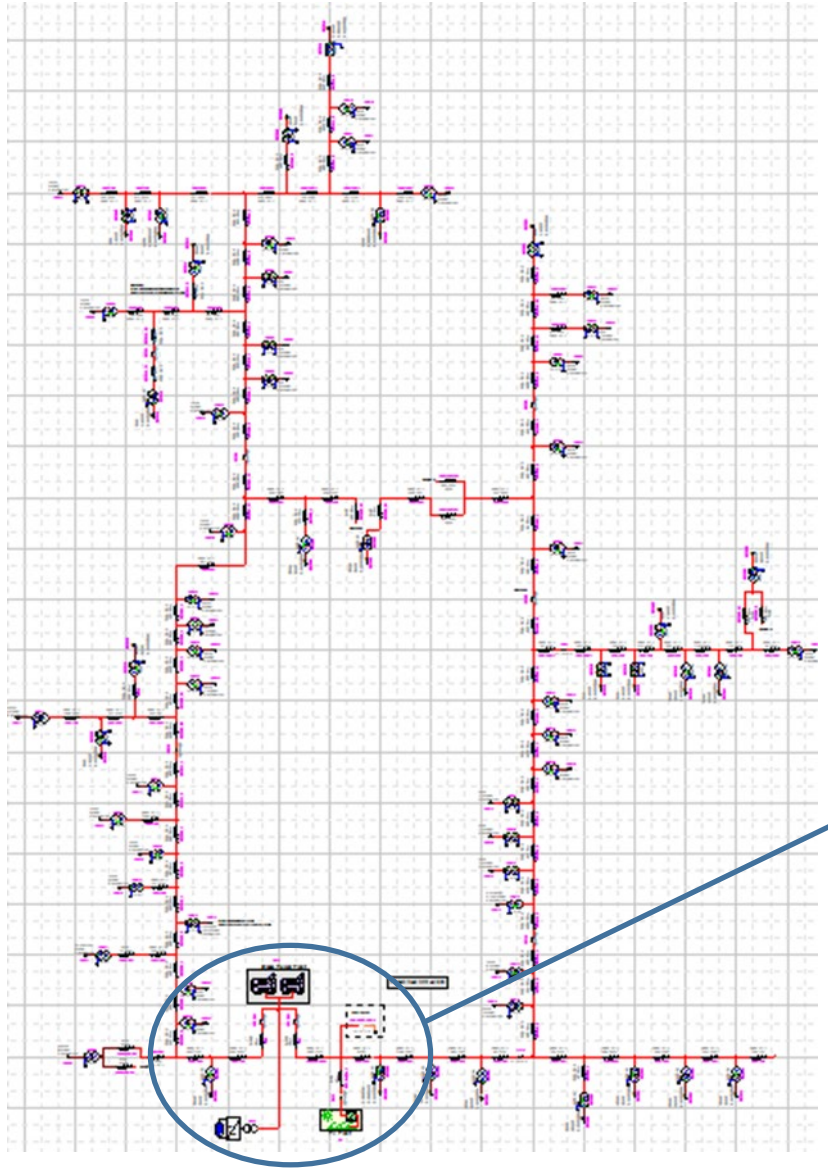


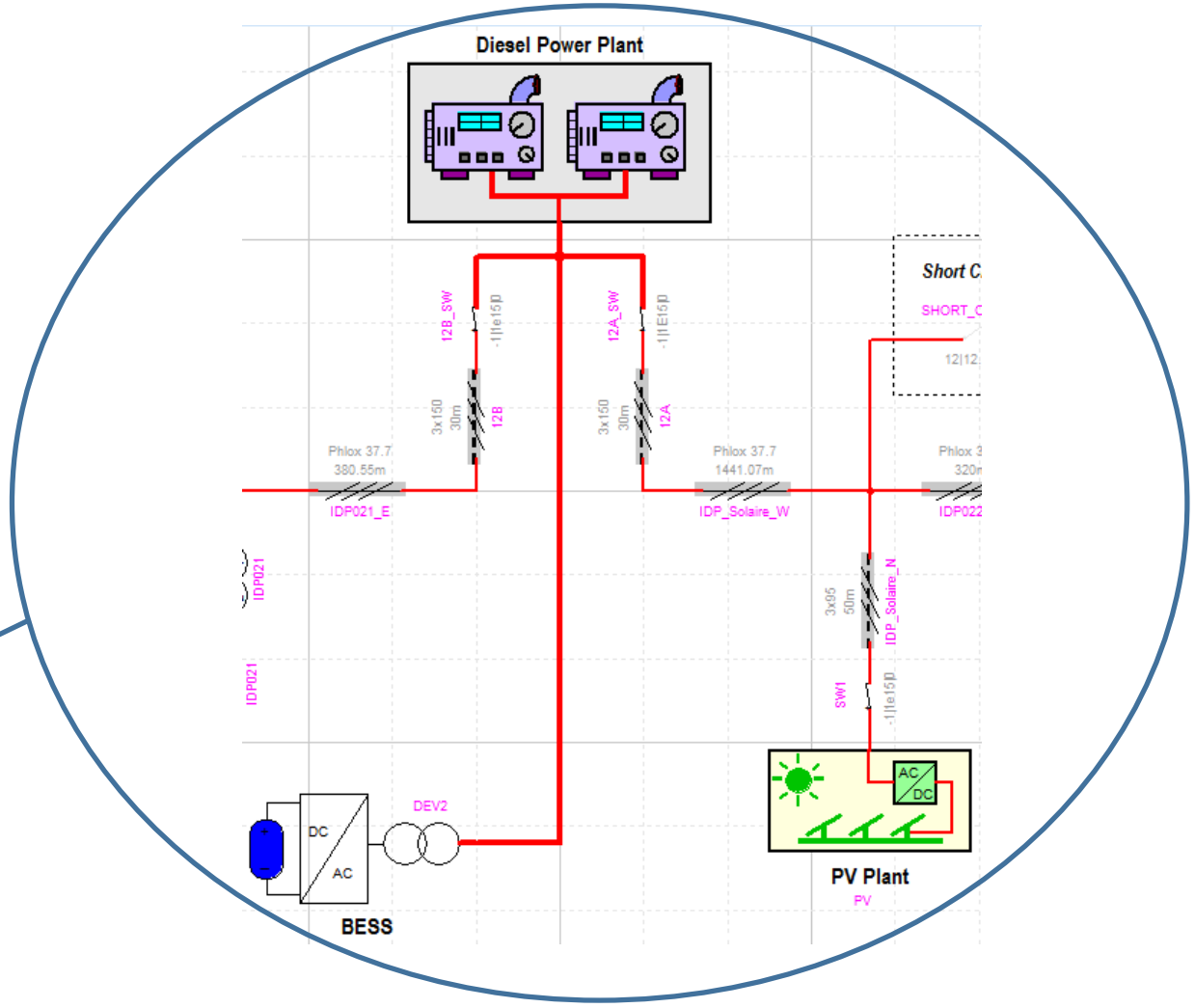
3. A. The industrial case

- Island of around 2000 inhabitants (few MW installed power)
- Transmission voltage : 15 kV
- Customer supply in 400 V
- Around 70 transformers
- Around 120 line devices
- Current generation: diesel generation
- It will be gradually replaced with a 100% renewable mix:
    - Photovoltaic
    - Biomass
    - Battery



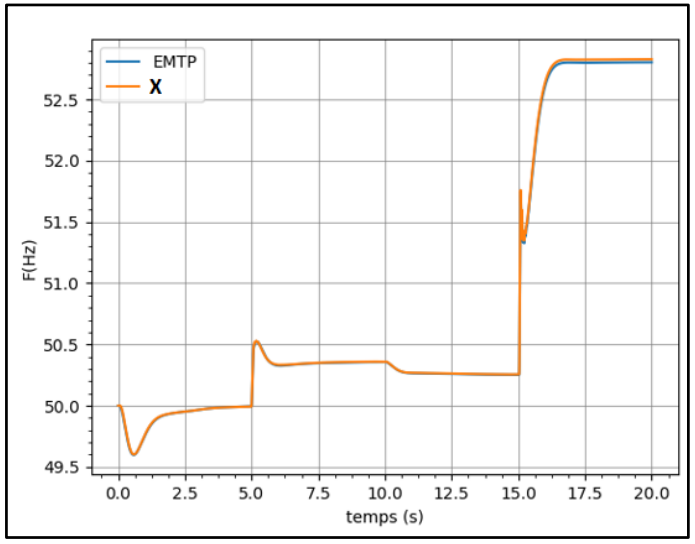
3. A. The industrial case in EMTP

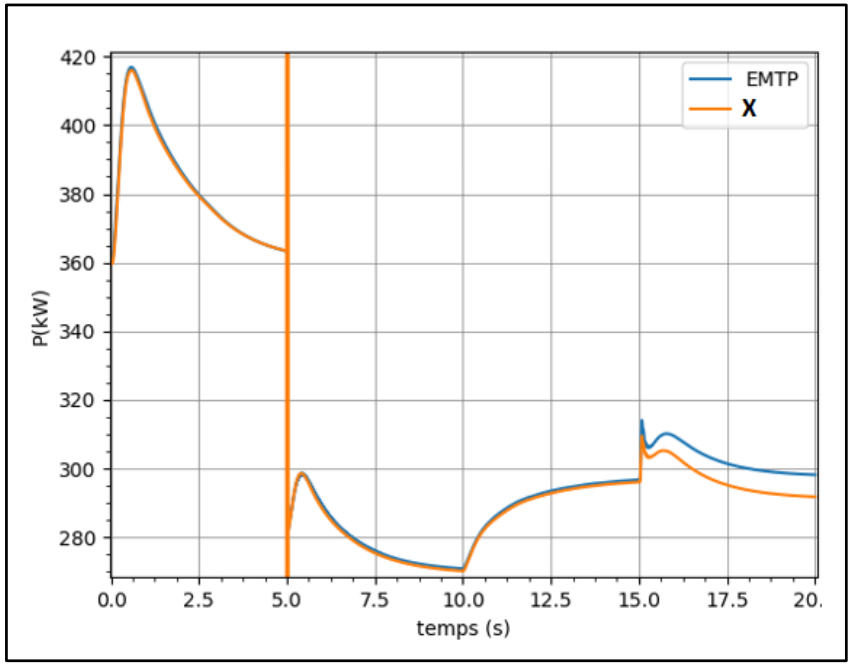


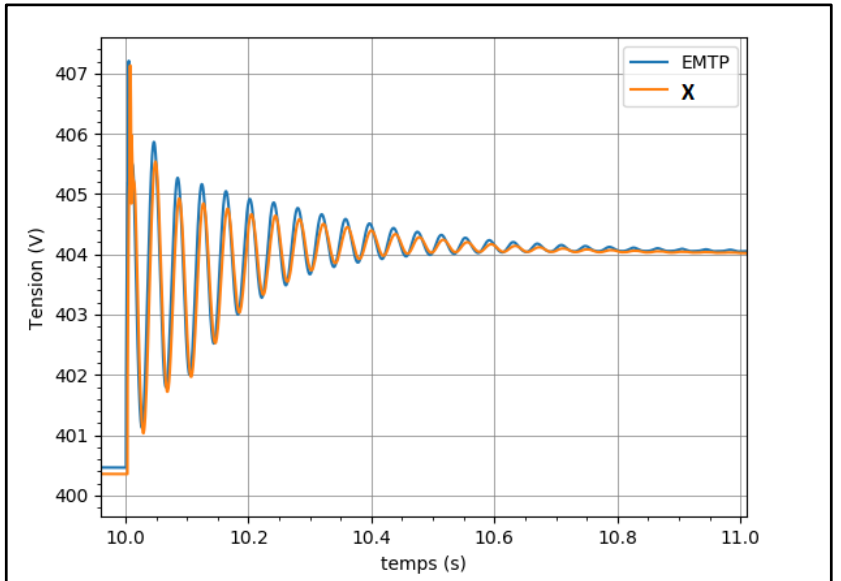


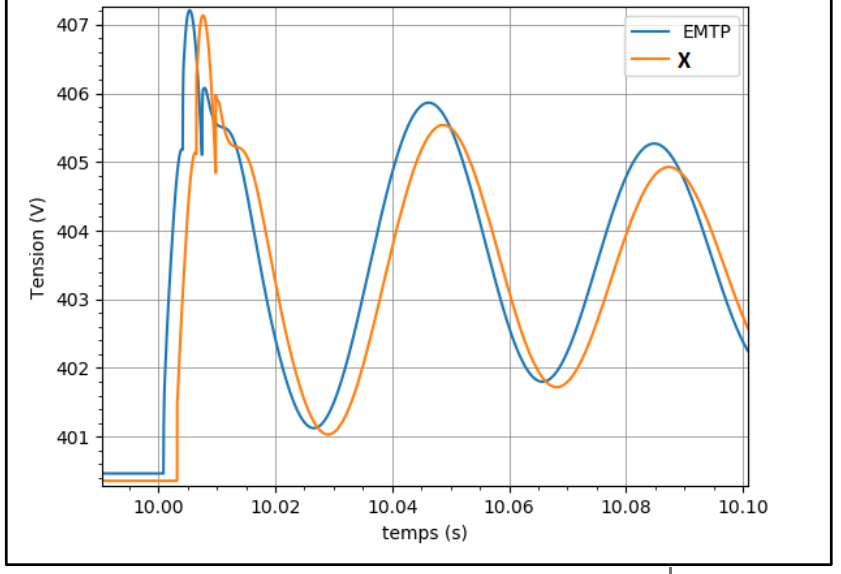
Model validation of the diesel generator

- T= 5 s: load connection
- T = 10 s: voltage step
- T = 15 s: frequency step
- Results have also been compared to an other EMT tool
- Curves are almost superimposed

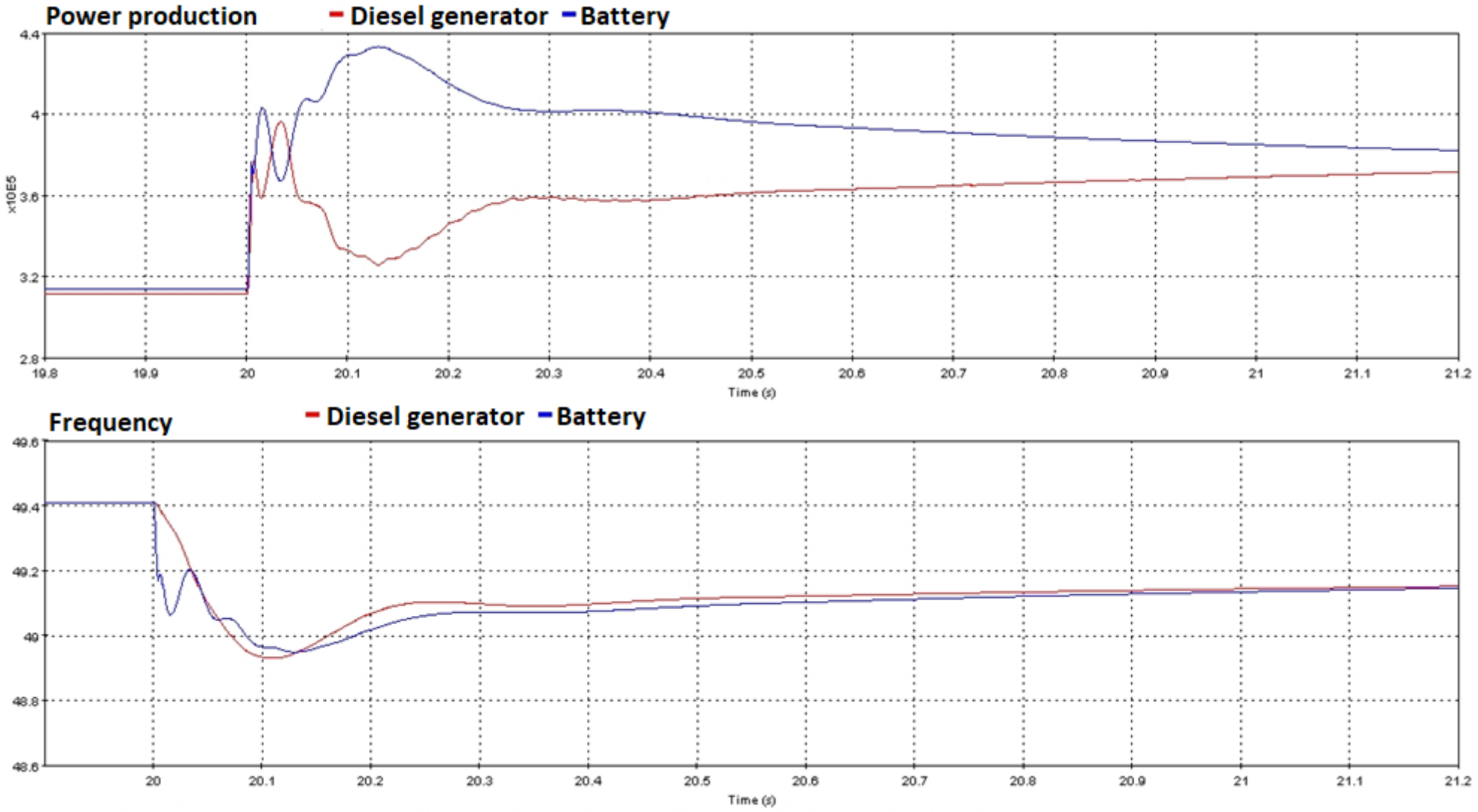








3.D. Results : Tripping of the PV farm



Conclusion

EMTP can easily simulate the transient behavior of micro-grids to study their stability

The new EMTP models of PV and wind turbines significantly reduce the modelling time

Its robust algorithm enables to carry out fast EMT simulations

Results have been validated against other software


Any questions ?
Thank You