Real-Time Power-Hardware-In-the-Loop system
Application to power electronics compensators

UI – 14e. Modelling, simulation and design methods
Dialogue/Lecture presentation

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Abstract

Today, we are witnessing a massive transformation in power systems around the world, due primarily to the opening of power markets, the evolution of technology, the exhaustion of natural resources, and changes in climate. In order to remedy problems occurring as a result of these challenges, countermeasures must be taken at all levels of the power system: generation, transmission and distribution. However, these countermeasures do not always work well together. In addition, due to their innovative character, they require increasingly powerful analysis tools that are well adapted to the multitude of involved dynamics. The current paper proposes and analyzes the use of a PC-based real time power system simulator to implement a Power-Hardware-In-the-Loop (PHIL) research facility to meet these complex requirements.

Keywords

real-time (RT), power-hardware-in-the-loop (PHIL), renewable energy systems, distributed flexible AC transmission systems (DFACTS), Wind energy.

1. Why PHIL?

In the above presented context, a 10 kVA analog power electronics (PE) benchmark was developed at Grenoble Electrical Engineering Laboratory (G2Elab). The synopsis of this facility is presented in *Figure 1*, and it permits the connection of two converters separately or together, in shunt (ex. STATCOM), in serial (ex. DVR) or hybrid (ex. UPFC). In the connection points (CP_i) power sources, rotating machines, loads, capacitors, or even grid parts can alse be connected. As a result, the facility can be configured in a wide variety of ways, depending on the desired application.

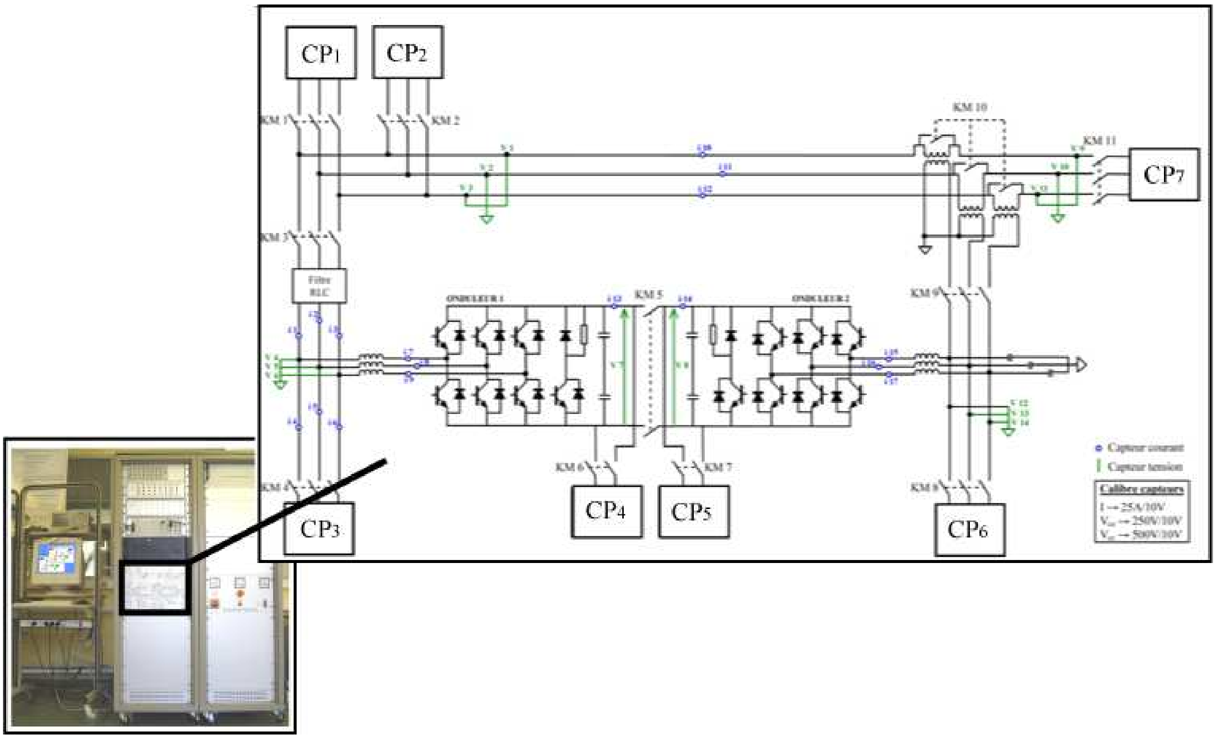

Fig.1: Synopsis of 10 kVA analogical power electronics benchmark

When connected to the real distribution grid (in CP_1), it is difficult (or even impossible) to generate and repeatedly replicate grid disturbances. This is due to the grid's high short-circuit power and connection restrictions imposed by the supplier.

This setback can be solved by connecting the analog power electronics benchmark to a virtual grid. *Figure 2* illustrates an example of a real-time digitally simulated power system [1], which includes: a 500 kV transport network consisting of 45 lines and 17 loads (of 120 MW and 30 MVar). The frequency is 60 Hz. There are seven 1000 MVA hydraulic generation turbine plants (synchronous machines and regulators) connected to the network and a wind farm has been connected to the middle of the transmission network. The wind farm consists of 8 wind turbines (double fed induction generator). This system is simulated in real time using a 7-CPU eMEGAsim real-time digital simulator [3](equipped with dual quad-core Intel processor running at 2.3 GHz) with step sizes of each CPU as follows: 60 microseconds for the network (4 CPUs), 120 microseconds for controls (1 CPU) and 30 microseconds for the wind turbines (2CPU).

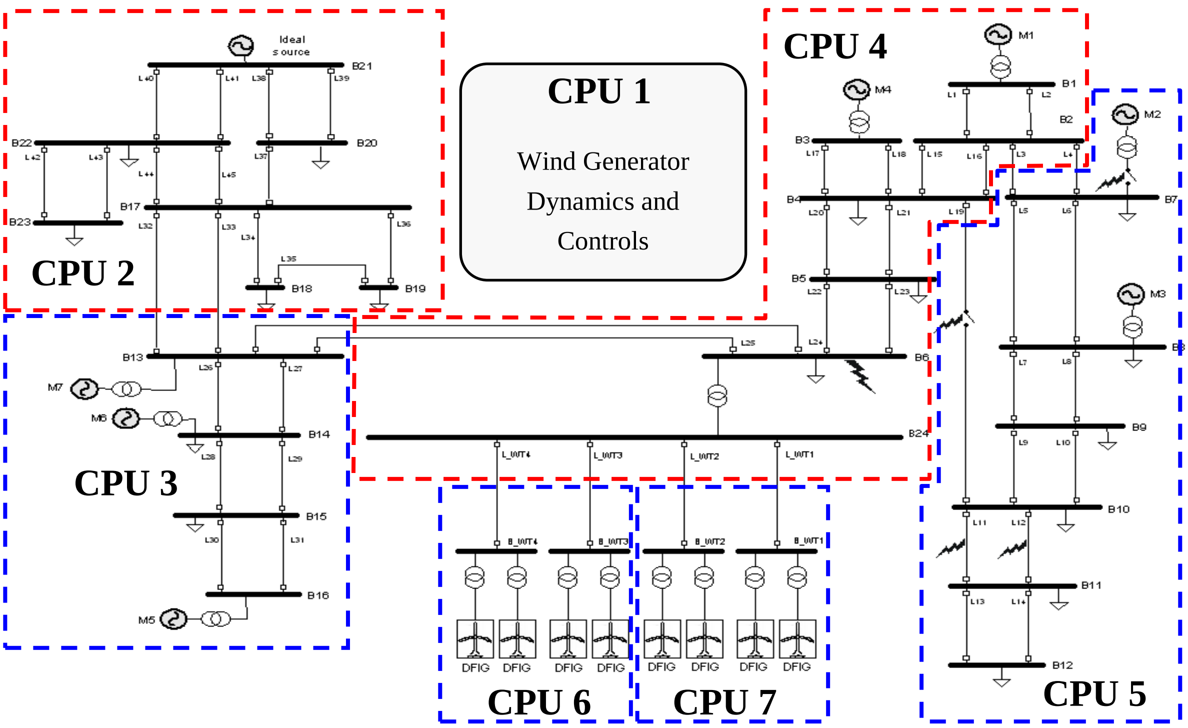

Fig.2: Example of a schematic diagram of a power network and wind farm distributed across a multi-core real-time simulator

In order to connect the 10 kVA analog PE benchmark to a digital simulated system (like the one presented in *Figure 2*), a power interface is used (power amplifiers and several sensors). This makes it possible to have real voltages and real currents exchanged between the two distinct parts. A RT PHIL configuration is therefore obtained.

The proposed approach demonstrates its value when used to study interaction between different generation sources, and between generation sources and the grid (harmonics disturbances, voltage dips, frequency fluctuations, islanding, etc.). By using the eMEGAsim real-time digital simulator, some generation sources can be real (analog) and some can be numerically modelled. As a result, a very acceptable compromise is achieved between accuracy, flexibility and size of the resulting benchmark.

The real-time digital simulator can be used, for example, to model a power system, which would be difficult to replicate in analog due to the size of the resulting benchmark. Depending on the desired application, several signals (proportional with the simulated voltages, currents, etc.) can be outputted.

Industrial devices (e.g. PV inverters) or prototypes are often "closed" (with classified content) and therefore impossible to numerically model. By using digital and analog simulators interconnected in PHIL mode , they can be studied as "black-boxes", as they were in real operating conditions [2].

2. Does PHIL really work?

Using these elements described above, several PE applications have already been developed at G2Elab, in the fields of:

- Renewable energy generation systems:
    - Grid interfacing of synchronous and doubly fed asynchronous wind generators. In these case studies, the PE as well as the wind generating systems are analog. A 20 kV distribution grid has been simulated. Operating conditions like variable wind speed or grid perturbations like voltage dips and frequency variations have been included.
    - Capability of asynchronous squirrel-cage wind generators to support grid perturbations [4]. In this case, only the PE is analog, while the wind farm and a 20 kV distribution grid are simulated using the digital simulator. Two PE solutions (one shunt and one serial) are proposed in order to satisfy increasingly critical regulations. For each case, different control strategies have been developed (for voltage and power factor regulation) and validated on the RT PHIL benchmark.
- Power flow control:
    - A DFACTS serial solution has been proposed in order to reduce (or, ideally, to eliminate) the incompatibility between the commercial sense and the physical laws . In this case the PE was analog and the grid was RT digitally simulated.

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3. Final paper objectives

In the final paper, the RT PHIL benchmark developed at G2Elab will be detailed. Several of the above mentioned applications will be also resented, accompanied by setting considerations for each configuration (shunt/serial) and by experimental results. Simulation accuracy wil be evaluated by comparing results obtained in fully numerical mode and in PHIL mode.

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