Real Time Simulations for Comprehensive Study of Smart Grid

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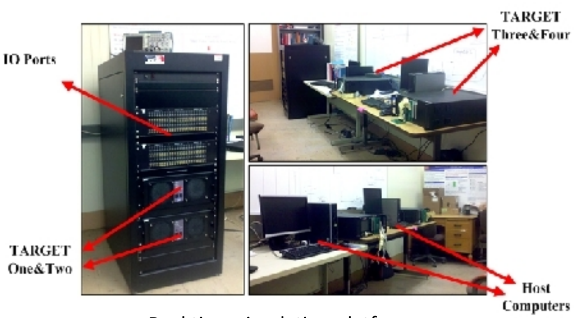
1. Motivation

➢ Smart grid is a combination of electric power networks and communication networks;
➢ A comprehensive real time simulation platform is needed to simulate these two types of interconnected networks at the same time.

2. Platform Introduction

2.1 Power network modeling resources

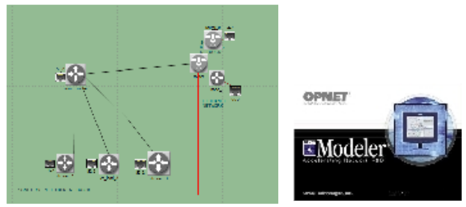
➢ 4 Opal-RT real time target machines;
➢ 1 OP5600 Hardware-in-the-Loop Box;
➢ 8 CPUs with 48 cores: Intel Xeon Six Core, 3.33 GHz;
➢ 5 user programmable FPGAs: 4 Xilinx Spartan-3 FPGAs and 1 Virtex-6 FPGA;
➢ 512 digital and 256 analog IO;
➢ Dolphin real time communication link (0.2 us delay).



Real time simulation platform

2.2 Communication network modeling resources

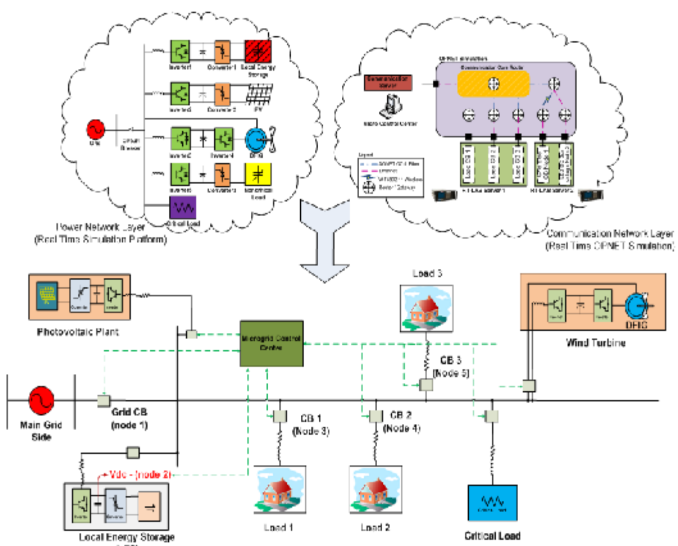
➢ OPNET's network modeler allows for System-in-the-Loop emulations: integrated simulations with the real time platform;
➢ Possible to simulate different types of networks such as: Ethernet, wireless, fiber optic, and others;
➢Manipulate parameters such as: delay, bandwidth, packet loss, etc.



3. Case Study

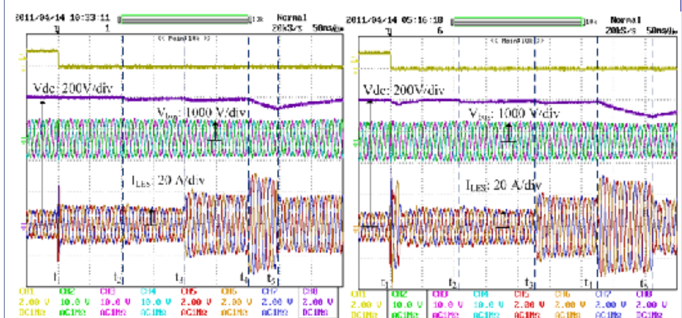
3.1 System description

➢ A smart grid model with Local Energy Storage (LES), PV, and Wind Turbine as renewable energy sources is built in the real time simulation system;
➢ A discrete communication network is combined with the real time simulation system to identify the influence of key communication factors to the smart grid, such as protocols, latency, bandwidth, and cyber security.



3.2 Simulation results

It is assumed at t1, **a three phase short circuit happens at grid side.** The fault detection unit gets this failure and opens the main circuit breaker. Then:
a) When grid is lost, all the noncritical loads are disconnected at the same time;
b) After each 0.1 s, at t2, t3 and t4, CB1, CB2 and CB3 are reclosed separately;
c) At t5, the LES dc bus voltage drops to the threshold level (LES cannot provide enough power), then CB3 is opened and load 3 is disconnected again.



(a) Without Communication Effect (b) With communication effect

Compare these two results. When considering the communication effect:
❖There is a bigger disturbance during the transition from grid connected mode to islanding mode;
❖ The dc bus voltage drops far below the threshold voltage at t5.

4. Conclusion

❖The platform is capable of evaluating the interactions between power networks and communication networks in smart grid;
❖ Hardware-in-the-Loop based verification of complex control strategy can be realized in the platform;
❖ A switching frequency up to 10 kHz can be achieved in the simulation, and a even higher switching frequency can be achieved with FPGA programming.