Co-Simulation of Power Systems and Computing Systems using the FMI Standard

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Abstract—Simulation-oriented research requires precise and validated simulators. Each community has its set of preferred and widely adopted software tools. Some works are multi-domain and require the use of dedicated tools and semantic of each domain to produce largely accepted results. In this work, we demonstrate how to realize co-simulation between power system networks, telecommunication networks and distributed computing resources. The demo will show a basic scenario to explicit the relevance of such a combination.

I. INTRODUCTION

Several research fields rely on simulators to explore their hypotheses, and many are at the crossing of several domains. Smart grids constitute such an example of multi-domain requirements as they rely on computing and telecommunication network resources to pilot the underlying power system networks. This article presents a way to combine simulation tools for power system networks, telecommunication networks and distributed computing resources in a coherent co-simulation framework. The co-simulation idea consists in using tried-and-tested simulators from the original communities. Such a combined tool will ease the study of complex smart grids scenarios where the performance of each part of the system impacts the rest of the system's functioning.

The vast majority of power network studies are based on power system simulators which mimic the behavior of actual power networks. These simulators allow researchers to perform experimentation campaigns without degrading the safe and reliable operation of actual power systems, while staying in a controllable, modular, and often reproducible environment. Some simulators are commonly used by the power system community like pandapower [5] or PowerFactory [3]. For similar reasons, the telecommunication network community also has its own set of preferred simulators, such as ns-3 [4] or OMNeT++ [6]. These simulators allow users to model and experiment several commonly used communication protocols, either wired or wireless, in packet-level simulations.

The SimGrid framework [2] is a toolbox to develop simulators of distributed platforms. SimGrid can either use its own communication system or a fully integrated ns-3 communication mode. In addition, SimGrid is part of the Functional Mock-up Interface (FMI) standard [1], making SimGrid an interface able to import Functional Mock-up Units (FMUs), i.e., simulation models from other simulators.

II. CONTRIBUTION

We developed a tool to generate pandapower networks FMUs[1]. It allows users to build and export power networks models that can then be imported into SimGrid. Inside SimGrid, the power network inputs can be modified and the electrical network load flow problem is only solved when trying to access its outputs. We chose to rely on pandapower as it is part of the open source initiative and thus fully free to use. As every part of the co-simulation is license-free, the deployment of the simulations on distant testbed servers is facilitated and reproducible. Figure 1 shows a simplified view of how ns-3 and pandapower are interacting with SimGrid, which acts as a co-simulation engine for running multi-models of complex systems in this case.

III. CONSIDERED SCENARIO

We chose to use a basic, though realistic, scenario to present our co-simulation environment. In this scenario, there is a load and a generator connected though a power network to a transformer. The generator provides a part of the power demand of the load, while the other part comes from the external grid through the transformer. We simulate an unexpected shutdown of the generator, increasing the power flow through the transformer, due to the load consumption. When the power flow through the transformer exceeds its rated power, the transformer sends a request to the load asking it to reduce its power demand. The power network we chose to rely on is part of the first tutorial of pandapower[2], presented in Figure 4.

Interactions between pandapower and SimGrid are done using the SimGrid-FMI plugin. This plugin makes SimGrid compatible with every FMU meeting the FMI standards, including FMUs created using pandapower-fmu, developed for this project. The plugin allows users to read and / or modify variables of FMUs dynamically during the co-simulation.

On top of the power network, we consider a distributed management orchestrated by SimGrid. Three actors coexist during the simulation:

- The master actor samples the power demand at the transformer every second. If the demand is above the

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[1]Tool available: https://framagit.org/Adrien.Gougeon/pandapower-fmu
[2]Tutorial available: https://github.com/e2nIEE/pandapower/blob/develop/tutorials/create_simple.ipynb
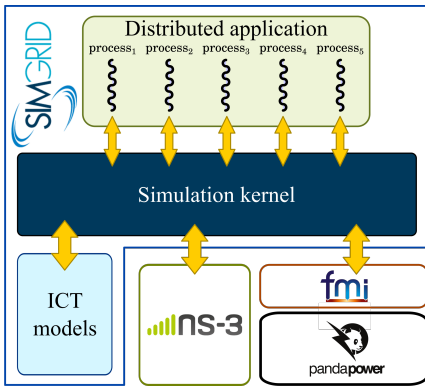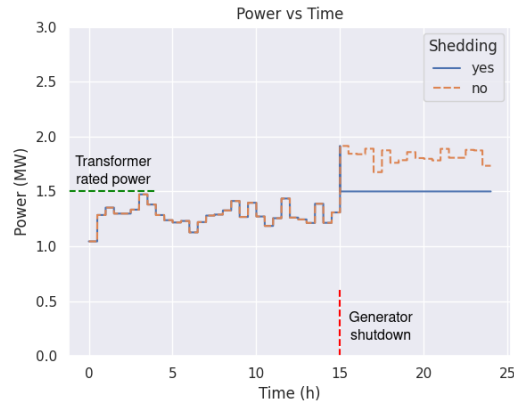
Fig. 1: Co-simulation framework.

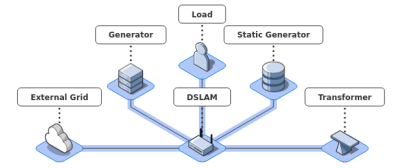Fig. 2: Power demand at the transformer.

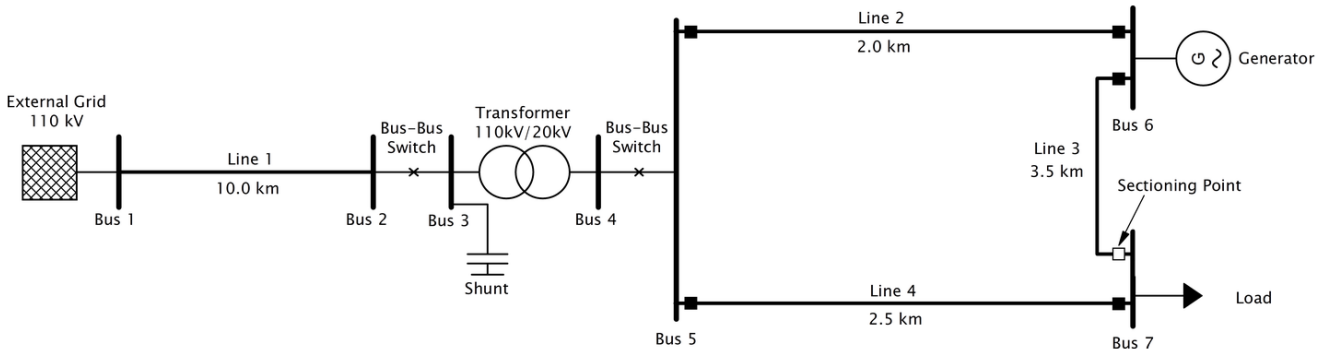Fig. 3: Star communication network.

Fig. 4: Minimal pandapower network.

transformer rated power, 1.5 MW, it sends a message to the load asking it to reduce its power demand;

- The generator crasher shuts down the generator after 15 hours of simulated time, changing its power generation to 0MW. This actor simulates an unexpected shutdown or disconnection of the generator;
- The load manager changes the load power demand every 30 minutes following a normal distribution, in order to simulate a typical fluctuating load profile.

For the communication network, we considered a star topology presented in Figure 3, where each entity is connected to a common router. We fixed a wired latency of 10ms from one entity to the router. We performed two simulations : one with a reactive master shedding the load if needed, and one with a passive master. The total simulated time is 24 hours. The power demand at the transformer during the simulations is depicted in Figure 2. The horizontal green line shows the rated power of the transformer. The vertical red line shows the moment at which the generator shutdown is simulated. The orange line shows the power flow through the transformer in a simulation without the master reacting to the excessive power demand above its rated power, i.e., when the master actor does not perform load shedding. The blue line shows the power trough the transformer in a simulation with the master reacting to the excessive demand by sending a message to the load, i.e., performs load shedding. As expected, with the active master the power flow stay below the transformer rated power.

IV. CONCLUSION

In this work, we proposed a scenario at the crossing of several domains : distributed networks, power networks and telecommunication networks. The tools presented here allows coherent co-simulations between several dedicated, domain-specific simulators. The proposed tools are all open source, facilitating the deployment of the co-simulation and providing a better cross-checking of the produced results.

ACKNOWLEDGMENT

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