TCIPG

GridStat Middleware Communication Framework: Application Requirements

Cyber-Power System Analysis Using a Real-Time Test Bed

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GOALS

- Develop a cyber-physical test bed integrating power grid, sensors, communication, controllers, and applications to model standard cyber physical test cases and enable real-time implementation of wide-area applications.
- Utilize developed cyber-physical test bed to analyze cyber-power interdependencies and impact of integrated cyber-physical attack on the transmission grid.

FUNDAMENTAL QUESTIONS/CHALLENGES

- Lack of real-time modeling and simulation capabilities to characterize the interactions among the power grid, controls, energy management system, and communication network.
- Lack of integrated cyber-physical standard test case models to allow integrated real-time simulation.
- Characterizing the communication needs and quantifying the impact on the power grid due to communication network failure.

RESEARCH PLAN

- Develop feasible communication architecture layer for standard IEEE power system test cases.
- Explore options for real-time implementation of integrated cyber-physical system using the Real Time Digital Simulator (RTDS) and a communication network simulator/emulator.
- Develop contingency metrics for impact of communication networks on the power grid.
- Conduct integrated cyber-physical vulnerability and security analysis using the developed communication architecture and test bed.

RESEARCH RESULTS

- Network Simulator 3 (NS-3) was used to simulate the communication network.
- A node in NS-3 is equivalent to the shell of a computer, while a net device represents the network cards and network device drivers. For the purpose of emulation, two kinds of net devices are used in NS-3: Emulation Net Device and Tap Net Device.
- The emulation net device allows the NS-3 simulations to send data on a real network.
- The tap net device allows real or virtual host systems that support TUN/TAP devices to participate in the NS-3 simulation.
- Figure 1 shows a conceptual representation of how NS-3 is set up for the purpose of simulating communication for real end systems.

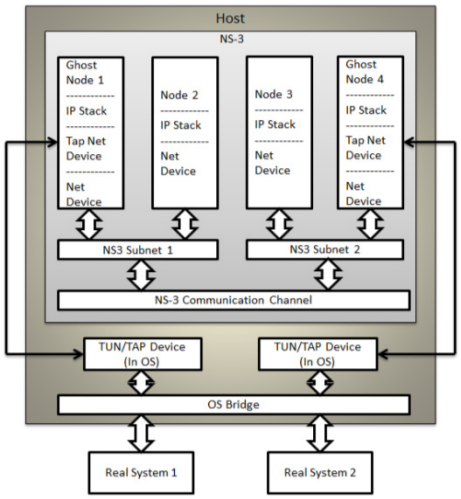

Fig. 1: NS-3 emulation mode configuration

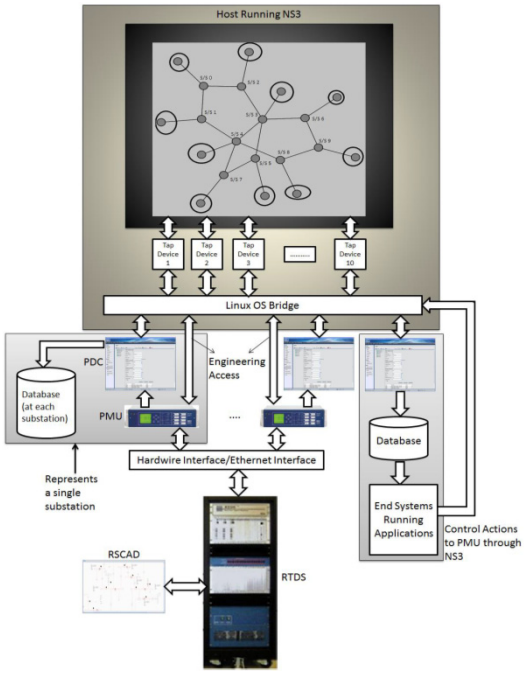

Fig. 2: Developed test bed using RTDS and NS-3

- The test bed allows hardware-in-the-loop capabilities, including a) phasor estimation by Phasor Measurement Units (PMUs), b) data collection/alignment by Phasor Data Concentrators (PDCs), c) data delivery to required end systems, d) data retrieval from databases to relevant applications, and e) sending of control signals back to actuators, as shown in Fig. 2.
- The test bed simulates the actual working conditions in a reasonable manner, allowing for real-time implementation and testing of algorithms.
- Developed test bed has already been used to implement aurora attack modeling, wide-area monitoring, and control algorithms specifically for voltage stability. Those applications demonstrated that communication is not generally the bottleneck.
- Evaluation scenarios for testing devices such as Phasor Data Concentrators have been developed.
- The vulnerability centrality index derived using the graph theory-based approach has been integrated with a cyber vulnerability index to provide a ranking for cyber-physical contingencies to be used with an Operator Training Simulator (collaboration with TCIPG alumnus Dr. Zonouz).

BROADER IMPACT

- Development of integrated cyber-physical system test cases will enable comparative analysis among several different algorithms and provides common platform to researchers.
- Will provide analytical framework to analyze impact of a coordinated cyber-physical attack on the reliability of the power grid.
- Will help demonstrate cyber-power concepts for educational purposes and outreach activities.

INTERACTION WITH OTHER PROJECTS

- Exploring option of using GridStat as a communication interface with RTDS to develop an integrated cyber-physical test bed.

FUTURE EFFORTS

- Utilizing the developed cyber-physical test bed to model additional power system test cases.
- Extending the developed test bed for cyber-physical training simulator.
- Integrate GridStat in the cyber-physical test bed.
- Analyze communication requirements for wide-area system applications.

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