TCIPG

Communication Architecture for Standard IEEE Power System Test Cases

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Goals

- Develop a feasible communication architecture for standard IEEE power system test cases to allow standard testing and validation.
- Use developed cyber-physical test cases for algorithms and applications testing as well as security analysis.

Fundamental Questions/Challenges

- The simulation capability to analyze the interaction between the power grid and communication network in a comprehensive manner is missing.
- Quantification of the impact on the power grid of communication network failure needs to be further investigated. Currently there is a lack of integrated cyber-physical standard test case models to allow integrated simulation. The challenge here is to develop such integrated cyber-physical test cases.

Research Plan

- Develop a feasible communication architecture layer for standard IEEE power system test cases.
- Explore options for real-time implementation of integrated cyber-physical systems 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 – 2 (NS-2) was used to simulate the communication network. Table 1 shows the parameters used for the different layers.

Layer	Parameter
Application	Constant Bit Rate (CBR)
Transport	User Datagram Protocol (UDP)
Network	Internet Protocol (IP)
Data Link	Ethernet

Table 1: Protocol layers for data transfer

- It is assumed that the system has only one control center. The data to be sent from each substation are given in Table 2. Different data types are assumed for the quantities. For example, circuit breaker status is taken as a digital signal.

Device in power system	Data to be sent
Bus	Voltage
Transmission Line	Voltage and Current
Generator	Voltage, Current, Real Power, Reactive Power, Frequency
Synchronous Condenser	Reactive Power
Load	Real Power, Reactive Power, Voltage
Circuit Breaker	Status

Table 2: Data to be transmitted to control center

- Figure 1 shows the reduction of the IEEE 14 power system test case into nodes/substations. Figure 2 shows the representation of the nodes in Network Simulator – 2.

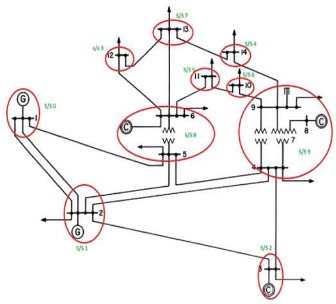

Fig 1: Reduction of IEEE 14 bus system into nodes

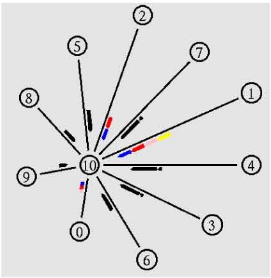

Fig 2: Node representation in NS-2

- The simulation was set to run for ten seconds. The total time taken to complete the simulation was three minutes and thirty-eight seconds.
- The bandwidth of the physical link was assumed to be 100 Mbps for the Phasor Measurement Unit (PMU) data. For non-PMU data, the bandwidth was assumed to be 1 Mbps.
- Congestion was not found to be an issue for the given network, mainly because a direct topology has been assumed, with enough bandwidth.
- Packet drops did not occur, as the bandwidth assumed was sufficient for the simulated network.
- It is clear that for PMU data, the bandwidth will need to be on the higher side (greater than 10 Mbps), because of the high rate at which data are transmitted.

Broader Impact

- Development of integrated cyber-physical system test cases will enable analysis of the possible impact of communication attacks or a coordinated cyber-physical attack on the reliability of the power grid.
- Will provide a way to validate vulnerability analysis algorithms for the smart grid.

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

- Improve communication architecture from a direct topology to a more complex topology to mirror actual communication systems.

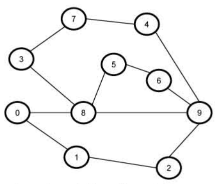

Fig 3: Sample network topology to be considered

- Do case studies for specific applications, like state estimation algorithms using developed cyber-physical network.
- Explore alternative communication simulation tools like GridStat and Emulab for real-time test-bed development.