Specifications for the Power Grid Simulator

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What is Simulation?

• Testbed?
• Analytical Tools?
• Apps?
• Simulation maybe a part of an analytical tool
• Analytical tool or app requires
  ▪ Input – static vs time variable
  ▪ Output – characterizes the app
• Simulation is a mathematical description of behavior
What is simulation?

• Is power flow a simulation?
• Power flow ‘simulates’ an instant
• Simulation usually implies behavior over time
  ▪ Electromagnetic (<msecs)
  ▪ Electromechanical (>msecs)
  ▪ Uniform frequency (secs)
  ▪ Economic Dispatch (min)
  ▪ Unit Commitment (hours-days-weeks)
  ▪ Hydro Coordination (seasonal)
  ▪ Planning (years)
What is Real Time?

• Is the computation time faster than the time step?
• What affects the computation time
  ▪ Size of the grid
  ▪ Complexity of the models (equations)
  ▪ Nonlinearities, particularly discontinuities
  ▪ Computer architecture
  ▪ Algorithm

Are there any real time simulators?
Simulator Characteristics

• Models
  ▪ Algebraic equations (power flow)
  ▪ Differential equations
  ▪ Logic (control, protection)

• Main concern is the speed of dynamic behavior

• Faster behaviors are harder

Many simulators are possible.
Can they be seamlessly connected?
Transmission vs Distribution

• Mostly simulated separately
• Distribution models usually smaller
• Do we have to model distribution in our transmission simulation?
• Distributed generation, dynamic load control
• How much detail?
Why New Simulation Testbeds?

- Faster sensing (PMU)
- Faster communication
- Faster computers
- Faster controllers (FACTS)

Can we operate the grid more efficiently and reliably?

Need better tools to design and test new operational procedures and controls.
Simulation Challenges

• What is missing in the existing simulators?
  ▪ New measurements
  ▪ New power electronics equipment
  ▪ New controls logic

Also
  ▪ PMUs
  ▪ Communications
  ▪ Computation

Handling of the feedback loop of streaming measurements, control logic and control signals
Real Time Simulation

• Does the simulation have to be real time?

Issues

• Synchronizing the simulation of different parts
  ▪ Power grid
  ▪ Communications
  ▪ Computation
  ▪ Control/protection logic

Don’t know how to do time simulation of communication and computation
SGDRIL Test Bed at WSU

OPAL-RT

PI SYSTEM

PI Interface

PI Server

C37.118

OPAL-RT 32-Core

PI Analytics
Real Time Digital Simulator and Other Devices

The test bed consists of –

a) Real Time Digital Simulator
b) Master Computer
c) Substation Automation Computer
d) 5 Nos. of PMUs
e) Software & Hardware PDCs
f) Synchrophasor Vector Processor (SVP)
g) Real Time Automation Controller (RTAC)
h) GPS Clocks (2 Nos.)
i) Ethernet Hub
j) Amplifiers
k) Different Softwares.

http://www.eecs.wsu.edu/~asrivast/SGDRIL/index.html
Cyber-Power System Modeling

- **Application Layer**
  - Control Center
  - OpenPDC

- **Communication Layer**
  - NS 3, GridStat, or Deternet

- **Sensor and Actuator Layer**
  - Database
  - PDC
  - PMU

- **Power System Layer**
  - Hardware Interface/Ethernet Internet
  - OP5600 32-Core

- **Real Time Power System Simulator**
  - RT-VSM
GridSim: High Level Diagram
Adaptation for GridCloud Architecture

GridCloud Replica 1
- COL1
- COL2
- SubstationSE1
- SubstationSE2
- 291 Substations

GridCloud Replica 2
- COL1
- COL2
- SubstationSE1
- SubstationSE2
- 291 Substations

GridCloud Replica 3
- COL1
- COL2
- SubstationSE1
- SubstationSE2
- 291 Substations

GridStat
- Time Alignment
- Computation
- Results
- Visualization

GridCloud running on Amazon Elastic Compute Cloud

Replay Process 1
- Client Handler
- PMU1
- PMU2
- PMU3
- PMUN

Replay Process 2
- Client Handler
- PMU1
- PMU2
- PMU3
- PMUN

Replay Process 3
- Client Handler
- PMU1
- PMU2
- PMU3
- PMUN

Internet

Time-Synchronized Data Sources

4632 Streams

291 Substations
Testbed Challenge

• What are we testing?
  ▪ A scenario
  ▪ A widget (sensor, relay, controller)
  ▪ A control process or protection scheme

• Inputs
  ▪ Streaming measurements (real time data)
  ▪ System data (static data)

• What simulation to use

• Output
  ▪ Must include performance metrics
Testbed Challenge

• Many testbeds?
• Or one very flexible testbed
  ▪ Changeable, flexible simulations
  ▪ Different system data sets
  ▪ Different scenarios (measurement data)
  ▪ Different output sets

This is difficult to design. Maybe a few testbeds can cover the whole range