



# Multi-Agent Testbed for Emerging Power Systems

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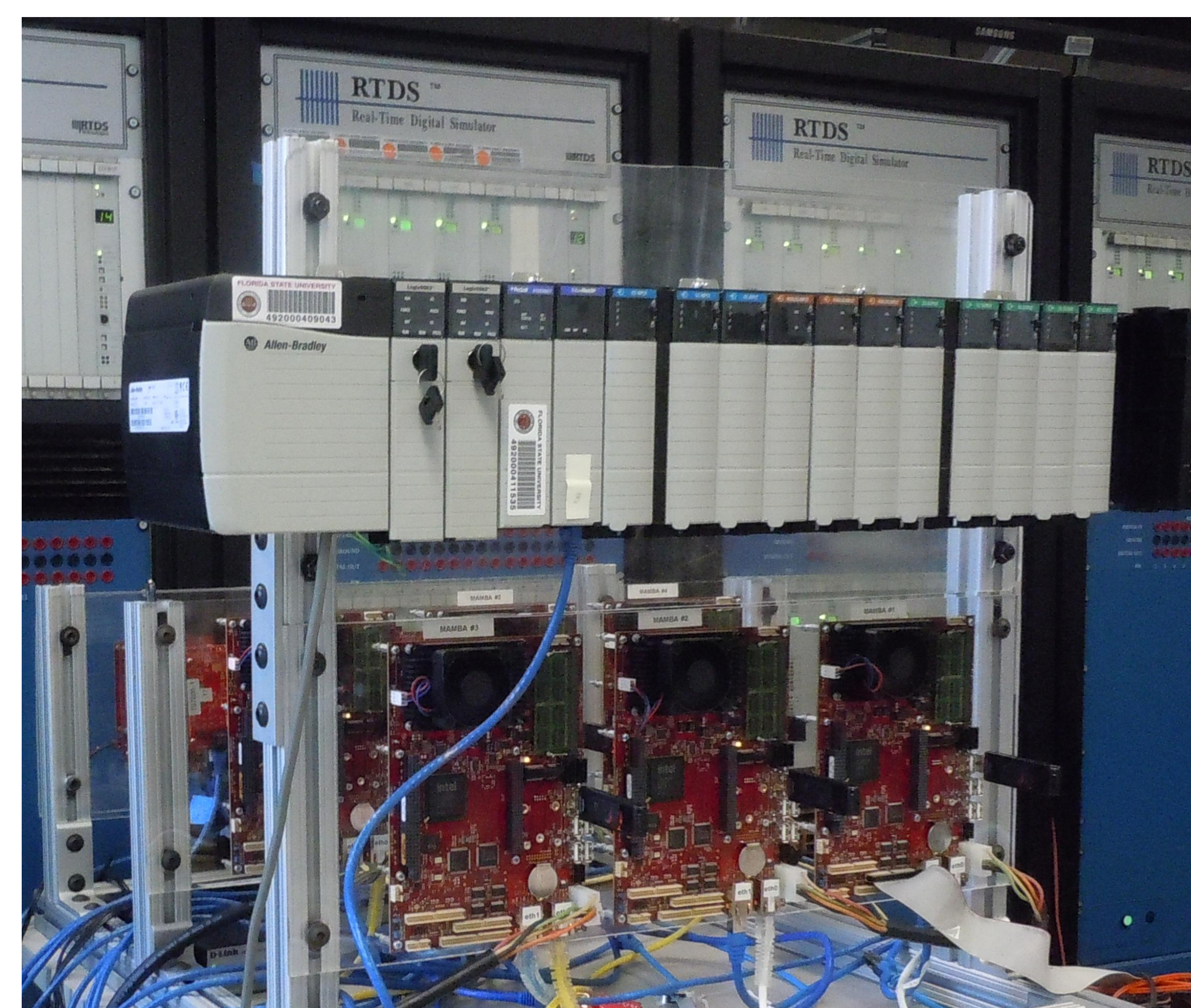
Appropriate testbeds for studying multi-agent systems are needed.

Existing power system simulation does not include facilities needed for studying multi-agent systems.

- Cyber-physical
  - Computational facilities
  - Data communications

## Requirements

- Real-time
- Ability to run a variety of software
  - Multiple OSs (e.g., Windows, Linux)
  - Languages and tools
    - C/C++, Java, Python
    - Matlab, JADE
- Sufficient computational power
- Communications
  - Inter-agent
  - Power system
- Portability
- Cost effective



## Features

### Computational Resources

- 6 Versallogic “Mamba” boards
- 6 TS-7800 embedded ARM boards
- 2 Rockwell PLCs
- 1 Xilinx ML507 board (FPGA)

### Communications

- 2 Ethernet communication networks
- OPNET real-time simulator

### Power System Simulation

- 14 RTDS “racks”

## Lessons Learned

### Need for automation

- Artifacts from one experiment to the next
- Less error prone
- Time consuming to manually setup testbed for various configurations
- “Wiring” for electrical connections (interface to power systems simulator)

### Benefits of real-time simulation

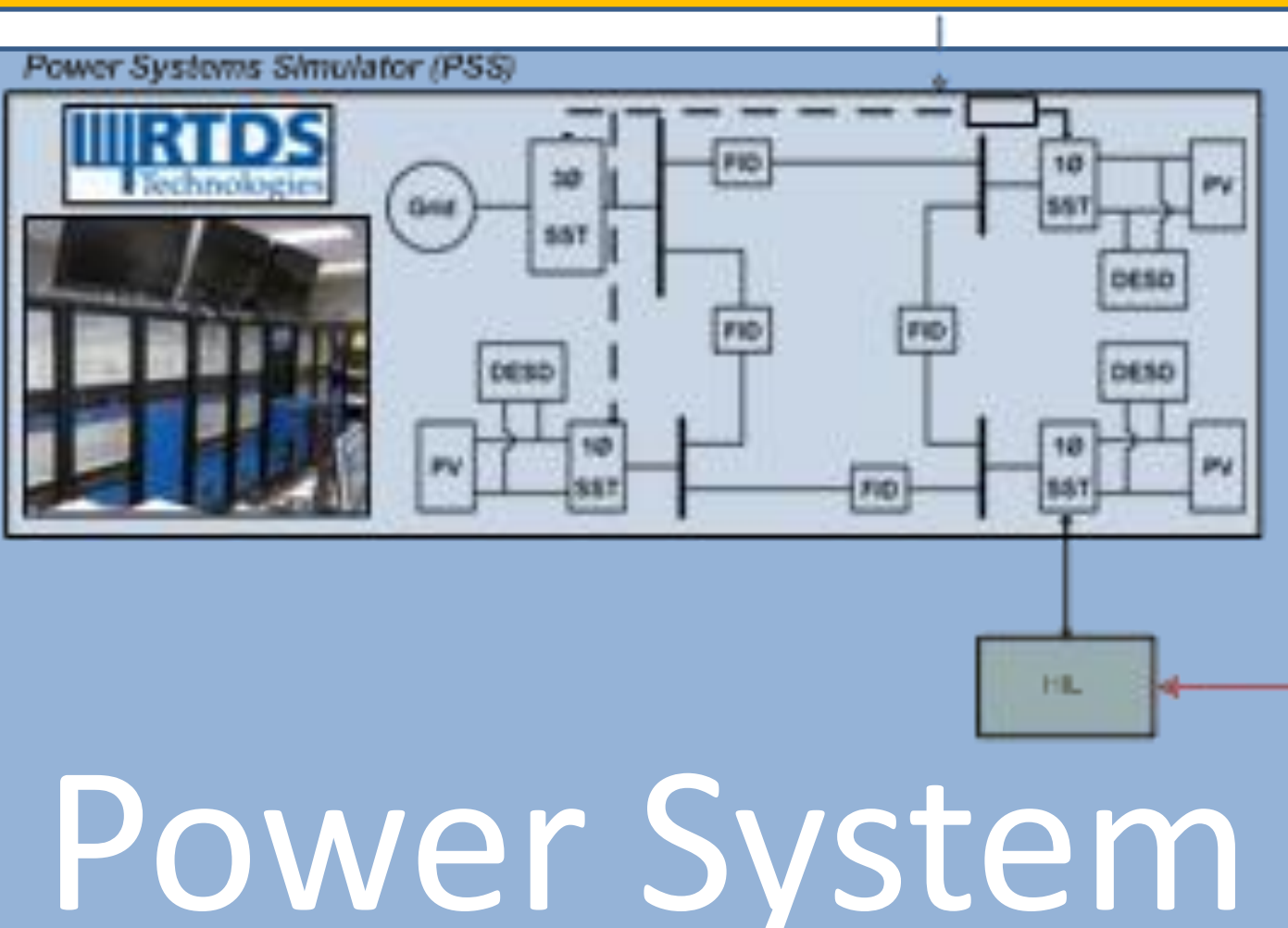
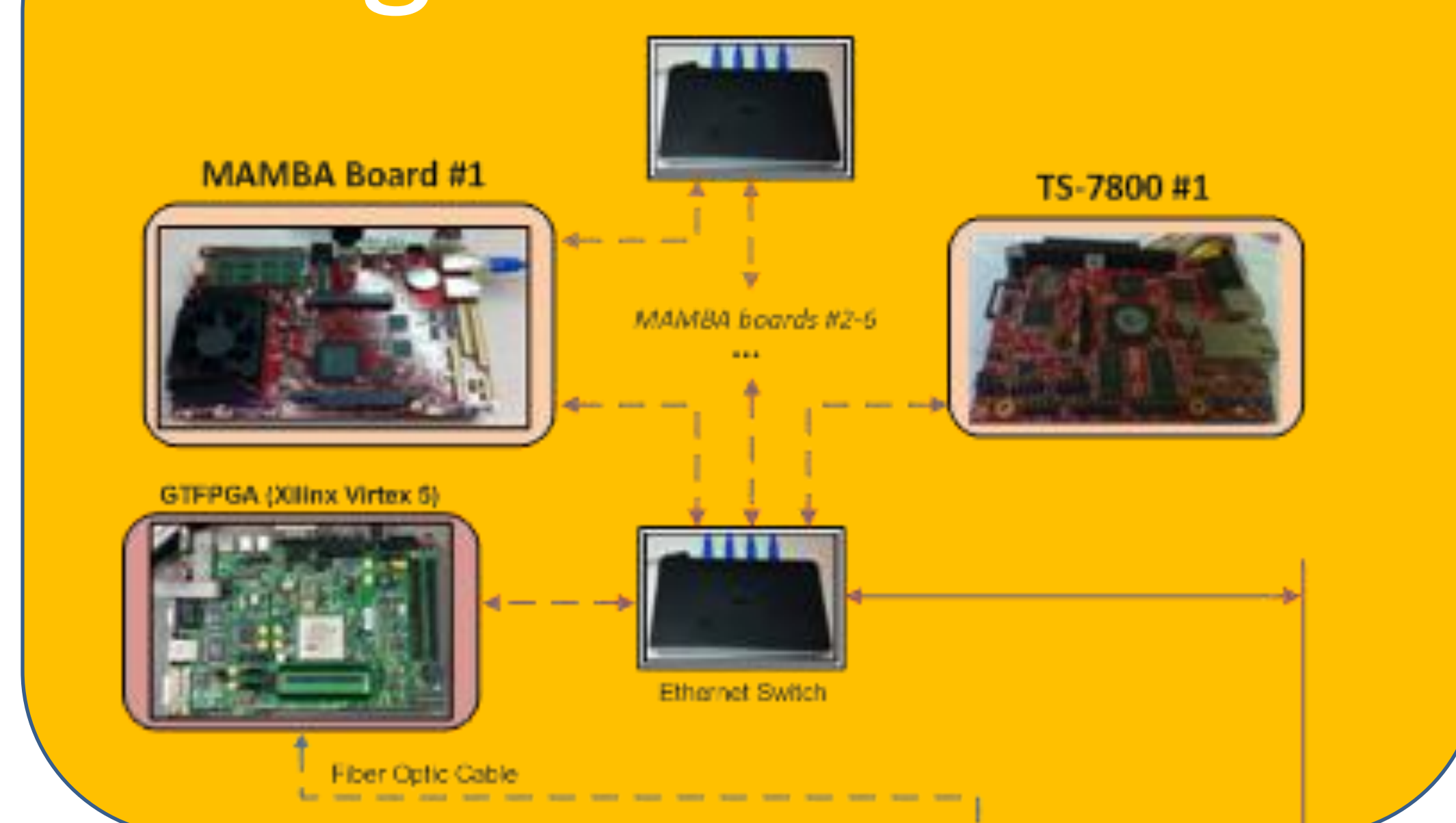
#### Multiple computational facilities

- General purpose
  - High and low performance
- FPGA
- PLC

### Data communications simulation

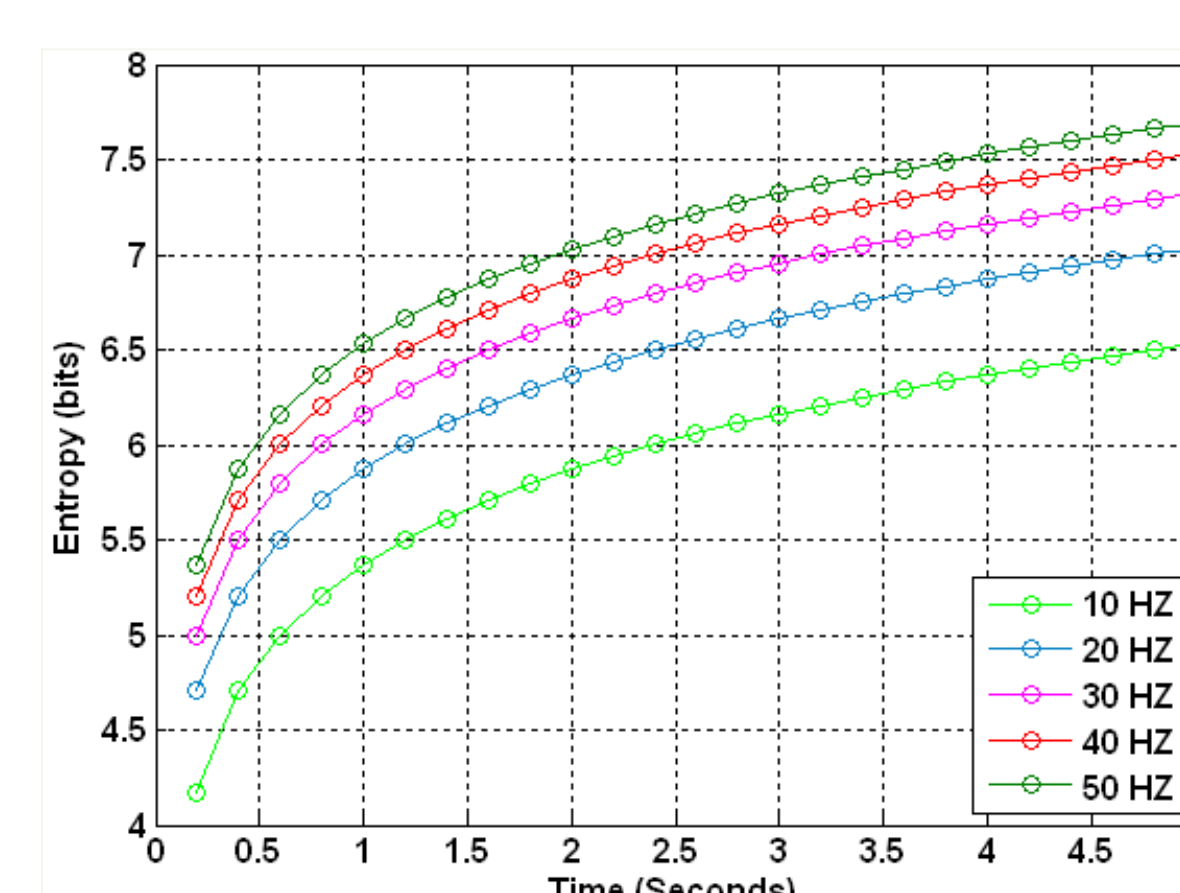
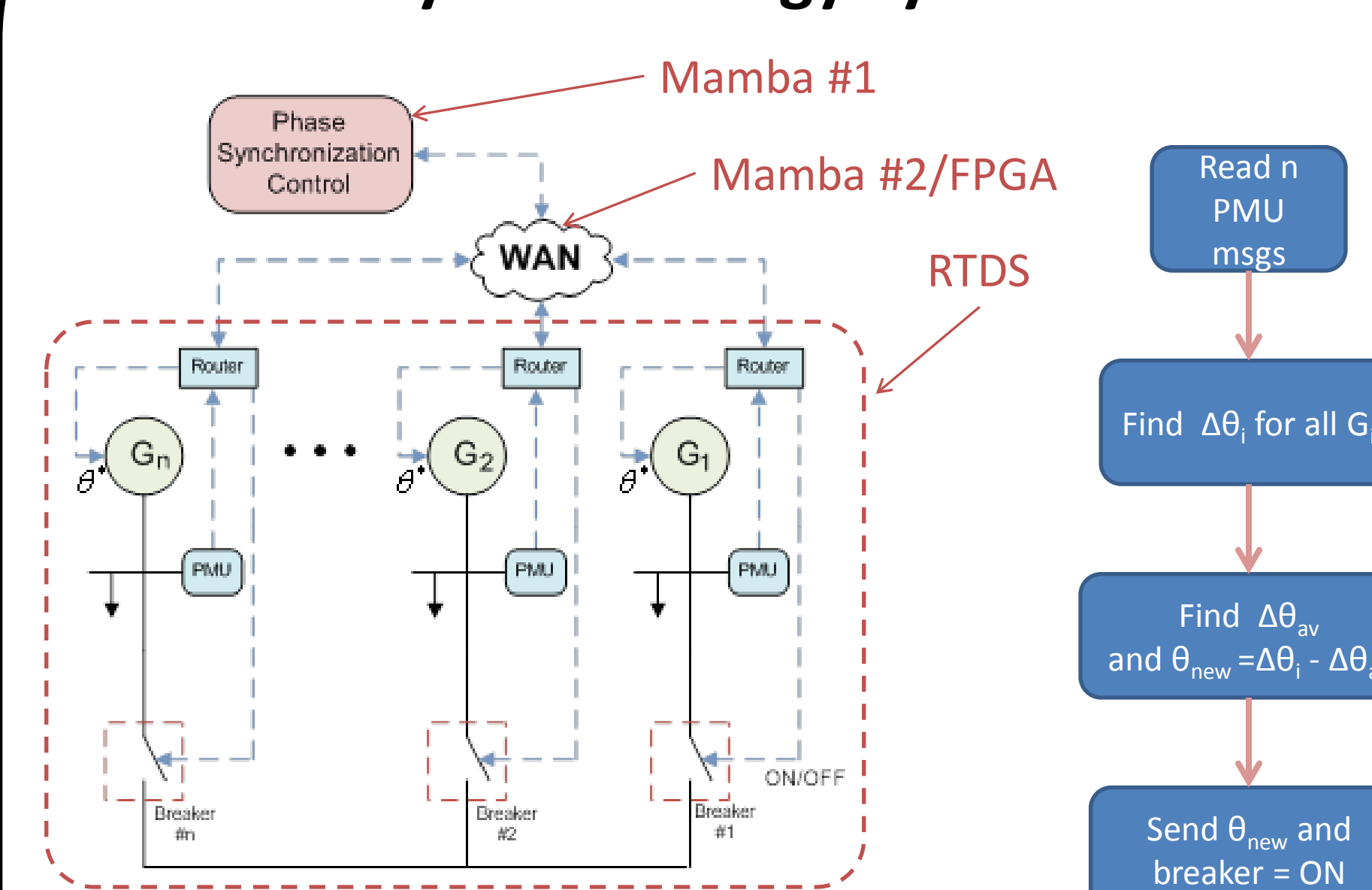
- Topologies
- Communication technologies (e.g., wireless, fiber-optic)

## Agent Platform

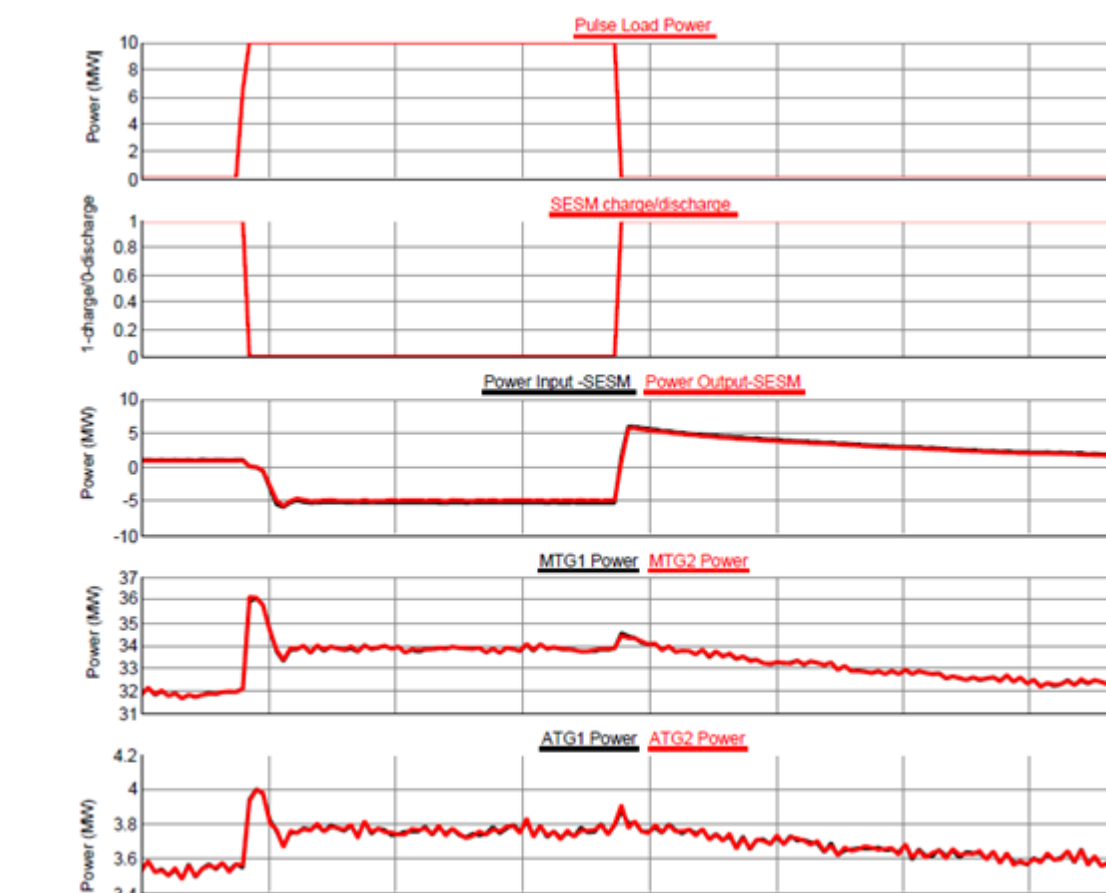
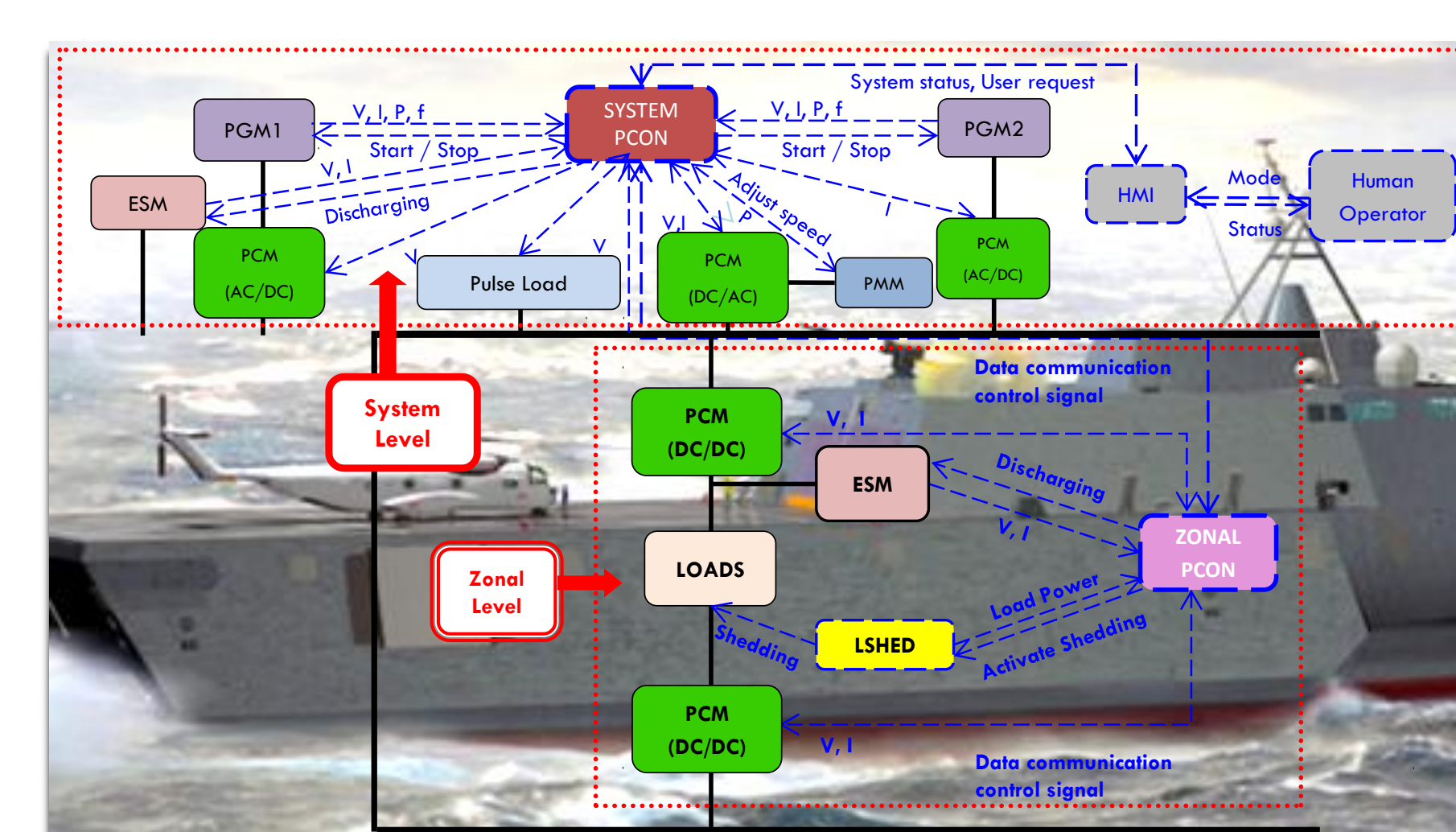


## Power System

## Information-Theoretic Characterization of Dynamic Energy Systems



## Distributed Control in a Shipboard Power System



## FREEDM Smart Grid

