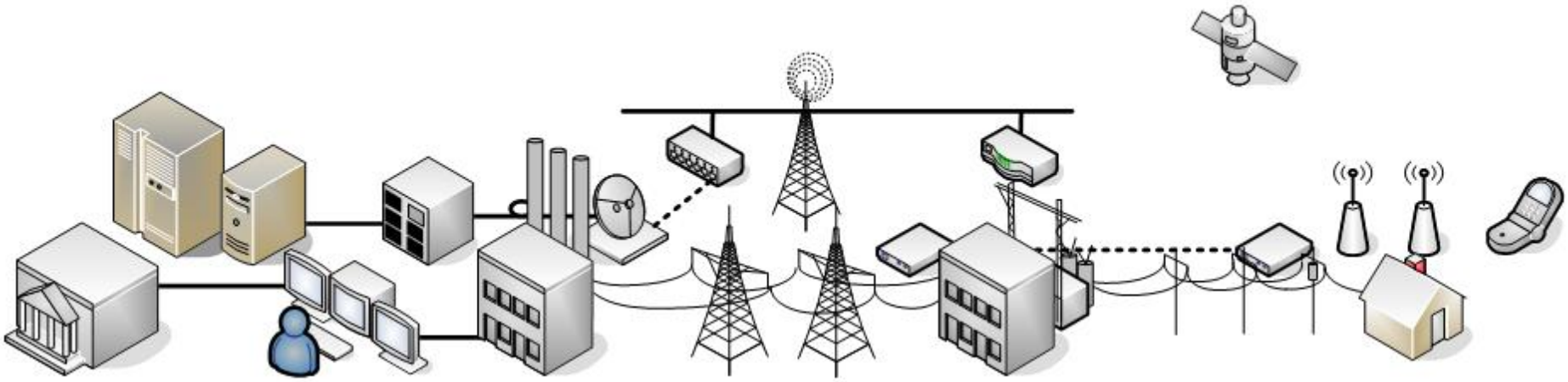


Securing critical loads in a PV-based microgrid with a multi-agent system

Taesic Kim

03/04/2013

Reference

M. Pipattanasomporn, H. Feroze, S. Rahman, “Securing critical loads in a PV-based microgrid with a multi-agent system," Renew Energy, 39 (1) (2012), p. 16174.

Appendix

H. Feroze, “Multi-agent systems in microgrids: Design and implementation,“ thesis, Virginia Polytechnic Institute and State University, Arlington, Virginia, August 7th, 2009.

Outline

- Introduction
- Design of multi-agent system
- Cyber-Physical system and their interactions
- Simulation results and discussion
- Conclusion
- Praises
- Critiques
- Proposed MAS for DC microgrid

Smart Grid

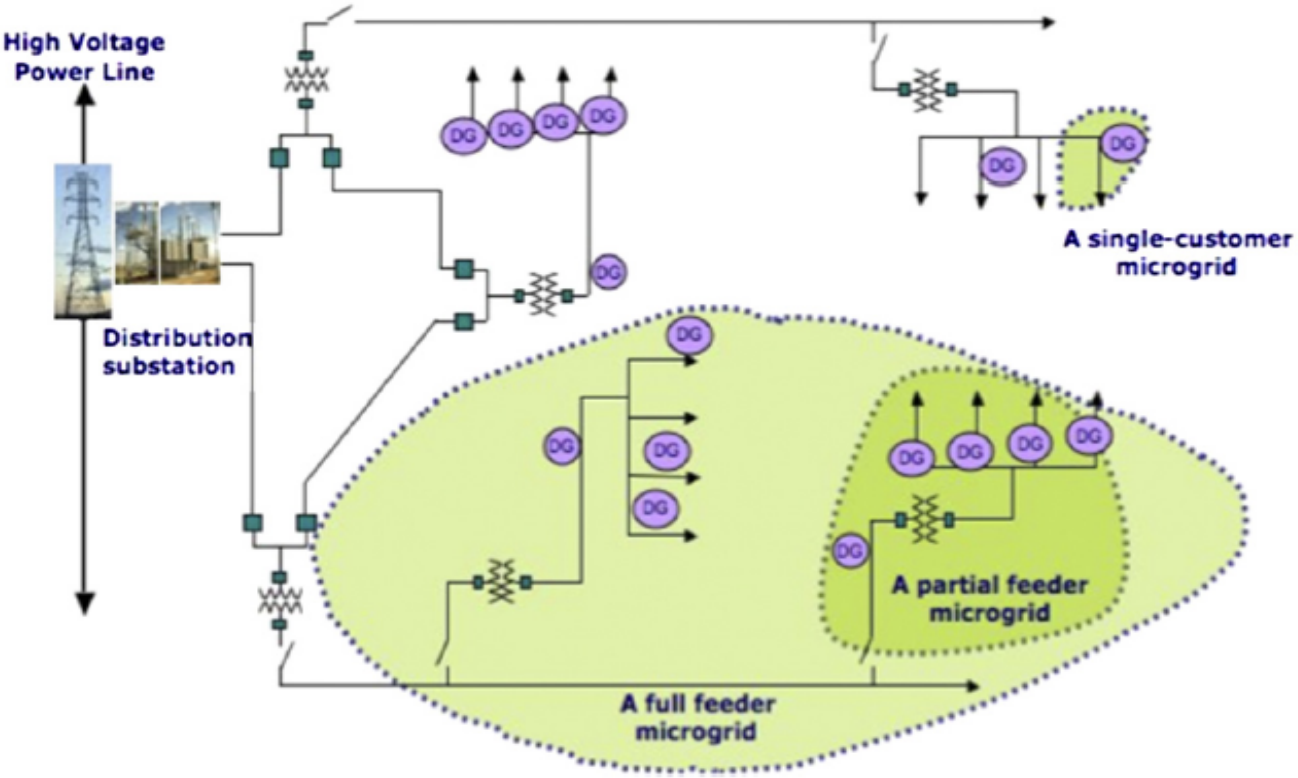
- Uses information technologies to improve how electricity travels from power plants to consumers
- Allows consumers to interact with the grid
- Integrates new and improved technologies into the operation of the grid

Issues:

Distributed Generation, Demand Response and Load Control, Energy Storage, Anticipated Massive Amount of Energy Transaction, Security

Micro Grid

- A subset of an electric power system
- Single customer; Partial feeder; full feeder
- Islanded grid



Control Methods and Topologies

- Traditional power system (SCADA) problems
  - Centralized
  - No local supervisory control unit
  - No fault isolation
  - Relied entirely on electricity from the main grid
  - Limits communication with different DER devices

*SCADA: Supervisory Control and Data Acquisition

IDAPS: Intelligent Distributed Autonomous Power Systems

- Distributed
- Loosely connected APSs
- Autonomous
  - Can perform automatic control without human intervention, such as fault isolation
- Intelligent
  - Demand-side management
  - Securing critical loads

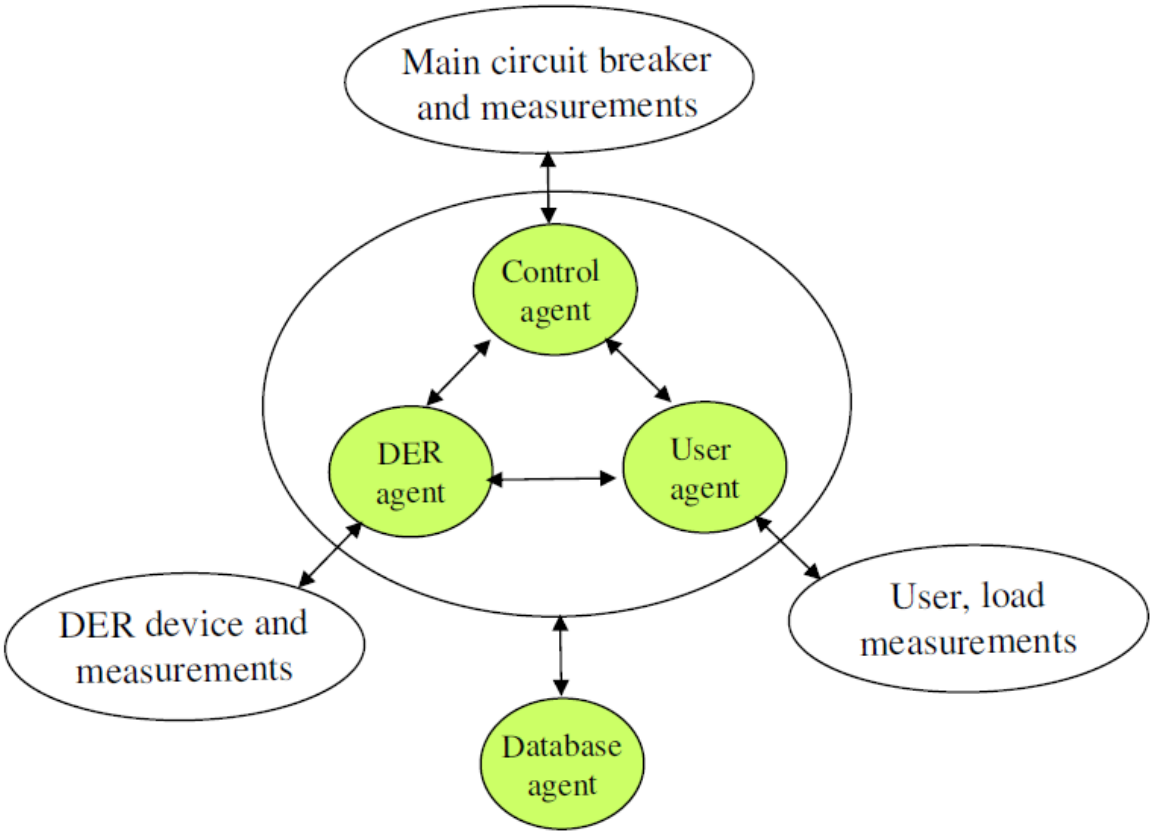
Micro Grid

- Operating strategies
  - Normal mode:
    - a part of the local utility
    - Optimal operation
  - Outage mode
    - Isolation
    - Operate autonomously to secure critical loads

- Intelligent, distributed and autonomous

Design of the MAS

- Four agents: control; DER; User; database
- Goal: island the microgrid and secure critical loads during external fault conditions



Agent architecture and specifications

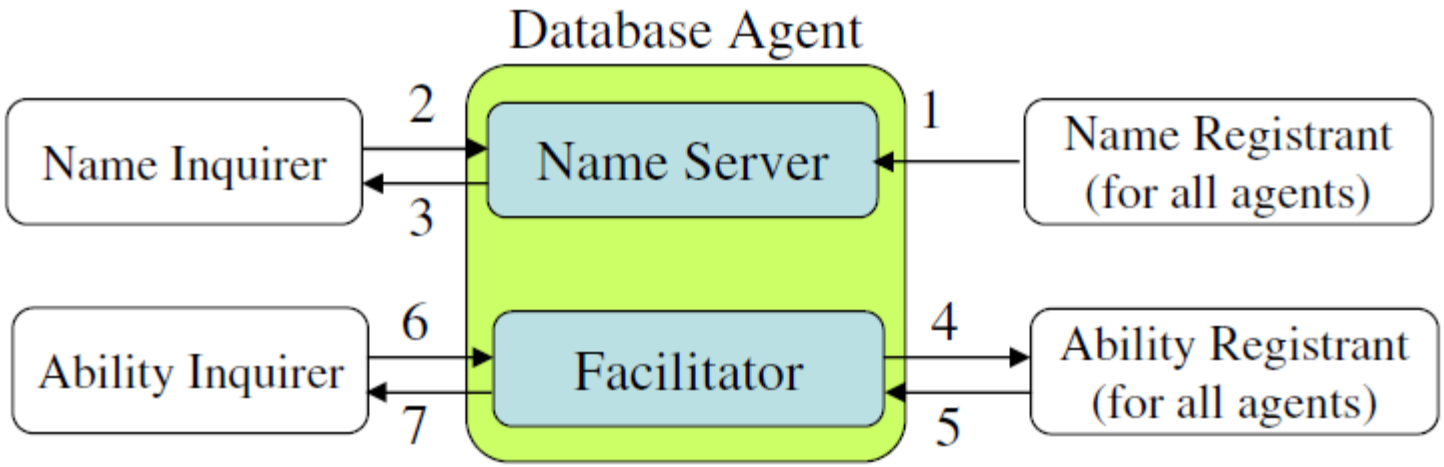
- Control agent
  - Monitoring the health of the utility network
  - Isolation and restoration
- DER agent
  - Monitoring and controlling DER power and its connection
  - DER info: ID, type, power rating (kW), local fuel availability, cost function (price) at which users agree to sell, DER availability (maintenance)

Agent architecture and specifications

- User agent
  - Customer gateway
  - Monitor voltage, current, active and reactive power consumption at each critical and non-critical loads
- Database agent
  - Storing system information, recording the messages and data shared among agents
  - Serves as a data access point for other agents, and keeps track of all available agents and their capabilities

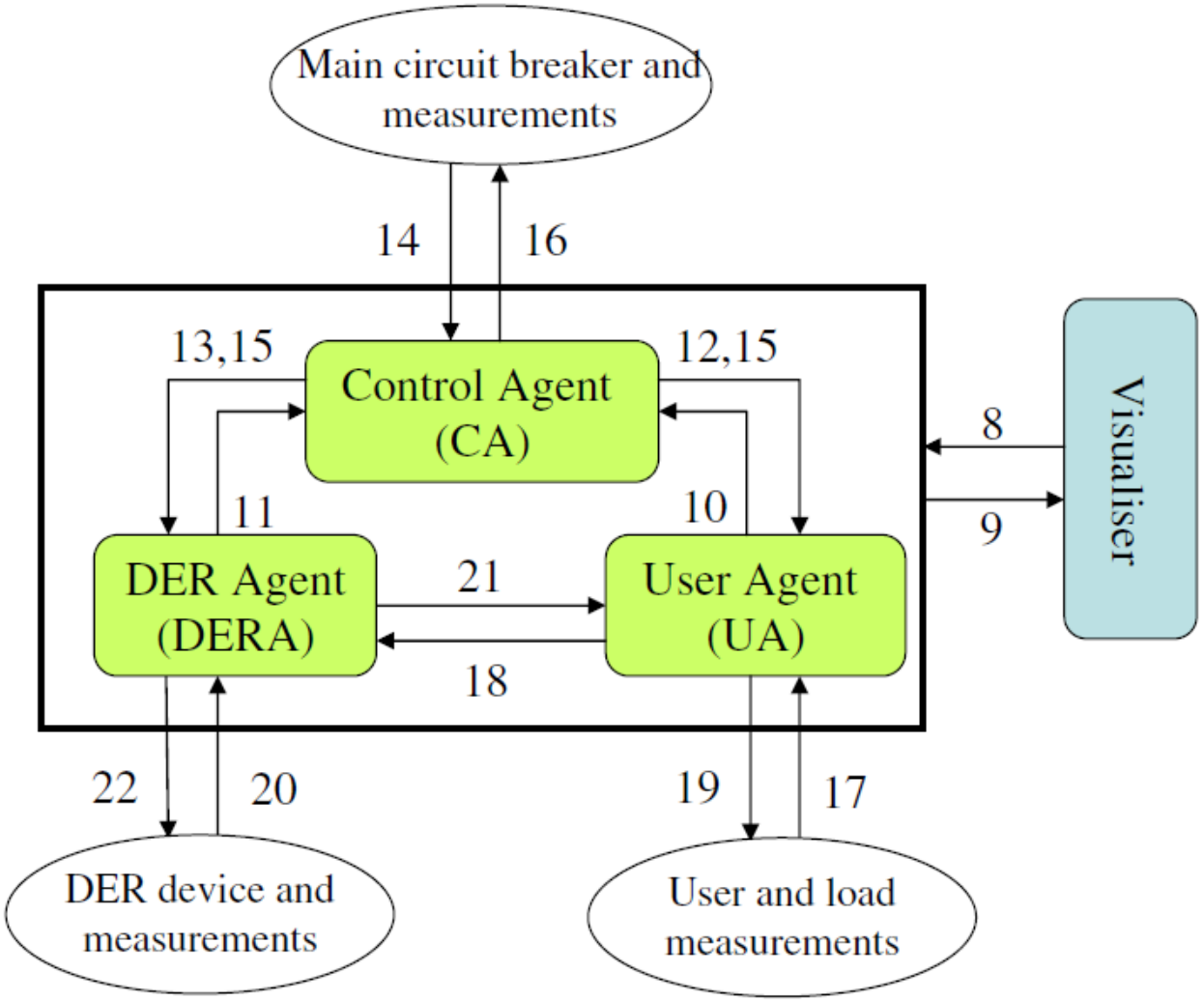
Agent collaborative diagram

Initialization:



- Name server: register and maintaining directory of the agents and their locations
- Facilitator: contain abilities of all agents in the MAS

Agent collaborative diagram



Physical system

- Distributed energy resources (DER)
  - Solar panels with battery storage
  - During grid-connected mode (normal) VS islanded mode: voltage magnitude, frequency and phase control
  - Assume DER has sufficient energy to secure all critical loads during outage

Physical system

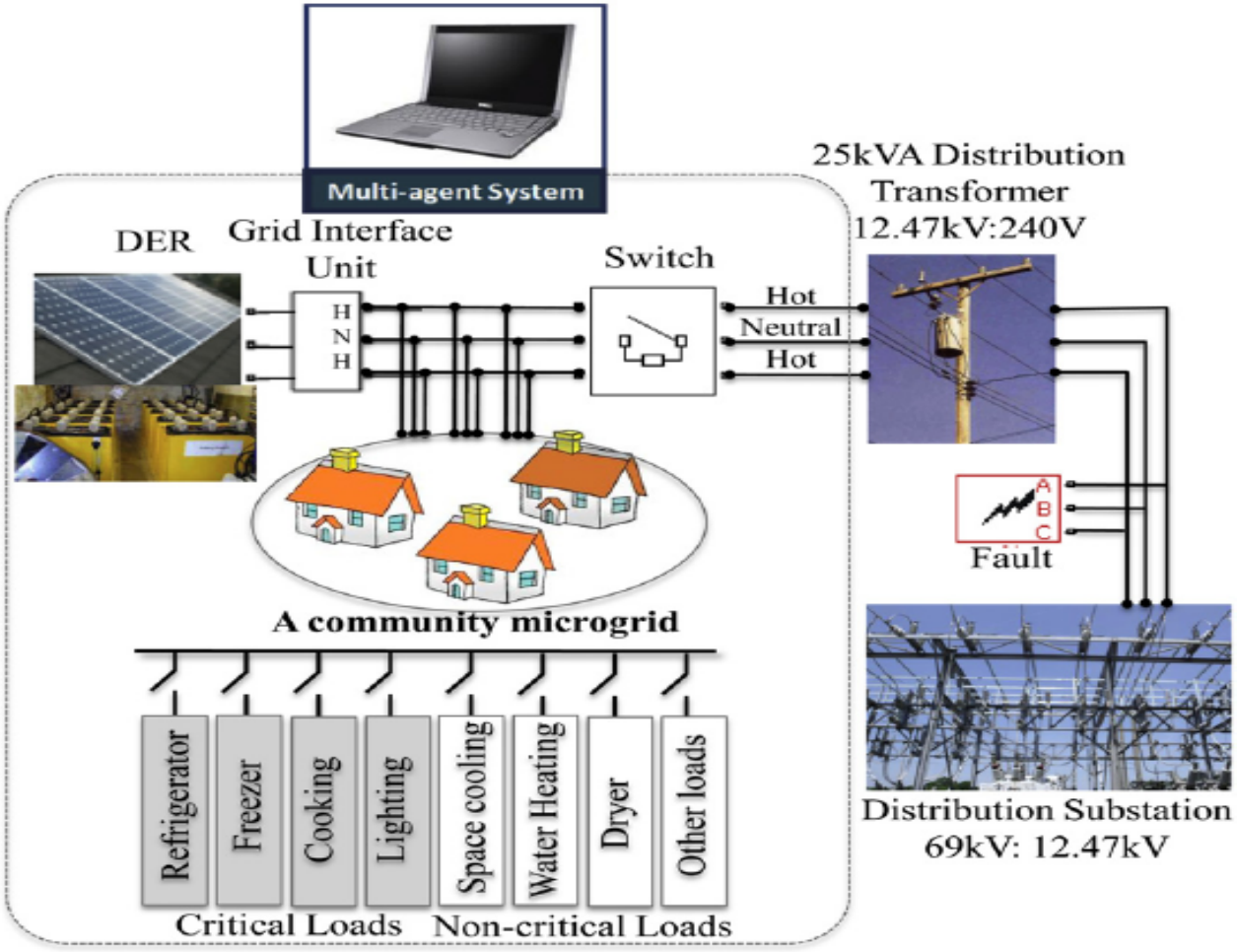
- Load profile and their priority
  - A group of three homes
  - Critical load VS non-critical load
    - Critical loads: refrigeration, freezer, cooking, and lighting
    - Non-critical loads: space cooling, water heating, dryer and others
- In 2007, Pacific Northwest National Lab

  “ Customers change their usage behaviors in response to variable electricity rate”

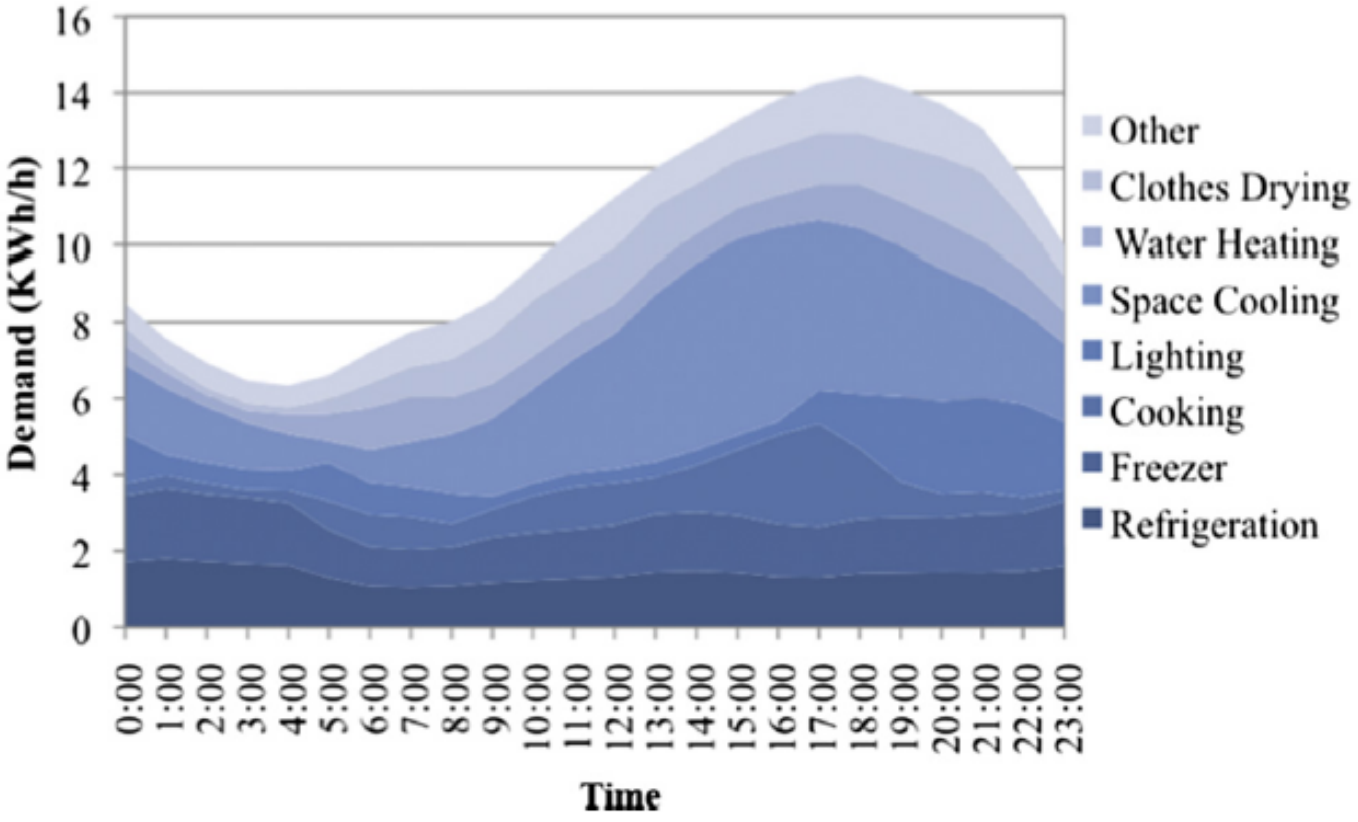
Simulation and discussion

- Island the microgrid once a fault is detected
- Secure critical loads during emergency
- Resynchronize the microgrid to the main grid after external fault is cleared

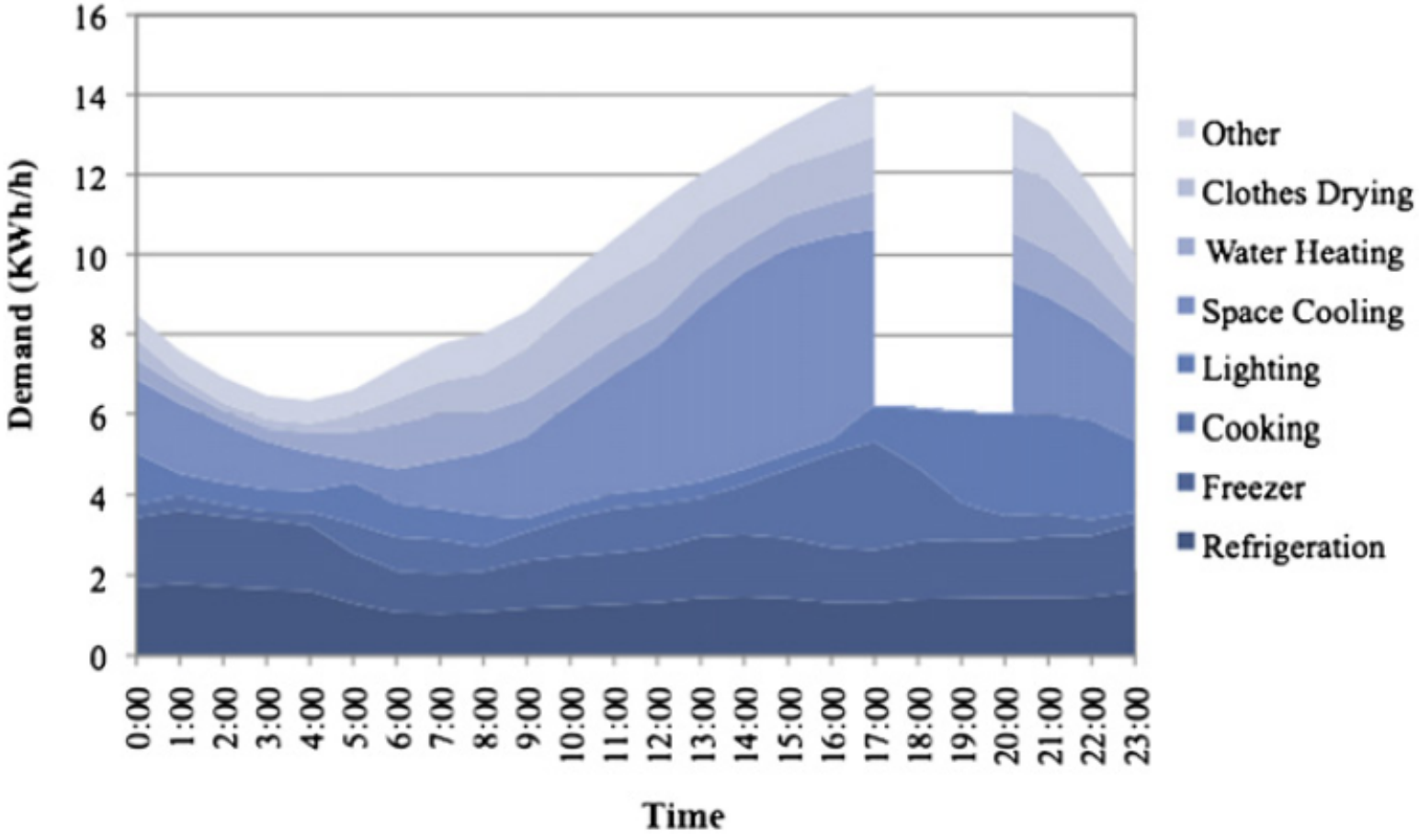
IDAPS multi-agent system



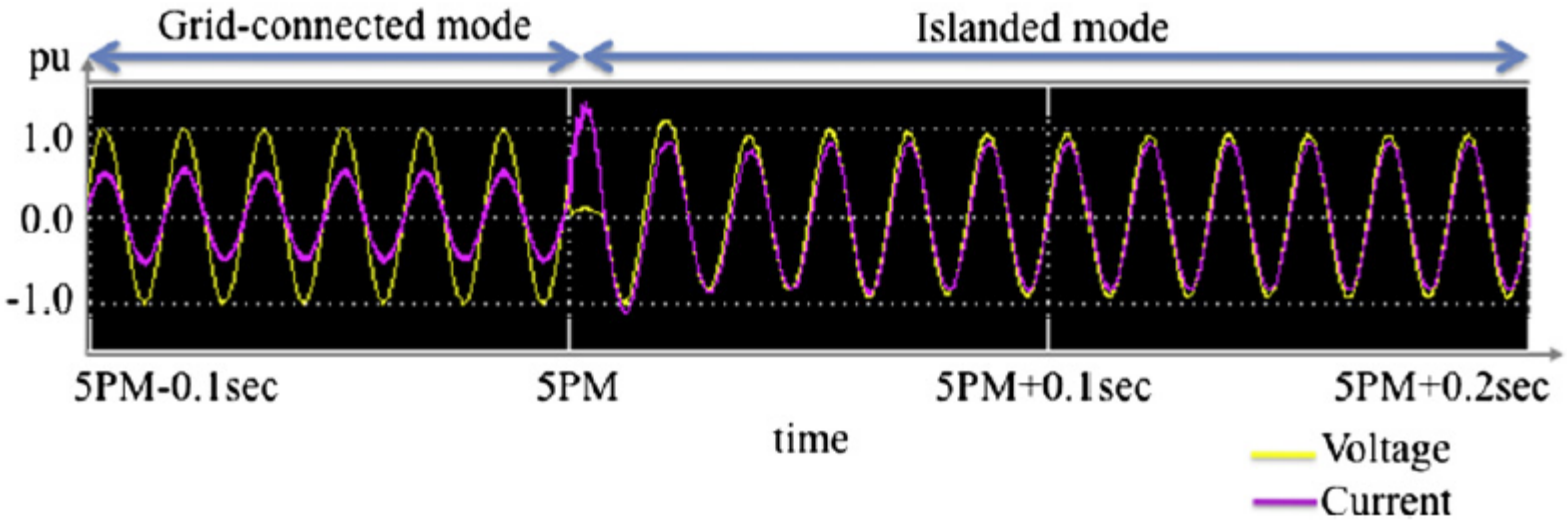
Demand power of loads



Critical load control

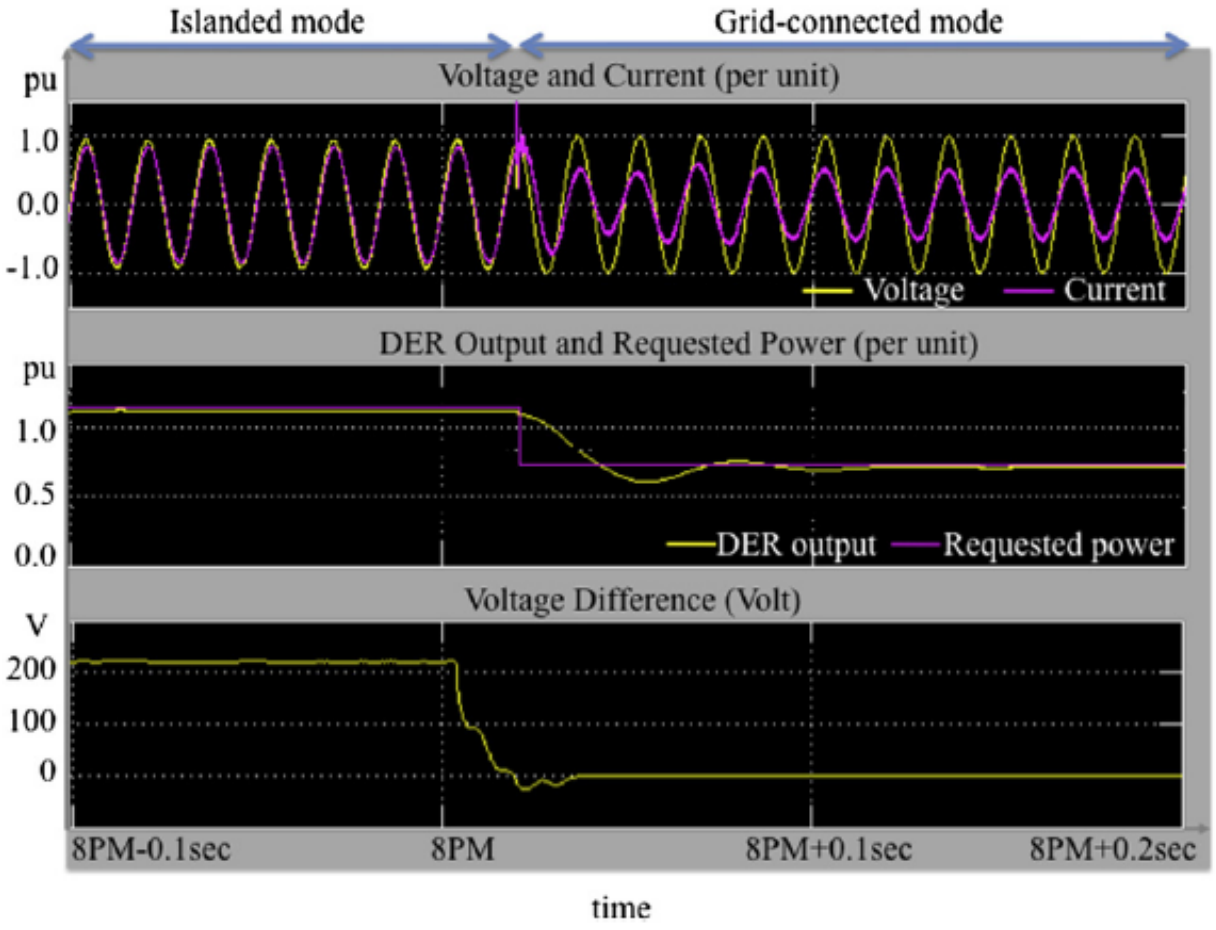


Islanded mode: isolation and stabilization



Autonomous decisions such as seamless transition from grid-connected to island mode

Resynchronization of the microgrid



Conclusion

- MAS was designed and implemented in a simulated environment to control and manage a PV-based
- This paper demonstrates the agent's abilities to isolate the PV-based microgrid and to secure critical loads during fault conditions, as well as resynchronizing the microgrid after the external fault is cleared

Praises

- Detailed description of the development of MAS for the control of a PV-based microgrid
- A guide for the practical implementation of an agent-based approach for resilient operation of a microgrid that has a solar photovoltaic (PV) system coupled with battery storage

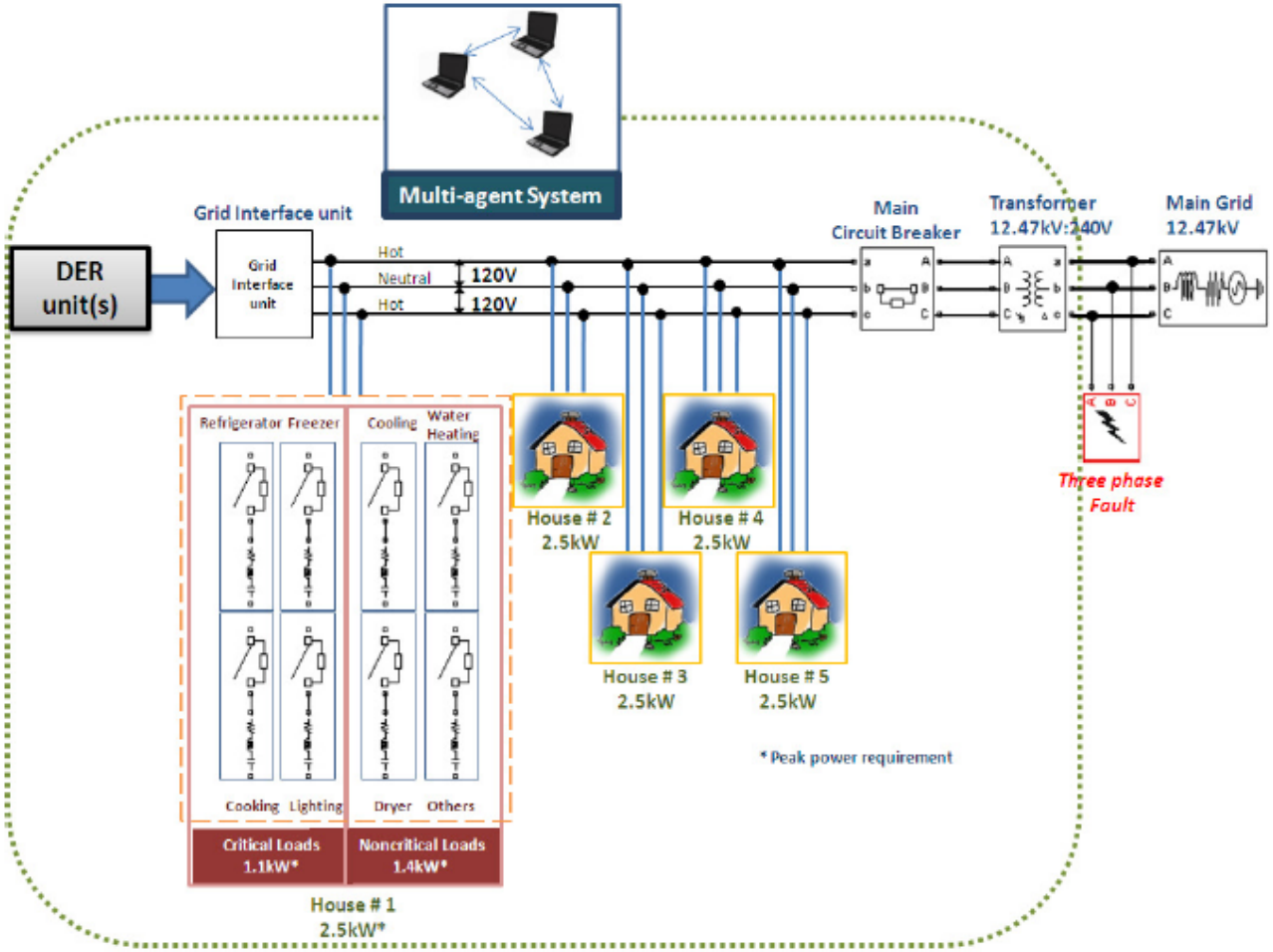
Critiques

- Can't say that database agent is an agent
- week description of how to decide the requested power level to DER
- DER unit has a limited capacity
- Need to include Trading feature in MAS to be microgrid
- Advanced components and subsystem having different ownerships will be DER agents or USER agents

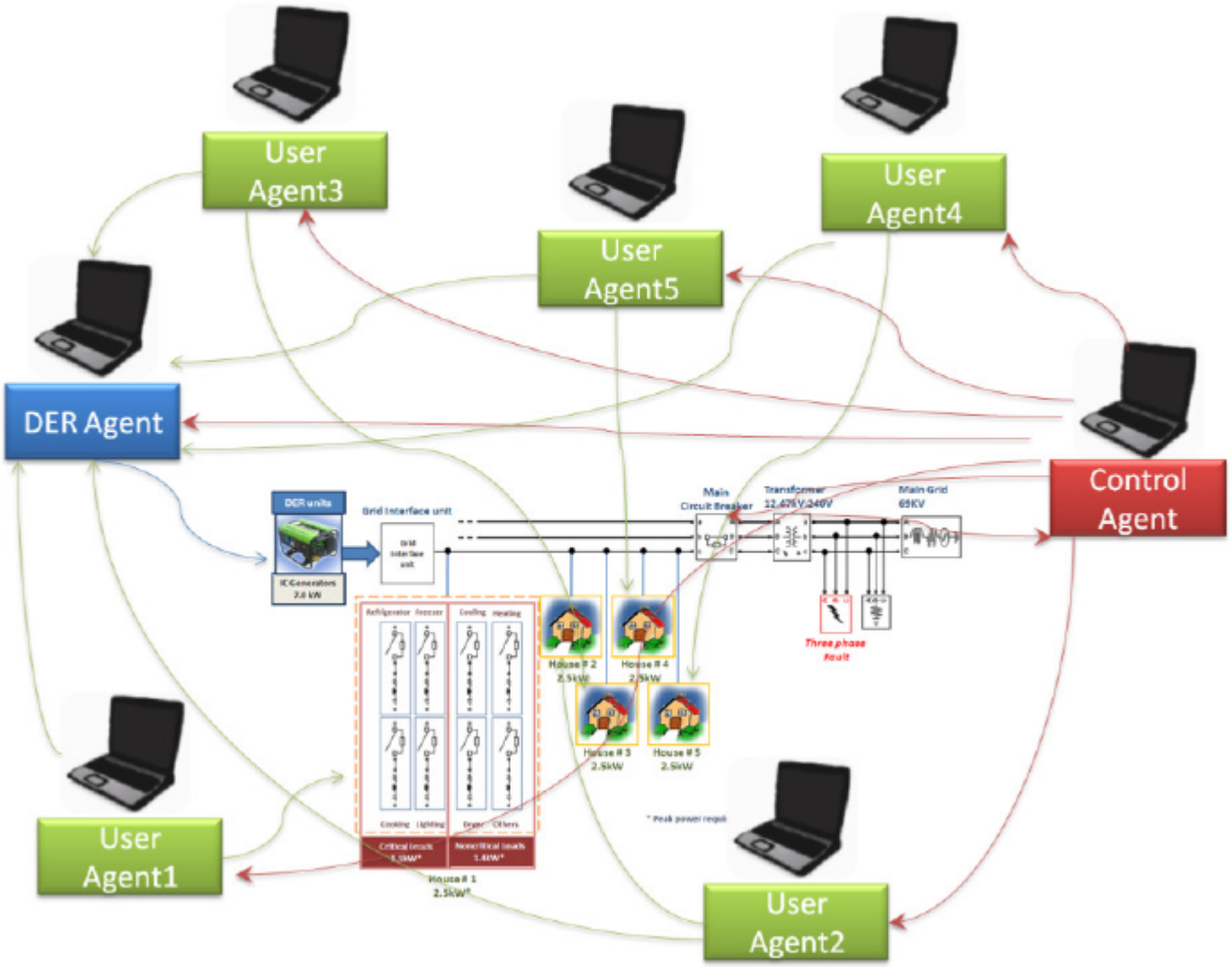
Ex) PHEV/EV: user agent, Smart Battery System: DER agent

Appendix: Multiple owners

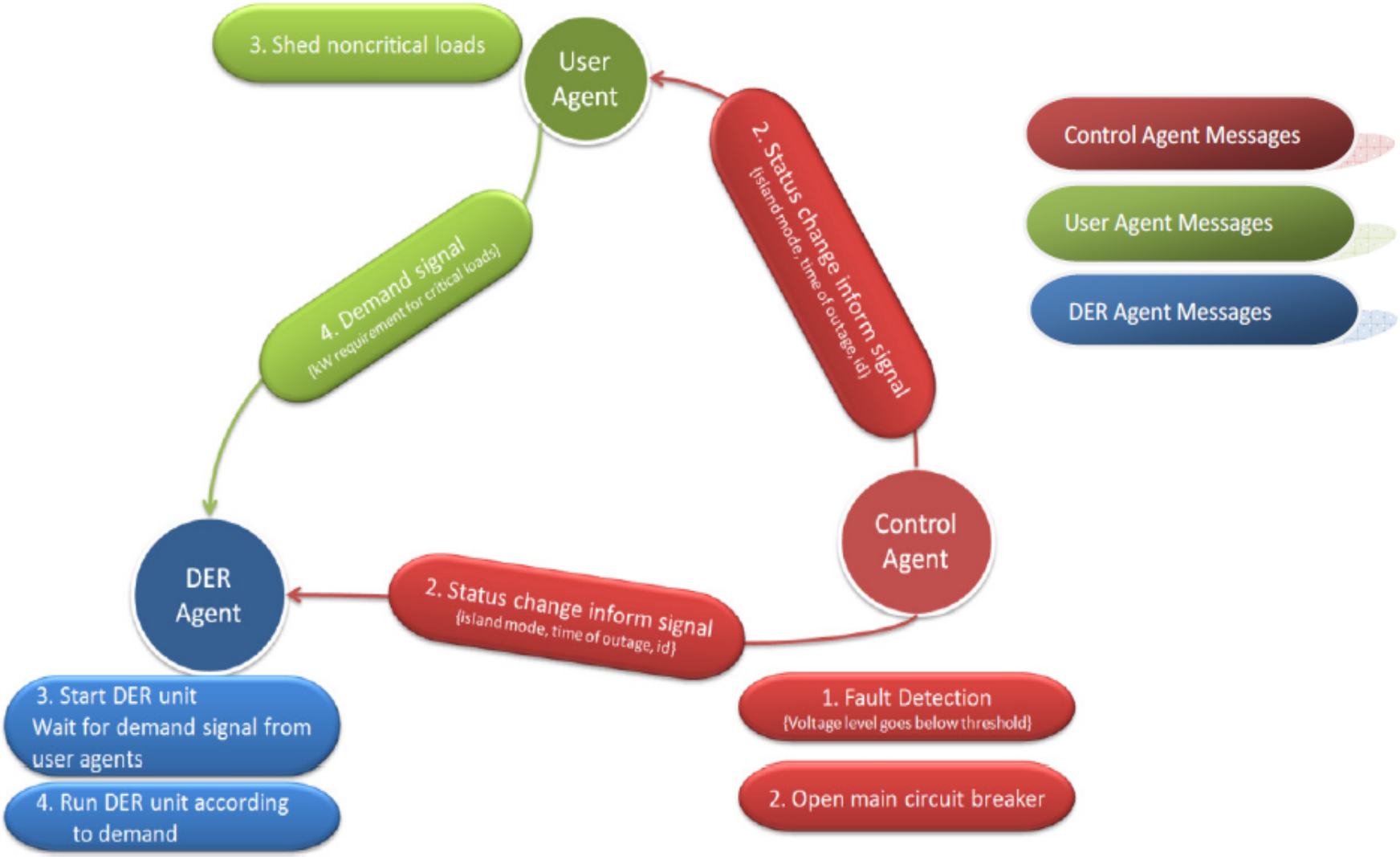
Five user agents sharing DER unit (one DER agent)



Appendix: Exchange of message

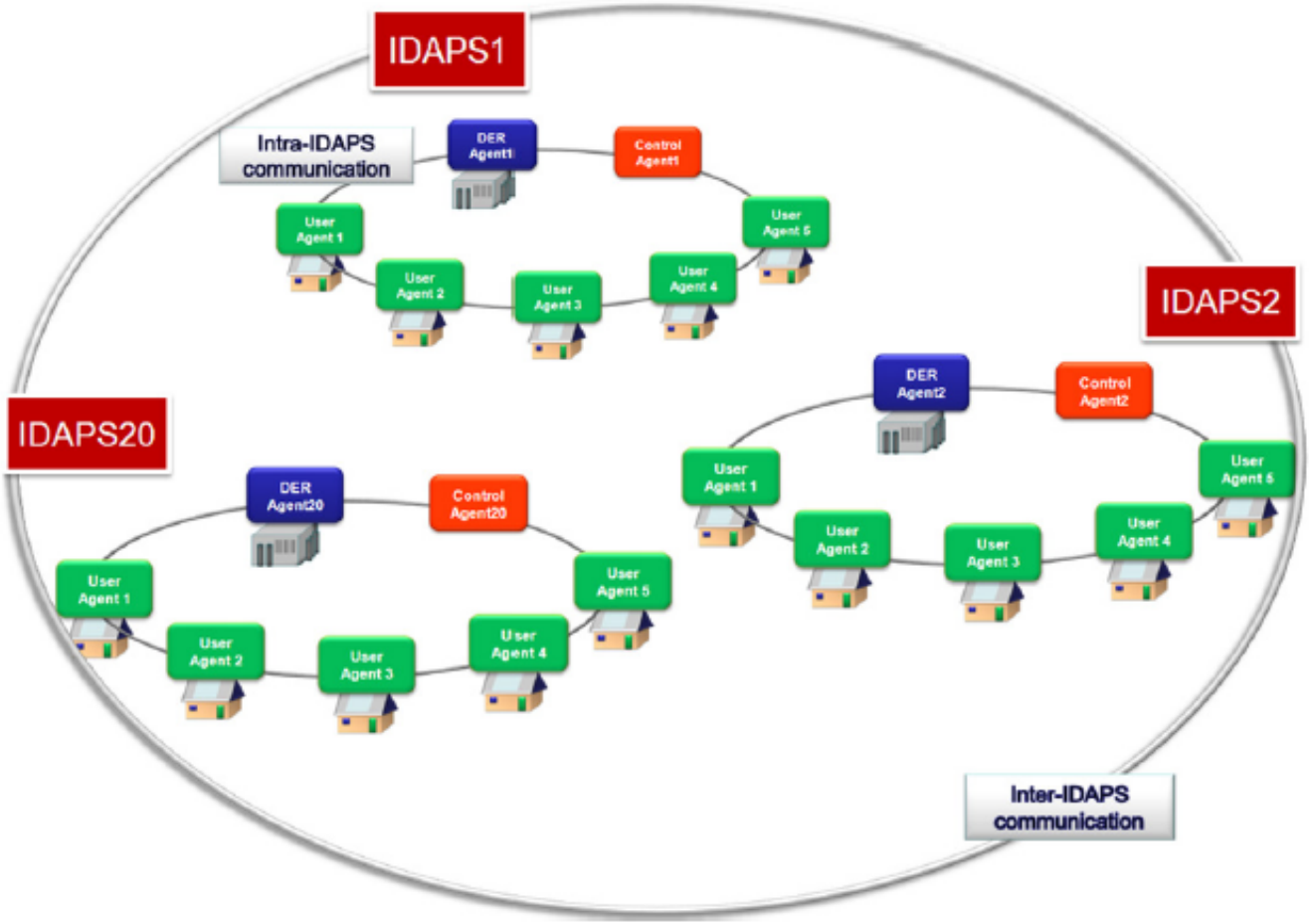


Appendix: Transition process



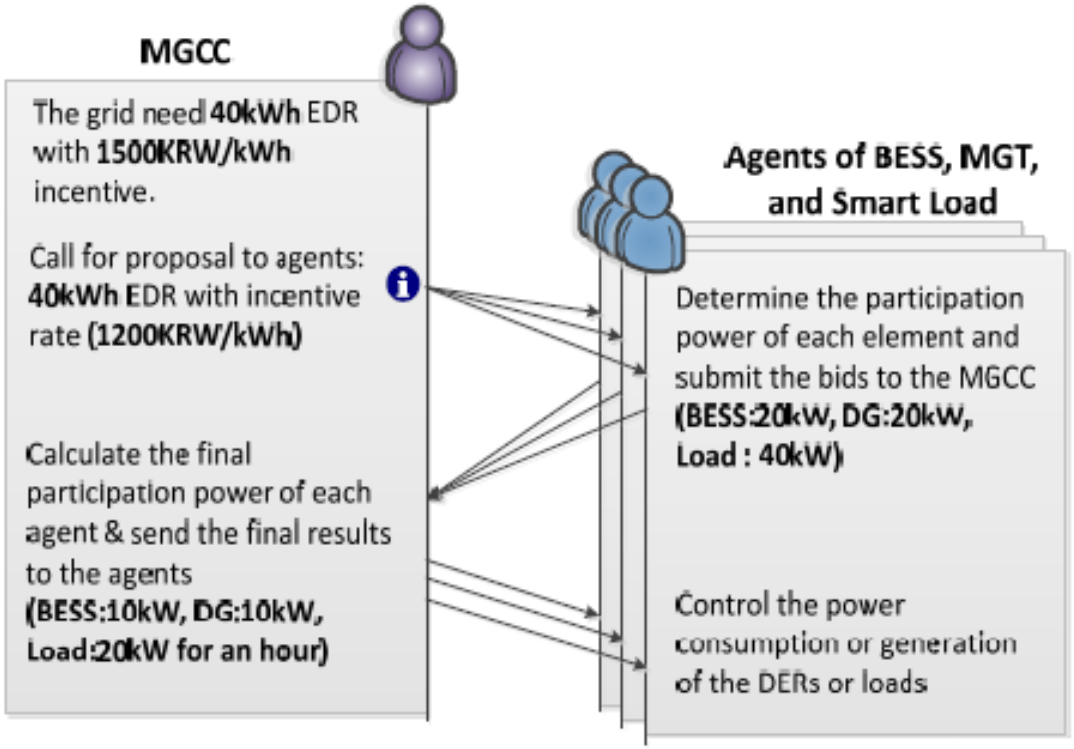
Appendix B: Envisioned IDAPS system

In real world, there will be many IDAPS systems



Different owners

- DERs, Storage, loads will have different owners
- Each owner would like to make their own decision locally



Advanced Components and Subsystems

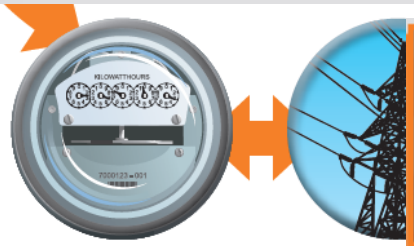
- Plug-in Hybrid Electric Vehicle (PHEV)
  - Grid-to-Vehicle(G2V) and Vehicle-to-Grid(V2G)
  - Peak load leveling

Grid-to-Vehicle (G2V)

Enable Time Charge – Schedules daily recharge start times for weekdays and weekends

PHEV User

Enable Price Control – Programs the vehicle to only accept a charge when electric rates are lower, such as off-peak hours



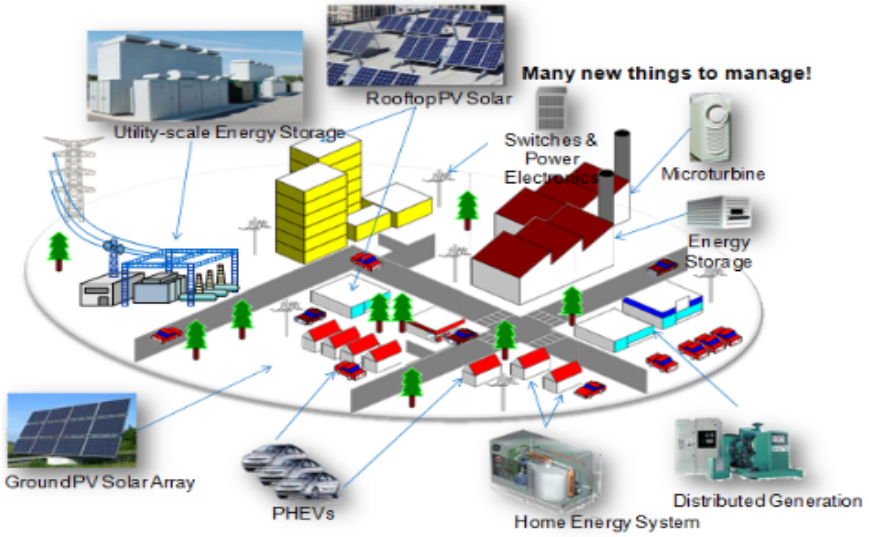
Smart Meter

Electri

Enable Charge Complete – Selects a recharge completion end time

DC Microgrid using a Multi-Agent System-based controller

- Extending and coordinating IDAPS to DC microgrid
- Several DER agents having different ownerships can make a decision by negotiating and cooperating with other agents
- Deferrable load (PHEVs) will be considered in MAS



Thank you.

Questions, Comments, …?