Real-Time Microgrid Power Management and Control with Distributed Agents

Christopher Colson
US Western Area Power Administration

Hashem Nehrir
Montana State University

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Background

Work followed one of the recommendations that came out of the

2011 DOE-Sponsored microgrid workshop:

Application of intelligent control for real-time power management of microgrids

Work sponsored by:

US DOE Office of Basic Energy Science

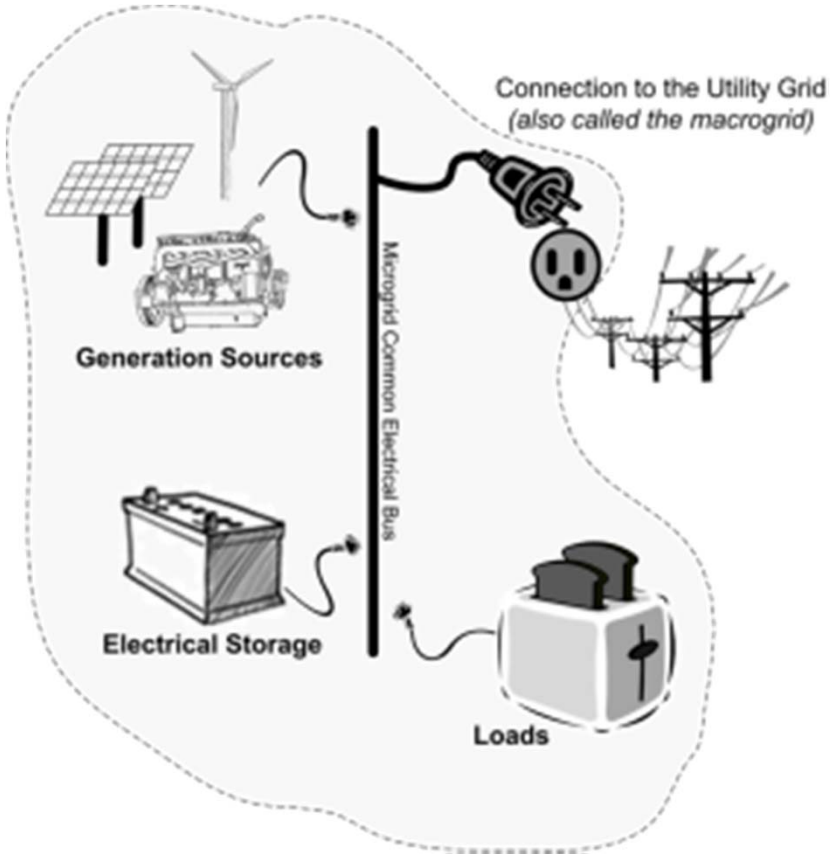
NEC-Labs America

Presentation Overview

- Microgrid (MG) assets and role
- Multi-objective multiagent (MAS)–based microgrid power management
- Simulation results:
  - A distributed MAS-Based microgrid
  - Cooperating MAS-based microgrids for power system self-healing
- Conclusions

Microgrid assets

- Small scale: Several kW to several MW
- Multiple DGs, storage and load
- Can be operated and controlled independently, grid-connected or islanded



Microgrid Role

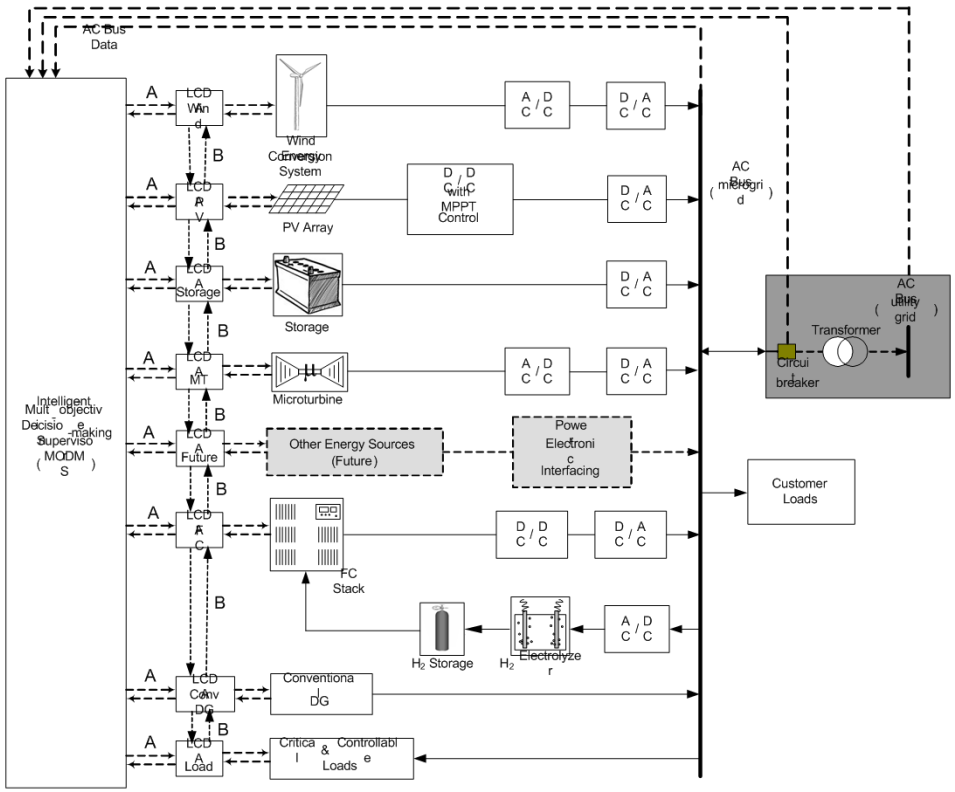
- Offers an opportunity to shift control burden to the local owner/operator
- Control is easier at the microgrid level than grid level
- Addresses customer-specific needs based on local requirements
- Offers distribution-level demand response - offsets capacity addition simply for peaking
- Can make power systems resilient/Self-healing

Challenges of MG Management and Control

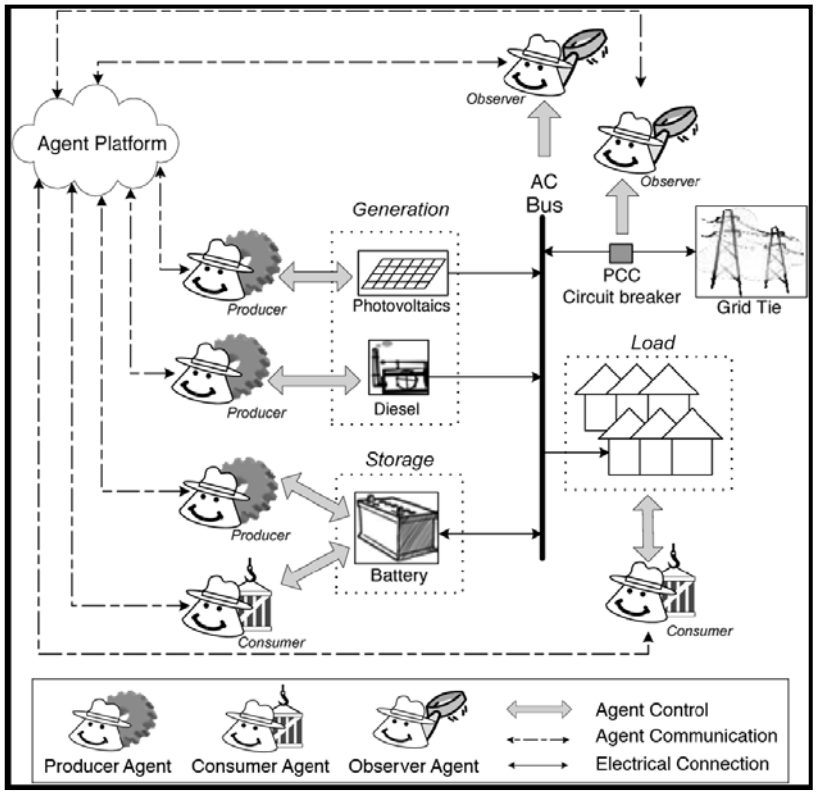
- Many challenges exist in implementation:
  - *Competing objectives*
  - *High degree of uncertainty for future conditions (uncertainty of availability of renewable generation – need for state-estimation)*
  - *Need for a real-time response*

- seeking optimal solution to the power management problem complicates the decision-making process further.

Agent-Based Microgrid: The big picture



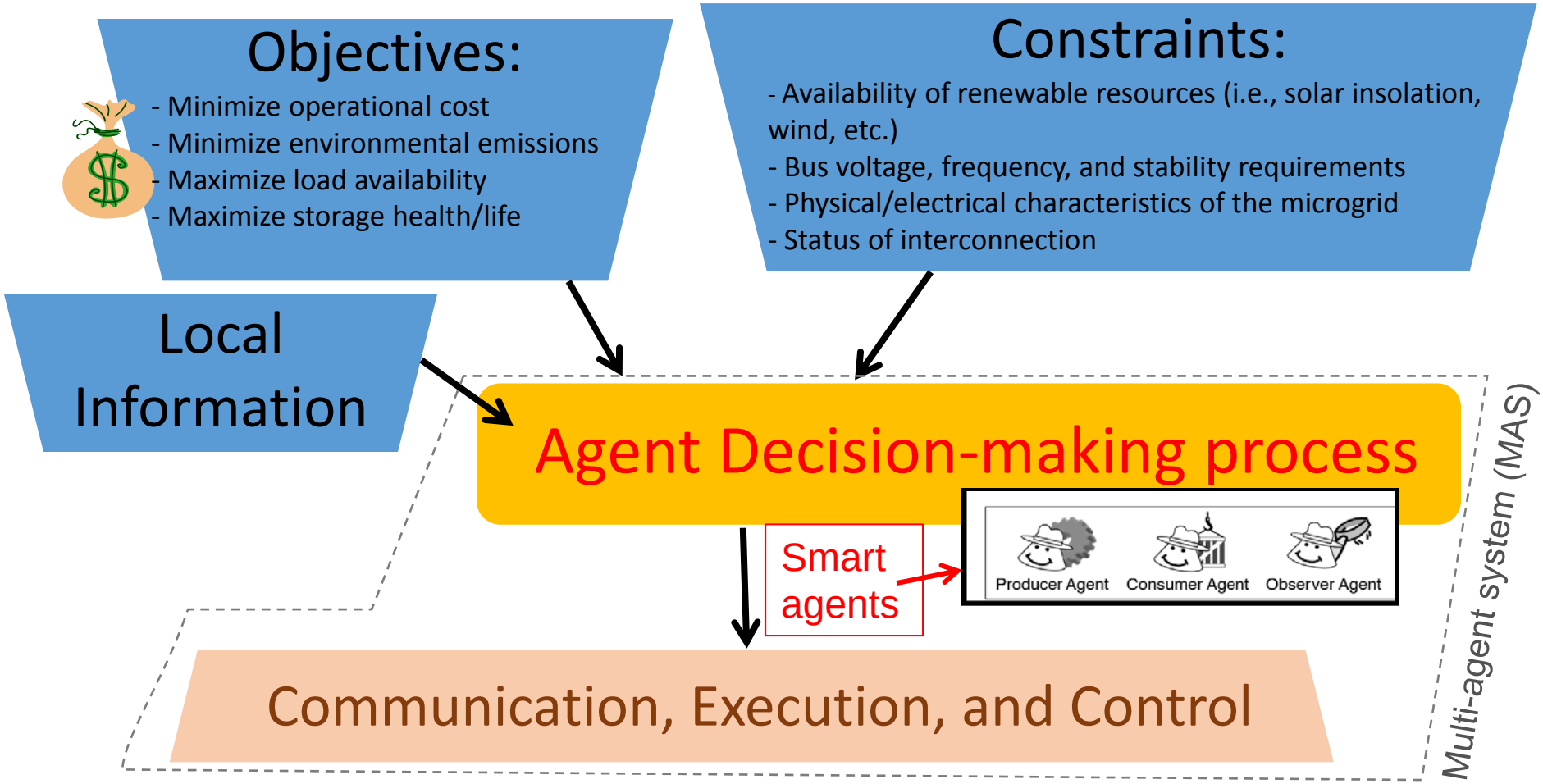
Generic



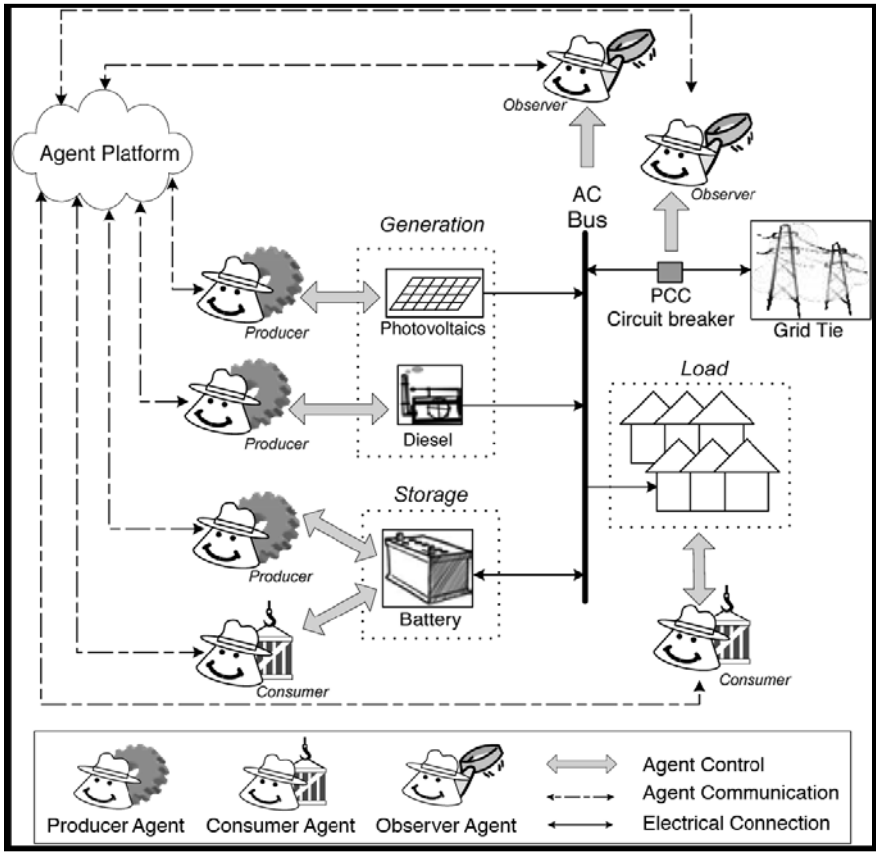
Actual MG used

Agents have adequate local information available to them for independent or cooperating decision-making.

MAS-Based Microgrid Multi-objective Operational Decision Framework



Microgrid Power Management with Distributed Agents



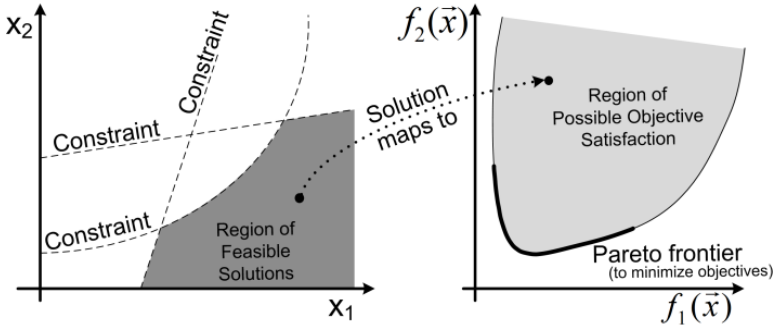
Microgrid Parameters

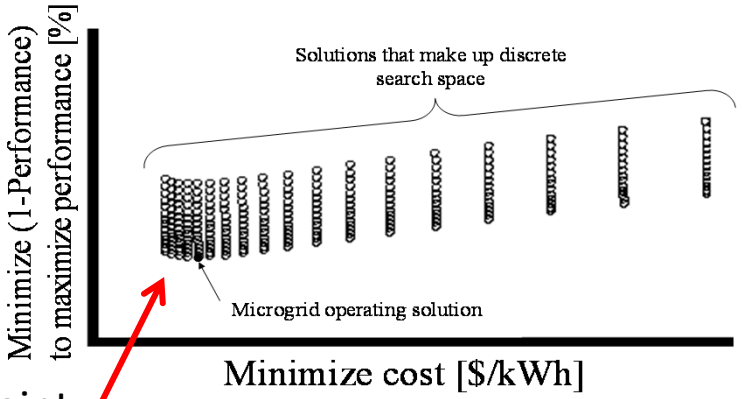
Asset	Rating
Diesel Genset	75kW
Photovoltaic Array	45kW
Storage Battery Bank	12kWh (30kW @ 10 min rate)
Load Center	100kW (1kW increments)

- Java-based agent development environment (JADE) used.

Intelligent agents seek optimal asset dispatch for user-defined goals.

MAS Seeks Tradeoff Solutions for the Multi-constraint, Multi-objective MG Power Management Problem



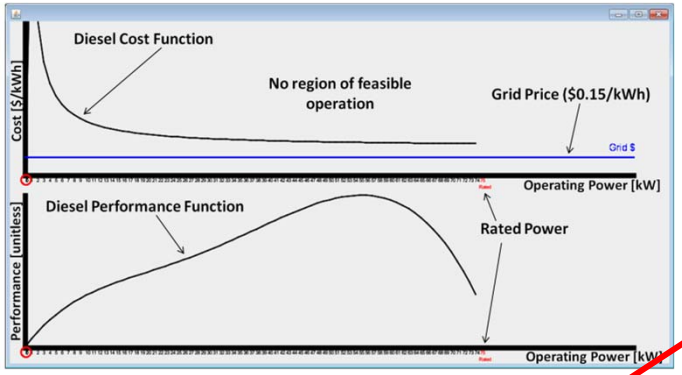


Representation of a multi-objective, multi-constraint optimization problem and resulting Pareto frontier.

- Constraints: Generation and storage capacities, load constraints, etc.
- Objectives: Minimize cost and maximize performance of MG assets
- Increasing performance increases cost and vice versa

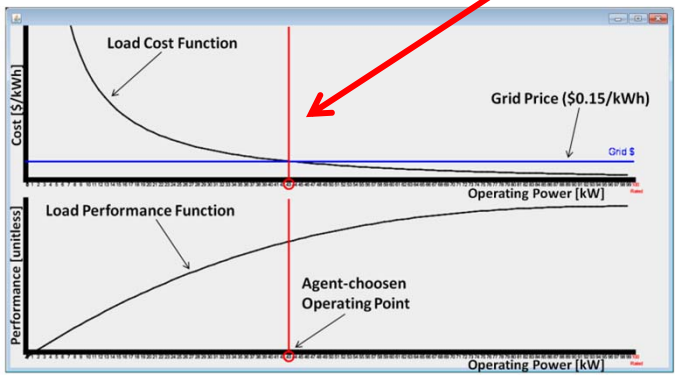
Grid-Connected MG:
Grid Price increases from $0.15/kWh to $0.3/kWh

Grid price=$0.15/kWh



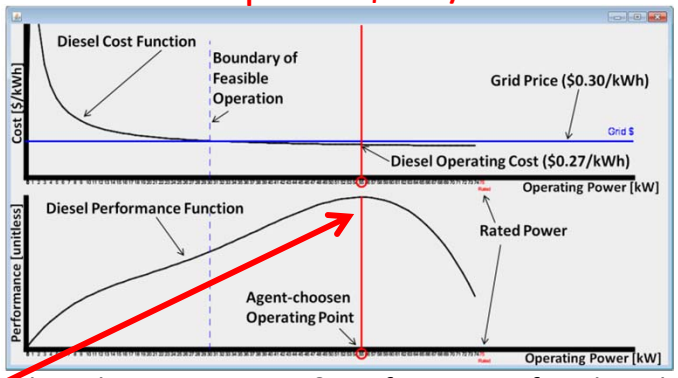
Diesel producer agent cost & performance metrics.
Note: no feasible, region for operation.

- Load = 43 kW
- PV = 77%, 35 kW
- Diesel OFF
- MG purchases 8 kW from Grid



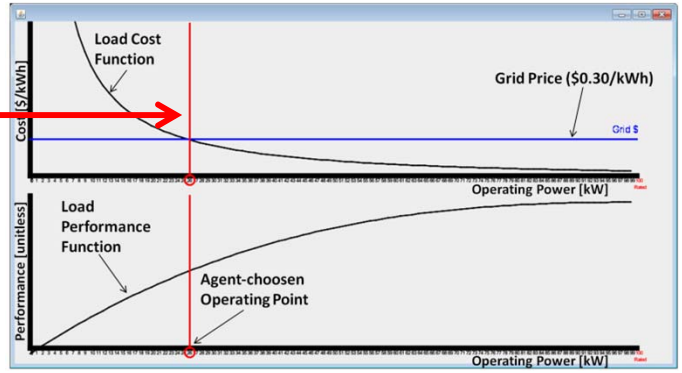
Load agent cost and performance metrics.

Grid price=$0.3/kWh



Diesel producer agent cost & performance after disturbance.

- Diesel=55 kW @ $.27/kWh
- PV=77%, 35 kW
- Load=26 KW
- Grid purchases 64 kW from MG



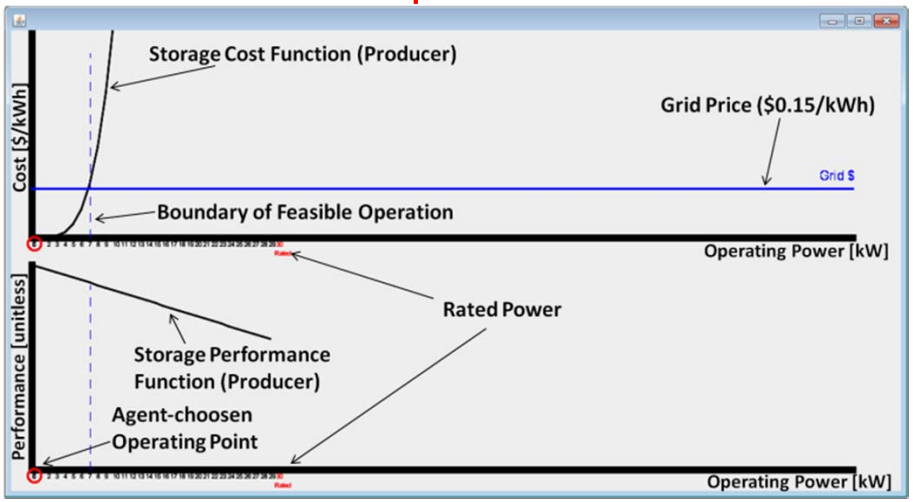
Load agent cost and performance metrics after disturbance.

Grid price ↑, Load is shed, Diesel starts, PV remains maximized, revenue ↑

Grid-Connected MG: Grid Price = $0.15/kWh

PV output power decreases from 45 kW to zero

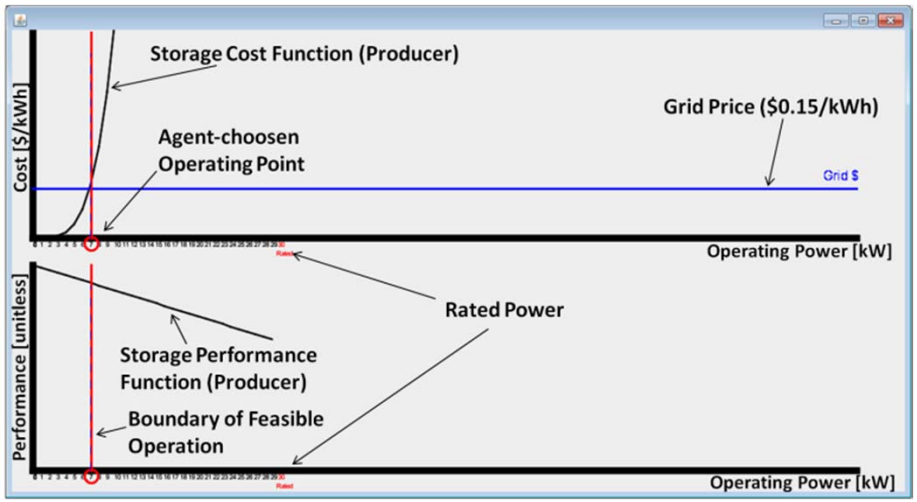
PV output=45 kW



Storage producer agent cost and performance metrics prior to disturbance.

- Diesel OFF
- Battery OFF
- Load = 43 kW
- Grid buys 2 kW from MG at $0.15/kWh

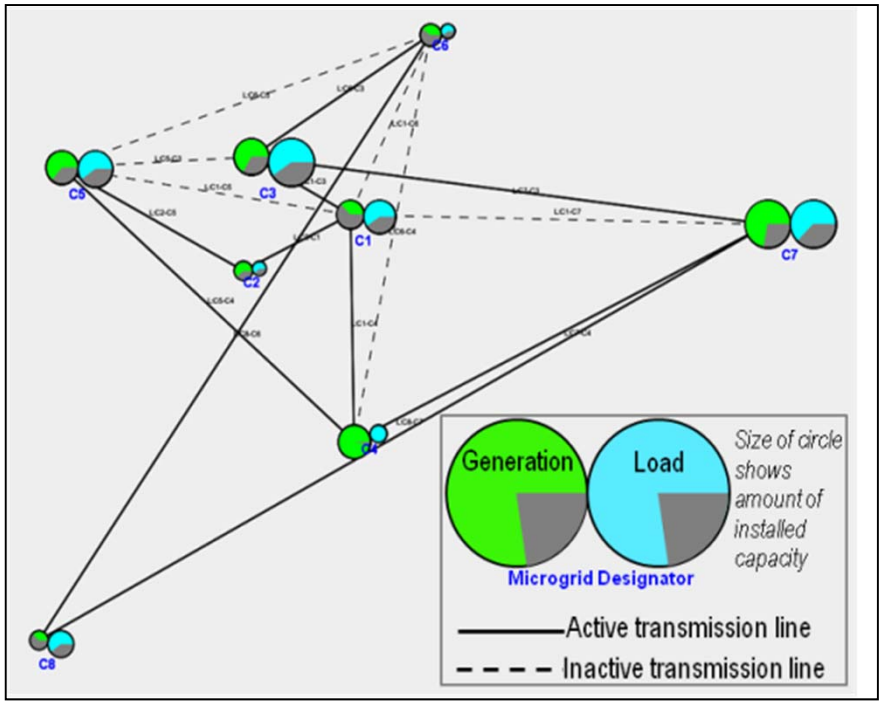
PV output=0



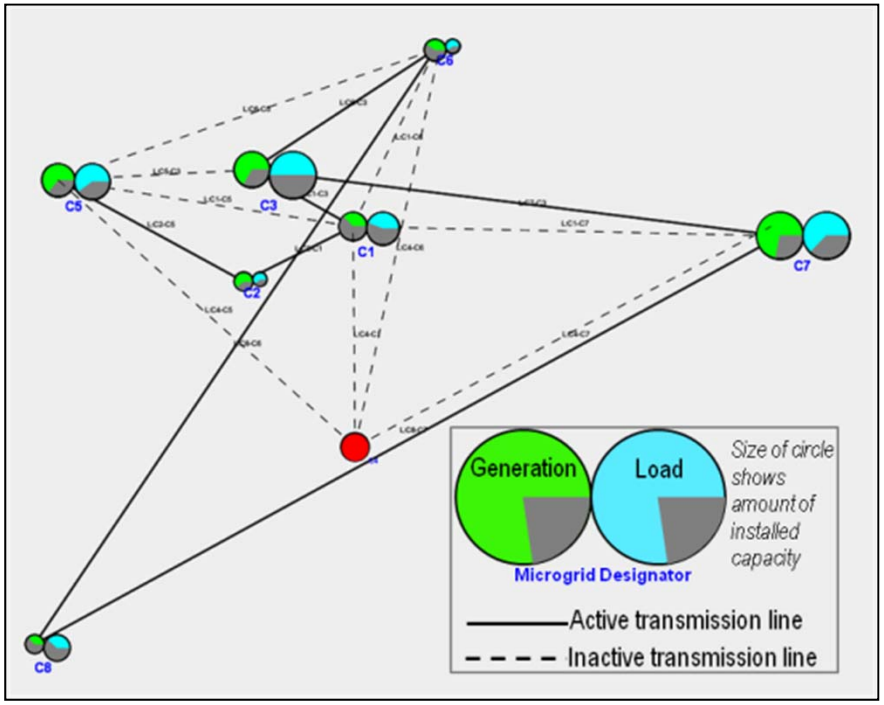
Storage producer agent cost and performance metrics after disturbance.

- Diesel OFF
- Battery discharges 7 kW @ 70 minute rate
- Load = 43 kW
- Grid sells 36 kW to MG at $0.15/kWh

Cooperating Microgrids for Resilient and Self-Healing Power System



Healthy system



Faulted microgrid

Each microgrid has an intelligent agent to talk to neighboring MGs.

Off-Grid Microgrids

- No transactions with grid
- Similar objectives to the grid-connected MG
  - Least cost
  - Maximum efficiency
  - Best battery performance

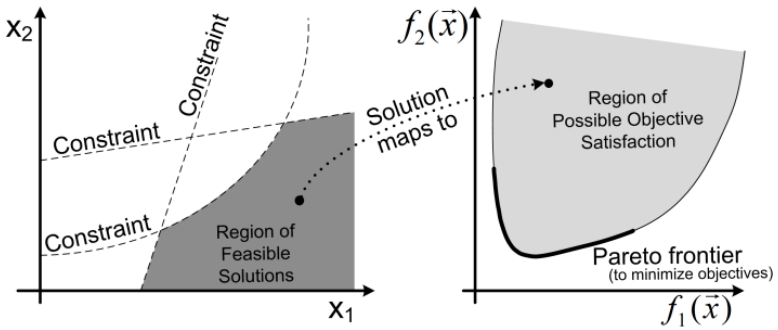
Conclusions

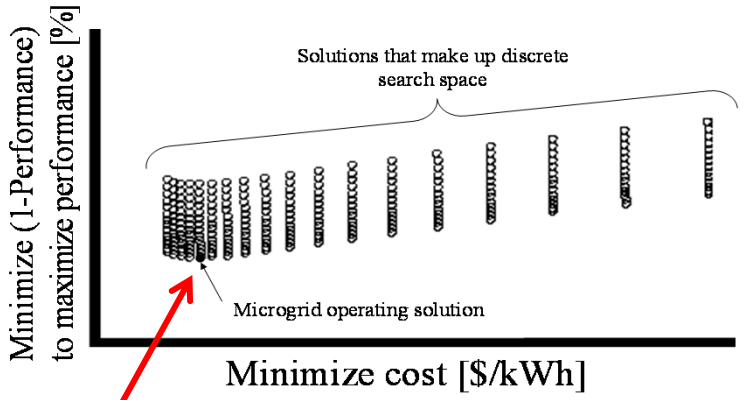
- Real-time MAS-based methods are effective for power management of grid-connected and off-grid MGs.

- MGs have the potential of making the grid resilient/self-healing.

Our Direction

To find the optimal solution of the multiobjective problem analytically (directly) with fully distributed MAS – no Pareto frontier.

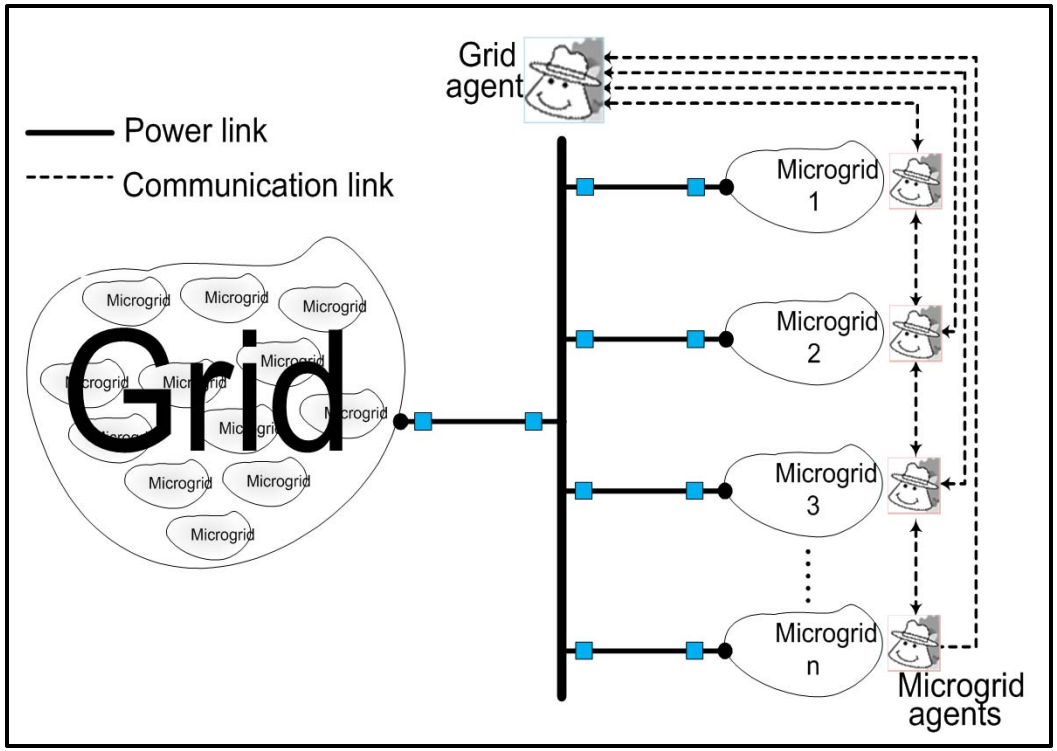




Representation of a multi-objective, multi-constraint optimization problem and resulting Pareto frontier.

Future work:

- Cooperating Microgrids controlled with Hierarchical MAS framework for resilient and self-healing grid.



Thank you!

Chris Colson: colson@WAPA.GOV

Hashem Nehrir: hnehrir@ece.montana.edu