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Spinning Reserve Based Topology Control in Holonic Distribution Grids

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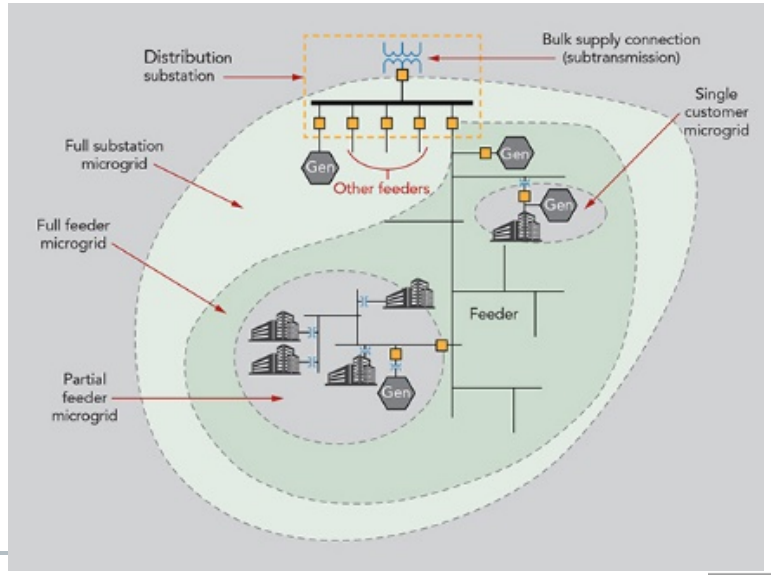
Introduction

- Microgrids as defined by the U.S. Department of Energy: A group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid, and can operate in grid-connected and island-mode.

- Characteristics:
  - employment of a local controller to operate the system as a single controllable entity
  - defined electrical boundaries
  - islanding capability



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Introduction (cont'd)

- Connecting the microgrids that are close to each other in the region to form an integrated microgrids system, or microgrid clusters, could
  - enhance the overall operational performance of the system
  - improve the individual economic objective
  - boost the utilization of renewable energy resources
  - contribute to mitigating the congestion during peak hours (by creating additional paths to supply the individual local demand)

Motivation

- Current distribution networks are not designed with microgrids in mind
  - It is necessary to develop smarter distribution networks to achieve the envisioned smart grids

- An innovative idea in restructuring the distribution grids is to move towards a holonic architecture

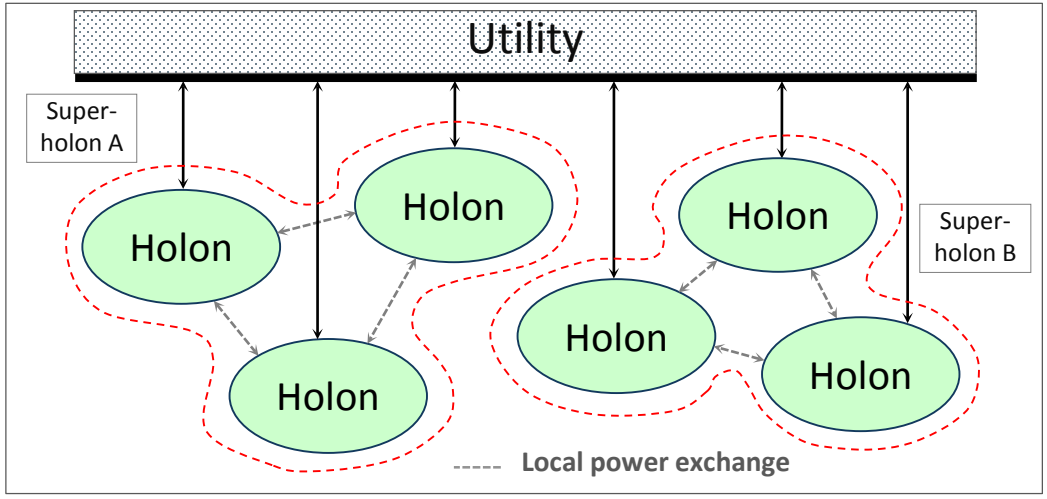
Holonic distribution grids

- Holonic distribution grid is based on the hierarchy concept, where each holon represents a self-contained and autonomous system
  - In holonic distribution grids a holon, e.g., a microgrid, could be a whole and at the same time part of a whole

- Holonic distribution grids can potentially
  i. optimize the overall system performance through the capability of a dynamic reconfiguration;
  ii. promote the diversity of resources, autonomy, and the connectivity;
  iii. facilitate the information and energy exchange among the integrated systems;
  iv. contribute to balancing the local customer and global system objectives.

Holonic distribution grids (cont'd)

- Connected holons in the system can create an aggregated holon called a **super-holon**
- The provided topology by the holonic distribution grids can therefore be recognized as a hybrid between the centralized and distributed approaches,
  - where the self-contained subsystems can be adapted within the holonic system autonomously and managed by a supervisory controller.



A holonic distribution grid structure

Contribution

- Integrated microgrids operation in the holonic distribution grids is discussed
  - based on the microgrids' spinning reserve and power deficiency
- Identifying the optimal system reconfiguration (super-holon combinations) in the holonic distribution grids
  - minimizes the aggregated system operation cost
  - maximizes the overall reliability
- Optimal super-holon combinations would be the one that best matches spinning reserve to deficient load, i.e., a minimum net spinning reserve solution
- Participated players (holons) in the proposed study involves microgrids and provisional microgrids

Provisional microgrids' definition

- A provisional microgrid is typically an elevated prosumer, which is introduced to support the use of renewable generation
- The provisional microgrid holds similar characteristics as microgrids
  - Its electrical boundaries are distinctly defined
  - (A master controller) operates and regulates existed loads and resources
- It does not have the ability to be islanded from the utility grid by itself
  - must be electrically connected to one or more microgrids, called coupled microgrids, to address its energy requirements during islanded operation
- The reason behind this selection is the necessity of existing master controllers in these systems (not necessary in prosumers)

Spinning reserve

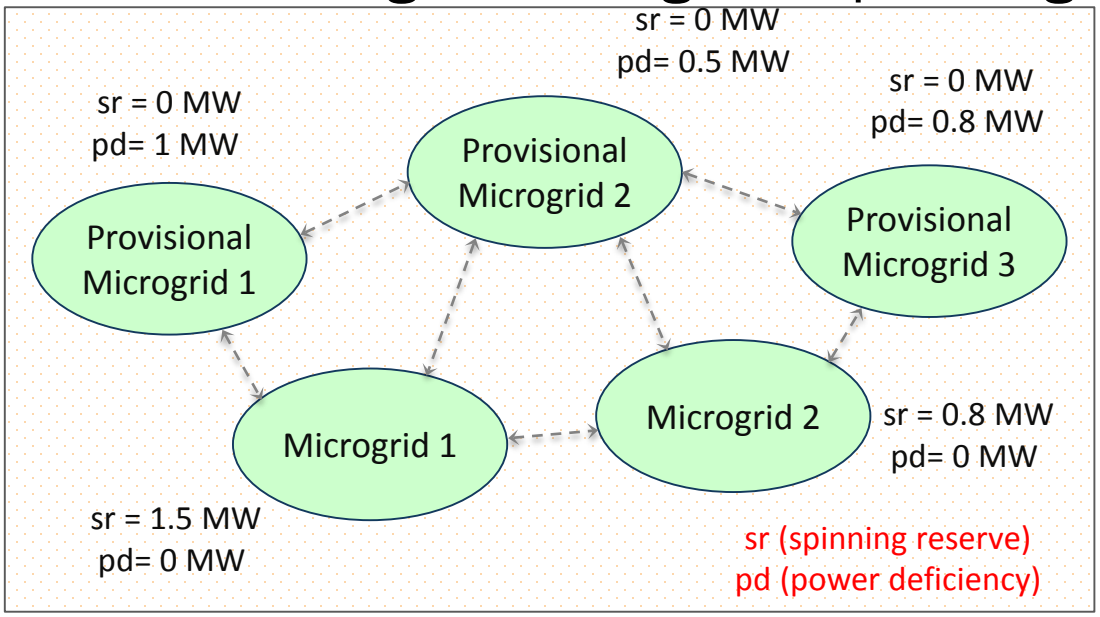
- The spinning reserve is considered as an ancillary service that is capable of providing the system with an immediate supply of power once a credible contingency takes place

- It supports the withstanding of the system towards:
  - uncertainty of the nondispatchable units' generation
  - unforeseen increase in load
  - the sudden outages

- Although the spinning reserve could help improve reliability,
  - it could further offer additional intelligent paths to improve the economic benefits by exploiting those unused capacities

Illustrative study

- A holonic distribution grid with five microgrids is used to demonstrate the impact of the microgrids' spinning reserve on enabling local power exchange among the integrated players.
- Initial spinning reserve and power deficiency in each holon are provided in below figure for a given operating hour.



Spinning reserve and power deficiency in each holon in the holonic distribution grid.

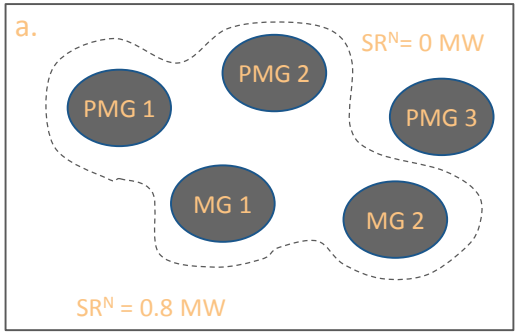
Illustrative study (cont'd)

- Since the investigated holonic distribution grid contains five holons, several rational combinations (i.e., super-holons) can be created within the holonic distribution grid.

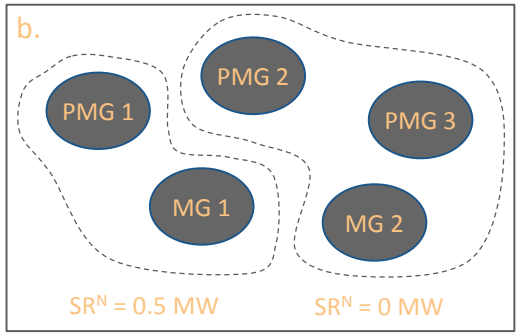
- Six different super-holons combinations are picked up, and the net spinning reserve of the super-holons once they are created are investigated.

Results

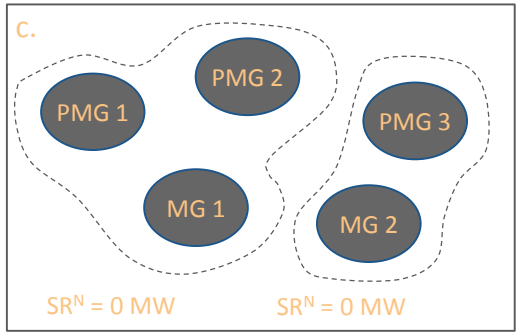
PMG 3 experiences load curtailment of 0.8 MW

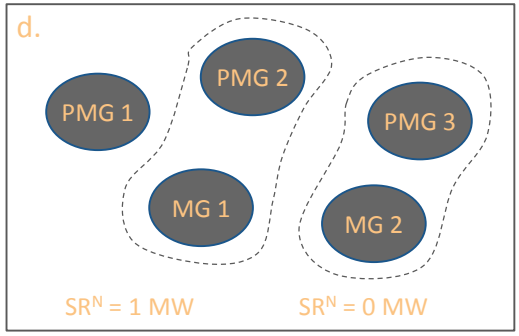


Either PMG 2 or 3 would experience load curtailment of 0.3 MW

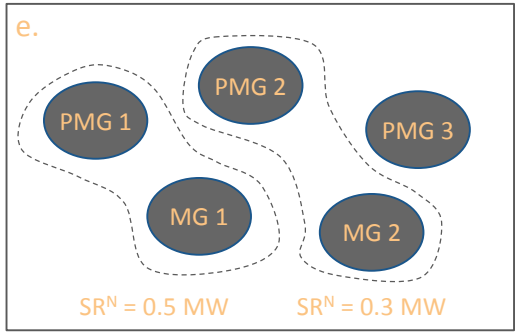


None of the PMGs would face load curtailment

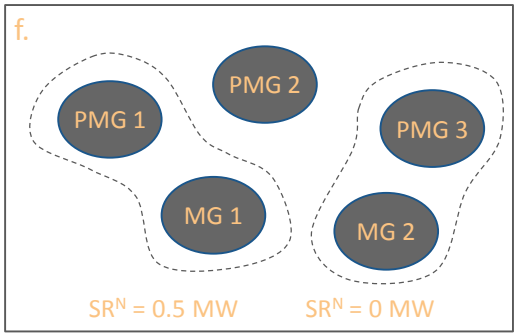




PMG 1 experiences load curtailment of 1 MW



PMG 3 experiences load curtailment of 0.8 MW



PMG 2 experiences load curtailment of 0.5 MW

Even though several super-holon solutions can be generated in the holonic distribution grid

- the optimal topology would be one that best matches spinning reserve to deficient load, i.e., a minimum net spinning reserve solution (figure c)

Conclusion

- Holonic distribution grids promote the systemic features of
  - diversity, autonomy, and connectivity in the system,
  - and further boost local and global objectives through identifying the optimal distribution network reconfiguration of distribution players
- This concept was investigated, and the microgrids' spinning reserve impact on the local power exchange in holonic distribution grids was further discussed
- An illustrative study was implemented to show the impact of identifying the optimal system reconfiguration and the microgrids' spinning reserve
  - on enabling the optimal local power exchange, and therefore improving the entire system reliability and economic objectives.

Thank you!

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