Transactive Energy in Network Microgrids

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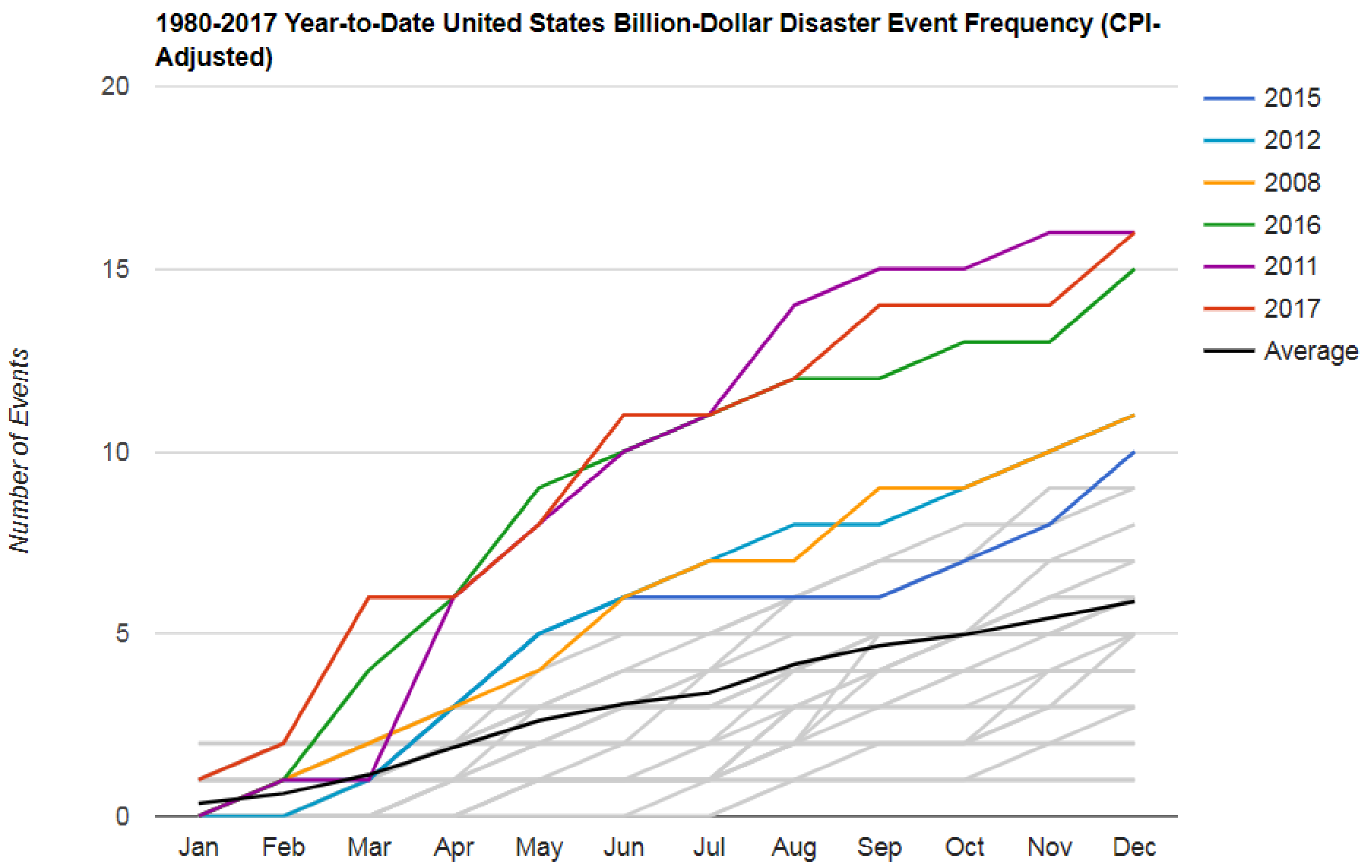
Outline

- Distributed Power Systems
- Microgrids in Power Systems
- Adaptive Islanding and Networked Microgrids
- Transactive Energy in Network Microgrids
- Conclusions

Extreme Events

- A more intense climate change has increased the frequency and the severity of weather-related extreme events throughout the world.
  - In 2017, there have been 5 extreme events with losses exceeding $1 billion each across the U.S.



Dynamic Islanding of Power Systems

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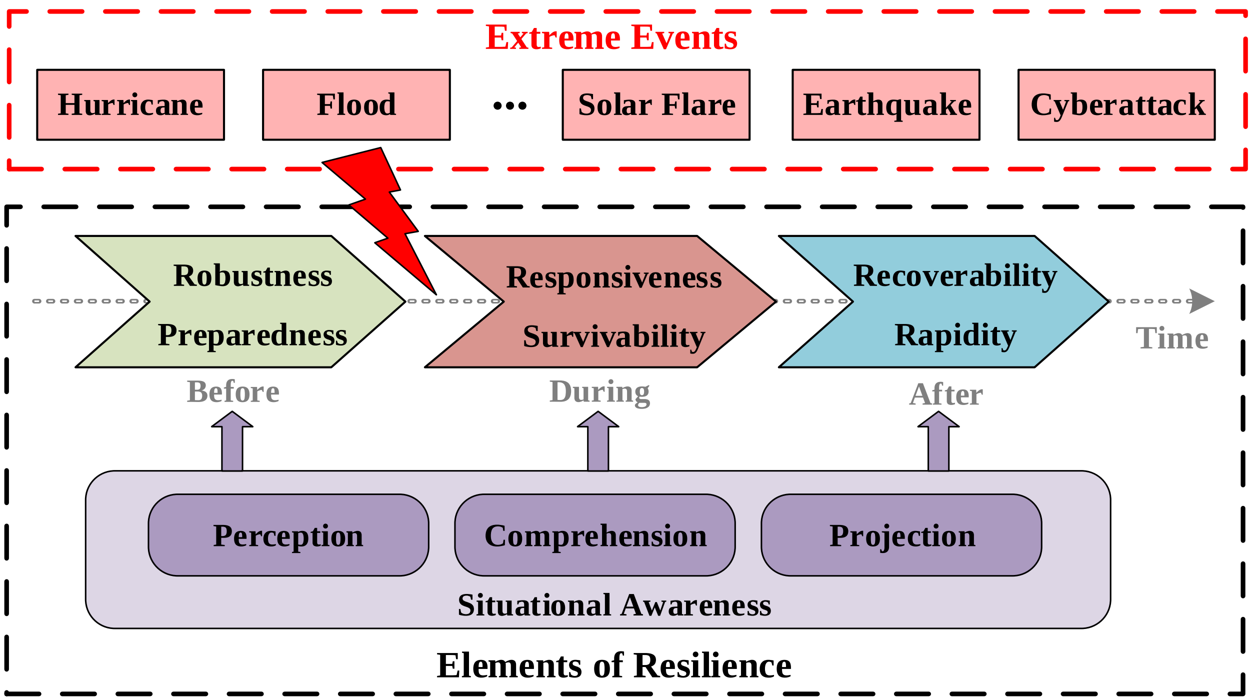
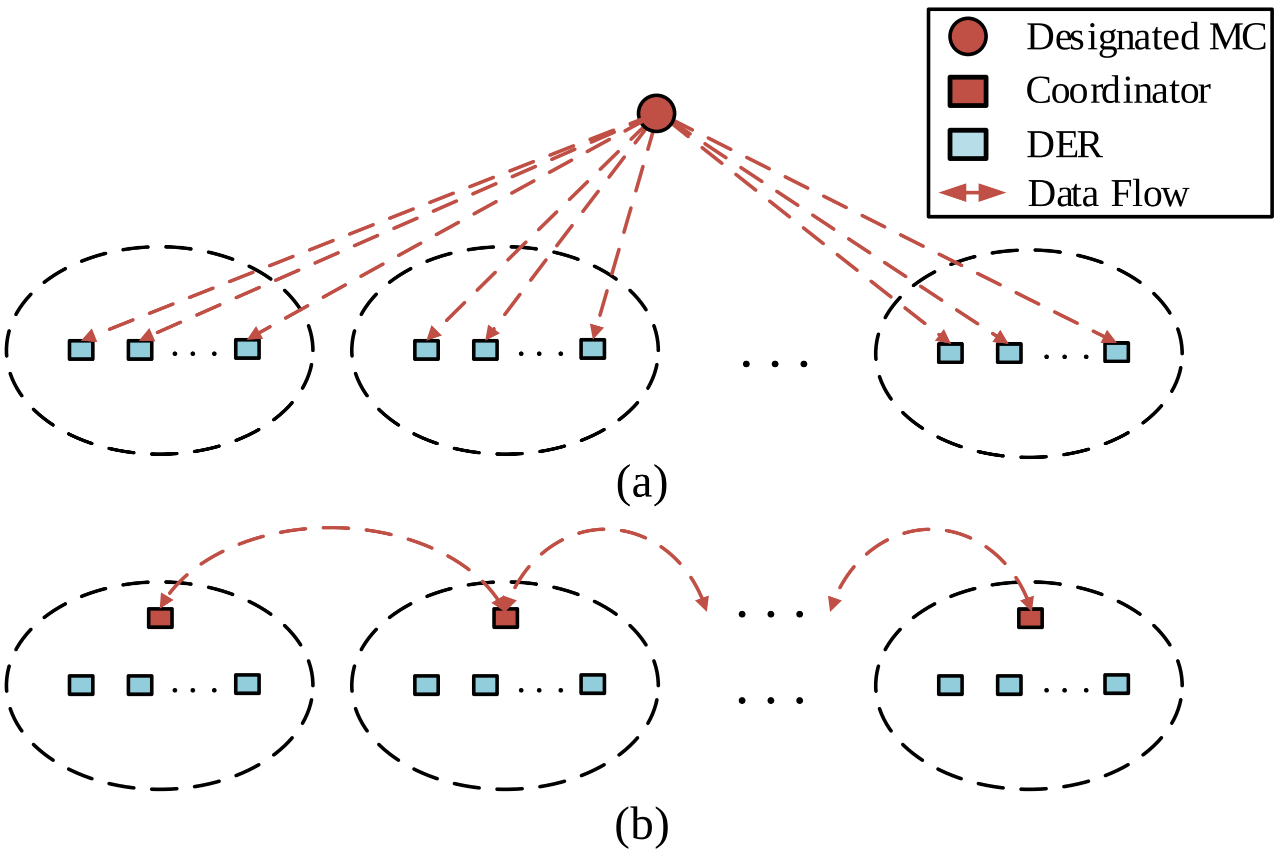
- Resilient Power system will prepare adequately for, respond comprehensively to, and recover rapidly from major disruptions.

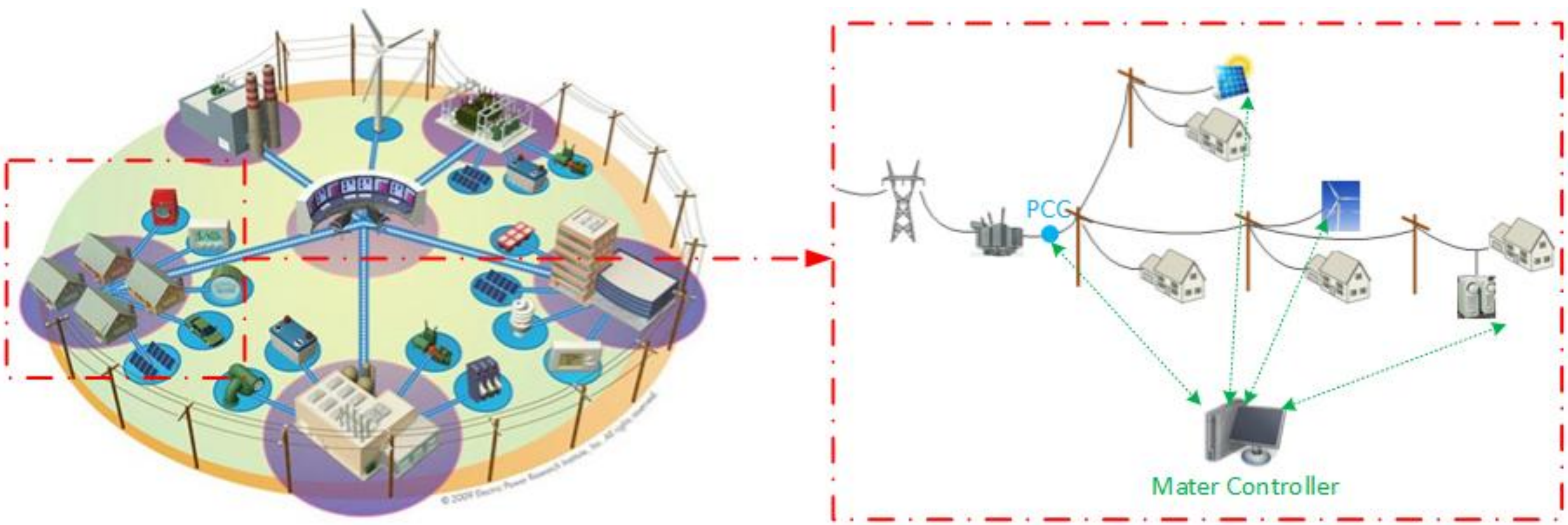


Distributed Power System: Unification and Compartmentalization

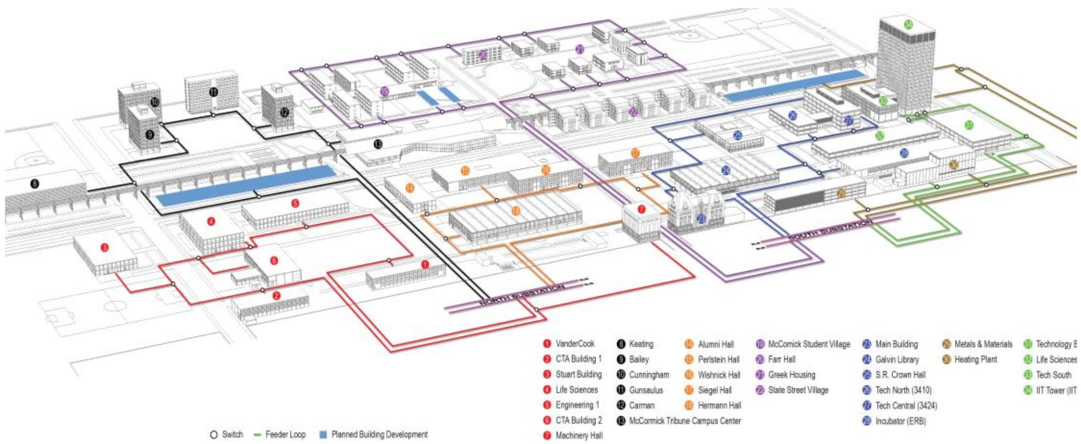


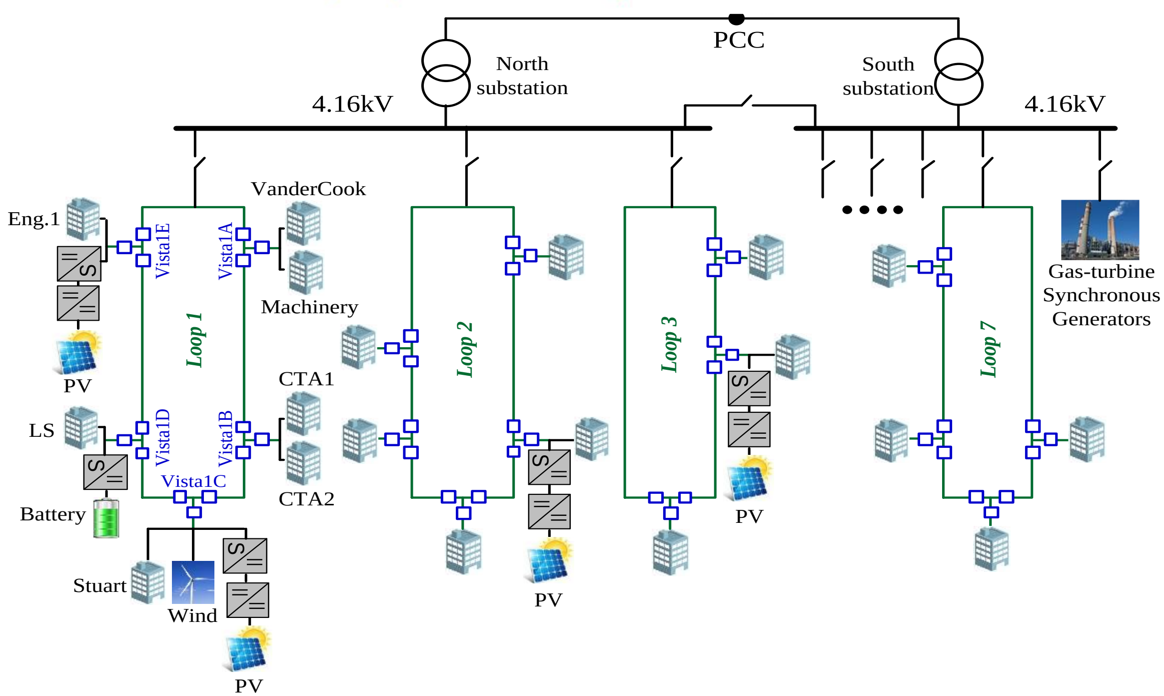
Formation of Microgrids

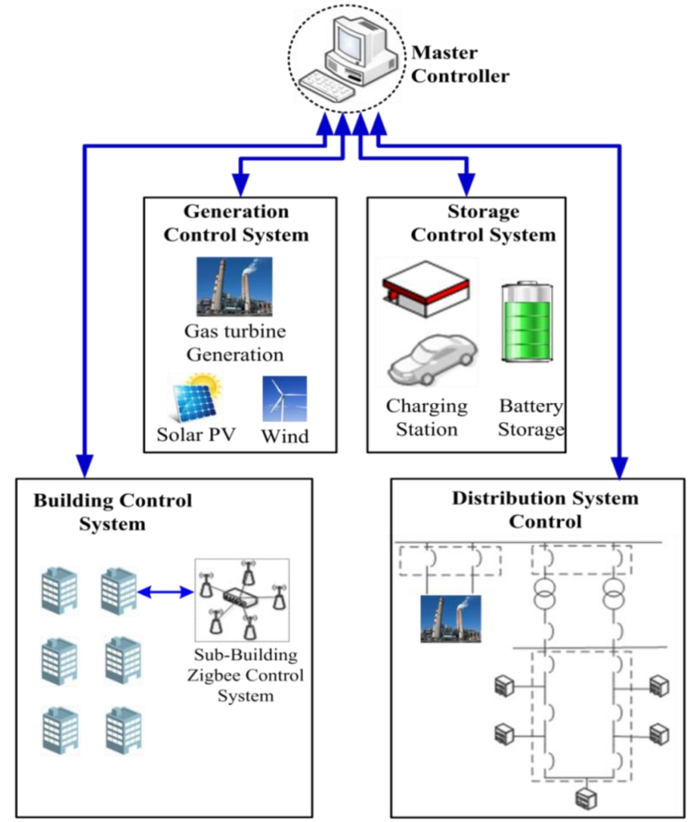
- Microgrids are small-scale self-controllable power systems that interconnect DERs and loads within clearly-defined electrical boundaries.
- Each microgrid interacts with the utility grid through a point of common coupling (PCC) at its boundary.
- Each microgrid is deployed with a microgrid master controller (MGMC) for centrally monitoring and controlling on-site resources.



Loop-Based Microgrid Control

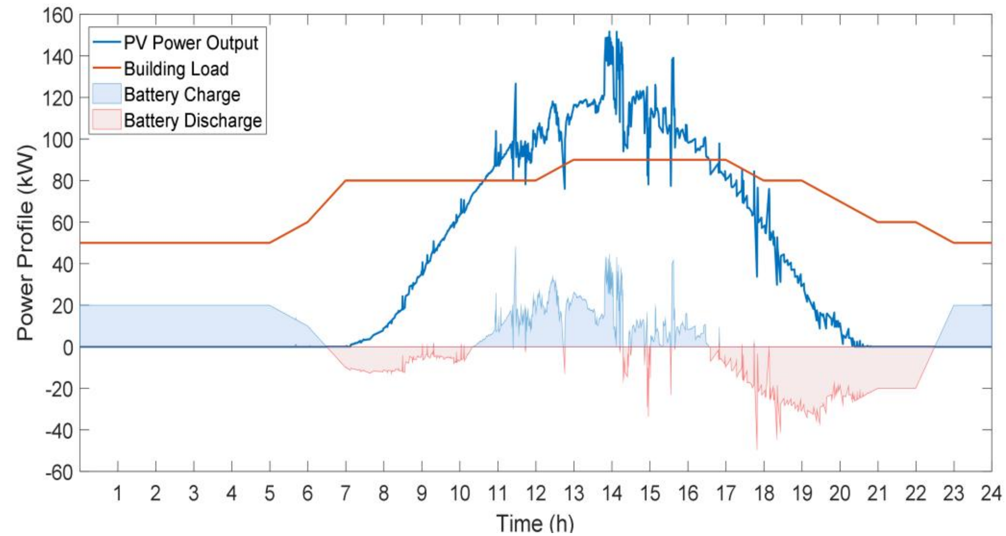


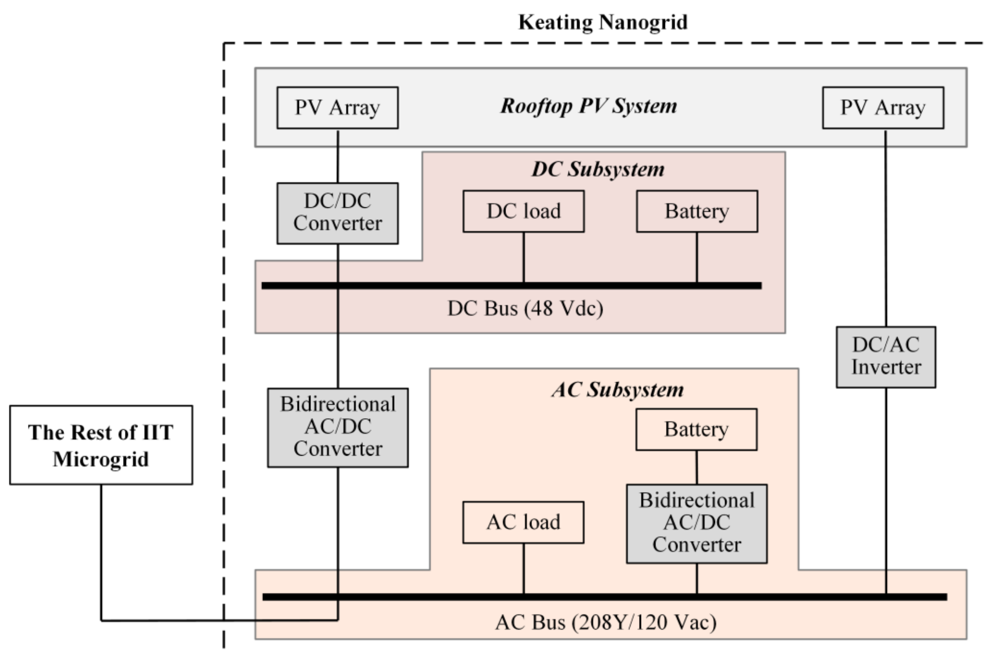




Loop-based microgrid topology introduces additional benefits in enhancing the reliability and resilience of energy supplies.

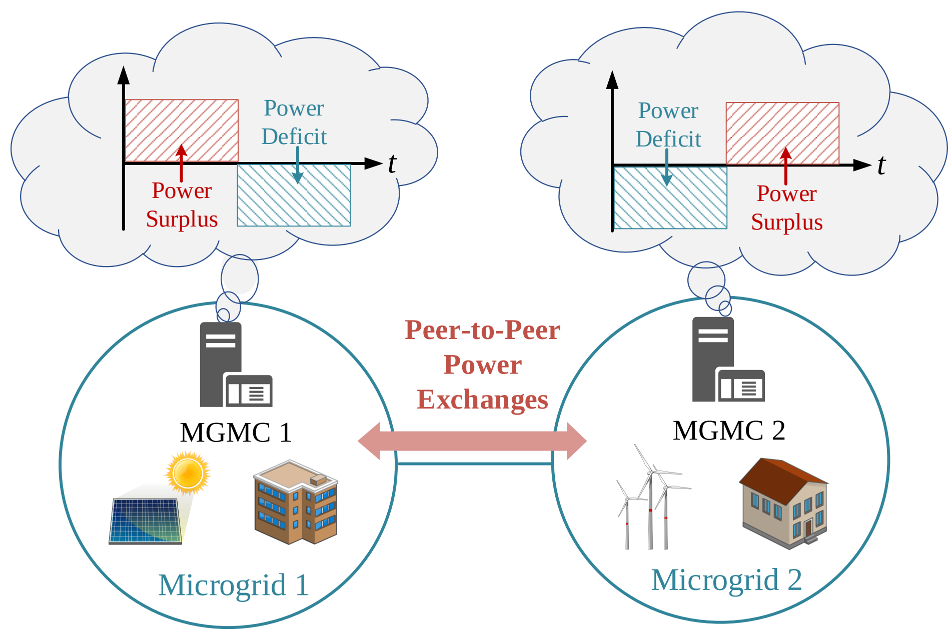
Operation of Control of Nanogrid





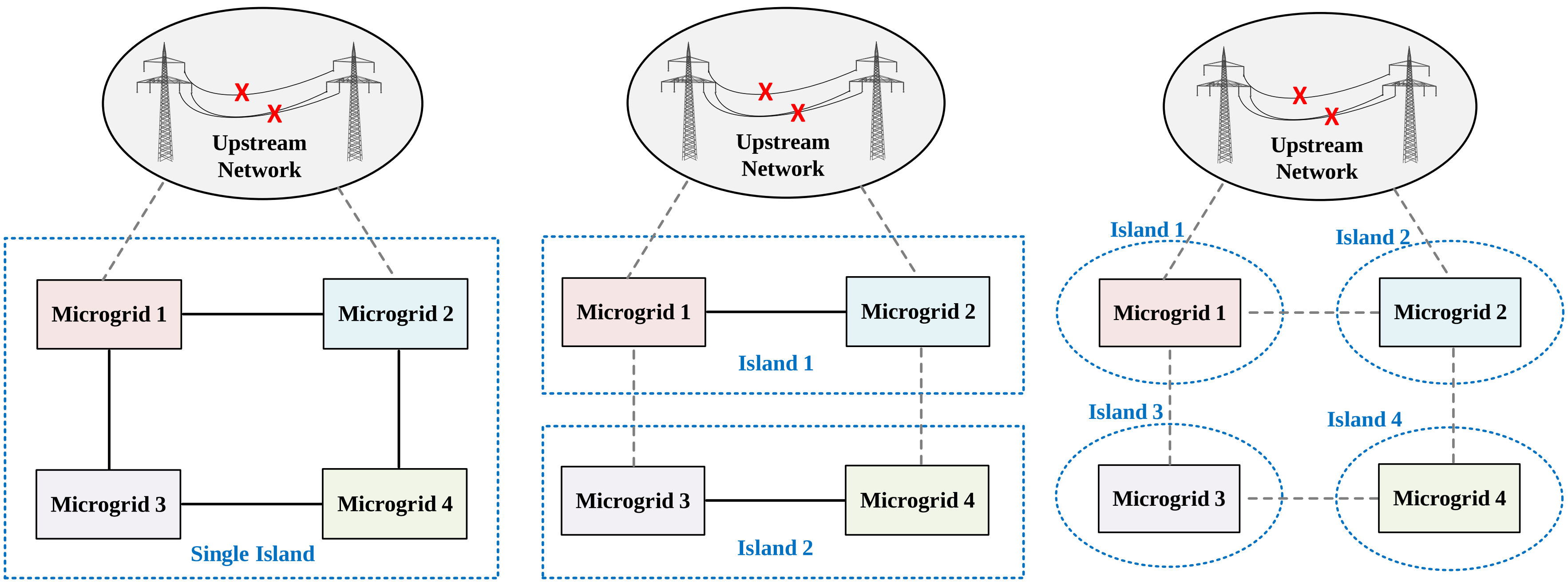
Islanded Power Systems: Peer-to-Peer Power Transactions

- Networked microgrids may often feature diversified profiles of renewable energy generation and power demand.
- Microgrids should be allowed to trade energy directly with their peers (especially when the utility grid is disrupted) in addition to exchanging energy at pre-specified rates with the utility grid.
- With non-discriminatory peer-to-peer energy transactions, microgrids would not only gain an additional degree of flexibility in their operations but also maintain a dynamic power balance in their service territories with reduced dependency on the utility grid.



Dynamic Islanding Schemes

- In each aggregated island, interconnected microgrids are enabled to transact energy directly and flexibly for surviving utility grid disruptions.
- The islanding scheme could be adjusted on an on-going basis according to temporal operation characteristics of individual microgrids and the progression of failures in the utility grid.

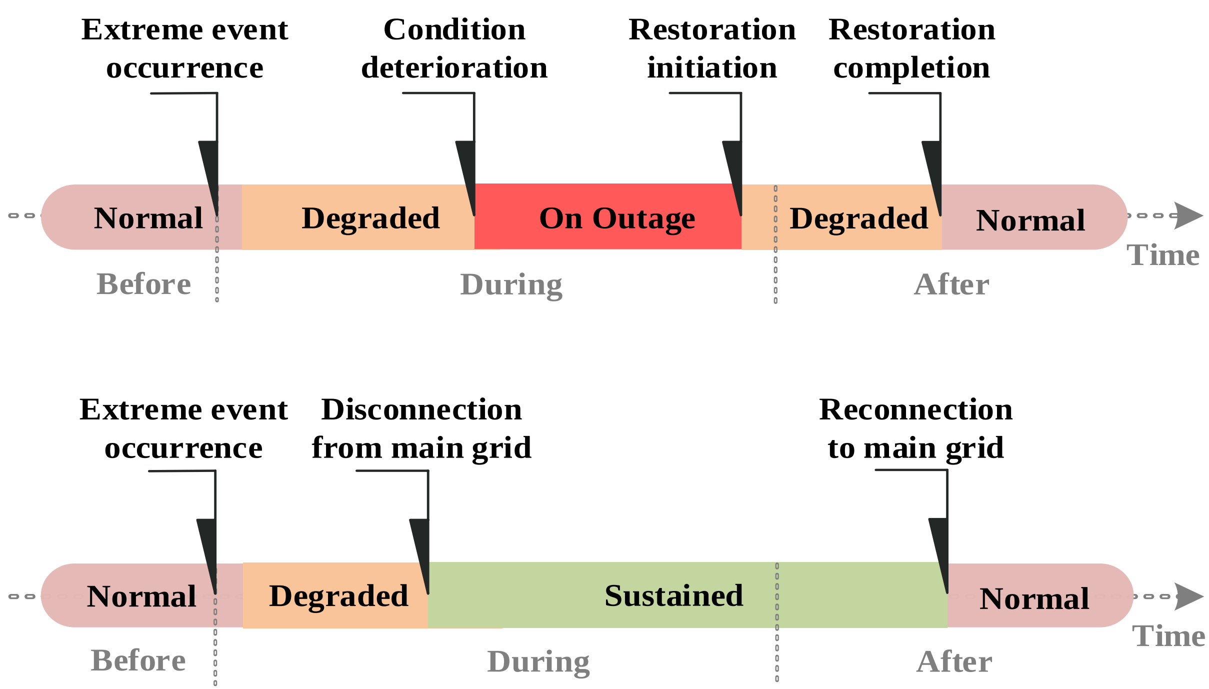


Microgrid Emergency Operating Conditions

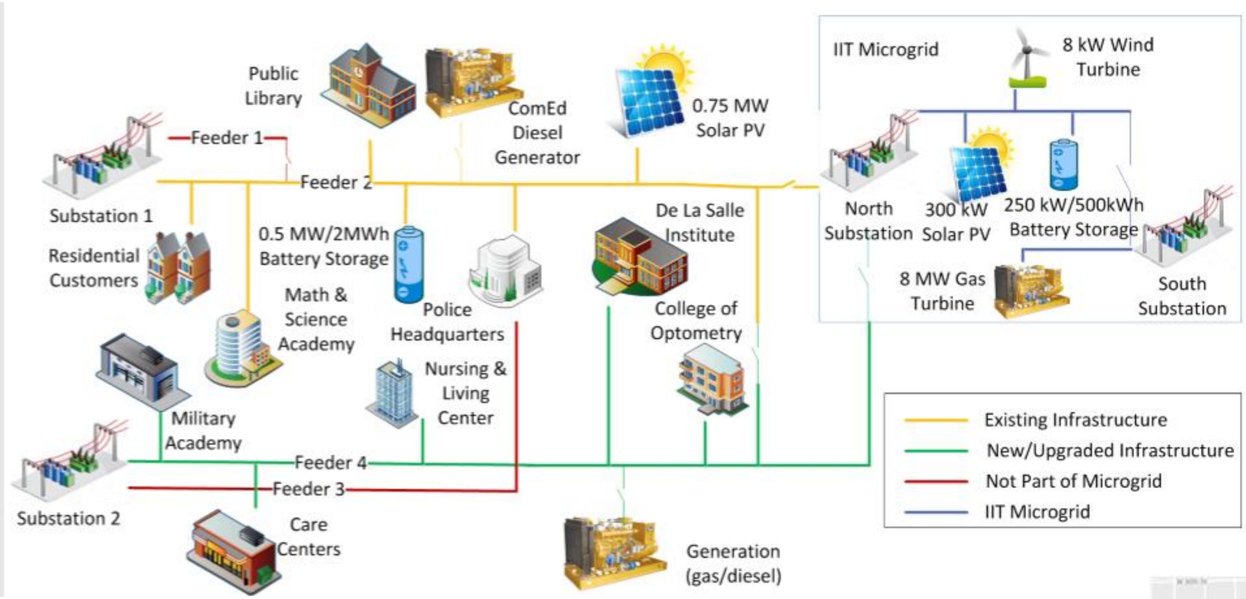
- During the extreme event, the system performance suffers a continuous degradation as the disruptions are prolonged.

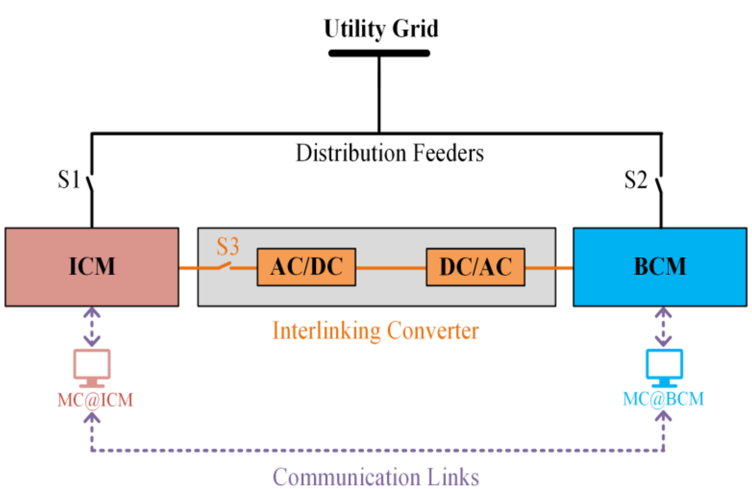
Outside Microgrid

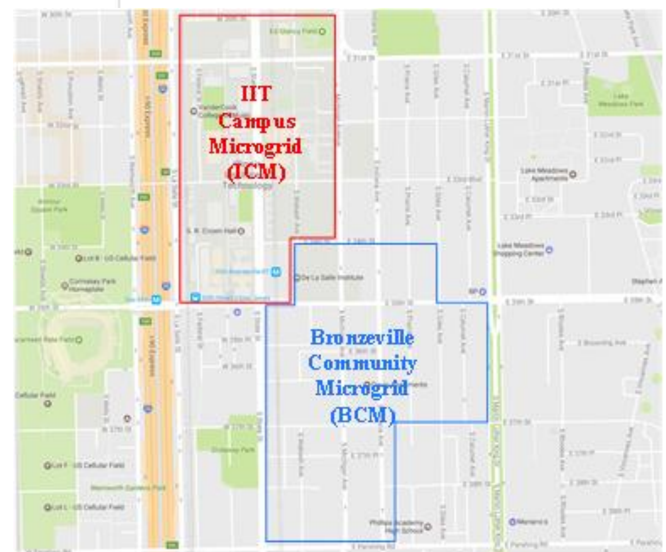
Inside Microgrid



Networked Microgrid Operation

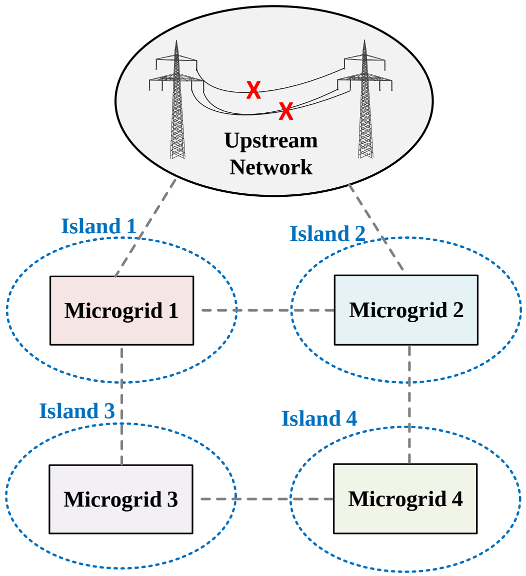




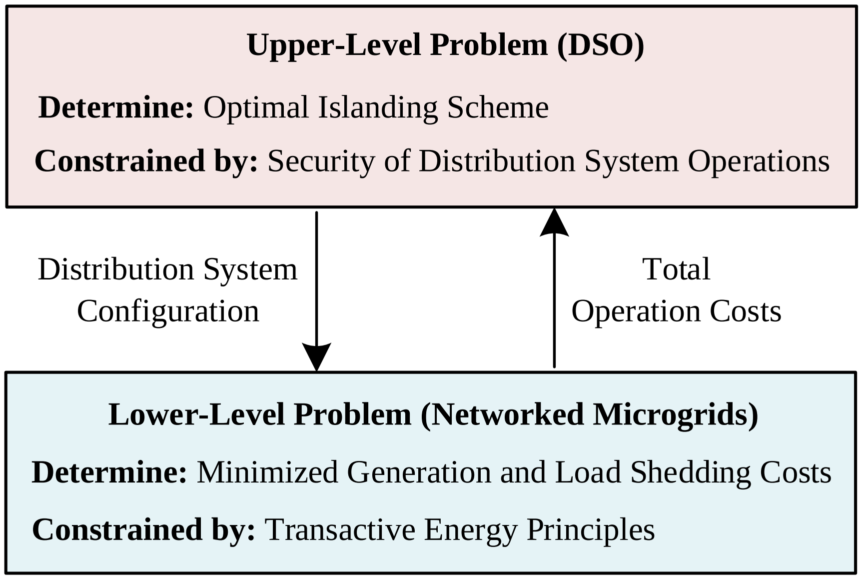


Decision for Optimal Islanding

- Transactive energy facilitates the formation of aggregated islands of multiple microgrids, boosting the flexibility of the islanding process.
- DSO determines and triggers the islanding of networked microgrids in a holistic manner by considering the role of transactive energy, instead of forcing islanded microgrids to rely solely on themselves.

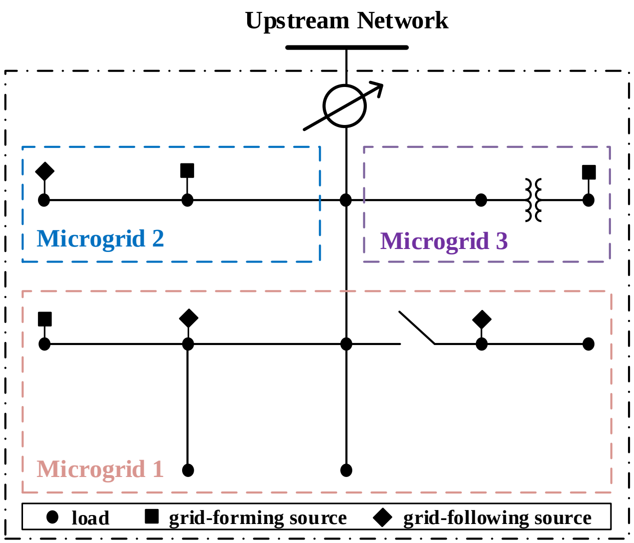


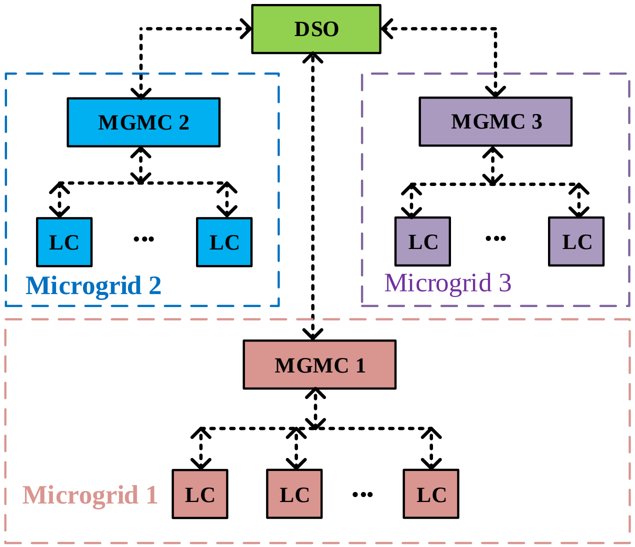
Flexible Energy Trading

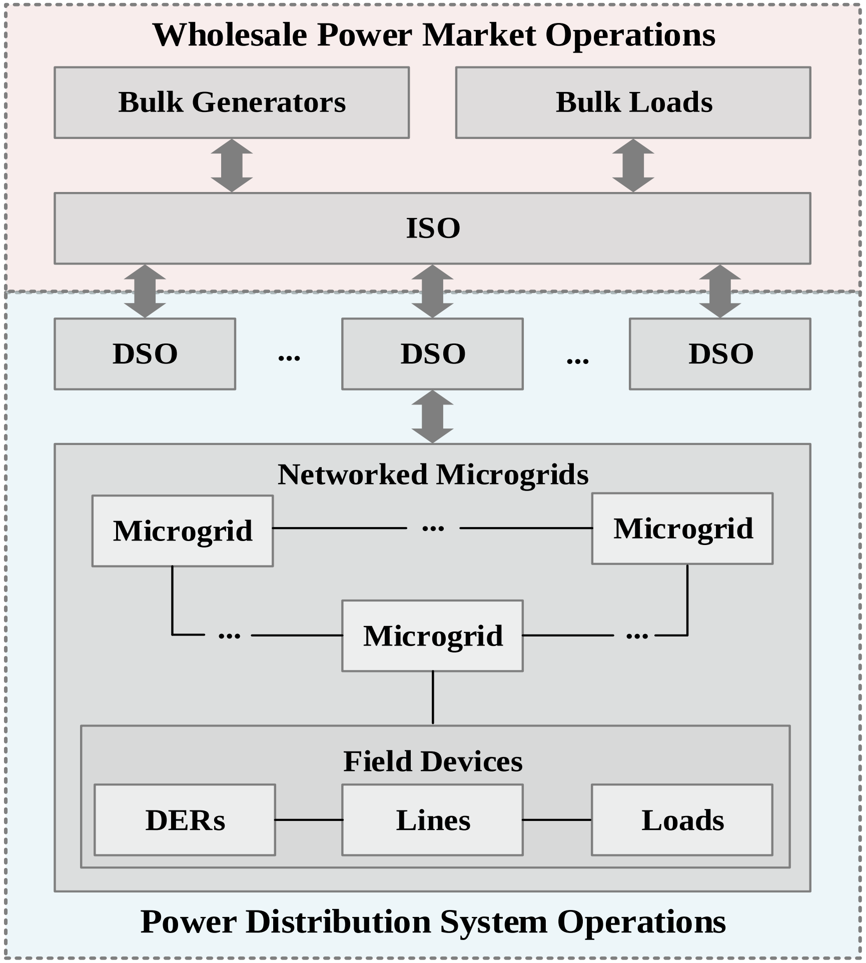


Two-Layer Decision-Making Scheme

DSO for Networked Microgrids

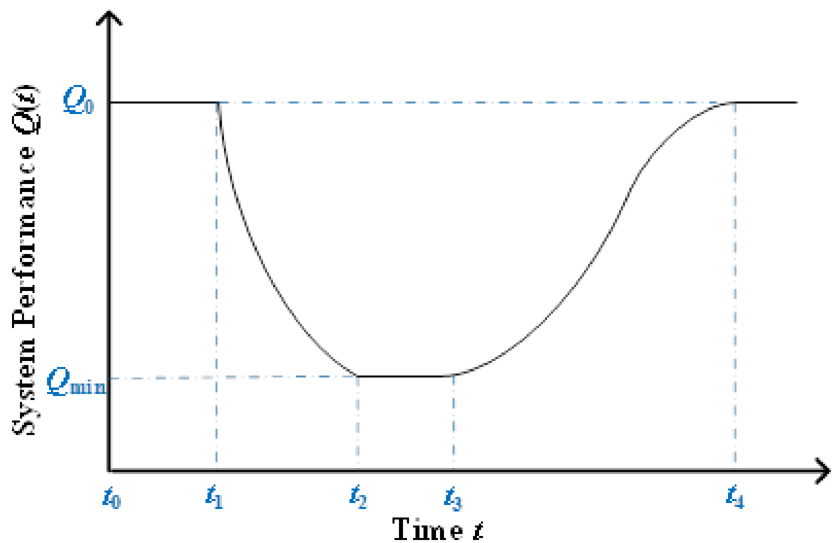






Microgrids for Distribution System Enhancement

- The unique benefits of networked microgrids are manifested in supporting power system resilience are further explored.



Integrated Decision Framework

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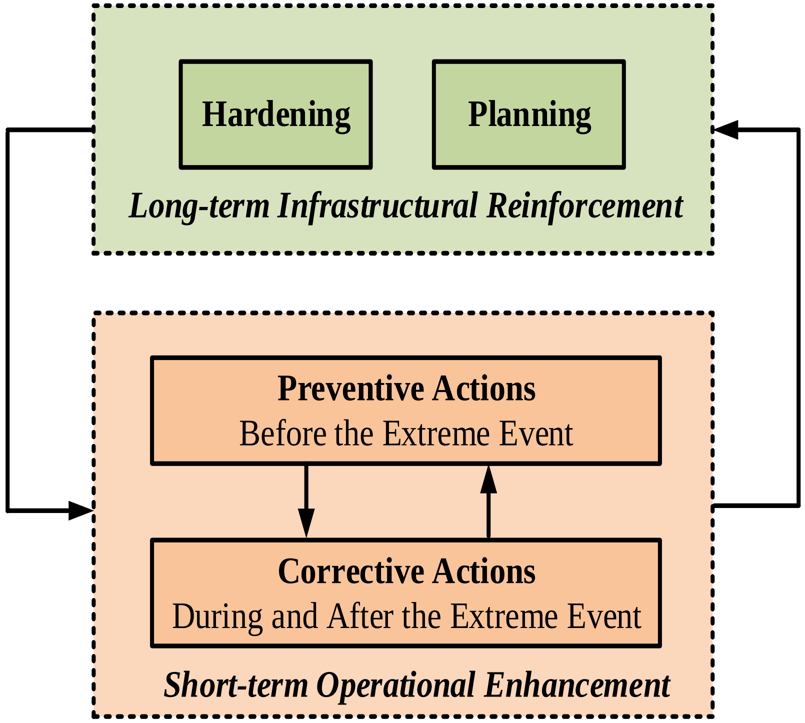
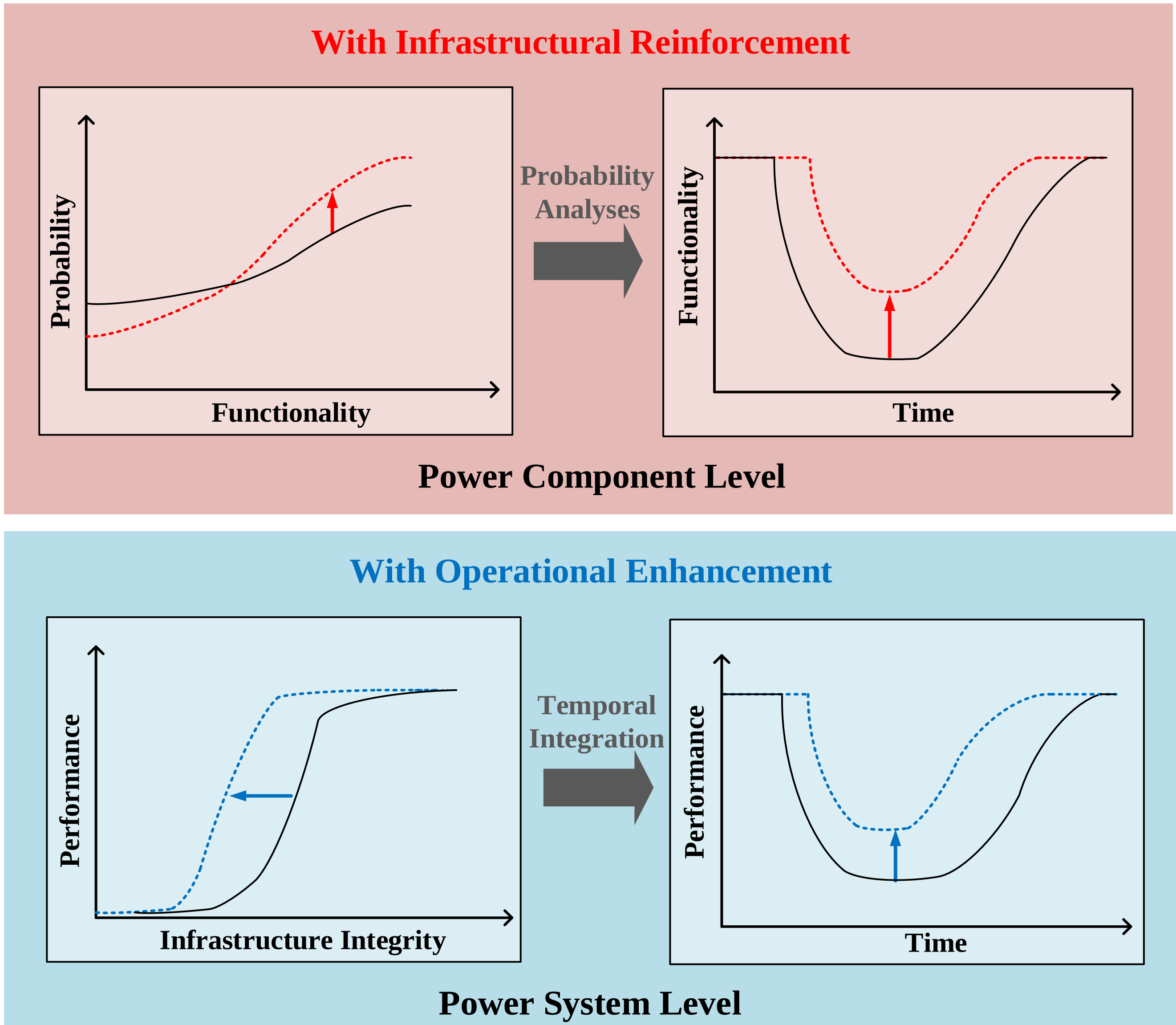
- In order to determine the most cost-effective solution to achieving the power system resilience to an extreme event, we consider the interdependency of infrastructural and operational measures, and the interactions of preventive and corrective actions.



- This multi-layer framework presents an inherent leader-follower relationship between infrastructural reinforcement and operational enforcement.
- In order to discover the optimal combination and the sequences for implementing the resilience enhancement measures, stochastic optimization or robust optimization problems can be formulated within this framework.

System Resilience Enhancement



Conclusions

- The development of networked microgrids will drive the conventionally centralized systems to migrate toward distributed localized systems, together with the significant changes in power system management.
- Resilience, as a key attribute of Smart Grid, is central to the efforts into modernizing power systems in the face of the growing number of widespread outages due to extreme events.
- Data analytics will play a key role in managing the power systems resilience via distributed power systems.
- Additional methods and solutions would have to be developed for managing the myriad of data presented in microgrid operation and planning.