Adaptive Prepositioning and Emergency Scheduling of Mobile Microgrids in Constrained Active Power Distribution and Urban Transportation Networks

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1. Introduction

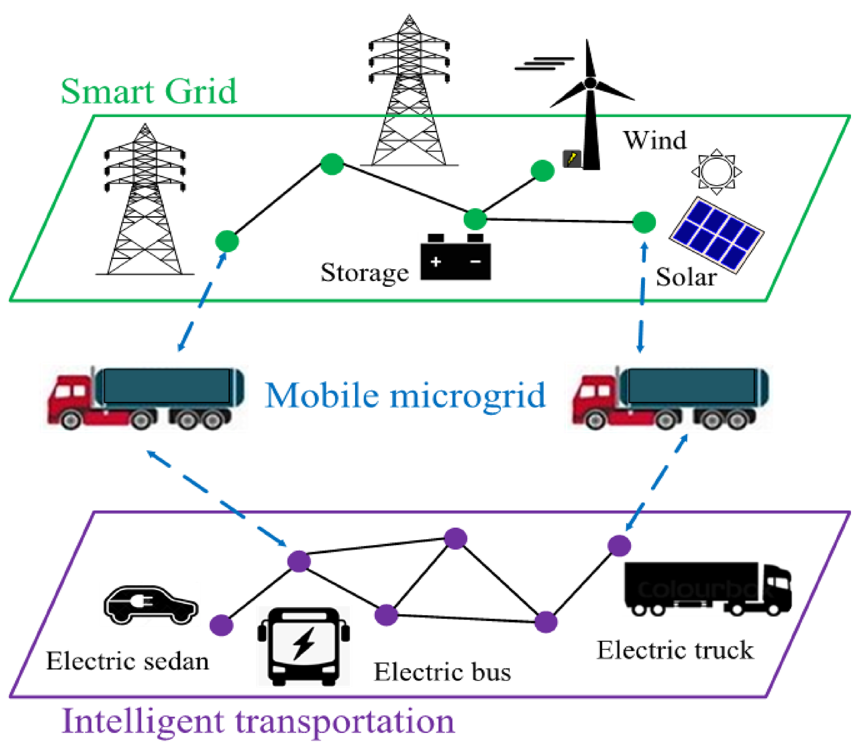
- Considering the proliferation of distributed energy resources (DERs) in active distribution networks (ADNs) and electric vehicles (EVs) in urban transportation networks (UTNs), it is imperative to coordinate the ADN and UTN for enhancing the power grid operation in normal steady state and extreme conditions.
- One example of such coordination is the integration of mobile microgrids in ADNs in which mobile DERs would be situated in day-ahead and optimally deployed in real-time to enhance the ADN economics, reliability, resilience, sustainability, and security in a constrained UTN.

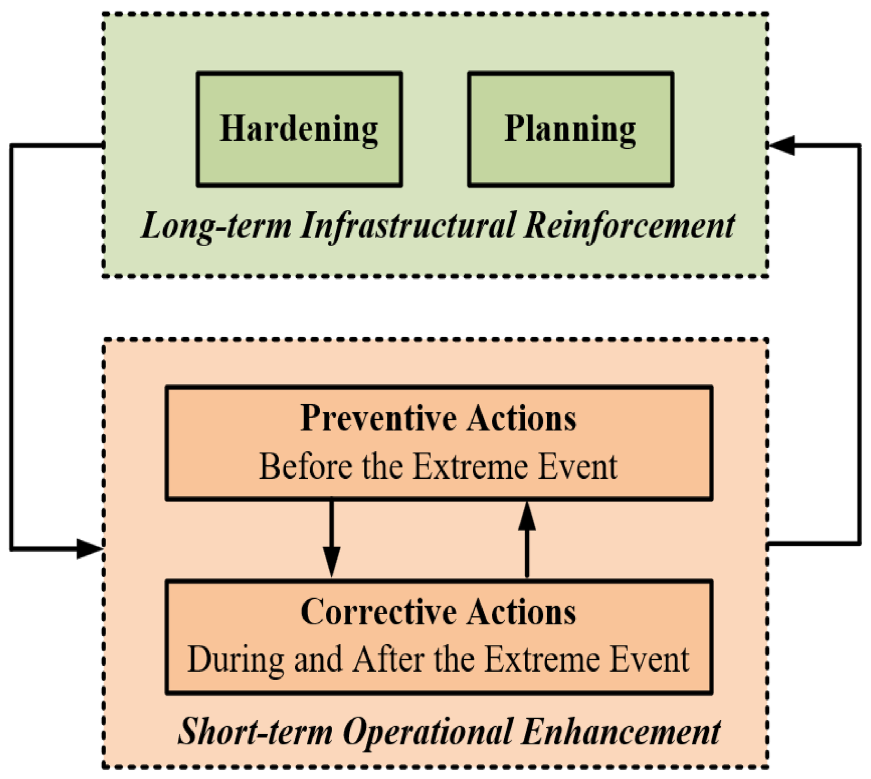
2. Basics of Mobile Microgrids

ADN and UTN are interdependent systems. This paper will focus on the day-ahead allocation and real-time deployment of mobile microgrids for enhancing the ADN resilience, including to integrate renewable generation, in constrained and coupled UTNs. Specifically, the following resources will be discussed:

a) Mobile Microgrids and DERs: Mobile microgrids coordinate the use of distributed generation (DG), including solar PV, and energy storage systems (ESSs) to bring into play the flexibility of MGs to control and enhance the performance of the damaged grid in real time. A lot of research has been done on its security and economy, and it has been explored as a means to enhance system resilience based on the above characteristics.

b) ADN-UTN (ATN) coordination: When extreme outage events occur in ADN, the following measures are necessary to quickly restore the power supply to critical loads: 1) Mobile microgrids need to be transported to the critical area using the existing UTN. 2) After completing the resilience tasks, mobile microgrid would need to return to the nearest EVCS/refueling stations quickly for recharging before they can resume their tasks.





3. ADN Recovery and Restoration Stages

A. Pre-event Planning for Preparedness

- The planning and design of ATN system will affect the scheduling of mobile microgrids after extreme events. ADN resilience planning stage includes all measures to improve ADN resilience, including ATN hardware design and implementation. A reasonable ATN planning will improve the ADN resilience in response and recovery stages after extreme events. This multi-layer framework presents an inherent leader-follower relationship between infrastructural reinforcement and operational enforcement. In Fig. 3, 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.

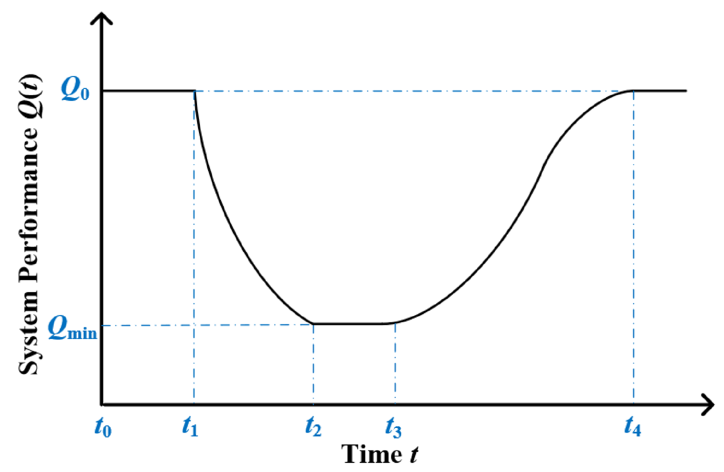
B. Resilience Responsiveness During and Extreme Event

- The load recovery by mobile emergency resources includes prepositioning in the day-ahead and optimal deployment of a mobile microgrid after the extreme event, in which case the mobile microgrids are used as flexible resources to restore the power supply of ADN. The optimal deployment strategy of mobile microgrids will consider the ATN coupling which can effectively improve the grid resilience and outage mitigation. After extreme events, the mobile microgrid can be quickly transported in UTN to the outage area to restore the critical loads and power supply. Therefore, considering the UTN traffic flow is crucial to the optimal deployment of mobile microgrids. The optimal deployment strategy of mobile microgrid in real-time can improve the resilience of power grid and reduce the chance for large ADN blackouts.

C. Post-event Restoration

- The recovery stage of power grid resilience is the process of restoring the normal operation of ADN after extreme events and is the core stage of power grid resilience. The truck mobility in UTN will be instrumental in the prepositioning and real-time deployment of mobile microgrids for the recovery process in ADN. The safe and reliable operation of ADN is improved by utilizing a recoverable ATN after the extreme event by considering the coupling of ADN and UTN.

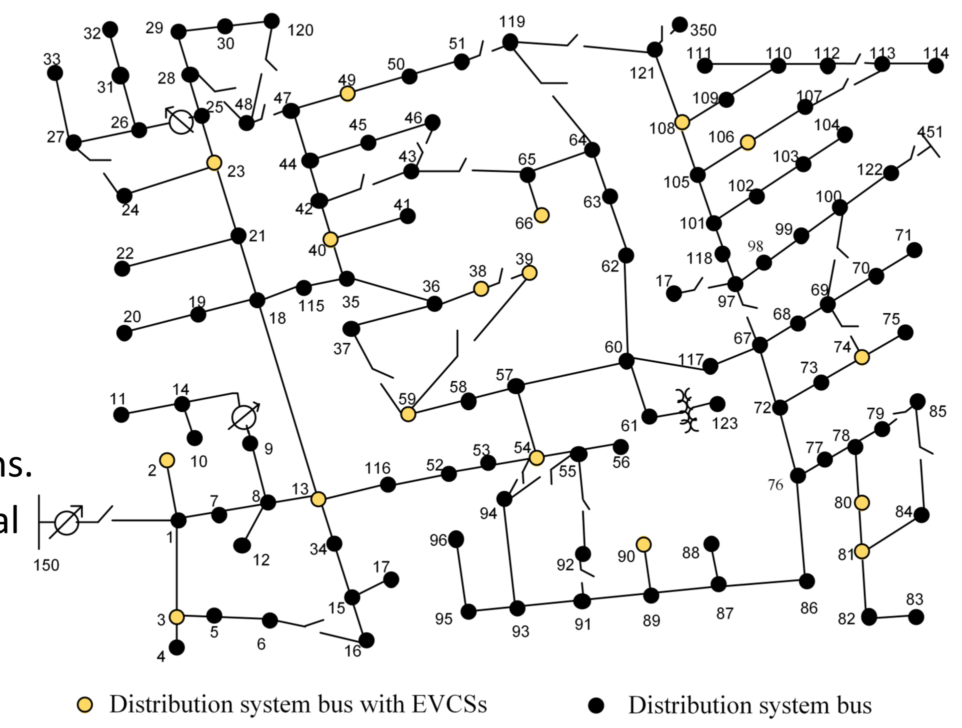
Period	Summary	Characteristic
Preparedness	Planning and design of ADN and UTN	Meet the UTN and PDN demand for resilient recovery
Responsiveness	Mobile microgrid positioning	Controllable, Flexibility, Fast response, Low maintenance, Strong mobility,
	Mobile microgrid deployment	Flexibility, Mobility, Better performance in power and energy density
Recovery	Recovery strategy	Optimal recovery of ADN and UTN resources and loads

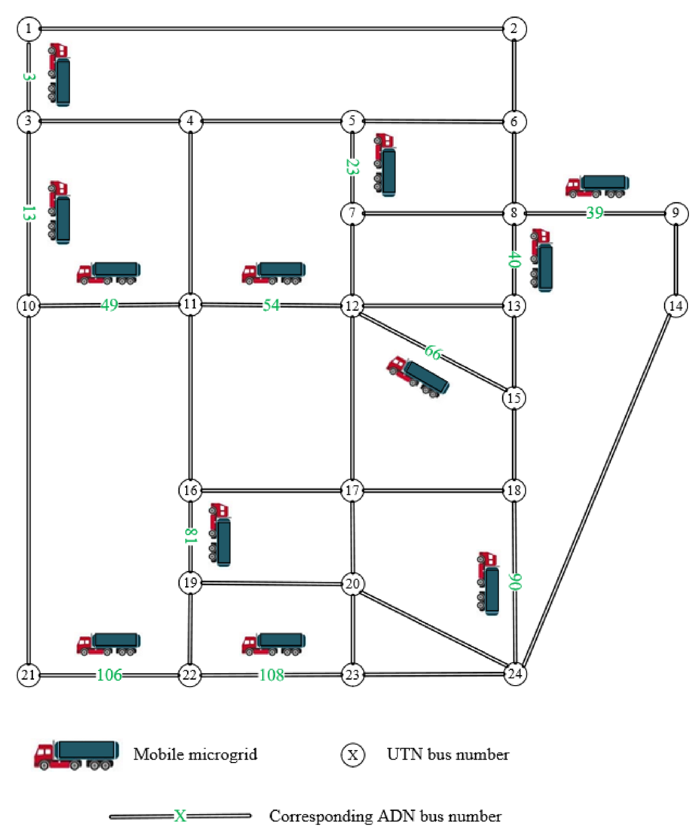


4. Adaptive Formation of Islanded Microgrids with Mobile Devices for Critical Service Restoration

To undertake the above challenges, this section proposes a mobile microgrid-based CSR strategy to ensure the highest service to critical loads when ADN encounters outages and damages under extreme events such as natural disaster and physical and cyber incidents.

The CSR method partitions an ADN into islanded microgrids supplied by mobile devices with the objective of maximizing the sum of restored loads. The CSR strategy (consisting of optimal mobile microgrid prepositioning and deployment as well as load switching sequence steps) focuses on restoring critical loads that deliver vital society services, e.g., hospitals, police and fire stations. CSR serves critical loads by forming islanded microgrids with radial and looped topologies by properly prepositioning mobile microgrids while taking into account the ADN survivability in extreme events.





5. Conclusion

- Today's power grids are facing an increasing frequency and a higher intensity of extreme outages caused by natural disasters like Hurricane Sandy, and the threat of terrorism (both physical and cyber).
- The impacts of extreme events on power grids underscore the need for enhancing the resilience, which is defined as the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from extreme outages.
- Integrating renewable generation to support resiliency is key. In this context, LUMA Energy has recognized mobile microgrids as a very promising solution to resilience enhancement and service restorations after extreme events in Puerto Rico and created integration plans.
- When mobile microgrids are prepositioned and deployed optimally by the proposed maximum-coverage criterion for CSR, they will energize the maximum number of ADN components for service recovery within a reasonable operation time.