Adaptive Microgrid Architecture to Manage System Resiliency

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Presenter’s Bio

- Senior Technical Leader at the Electric Power Research Institute (EPRI).
- Became a Senior member of IEEE in 2010. He is a Chartered Engineer (CEng), and an International Professional Engineer (Int.PE) with the Engineering Council in the United Kingdom (UK).
- Has more than 25 years’ industry experience.
- Research focus
  - Renewable grid integration challenges and mitigation strategies for utilities.
  - Interconnection screening criteria for Inverter Based Resources (IBR).
  - Advanced inverter functionalities and communications for provision of grid support; including Volt/Var optimization and performance monitoring.
  - Mitigation strategies for network optimization, system resilience and operations.
  - Microgrid modelling, operations, control, and grid impact analysis
  - Forecasting methodologies for variable IBRs.
  - Transmission and distribution network planning, design and operation.

Outline

- Introduction - Motivation
- Resilient microgrid architecture
- Use case
- Conclusion and Future work

Introduction and Motivation

Aging Infrastructure Risks

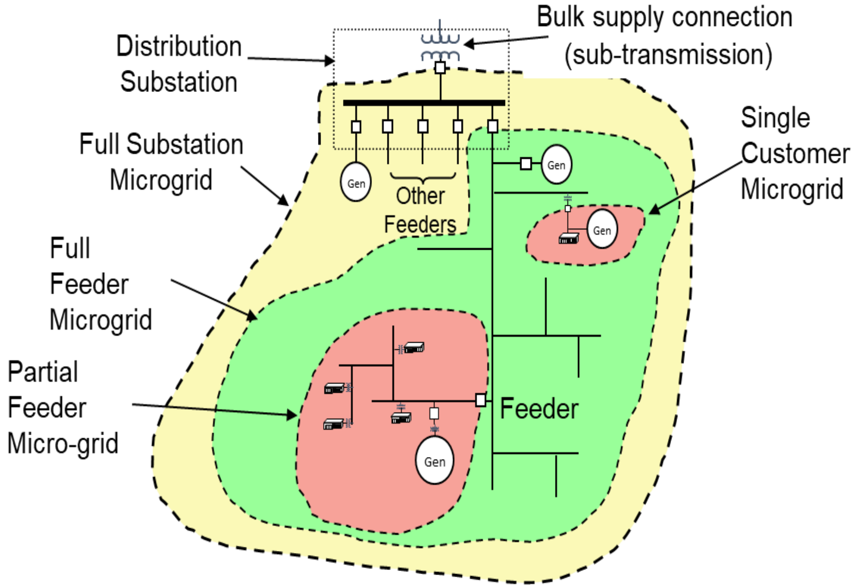
Old infrastructure poses risks to consistent power delivery, highlighting the need for modernization efforts.

Reliability and Service Quality

Reliability assessments focus on outage restoration and infrastructure performance to maintain high service quality.

System Resilience Challenges

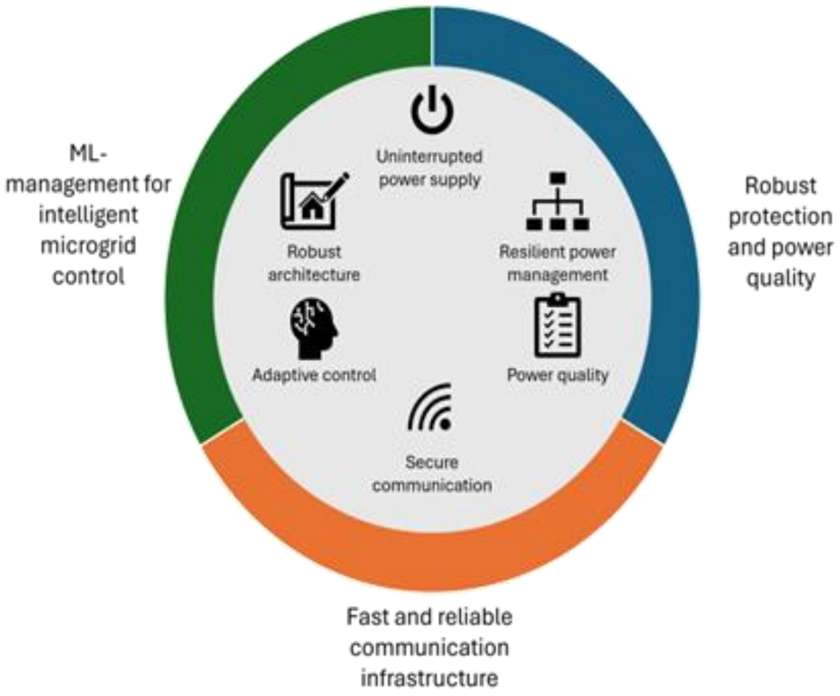
Resilience is the grid's ability to recover from severe events like natural disasters, cyber-attacks, and societal disruptions.



Source: CIGRE: WG C6:22, Microgrids Evolution Roadmap, Microgrids 1: Engineering, Economics, & Experience, France, 2015

Key contributions - Resilient microgrid architecture

Core Resiliency Pillars and Performance Objectives



- Uninterrupted Power Supply
- Resilient Power Management
- Current Imbalance Minimization
- Secure Communication
- Adaptive Control
- Robust System Architecture

Operational Strategies for Microgrid Resilience

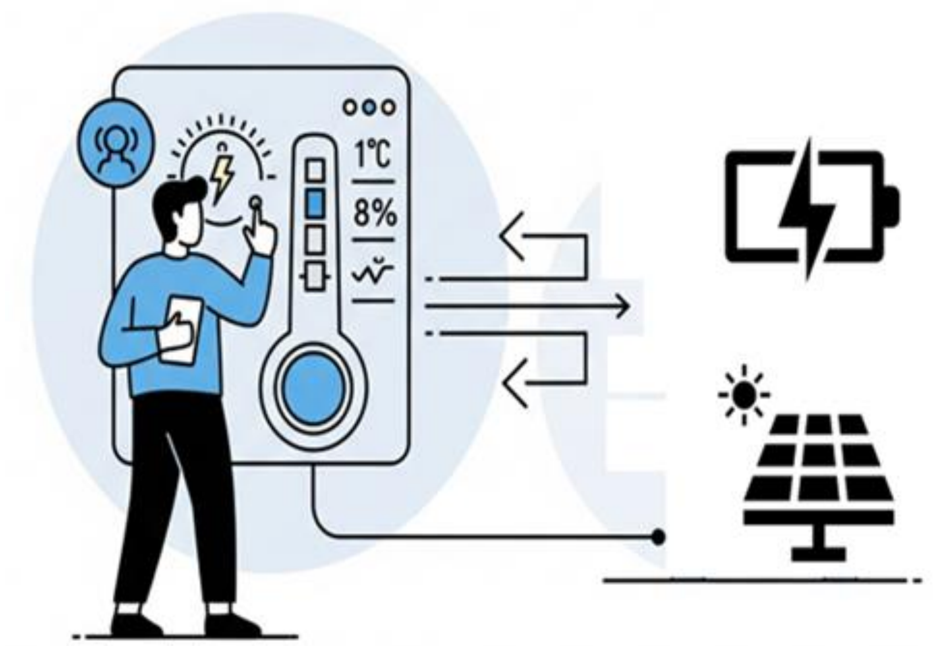
1 Uninterrupted Power Supply and DER Coordination

- Distributed Energy Resource Coordination
- Grid Forming and Following Inverters
- Microgrid Autonomy and Resilience

Operational Strategies for Microgrid Resilience

2 Resilient Power Management and Demand Side Control

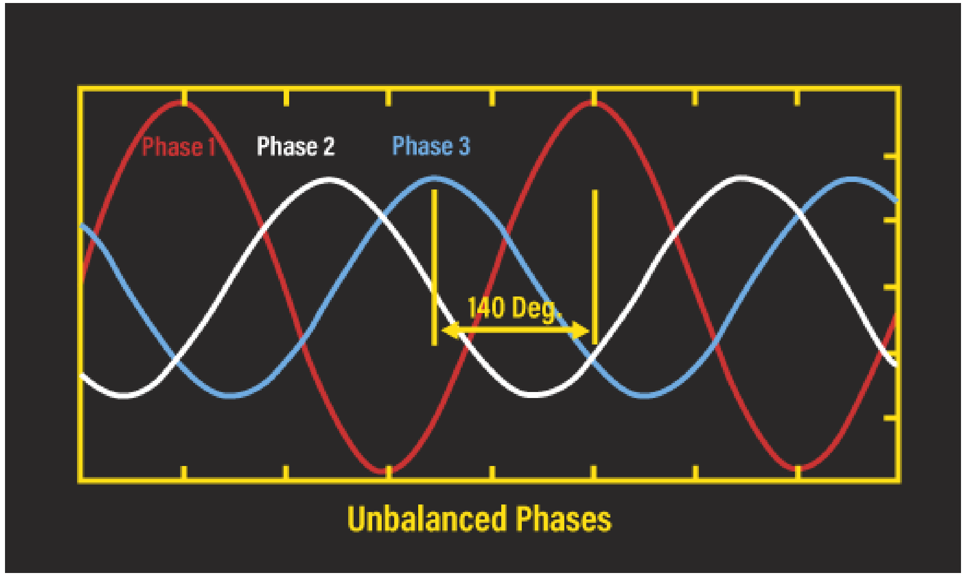
- Intelligent Load Control Devices
- Energy Storage and Demand Management
- Demand Response Strategies



Operational Strategies for Microgrid Resilience

3 Current imbalance minimization

- Current Imbalance Impact Metric quantification
- Phase swapping and load adjustment
- Load adjustments using Optimization control algorithms

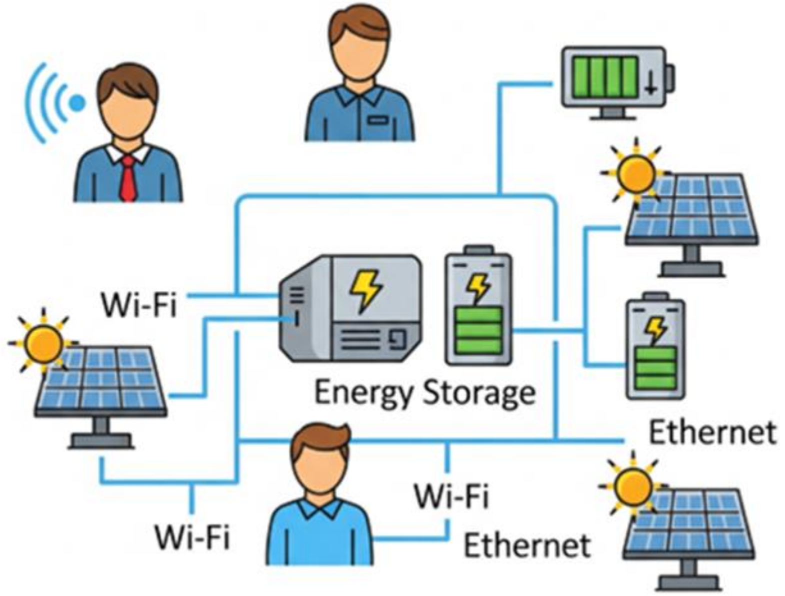


https://www.energymanagermagazine.co.uk/the-importance-of-not-losing-your-balance/

Operational Strategies for Microgrid Resilience

4 Secure communication framework

- Real-time data exchange
- Advanced Security Measures
- Low-Latency and Reliable Communication
- Multilayered Internet of Things (IoT) Communication Stack



Operational Strategies for Microgrid Resilience

5 Adaptive control and Machine learning Integration

- Adjust parameters in real time
- Utilizing Generation and Load Forecasting leverages Long Short-Term Memory (LSTM) networks
- Optimization with Reinforcement Learning
- Enhanced Protection and Security

Use Case - IEEE 8500 Node Test System

Microgrid Architecture

Consists of 50 residential solar customers and a commercial site with 100 kW solar and 2 MWh battery storage.

Outage and Separation

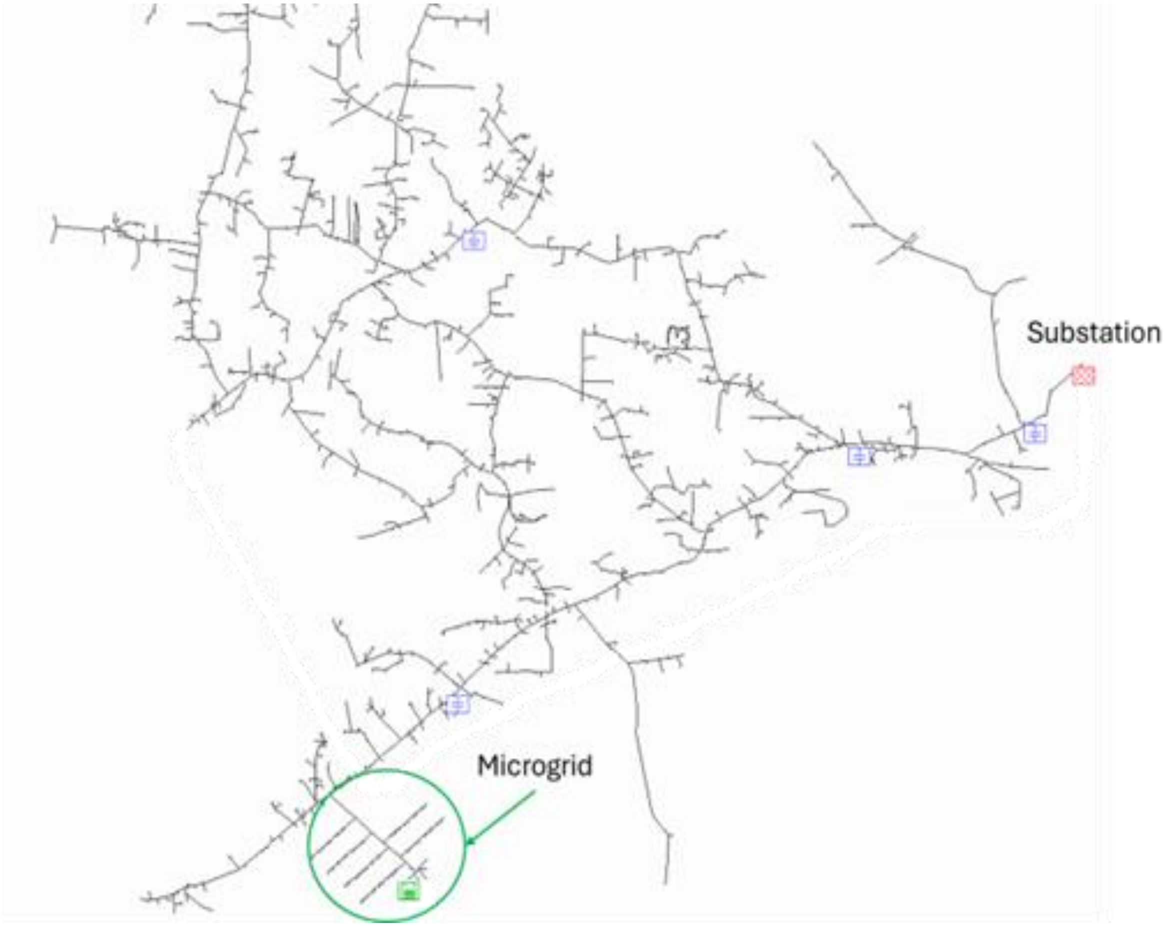
During outages, the microgrid disconnects from the main grid via a recloser to operate independently.

Adaptive Control and Inverter Roles

Manages the battery state of charge (SoC), disconnects solar PV, and uses Grid Forming and Following Inverters for stabilization.

Coordinated Power Sharing

Battery delivery reduces as Grid Following Inverters contribute power, balancing load and extending battery capacity.



Conclusion and Future work

Resilience-Enhancing Pillars

The microgrid architecture relies on protection and power quality, high speed and reliable communication, and machine learning driven control and management for resilience and stability.

Operational Goals

The framework maintains service continuity, optimizes energy usage, and ensures system stability.

Future Research Focus

Future work targets Device to Device (D2D) Quality of supply (QoS) analysis, secure communication, and resilience metrics with optimization models.

Thank You!