Fact Sheet:
A Resilient Power Grid for ZEV-Based Evacuations

Task 2 of ZEV Evacuation

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0.1 Introduction

The *Viejas Tribe's Renewable Backup Power System* in San Diego County, California, is a prime example of how renewable energy can enhance community resilience. In 2022, the California Energy Commission awarded a $31 million grant to deploy a 60 MWh long-duration energy storage system for the tribe. This system is designed to provide 100% renewable backup power, ensuring that critical operations can continue during grid emergencies [1].

Another pertinent example is the microgrid on *Ocracoke Island*, North Carolina. Following Hurricane Dorian in 2019, the microgrid restored power within three days, significantly aiding evacuation efforts and community recovery. The system's ability to operate independently from the main grid during emergencies underscores the vital role of microgrids in disaster response [2].

These examples illustrate the importance of integrating microgrids and renewable energy storage systems into community infrastructure to support evacuation processes and maintain essential services during emergencies.

The *Blue Lake Rancheria Microgrid* in Northern California serves as a model of energy resilience and community preparedness. This microgrid integrates solar power, battery storage, and backup generators to ensure uninterrupted energy supply during emergencies. During the 2019 Public Safety Power Shutoffs caused by wildfires, the microgrid provided continuous power to the community, supporting essential services such as a Red Cross evacuation shelter, a medical facility, and a hotel that housed evacuees. By reducing reliance on fossil fuels and ensuring reliability, the system exemplifies how microgrids can enhance community resilience and sustainability in the face of increasing climate risks [3].

Another notable example is the *Bronzeville Community Microgrid* in Chicago, Illinois, which powers approximately 1,000 residences, businesses, and public organizations. As the first microgrid cluster in the United States, this system demonstrates the feasibility of grid-independent operation during outages, ensuring energy reliability for critical infrastructure in the community [4].

Similarly, the *Alliance Medical Center* in Healdsburg, California, installed a $500,000 solar and battery storage system as part of the Power for Health initiative. This system ensures continuous power for critical medical services and the preservation of vital medications, serving over 13,000 underinsured and uninsured patients annually, even during extended power outages [5].

Lastly, in New Orleans, the *Community Lighthouse Project* equips churches with solar panels and batteries, creating microgrids capable of functioning as refuges during blackouts. These locations provide air conditioning, power for medical devices, and other critical services, aiming to expand to 500 sites across Louisiana to bolster emergency response capabilities [6]. Emergencies like natural disasters, such as hurricanes and earthquakes, especially wildfires in California, can put immense pressure on the power grid. When communities rely on Zero Emission Vehicles (ZEVs) for evacuations, a reliable power supply is essential to keep ZEV charging stations operational and ensure public safety. This fact sheet provides practical ways to make the power grid more resilient during emergencies, as shown in Fig. 1, with a focus on key strategies like backup power, renewable energy, microgrids, and an explanation of Optimal Power Flow (OPF) and infrastructure siting and sizing investment.

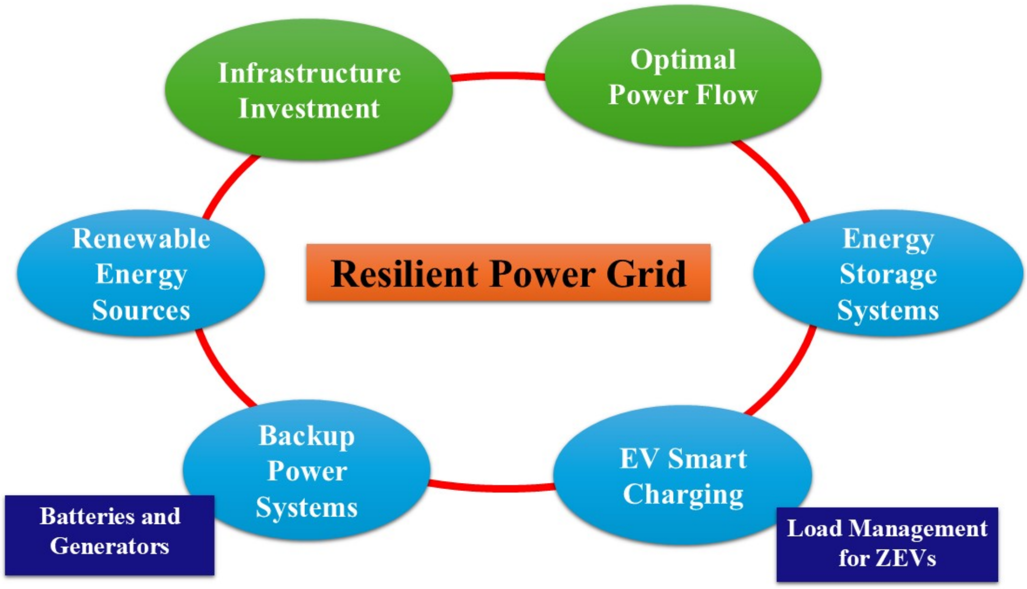

Figure 1: Block diagram of the resilient power systems.

0.2 Backup Power Systems

0.2.1 What are they?

Backup power systems, like batteries and generators, provide electricity when the main grid is down due to a high-demand situation like the evacuation of a city or county. They help keep essential services running during emergencies, especially at places like ZEV charging stations, hospitals, and shelters.

0.2.2 How can they help during evacuations?

In an emergency evacuation, ZEVs will need power to recharge, i.e., pre-departure and post-arrival charges, in case of natural disasters like wildfires. Backup systems ensure that charging stations stay powered even if the main grid fails.

0.2.3 Recommendations

- Install battery storage systems at ZEV charging stations and emergency shelters to ensure continuous power.
- Consider portable generators for smaller, critical facilities.
- Use renewable energy (solar or wind) with batteries to create eco-friendly backup power options.

0.3 Microgrids

0.3.1 What are they?

Microgrids are smaller, independent grids that can generate and distribute electricity locally. Microgrids can operate in two conditions, i.e., grid-connected microgrids and islanded microgrids. They can continue working even if the main grid goes down and are often powered by renewable energy sources. Figure 2 represents a hybrid AC/DC microgrid, which integrates renewable and conventional energy sources to serve a variety of loads. The key components of the system are as follows:

1. *Utility Grid Connection:*
   - The microgrid is connected to the utility grid via power converters.
   - This connection ensures power supply during high demand or emergencies.
2. *AC and DC Buses:*
   - The system is divided into two main buses:
     - The AC bus serves loads requiring alternating current (AC).
     - The DC bus handles direct current (DC) loads.
   - This design minimizes energy conversion losses and optimizes energy flow.
3. *Generation Sources:*
   - The microgrid integrates:
     - Renewable sources such as solar panels and wind turbines.
     - Conventional sources such as diesel generators and thermal plants.
   - Energy storage systems (ESS) are included to balance supply and demand.
4. *AC Loads:*
   - These include:
     - Residential loads such as homes and small-scale consumption.
     - Commercial loads such as businesses and offices.
     - Critical loads such as hospitals and data centers.
5. *DC Loads:*
   - These include:
     - Electric vehicle (EV) charging stations.
     - Industrial loads such as factories and large-scale production.
     - Data centers that rely on high-reliability DC-powered systems.
6. *Power Converters:*
   - Power converters interface between:
     - The AC and DC buses.
     - The utility grid and the microgrid.

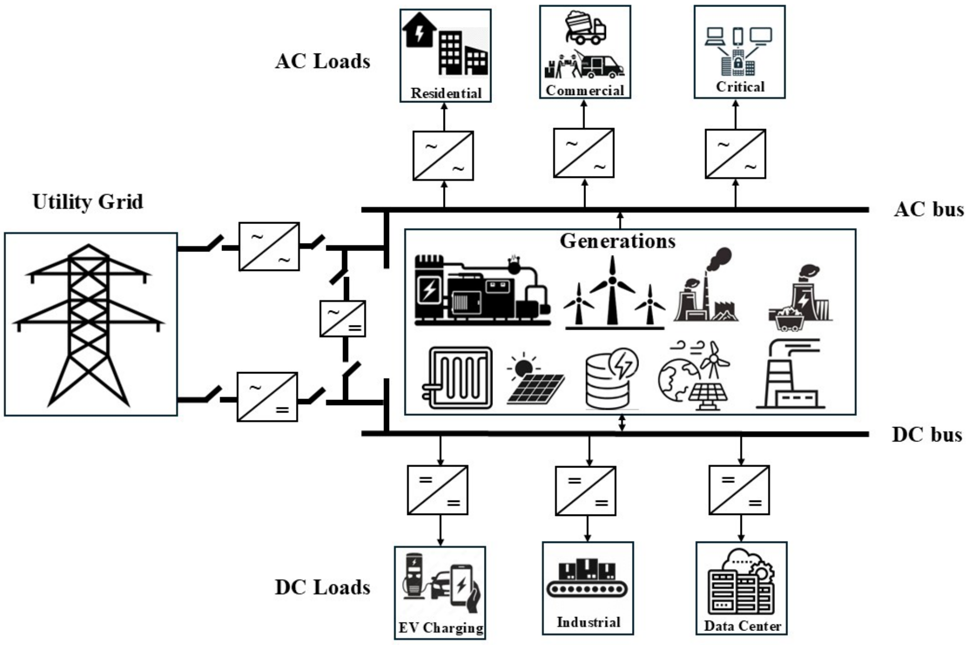

Figure 2: General structure of a typical hybrid microgrid.

- These converters include rectifiers (AC to DC), inverters (DC to AC), and bidirectional converters for two-way power flow.

This microgrid design ensures efficient operation, resilience, and sustainability by integrating diverse generation sources and loads while maintaining flexibility to meet AC and DC power demands.

0.3.2 Why are they important during emergencies?

Microgrids can keep ZEV charging stations, emergency shelters, and hospitals running when the main grid is compromised. They are particularly useful during extended evacuations where power is critical.

0.3.3 Recommendations

- Install microgrids in areas like major ZEV charging stations, hospitals, and emergency shelters.
- Use renewable energy (like solar or wind) as part of the microgrid to ensure a continuous supply of clean power.
- Ensure that microgrids are properly sized to handle local electricity demands during emergencies.

0.4 Renewable Energy Integration

0.4.1 What is it?

Renewable energy sources, like solar and wind, provide clean and sustainable power. These can be combined with batteries to store energy for use when it's needed most, especially during a power outage.

0.4.2 How does it help during evacuations?

Renewable energy helps reduce reliance on fossil fuels and can be an independent power source for ZEV charging stations and emergency shelters when the main grid is down.

0.4.3 Recommendations

- Install solar panels with battery storage at community centers and ZEV charging stations.
- Consider wind energy for areas with consistent wind patterns to supplement energy needs.
- Ensure that renewable systems are connected to microgrids for better reliability.

0.5 Electric Vehicle (EV) Smart Charging

0.5.1 What is it?

Smart charging technology helps manage how and when ZEVs are charged to avoid overloading the power grid. This is particularly important during emergencies, when multiple vehicles may need to charge simultaneously, both before departure and after arrival, while evacuating from a hazardous region near a natural disaster, such as a wildfire, to a safer area.

0.5.2 Why is it important?

Smart charging can prioritize essential vehicles and distribute charging times to prevent grid overload. This ensures that power remains available for both critical services and ZEV charging during evacuations. The high ramp-up rate of ESSs can help maintain power system stability during failures or overloads, enabling faster evacuations. As a result, these technologies play a crucial role in safeguarding lives during wildfire emergencies.

0.5.3 Recommendations

- Install smart charging systems that can automatically manage and balance power use at ZEV charging stations.
- Encourage off-peak charging to reduce grid strain during high-demand periods.

- Ensure that ZEV charging stations are connected to backup power or microgrids for continuous operation during emergencies.

0.6 Energy Storage Systems (ESSs)

0.6.1 What are ESSs?

Energy Storage Systems (ESSs) are devices that store energy, such as batteries, for later use. They can provide power during outages or peak demand times, ensuring that critical facilities like ZEV charging stations have continuous electricity.

0.6.2 Why are they important during evacuations?

During an evacuation, ZEV charging stations and emergency shelters need reliable power. ESSs can store excess energy generated during normal conditions and release it during emergencies, helping reduce strain on the main grid and ensuring uninterrupted power for critical services.

0.6.3 Recommendations

- Install community-scale ESSs near ZEV charging stations and emergency shelters to provide stored power during peak evacuation times.
- Combine renewable energy sources (e.g., solar or wind) with ESSs to maximize the use of stored energy during grid outages.
- Ensure ESSs are sized appropriately to handle the expected energy demand during evacuations and emergencies.

0.7 Understanding Optimal Power Flow (OPF)

0.7.1 What is OPF?

Optimal power flow (OPF) is a technology that helps manage electricity distribution across the power grid. It ensures that power is sent to the places that need it most, like ZEV charging stations and emergency centers, especially during a natural disaster.

0.7.2 Why is OPF important for evacuations?

During evacuations, which is a high-demand scenario, power demand can increase rapidly, and parts of the grid may fail due to weather or other disruptions. OPF helps to reroute electricity efficiently, keeping critical services running while minimizing disruptions.

0.7.3 Explanation

- OPF helps optimize power use across the grid, making sure electricity is used where it's most needed.

- It prevents overloading by balancing the demand at ZEV charging stations, shelters, and other essential services.

0.7.4 Recommendations

- Work with utilities to implement OPF systems that ensure critical services like ZEV charging stations receive uninterrupted power during emergencies.
- Ensure that OPF systems are integrated with backup power and microgrids to provide additional resilience.

0.8 Optimal Sizing and Siting (Infrastructure Investment)

0.8.1 What is it?

Optimal siting refers to placing backup systems (like batteries and generators) in the right locations, while optimal sizing means making sure these systems are large enough to meet the needs of the community during an emergency. Therefore, there is an optimal program for the investment of infrastructure for both optimal location and capacity.

0.8.2 Why is it important?

Inadequate sizing or improper placement of backup power systems may result in insufficient electrical supply during critical periods. For instance, a Zero ZEV charging station may experience power shortages if the backup system is not appropriately sized or optimally positioned to meet the demand.

0.8.3 Recommendations

- Work with experts to determine the best places for backup power systems near ZEV charging hubs, hospitals, and shelters.
- Ensure that backup systems are sized appropriately to meet the power demands during peak times, such as when many ZEVs are charging simultaneously during an evacuation.

Figure 3 outlines a comprehensive approach to integrating system specifications, vulnerability analysis, and cost-benefit infrastructure planning for enhancing decision-making in evacuation scenarios. It begins with identifying critical systems such as power systems, microgrids, renewable energy sources, electric vehicles (EVs), energy storage systems (ESS), charging stations, and existing road networks. These inputs feed into a detailed vulnerability analysis, which evaluates electrical factors (e.g., failure rates and uncertainties), infrastructure vulnerabilities using predictive methods, and transportation network dynamics such as traffic patterns and road expansion needs. The outcomes of this analysis inform a cost-benefit infrastructure evaluation through optimization models and operational planning strategies. Central to this framework is a decision-aid tool that incorporates expert-assigned weights to recommend the most effective actions during evacuations, ensuring resilience, efficiency, and optimal resource allocation. This structured methodology facilitates robust and data-driven planning for emergency preparedness and sustainable infrastructure development.

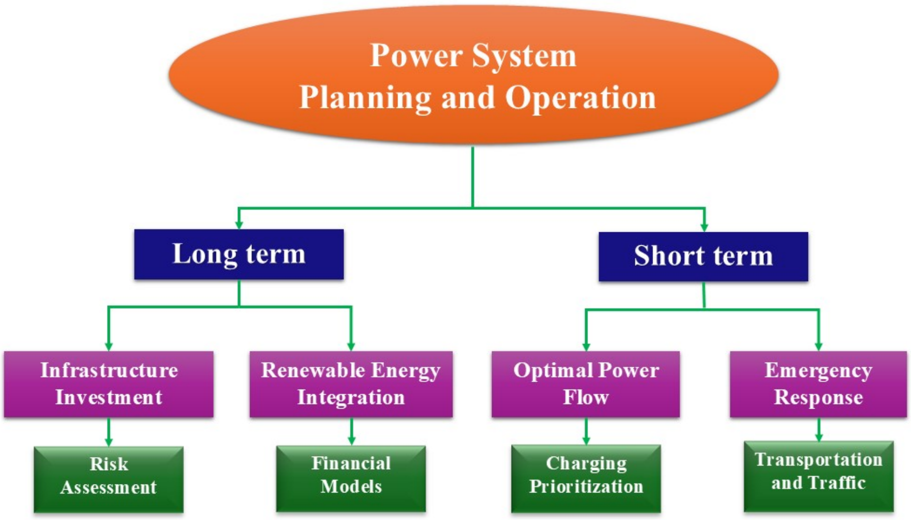

Figure 3: Configuration of the power systems studies.

0.9 Conclusion: Having a Resilient Power Grid for Emergencies

To ensure smooth and secure evacuations and reliable power during emergencies, communities must focus on enhancing their power grid's resilience. Using backup power systems, microgrids, renewable energy, and smart charging technologies, alongside careful planning through OPF and optimal siting and sizing for infrastructure investment, will ensure that essential services like ZEV charging stations and emergency shelters are well-prepared for any disasters, such as wildfires, hurricanes, and so on.

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