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Resilience Evaluation of Interconnected Urban Transportation and Electric Power Systems against Seismic Events: Addressing Uncertainty and Dependencies

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Introduction

Urban areas worldwide are increasingly vulnerable to the cascading impacts of natural disasters such as earthquakes, which can disrupt critical infrastructure networks essential for daily life and economic activities. Among these, urban transportation and electric power systems play pivotal roles, facilitating mobility, communication, and essential services. However, their interdependencies pose significant challenges during seismic events, where damage to one system can amplify vulnerabilities in another, leading to extended disruptions and socio-economic consequences. Seismic resilience, therefore, refers to the ability of interconnected urban transportation and electric power systems to withstand and recover from earthquake-induced disruptions efficiently. Assessing this resilience involves understanding complex interactions and dependencies between these systems, as well as addressing uncertainties inherent in seismic hazard modeling and infrastructure response. This study focuses on evaluating the resilience of interconnected urban transportation and electric power systems against seismic events, emphasizing the integration of uncertainty management and dependency analysis. By comprehensively assessing these interconnected systems' performance under seismic stress, this research aims to inform strategies for enhancing infrastructure resilience and minimizing societal impacts in earthquake-prone regions [1].

Description

Urban transportation and electric power systems are critical components of modern cities, essential for facilitating mobility, supporting economic activities, and ensuring the delivery of essential services. Transportation systems encompass a complex network of roads, bridges, tunnels, and public transit infrastructure that enable the movement of people and goods. Electric power systems encompass power generation facilities, transmission lines, substations, and distribution networks, providing electricity for transportation operations, residential, commercial, and industrial needs. During seismic events, such as earthquakes, these interconnected systems face substantial risks. Ground shaking can damage transportation infrastructure, including bridges and tunnels, disrupting vital road and rail networks crucial for daily commuting, emergency response, and commerce. Concurrently, seismic activity can cause failures in electric power infrastructure, leading to widespread outages that affect transportation operations, communication networks, and overall societal functionality [2,3].

Operational uncertainties involve the dynamic nature of system operations and usage patterns. For transportation systems, this includes variability in traffic volumes, which can influence the effectiveness of emergency response and evacuation. For electric power systems, operational uncertainties include fluctuations in demand and supply, as well as the performance of protective relays and control systems. Incorporating these uncertainties into resilience evaluations requires advanced modeling techniques that capture the stochastic nature of system operations. Modeling the dependencies between transportation and electric power systems is essential for understanding the potential cascading effects of seismic events. Interdependency models, such as coupled network models, are used to simulate the interactions between these systems. These models can capture the bidirectional dependencies and help identify critical nodes whose failure could trigger widespread disruptions [4].

Assessing the resilience of urban transportation and electric power systems against seismic events involves evaluating their capacity to withstand and recover from disruptions. Key considerations include understanding regional seismic hazards, assessing the vulnerability of infrastructure to seismic forces, analyzing dependencies between transportation and power systems, and quantifying the socio-economic impacts of disruptions. Managing uncertainty in resilience assessment entails utilizing probabilistic modeling, scenario analysis, and sensitivity testing to account for variability in seismic hazard characteristics and infrastructure response [5].

Conclusion

Enhancing the resilience of interconnected urban transportation and electric power systems against seismic events is essential for ensuring the continuity of essential services, safeguarding public safety, and promoting sustainable urban development. By improving infrastructure resilience, cities can mitigate the socio-economic impacts of earthquakes, enhance emergency preparedness and response capabilities, and foster greater community resilience in seismic-prone regions globally. Achieving resilience involves proactive measures such as infrastructure retrofitting, adherence to seismic design standards, robust risk management frameworks, and adaptive planning strategies. These efforts are crucial for minimizing disruptions to transportation and power systems during seismic events, thereby maintaining critical services and supporting economic stability. Moving forward, continued research and investment in resilient infrastructure, advanced monitoring technologies, and interdisciplinary collaborations will be pivotal in enhancing the resilience of urban transportation and electric power systems against seismic hazards. By strengthening these foundational systems, cities can better withstand natural disasters, promote sustainable development, and improve overall quality of life for residents and businesses alike.

Acknowledgement

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Conflict of Interest

None.

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