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Microgrids and Resilience: A Comprehensive Review of Research Approaches and Optimization Strategies

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Abstract

Today, microgrid (MG) implementation in the power system is considered one of the most promising solutions for the future because of the sustainability, reliability, and resilience that these structures provide. However, there are challenges that arise when we incorporate these systems into the power grid that need to be addressed. Researchers from various fields have focused on these challenges, examining the subject from different perspectives. One particularly challenging area is resiliency, which has generated a substantial body of research papers. This paper reviews the state-of-the-art research in this field, categorizing studies into branches based on their objectives. This classification aims to provide a clearer understanding of the challenges and the pathway that should be taken to address them. In our analysis, we identified six different categories, with innovative solutions potentially representing the future direction that deserves greater attention.

Introduction

The increasing penetration of renewable energy sources and the need for advanced control strategies have driven the adoption of Microgrids (MGs) in modern power systems. MGs offer multiple benefits, including facilitating renewable integration, supporting a zero-carbon energy transition, and lowering energy costs, which improves social welfare. They also enhance the functionality of Energy Hubs and allow for profitable participation in electricity markets. A key advantage is their ability to switch between grid-connected and islanded modes, improving system reliability during disruptions. Despite these strengths, MGs face challenges such as protection and reliability issues, which require innovative management solutions. Research continues to address these challenges from various angles, including technical optimization, component performance, and societal benefits. MGs also play a crucial role in enhancing resilience against cyber threats and natural disasters. Their capability to supply critical loads during emergencies and their reliance on advanced power electronics further underscore the importance of improving their operational stability and reliability.

This paper reviews various objective functions related to the unique challenges of Microgrids (MGs), offering a detailed categorization of the perspectives researchers adopt in their analyses. It presents a comprehensive literature review that highlights the current state and challenges in MG development. Moreover, the study synthesizes diverse optimization approaches and points out emerging trends expected to influence future research. The structured analysis serves as a helpful guide for both seasoned researchers and newcomers. The paper is organized into sections covering methodology, literature review, discussion of categories, and conclusion.

Methods

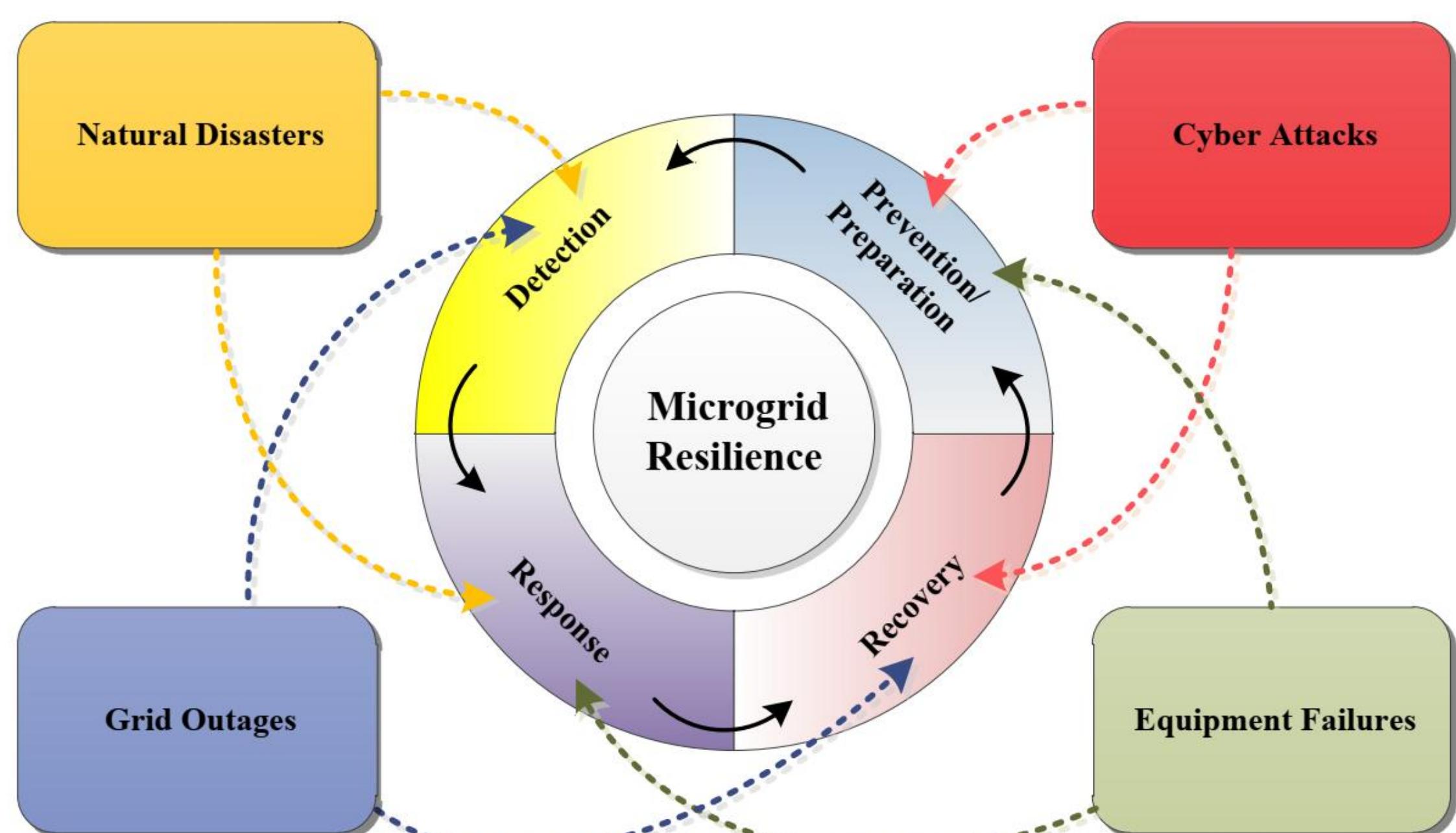


Fig. 1. Different threats and the steps needed to tackle them in MGs to ensure resiliency

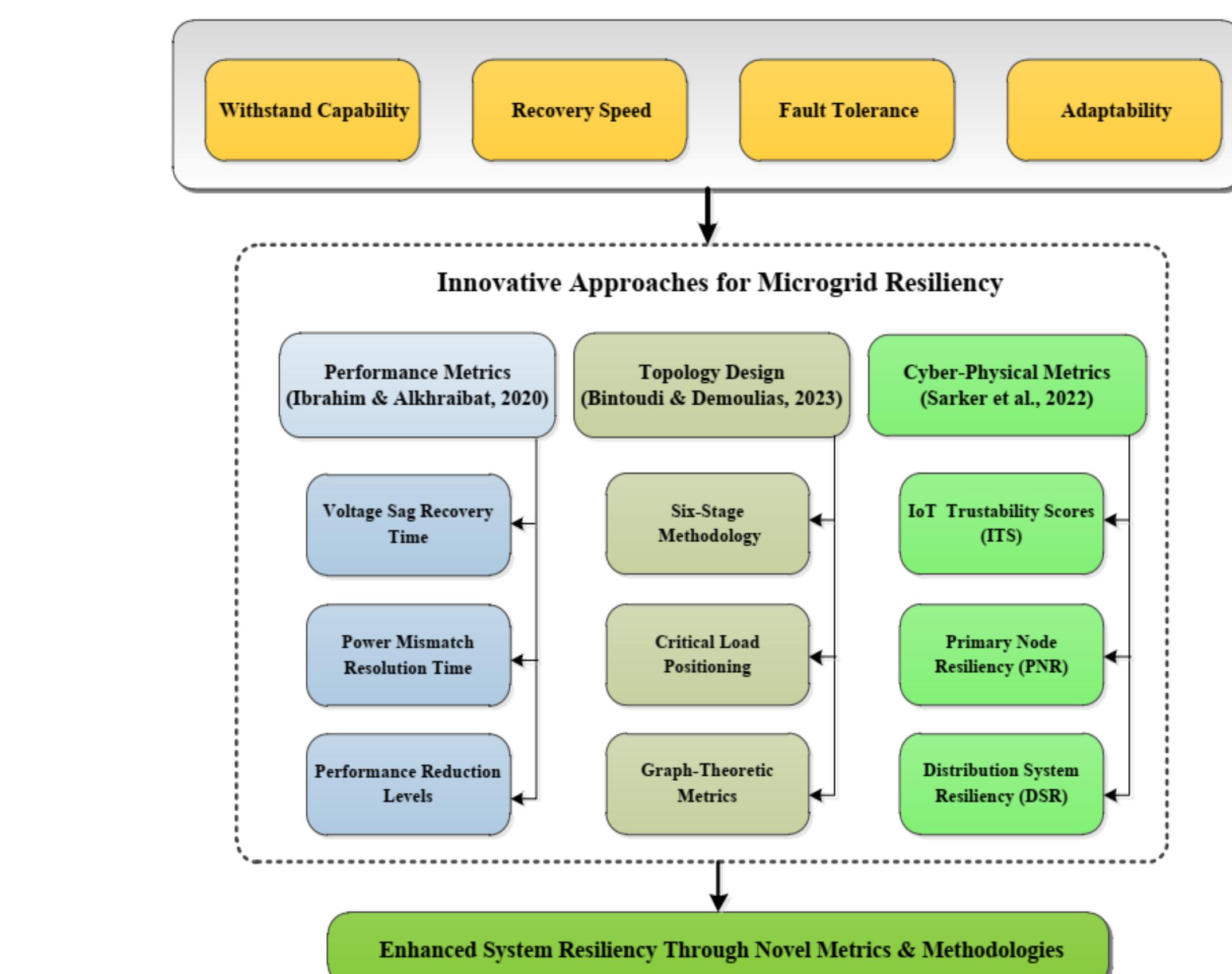


Fig. 2. Challenges addressed through innovative approaches, and the metrics considered by authors.

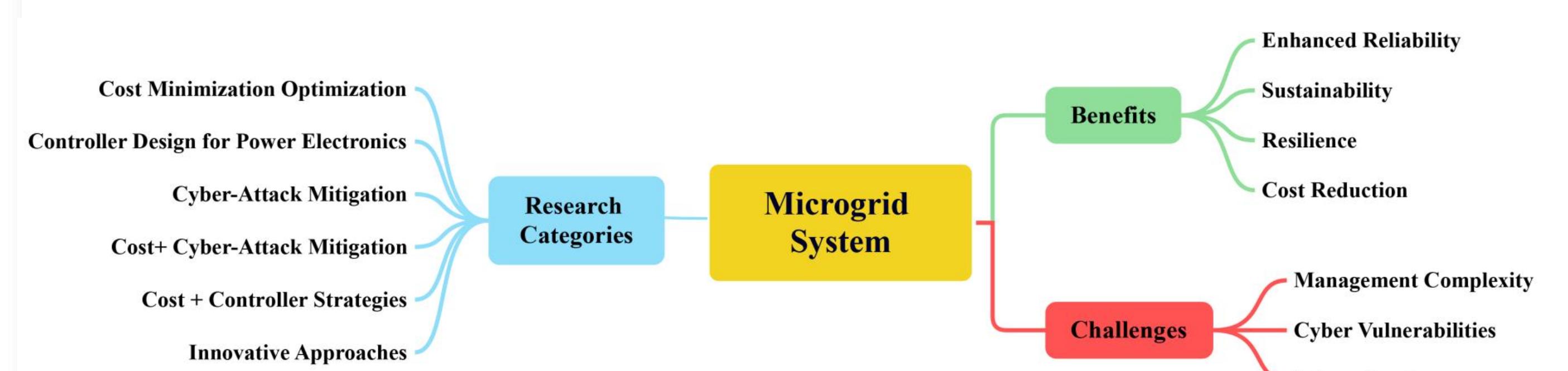


Fig. 3 Different challenges, and benefits in MGs , and the approaches authors considered to address them.

Conclusions

Given the importance and potential of microgrid (MG) implementation in the future of power systems, addressing the various challenges associated with MGs has become essential. Researchers have explored these challenges in their work, often proposing innovative solutions to tackle specific problems. The literature underscores the necessity of considering diverse sources of issues in MGs and adopting tailored approaches to address them effectively. In this context, the present paper focuses on categorizing the existing research in the field based on the objectives of the studies. Six distinct categories were identified, with each section detailing the corresponding papers and their contributions. This structured approach provides a clear understanding of the diverse challenges faced by MGs and the solutions proposed in the literature. Ultimately, acquiring comprehensive knowledge of these challenges and taking proactive steps to mitigate them is crucial for the successful implementation and advancement of MG technology.

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