Event-Triggered Control and Multi-Time Scale Coordination for Microgrid Stability and Optimization

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Abstract. Microgrid operations require precise control strategies that account for both fast and slow dynamics to maintain stability and optimize performance. This paper introduces a novel control framework integrating multi-time scale coordination with event-triggered control for improved microgrid management. By dynamically adjusting control actions based on real-time events and system states across different time scales, the proposed method reduces control effort while maintaining high system performance. Simulation results validate the approach's capability to respond to varying load demands, renewable energy fluctuations, and other uncertainties in a microgrid environment.

Keywords: Microgrid Control, Event-Triggered Systems, Multi-Time Scale Optimization, Stability, Renewable Energy, Adaptive Control

Introduction:

As the energy landscape transitions toward more decentralized and renewable-based systems, microgrids have emerged as a promising solution for enhancing the reliability, resilience, and sustainability of local energy networks. A microgrid typically comprises multiple distributed energy resources (DERs) and operates either in grid-connected or islanded modes. Given the diverse sources and consumption patterns within a microgrid, effective control becomes crucial for ensuring both operational stability and economic efficiency.

One of the key challenges in microgrid control is managing decisions that operate over different time scales. Fast-scale dynamics, such as frequency and voltage regulation, must be controlled in real time, whereas slower processes, like energy management and load forecasting, involve longer-term optimization. A multi-time scale approach offers a comprehensive framework that coordinates decisions at these different levels, but it can be computationally intensive if not efficiently designed.

To address this, event-triggered control has been introduced as a complementary strategy that activates control actions only when certain conditions are met, thus reducing unnecessary updates and computation. This paper proposes a hybrid control strategy that integrates multi-time scale coordination with event-triggered mechanisms to achieve a balance between control performance and computational efficiency. The proposed framework is tested on a representative microgrid model under various operational scenarios, demonstrating enhanced system stability and optimized energy usage.