

Chapter 6

AI and ML Adaptive Smart-Grid Energy Management Systems: Exploring Advanced Innovations

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ABSTRACT

The chapter explores the transformative role of artificial intelligence (AI) and machine learning (ML) in shaping smart energy management systems (SEMS) and predicts innovations by 2030. It discusses AI principles in energy optimization, predictive analytics in smart grids, and renewable energy integration through AI-driven strategies. The chapter also addresses critical aspects like predictive maintenance, consumer-centric solutions, cybersecurity challenges, ethical considerations, and regulatory frameworks for responsible AI implementation. By examining challenges and prospects, it provides insights into the dynamic future of energy management driven by AI and ML advancements.

INTRODUCTION

Technological advancements and a shift towards sustainable practices have significantly transformed energy management systems. The shift from conventional methods to sophisticated, data-driven systems have reshaped energy production, distribution, and consumption. The energy sector is at the forefront of this transformation, with the integration of Artificial Intelligence (AI) paving the way for a new era of efficiency, optimization, and sustainability in energy management. The integration of AI into energy management systems has revolutionized the industry by processing vast datasets, enabling predictive analysis, and adaptive decision-making. AI algorithms, powered by Machine Learning models, extract valuable insights from energy grids, consumption patterns, weather fluctuations, and infrastructure conditions. This data enables proactive strategies, real-time optimization, and agile responses to changing energy demands (Ganesh & Xu, 2022a).

AI is revolutionizing energy management by transforming the core architecture of energy systems into intelligent, self-learning entities capable of foreseeing, adapting, and optimizing with precision. This includes predictive maintenance, demand forecasting, and grid optimization. AI also plays a crucial role in the seamless integration and harnessing of renewable energy sources, offering sustainable solutions to meet growing energy needs (Satav, Lamani, K. G., et al., 2024; Venkateswaran et al., 2023). This chapter explores the multifaceted realm of AI-driven energy management, navigating its applications, challenges, and ethical considerations. It envisions a future where AI not only optimizes energy but also paves the way towards a sustainable, interconnected, and resilient energy ecosystem. The journey of AI in energy management is not just about innovation but also a testament to the synergy between human ingenuity and technological advancement (Z. Liu et al., 2022a).

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