Chapter 6
AI-Driven Semiconductor Optimization for Sustainable Smart Grids:
Enhancing Energy Efficiency and Resilience in Renewable Power Systems

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ABSTRACT

The integration of artificial intelligence (AI) and semiconductor technologies in smart grids is redefining energy efficiency, reliability, and sustainability in renewable power systems. As global electricity demand surges, AI-powered semiconductor systems are enabling real-time monitoring, predictive maintenance, and automated energy distribution. This chapter investigates how these technologies optimize grid resilience, fault detection, and demand-side management across diverse infrastructures. Adopting a mixed-method approach, including case studies and policy reviews,

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it illustrates the role of machine learning, edge computing, and smart sensors in enhancing energy storage and reducing carbon emissions. The findings underscore the potential of AI-optimized semiconductors to support net-zero energy goals. This research offers a strategic roadmap for stakeholders aiming to implement intelligent, sustainable, and adaptive smart grid solutions.

1. INTRODUCTION

Contextual Background: Global Shift to Renewables; The Emergence of Smart Grids as Critical Infrastructure

In recent decades, the global energy landscape has undergone a significant transformation driven by the urgent need to reduce greenhouse gas emissions and transition towards sustainable power systems. This shift is primarily fueled by the rapid deployment of renewable energy sources such as solar, wind, and hydropower. According to Chaturvedi et al. (2024), India alone has committed to achieving net-zero carbon emissions by 2070, reflecting a broader international effort aligned with the Paris Agreement and United Nations Sustainable Development Goals (SDGs). The increasing penetration of distributed renewable energy resources (DERs) necessitates a parallel evolution in grid architecture to accommodate variability, enhance reliability, and ensure real-time energy balance.

Traditional centralized power grids, which were designed for one-way electricity distribution, struggle to integrate intermittent and decentralized renewable sources efficiently. In this context, smart grids have emerged as a pivotal solution. A smart grid is an intelligent energy network that uses digital communication technologies, advanced sensors, and automation to monitor, predict, and optimize electricity flow in real time (Ghiasi et al., 2023). Smart grids represent a transformative model, enabling bi-directional energy flow, demand-side management, and real-time fault detection, thereby supporting the integration of renewables and storage systems.

Moreover, smart grids are fundamental to the concept of the "Internet of Energy," which envisions interconnected, data-driven, and self-regulating energy networks capable of dynamic adaptation (Ghiasi et al., 2023). As nations strive to meet decarbonization targets, the convergence of artificial intelligence (AI) and smart electronics within grid infrastructure is redefining operational efficiency and resilience (Cavus, 2025). AI-enabled systems enhance decision-making at the edge, while semiconductor-based sensors and intelligent controllers play a crucial role in achieving grid reliability and energy optimization (Arévalo & Jurado, 2024).

This dynamic interplay between AI, semiconductors, and smart grid technology has led to a growing body of research focused on how intelligent power systems can

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