

# Chapter 15

## Integrating AI– Optimized Smart Grids With Renewable Energy for Accelerated Net– Zero Transition

**Nikhil Jain**

*SmartThings, Inc., USA*

### **ABSTRACT**

*This chapter explores how artificial intelligence (AI) transforms smart grid design to support net-zero energy systems. Drawing from computing, civil, and electronics engineering, as well as energy policy and ethics, it combines literature synthesis with case and policy analysis. The chapter highlights AI's role in enabling predictive load management, renewable energy integration, real-time control, and decentralized energy trading. It also addresses algorithmic bias, data governance, and socio-technical challenges in developing regions. Key findings include a framework for AI-enabled infrastructure, digital twin applications, and a model for ethical, sustainable energy transfer. Ultimately, AI is shown not just as a tool, but as a driving force for adaptive, inclusive, and climate-resilient energy systems.*

### **INTRODUCTION: AI AND THE ENERGY TRANSITION IMPERATIVE**

Meetings between scientists, government officials and industry leaders now stand as a central challenge for the modern age because of the pressing need to reach zero

DOI: 10.4018/979-8-3373-3226-0.ch015

carbon emissions. Global institutions recognize the increasing level of urgency to repurpose energy systems radically because heat-induced climate change triggers more frequent extreme weather along with resource depletion and biodiversity collapse. The 2023 Synthesis Report from the Intergovernmental Panel on Climate Change (IPCC) states that reaching the 1.5°C warming target needs greenhouse gas emission reduction to 50% before 2030 followed by total carbon emissions elimination by 2050 (Change, 2023). The necessity emerges from scientific evidence and represents a critical timeline. The absence of these target achievements will trigger self-sustaining climate processes which endanger ecological frameworks together with social-economic frameworks.

According to the International Energy Agency (IEA) the global energy system needs to execute a radical rebuilding process if it wants to reach the 2050 net-zero target (Net, 2021). The transition needs immediate progress from fossil fuel reliance to renewable power systems featuring solar, wind, hydro and bioenergy technology together with improved energy network equipment and full conversion of energy utilization sectors and digitized electricity system optimization. The conventional energy infrastructure operates under severe limitations while trying to expand renewable energy deployment at a rapid pace. The energy infrastructure faces fundamental operational obstacles which stem from physical elements as well as systemic components of the energy system.

The existing power grid technology was built for unidirectional energy transmission from centralized power plants to final consumers yet it lacks enough adaptive capabilities to merge variable renewable energy sources (Gielen et al., 2019). The outdated design of power systems restricts clean energy system potential because renewable energy cannot be dispatched while being sensitive to both time and space variations. The transportation sector along with heating and industrial processes needs elevated amounts of electricity while the power grid operates under strain due to expanding energy requirements (Alova, 2020). The current grids experience reduced real-time adaptability because they lack smart capabilities and face aging infrastructure problems (Kirk, n.d.).

Artificial Intelligence stands as a critical solution which helps overcome present challenges to guide the shift toward zero-net emissions in the energy sector. The application of machine learning with deep learning and optimization algorithms along with data analytics mechanisms enables essential management of present-day power systems. AI technologies make possible the creation of load predictive algorithms alongside fault detection systems among other functionalities including DER intelligent management and user-driven grid responsiveness (Alahakoon & Yu, 2015). Neural networks combined with deep reinforcement learning help forecast energy consumption patterns and dispatch hybrid system operation at its optimal level (Maino et al., 2021). At the grid's edge, AI systems have been deployed to

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