


Chapter 5

AI and ML for Energy Management: Innovations and Challenges in a Sustainable Future

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ABSTRACT

The rising international energy consumption and the necessity of looking for environment-friendly solutions have necessitated the use of technology such as AI and ML for the energy management. This paper provides a state-of-art review of AI and ML in energy efficiency and microgrid systems, smart grid, and renewable energy systems, industries, and smart buildings. AI and ML enable predictive modeling, realtime optimization, advanced control methodologies that enhance the energy efficiency, operation cost and facilitate the integration of renewable energy systems. The paper outlines some of the important methodologies like reinforcement learning,

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deep learning and optimization algorithms in energy systems and their limitations like data quality, model interpretability and scalability. The results imply that the use of AI and ML systems is crucial in determining the direction of the future of energy management and ensuring the sustainability of the process.

1. INTRODUCTION

1.1 Overview of Global Energy Challenges and the Need for Optimization

The energy crisis is becoming a global concern due to the following factors. Global energy demand is on the increase as a result of the increasing population, increasing rate of urbanization and industrialization particularly in the developing world(Kumar et al 2018). This increase in demand puts a great deal of stress on the current energy systems which in turn, results in energy losses, wastage of energy and high dependence on fossil resources. Further, the increasing focus worldwide on renewable energy production solar, wind or hydropower sources – has made things more challenging. Although these energy sources are vital in the fight against climate change they are mobile and volatile, and thus provide difficulties in areas such as the stability and reliability of the grid. In addition, the shift of the global energy system to renewable energy sources requires more efficient technologies for energy storage that are still weak in capacity, efficiency, and affordability(Boopathi et al 2024). However, levels of energy intensity continue to be high in various sectors, enterprises, transport and residential sectors. Poor energy utilization leads to unutilized resource, extra expenditure, and avoidable effects on the environment. The increasing demand for efficient energy systems calls for advanced solutions that can solve these problems in large scale. The rational use of energy is not only important as a component of sustainable economic development but also one of the key drivers in the fight against climate change and the achievement of climate objectives.

1.2 Role of AI and ML in Addressing Energy Consumption and Efficiency

Modern technologies such as Artificial Intelligence (AI) and Machine Learning (ML) are now becoming significant solutions to these global energy challenges(Gaur et al 2024). Artificial Intelligence can be defined as the use of technology to solve problems that were formerly solved by human intelligence. AI is a broader concept which includes a subfield known as machine learning, which involves training a

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