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Role of Advanced Metering Infrastructure in Smart Grids Enabling Precise Data Analytics for Renewable Energy Optimization

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Abstract

This chapter explores the pivotal role of Advanced Metering Infrastructure (AMI) in optimizing energy consumption and promoting sustainability within modern smart grids. AMI, through its advanced data collection, real-time analytics, and secure communication systems, enhances energy management in both residential and industrial sectors. The integration of AMI enables precise monitoring, efficient load management, and consumer engagement, driving energy efficiency and cost reduction. By utilizing encryption and secure communication protocols, AMI ensures the protection of sensitive data while supporting the seamless exchange of information. Additionally, the chapter delves into the regulatory landscape governing consumer data privacy, balancing legal constraints with the need for data-driven decision-making. The application of AMI in enabling demand response programs, time-of-use pricing, and predictive analytics was also discussed, highlighting its impact on reducing energy waste and facilitating the adoption of renewable energy sources. Key topics include Smart Grids, Data Analytics, Energy Efficiency, Consumer Privacy, Demand Response, and Sustainability.

Keywords:

Advanced Metering Infrastructure, Smart Grids, Data Analytics, Energy Efficiency, Consumer Privacy, Sustainability.

Introduction

AMI was a critical component in the development of modern smart grids, enabling utilities to gather, analyze, and manage energy consumption data in real time [1,2]. AMI systems consist of smart meters, communication networks, and data management platforms that allow for the continuous monitoring of energy usage patterns across residential, commercial, and industrial sectors [3-6]. By providing precise and granular data on energy consumption, AMI facilitates more accurate billing, reduces operational inefficiencies, and enables utilities to implement demand response programs [7-9]. As energy systems evolve towards greater reliance on renewable sources, AMI serves as a fundamental tool for integrating intermittent energy sources, such as solar and wind, into the grid [10]. The deployment of AMI not only optimizes energy distribution but also fosters a more sustainable and resilient energy infrastructure [11].

One of the primary benefits of AMI was its ability to empower consumers to actively manage their energy consumption [12,13]. With access to real-time data on energy usage, consumers are able to make informed decisions about how and when to use electricity, resulting in significant energy savings [14]. This data can be accessed through in-home displays, mobile applications, or utility-provided platforms, offering users insights into their consumption habits and enabling them to adjust their behavior accordingly [15-17]. Time-of-use pricing, enabled by AMI, further incentivizes consumers to reduce energy consumption during peak demand hours, thus easing pressure on the grid and reducing costs [18]. The integration of smart devices, such as thermostats and lighting systems, into AMI networks allows for automated adjustments based on energy usage patterns, promoting further energy conservation [19]. This shift towards more active consumer participation was vital in building a culture of energy efficiency and sustainability [20].

In industrial settings, AMI systems provide significant opportunities for improving energy efficiency [21]. Manufacturing facilities, large commercial buildings, and other energy-intensive operations can use real-time consumption data to identify inefficiencies and optimize their processes [22]. By monitoring energy usage at a granular level, industries can pinpoint equipment or processes that consume excessive amounts of energy, allowing for targeted improvements [23]. Additionally, AMI systems facilitate predictive maintenance, helping to prevent equipment failures and minimize energy waste [24]. Through automated energy management systems (EMS), industries can adjust their operations to align with energy availability, shifting energy-intensive tasks to off-peak hours or adjusting processes to match renewable energy generation [25]. The use of AMI in industrial applications not only helps reduce operational costs but also contributes to broader environmental sustainability goals by minimizing the carbon footprint of energy-intensive industries.