

A Review of Smart Grid Technologies: Past, Present and Future Outlook

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Abstract

The rapid evolution of smart grid technologies has transformed the traditional energy landscape, ushering in an era of enhanced efficiency, reliability, and sustainability. This comprehensive review delves into the latest developments in smart grid technologies, analyzing their impact on modern power systems. The paper begins by outlining smart grids' fundamental principles and components, encompassing advanced metering infrastructure, communication networks, and intelligent control systems. It explores the integration of renewable energy sources and energy storage within smart grids, assessing their role in optimizing energy generation, distribution, and consumption and minimizing the downtime of Power Plants. Emphasis is placed on deploying machine learning algorithms and artificial intelligence in smart grid management, showcasing their ability to forecast demand, detect anomalies, and optimize grid operations in real-time. The real-time accurate monitoring of parameters with the help of smart technologies applied in the grid enhances the safety of manpower, and protection of the environment, assets, or equipment to prevent system damage. The inclusion of renewable energies in the system will cause complications due to its inconsistent generation that affects the balance of Voltage and Frequency in the grid, application of Smart Grid Technology can sense these imbalances faster to make adjustments before a cascading problem exists. Furthermore, the paper addresses the challenges associated with the widespread adoption of smart grid technologies, including cybersecurity risks, interoperability issues, and standardized protocols. It critically evaluates the economic and regulatory factors influencing the deployment of smart grids on a global scale, highlighting successful case studies and lessons learned from real-world implementations.

Keywords: Smart Grid Technologies, Renewable Energy, Electrical Grid Evolution, Energy Efficiency, Distributed Energy Resources