Federated Learning-Enabled Smart Solar Grid Optimization Using Transformer-Based Load Forecasting and Energy Management

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Abstract:
The increasing integration of distributed solar energy resources into smart grids necessitates advanced forecasting and energy management systems that are both privacy-preserving and highly adaptive. This paper introduces a novel Federated Learning-Enabled Smart Solar Grid Optimization framework that utilizes transformerbased architectures for accurate and context-aware load forecasting. Unlike conventional centralized models, the proposed system enables multiple energy nodes to collaboratively learn from local data without exposing sensitive information, thereby enhancing data privacy and system security. The use of transformer models, particularly those embedded with temporal attention mechanisms, allows the framework to effectively capture long-range dependencies in energy usage patterns and environmental conditions. Furthermore, an energy optimization layer is integrated to dynamically balance energy production, storage, and consumption based on predictive insights. Extensive experiments on real-world datasets demonstrate the superiority of our approach in terms of forecast accuracy, computational efficiency, and scalability. The proposed methodology holds significant potential for large-scale deployment in smart solar energy grids, paving the way for intelligent and resilient energy infrastructures.

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