

Predictive AI and Reinforcement Learning for Autonomous Microgrid Energy Management in Rural Areas

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Abstract

Rural microgrids incorporating solar, wind, and battery storage frequently rely on rigid, rule-based edge controllers for energy distribution. These static IF/THEN systems react only to immediate electrical states and fail to anticipate upcoming meteorological changes, leading to suboptimal energy routing and accelerated battery degradation. This paper proposes a novel machine learning architecture to replace conventional reactive logic with a predictive and autonomous energy management system. By extracting and merging historical minute-resolution telemetry logs from baseline microgrid hardware installed at Mysuru, India, with synchronized retroactive satellite weather data (e.g., NASA POWER), a comprehensive training dataset is established. A deep learning sequence model, utilizing architectures such as LSTM or Transformer, is developed to accurately forecast short-term renewable generation and local power demand. Simultaneously, a Reinforcement Learning (RL) agent, employing Proximal Policy Optimization (PPO), is trained in a custom virtual environment to act as an autonomous energy router. Deployed on a localized edge device (Raspberry Pi) communicating via an MQTT broker, the system dynamically optimizes power distribution in real-time through GPIO control signals. This predictive AI system aims to maximize renewable energy efficiency, offering a scalable blueprint for resilient off-grid rural communities.

Keywords: *autonomous microgrids; deep learning; energy management system (EMS); predictive AI; reinforcement learning; rural electrification*