College of Engineering
LAMAR UNIVERSITY

Renewable Energy Microgrid

Project Overview

The Renewable Energy Microgrid project required the development of a renewable energy microgrid system for locations that lack reliable access to primary power grids. The self-sustaining microgrid combines solar and wind energy sources with battery storage and inverter systems to deliver uninterrupted reliable power. The system verification process included MATLAB/Python simulations which demonstrated system performance under real-world environmental conditions and validated stability and fault tolerance.

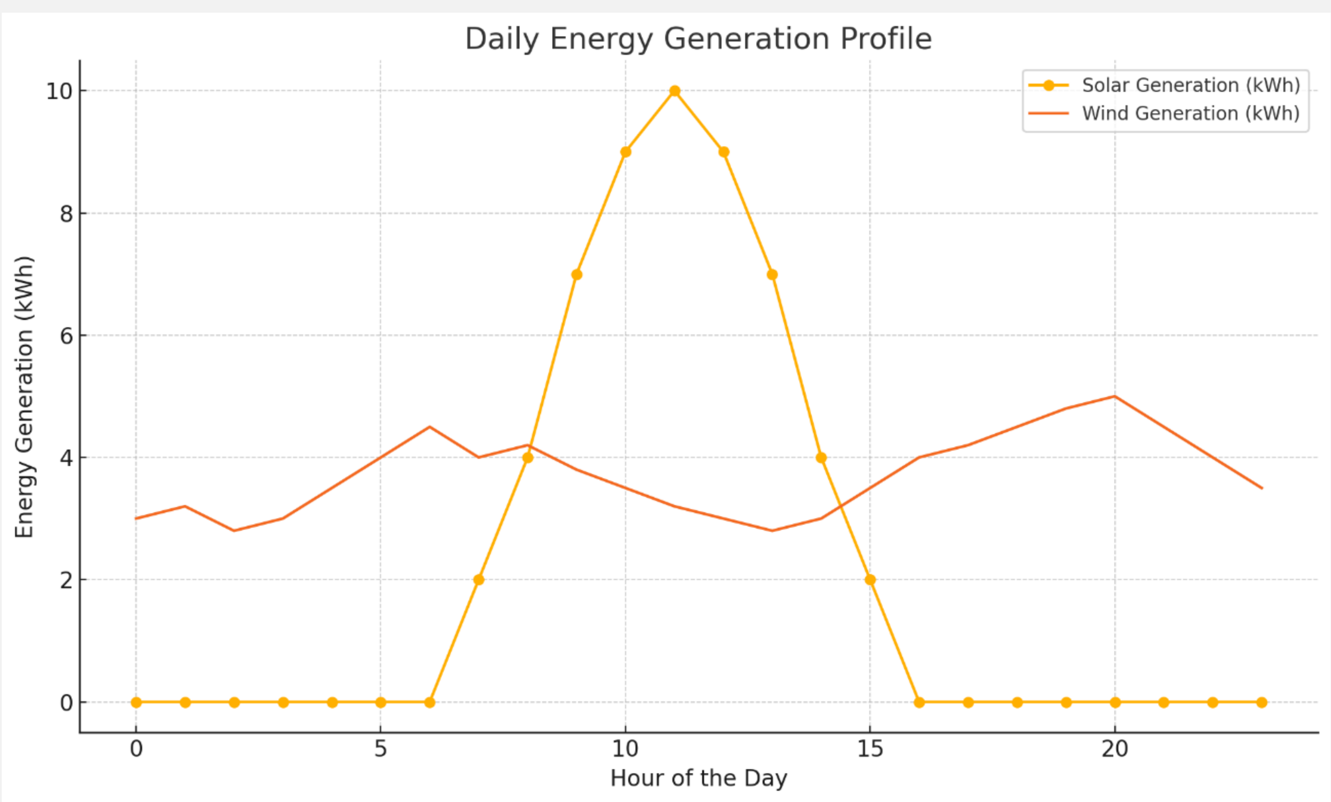
Renewable Sources & Battery Storage

Renewable Energy Generation:

- Solar Power: $P_{solar}(t) = Irradiance(t)\left[\frac{kW}{m^2}\right] \times PanelArea[m^2] \times Efficiency \times WeatherFactor(t)$. (Weather Factor: 07 cloudy, 1.0 clear)
- Wind Power: $P_{wind}(v) = k \times v^3$ $\left(k = 0.5\left[\frac{Mg}{m}\right]; v_{cut-in} = 3 - 4\frac{m}{s}; v_{cut-out} = 25\ m/s\right)$
- Battery Storage System: $SOC(t + \Delta t) = SOC(t) + \frac{P_{charge}(t)\eta_{charge} - P_{discharge}(t)/\eta_{discharge}}{Capacity_{battery}} \times \Delta t$
- Battery autonomy verified ≥ 12 hours under minimal renewable input conditions.

Result:

- Solar Efficiency: Achieved ≥ 18%
- Wind Output: Variable power confirmed within expected cut in and cut out controls.



Inverter and Load Management

Inverter Simulation:

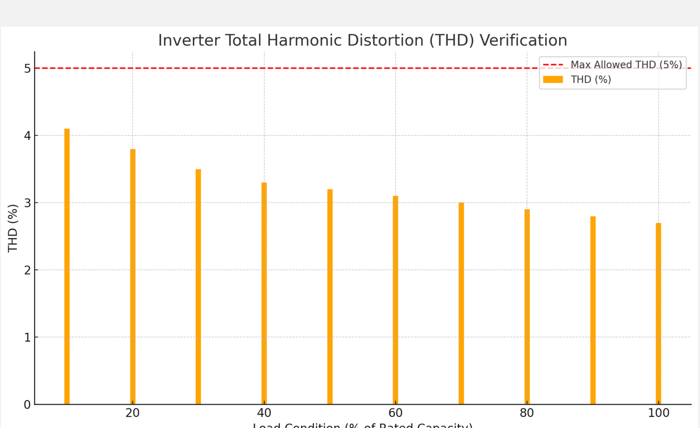
- Conversion from DC to AC: $P_{AC} = Efficiency \times P_{DC}$
- Efficiency: $\geq$ 95%, Total Harmonic Distortion (THD) below 5%.

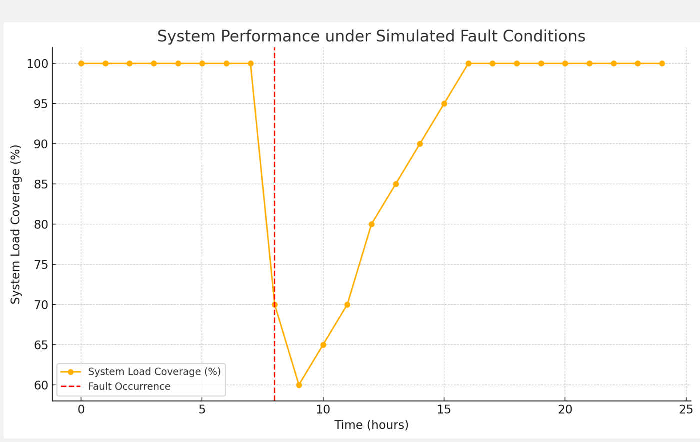
Load Management:

- Dynamically prioritizes critical load.
- Maintains Voltage stability under variable load conditions and fault scenarios.

Verification Results:

- Fault tolerance verified; maintained **≥60% load coverage** during inverter failure scenarios.
- Rapid fault recovery demonstrated (~7 hours).



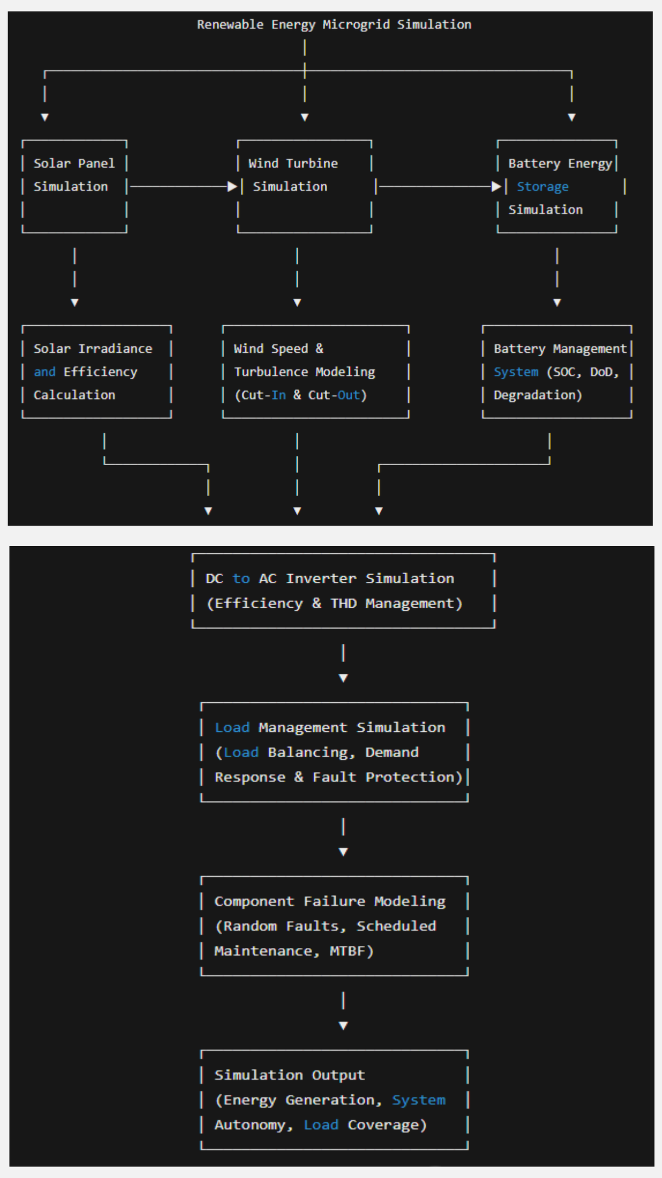


System Architecture and Functional Block Diagram

System Components:

- **Solar Panel & Wind Turbine Simulation:** Irradiance, Wind Speed, Temperature data.
- **Battery Storage System:** SOC tracking, Capacity fade modeling.
- **Inverter Simulation:** DC-AC conversion, efficiency, fault handing.
- **Load Management:** Critical/non-critical load prioritization, voltage stability.

Functional Block Diagram



Key Features & Benefits

Features	Benefits
Integrated Solar & Wind Sources	Continuous renewable power generation.
Advanced Battery Storage	Reliable power during low generation periods.
Fault-Tolerant Inverter System	Enhanced reliability and operational safety.
Dynamic Load Management	Optimal utilization of generated power.
Scalable Modular Design	Easy capacity upgrade to meet growing demand.

Verification Matrix Results

Design Input	Test Method	Result
Solar Efficiency ≥18%	Efficiency Tests	Pass
Battery Autonomy ≥12 hrs	Discharge Tests	Pass
Inverter THD <5%	Oscilloscope Tests	Pass
System Stability	Fault Simulations	Pass
Voltage Stability	Load Flow Tests	Pass

Economic Analysis

- **Estimated implementation cost significantly lower than grid extension.**
- **Projected energy coast savings:** ~20% annually compared to diesel generators.

Conclusion & Future Scope

Outcome:

A renewable microgrid simulation prototype effectively addressed the need for reliable electricity in remote areas by integrating renewable generation, battery storage, and advanced inverter control systems. The design ensures continuous power supply, improved reliability, reduced carbon footprint, and enhanced economic viability.

Major Challenges:

- Acquiring precise environmental data.
- Accurately simulating battery degradation and inverter faults.
- Balancing complexity with computational efficiency in simulations.

Future Scope:

- Real-world prototype validation.
- Incorporating advanced battery temperature modeling.
- Scaling to serve larger communities and exploring microgrid interconnections.

Lessons Learned & Skills Developed:

- Enhanced proficiency in Python/MATLAB.
- Deepened understanding of renewable systems and fault tolerance strategies.
- Valuable experience managing complex simulation projects independently.

Students & Faculty Advisors

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