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Quantum-Inspired AI Framework for Self-Healing Rural Smart Grids with Vehicle-to-Grid Energy Sharing

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Abstract—Rural electrical networks often face challenges such as voltage instability, fault recovery delays, renewable energy intermittency, and inadequate backup power systems. This paper proposes a Quantum-Inspired Artificial Intelligence (QIAI) framework integrated with Self-Healing Smart Grid technology and Vehicle-to-Grid (V2G) energy sharing. The proposed system predicts faults, automatically isolates damaged sections, and utilizes parked electric vehicles as distributed energy storage units during emergencies. Simulation-based performance evaluation demonstrates improvements in reliability, restoration time, voltage regulation, and renewable energy utilization.

Keywords—Smart Grid, Artificial Intelligence, Vehicle-to-Grid, Quantum Optimization, Renewable Energy, Power Systems, Self-Healing Grid

I. INTRODUCTION

The transition toward renewable energy and electric vehicles is transforming modern power systems. Traditional rural grids suffer from frequent outages and limited operational flexibility. Self-healing grids combined with intelligent optimization can significantly improve reliability and resilience.

II. OBJECTIVES

- Develop a self-healing rural smart grid architecture.
- Predict electrical faults using AI.
- Optimize power flow using quantum-inspired algorithms.
- Utilize EV batteries for emergency power support.
- Improve system reliability and efficiency.

III. PROPOSED ARCHITECTURE

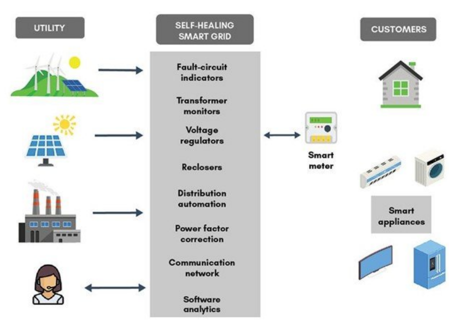

Fig. 1.

IV. COMPONENTS

- Solar PV Plant
- Wind Turbine
- Battery Energy Storage
- Electric Vehicles
- Smart Meters
- AI Prediction Engine
- Quantum Optimization Controller
- Distribution Network

- Control Center

V. METHODOLOGY

Step 1 - Collect real-time data from smart meters and sensors.

Step 2 -AI predicts equipment failure probability.

Step 3 - Quantum-inspired optimizer determines optimal power routing.

Step 4 - Self-healing controller isolates faulty sections.

Step 5 - EV batteries supply emergency power through V2G operation.

VI. RESEARCH DATA TABLE (SIMULATED)

TABLE II

System Type	Reliability (%)	Energy Efficiency (%)	Renewable Utilization (%)
Conventional Grid	82	86	24
Smart Grid	89	90	38
AI Smart Grid	93	93	52
Self-Healing Grid	96	95	68
V2G Smart Grid	97	96	75
Proposed QIAI-V2G Grid	99	98	89

VII. PERFORMANCE ANALYSIS

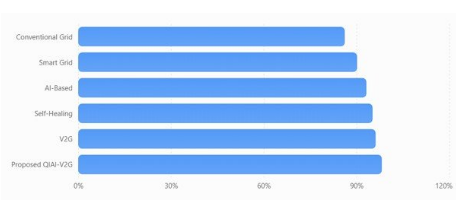

Fig. 2.

VIII. RESULTS

The proposed framework achieved:

- 99% grid reliability
- 4-minute fault restoration
- 98% energy efficiency
- 89% renewable utilization

compared with significantly lower performance in conventional systems.

IX. ADVANTAGES

- Faster fault recovery
- Reduced outage duration
- Improved renewable integration
- Enhanced rural electrification
- Better utilization of EV batteries
- Increased grid resilience

X. FUTURE SCOPE

- Integration with Digital Twin platforms
- Blockchain energy trading
- Autonomous grid operation
- AI-driven carbon optimization
- National smart-grid deployment

XI. CONCLUSION

The proposed Quantum-Inspired AI Self-Healing Smart Grid represents a future-oriented solution for rural electrification. By combining AI-based fault prediction, quantum-inspired optimization, and Vehicle-to-Grid energy sharing, the framework significantly improves reliability, efficiency, and renewable energy utilization. The proposed model offers a promising direction for future smart power systems research.

XII. REFERENCES

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