Escuela Superior Politécnica del Litoral

PARES o NONES Un break científico

Authors:
Manuel S. Alvarez-Alvarado
Maria J. Ramirez-Prado
Nabih Pico
Estrella Montero
Carlos D. Rodríguez-Gallegos
Washington Velasquez

corresponding author:
mansalva@espol.edu.ec

Quantum Computing for Power System Reliability Assessment with Distributed Energy Resources

PROBLEM IDENTIFICATION

Recent studies rely on classical simulations to assess power grid reliability. However, as distributed energy resources (DERs) increase grid complexity, these methods struggle with severe computational bottlenecks and oversimplify unpredictable renewable behaviours. To bridge this gap, clear problem identification is vital; pinpointing these limitations justifies a paradigm shift—such as using quantum computing to accurately capture the true dynamics of resilient, modern energy systems.

GENERAL OBJECTIVE

to develop a novel quantum computing methodology for assessing the reliability of power systems integrated with DERs. This approach aims to overcome the computational bottlenecks of classical methods, drastically reducing processing time while accurately capturing the dynamic behaviour of renewable energy. For more details see **Figure 1**.

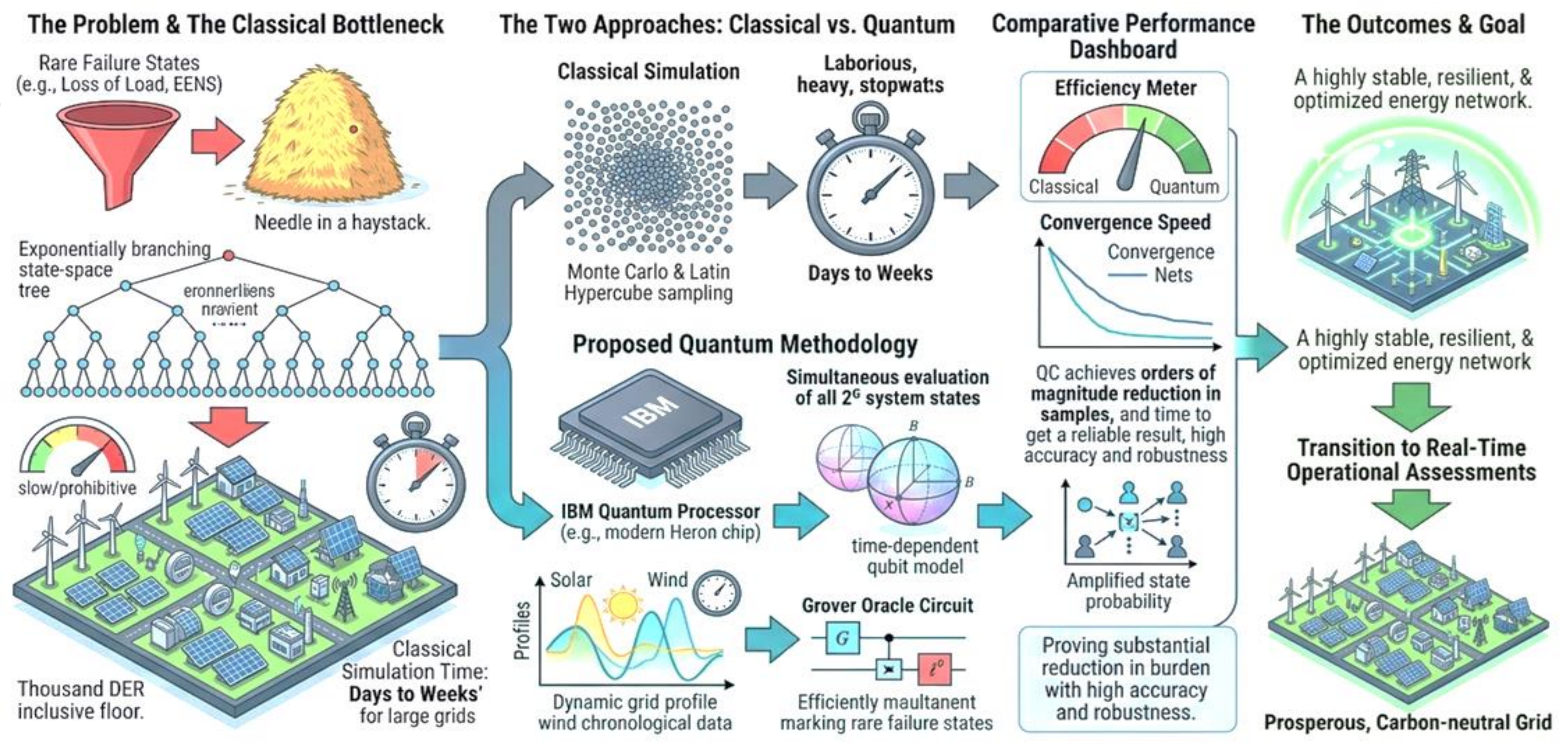

Figure 1 Research objective

PROPOSED APPROACH

As illustrated in **Figure 2**, the proposed hybrid approach begins with MATLAB processing input data into time-dependent rotational angles. Qiskit then uses these angles to generate a quantum superposition that represents all possible generation states. Finally, Quantum Amplitude Estimation (QAE) efficiently extracts the probability distributions to output the final reliability indices (LOLE, LOLP, EENS, and XLOL).

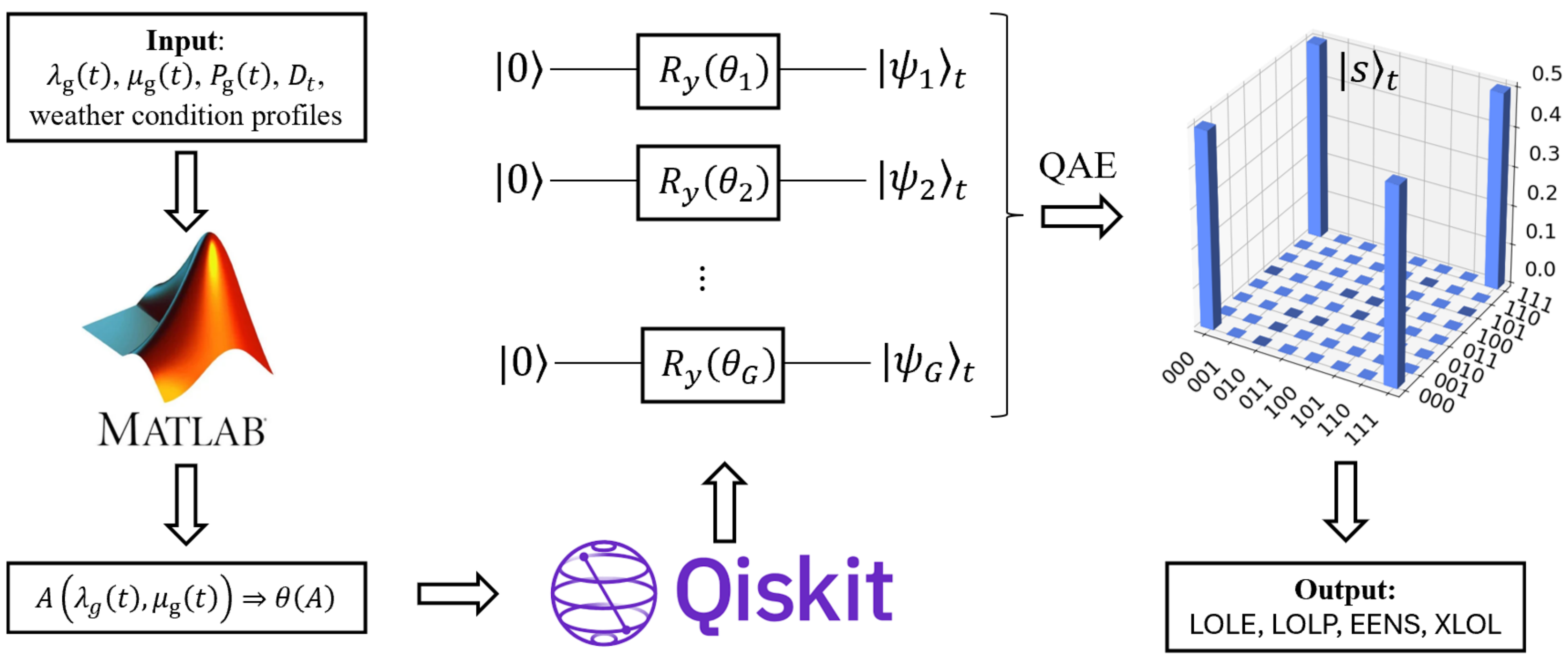

Figure 2 Quantum computing workflow and circuit implementation

RESULTS

- **Figure 3** shows the system used in this study. Two scenarios were considered: 1) no DERs; 2) with DERs installed. As shown in **Table 1**, integrating DERs significantly enhances overall grid reliability, i.e., Loss of Load Expectation (LOLE), Loss of Load Probability (LOLP), Expected Energy Not Supplied (EENS) and Expected Loss of Load (XLOL). By adding DERs to the system, there is a substantial drop in both the frequency of power outages and the total volume of unmet energy demand. While the average severity of individual outages remains stable, this overall reduction in expected shortfalls proves that DER integration is a highly effective strategy for building resilient power networks.

- To validate the results and show the efficacy of the proposed approach, Monte Carlo (MC), Latin Hypercube (LH) and QC with 3.5 million experiments (or shots for the case of QC) are tested through reliability assessment with CPT for SCADA. The metrics to measure the computational efficiency in terms of accuracy, precision, convergence, and time simulation. The normalized results are illustrated in **Figure 4**, providing a clear and comparative visualization of the effectiveness of each employed technique.

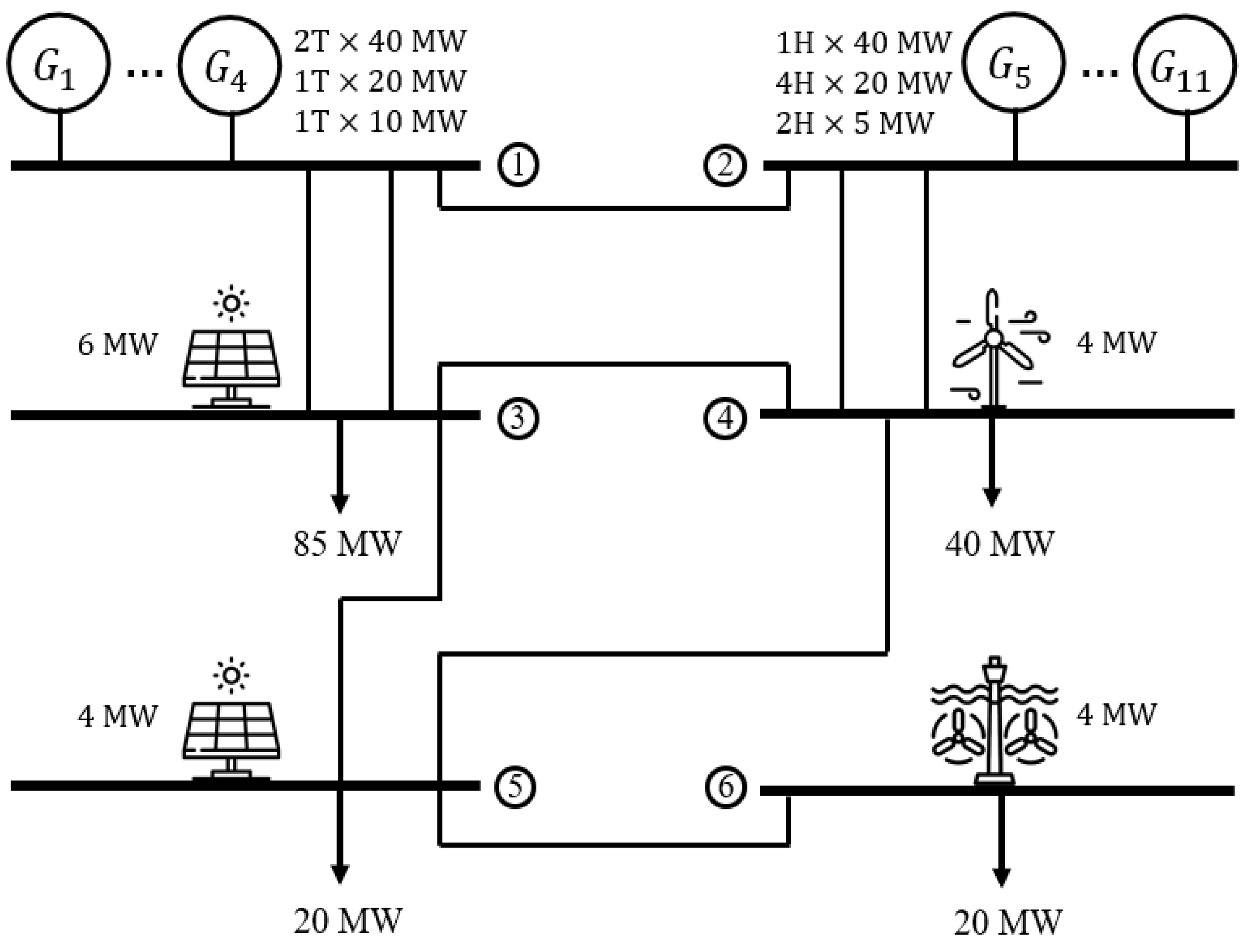

Figure 3 Power system used in the research

Table 1 Reliability Indices

Index	LOLE [h/yr]	LOLP [%]	ENNS [MWh/yr]	XLOL [MWh]
No DERs	24.4	0.28	307.6	12.6
DERs	15.1	0.17	185.5	12.3

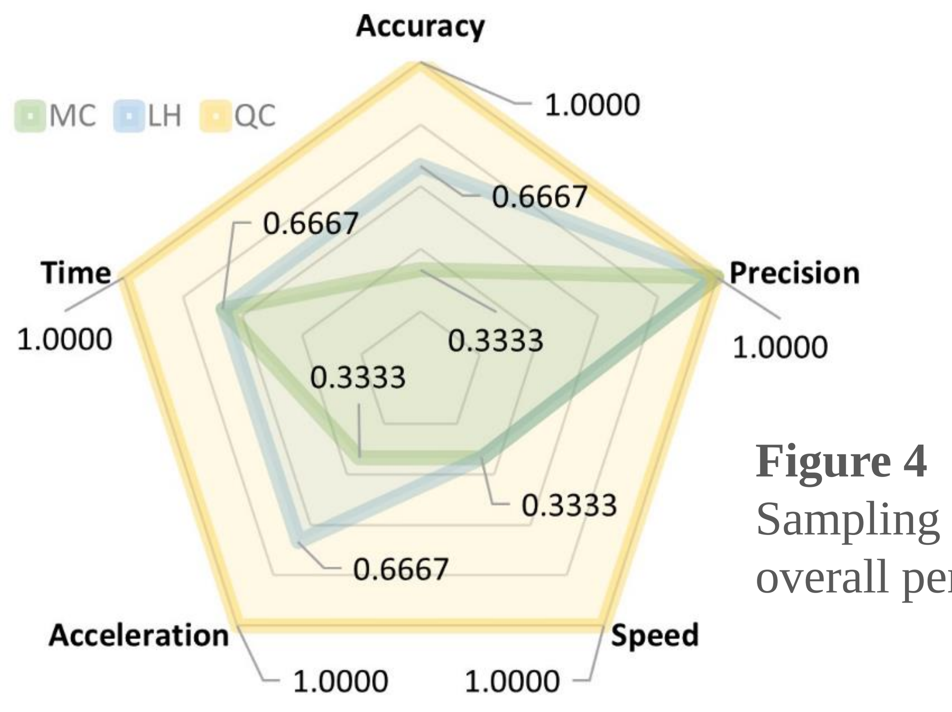

Figure 4 Sampling techniques overall performance

CONCLUSIONS

- **Quantum Superiority:** The novel time-dependent qubit framework successfully captures renewable energy dynamics and drastically outperforms classical methods in speed and accuracy, validated on real IBM hardware.

- **Real-Time Scalability:** By eliminating classical computational bottlenecks, this methodology enables near real-time grid evaluations and lays the groundwork for advanced, large-scale energy network management.

ACKNOWLEDGEMENT

- This study was financially supported by the Decanato de Investigación from the Escuela Superior Politécnica del Litoral (ESPOL).

PUBLISHED PAPER

- This research was submitted on the Electric Power Systems Research (Elsevier). For more details about the research, do not hesitate to write to the email mansalva@espol.edu.ec