

REVIEWER'S REPORT

Manuscript No.: IJAR-59351

Title: Digital Twin-Based Smart Grid Management Framework for Sustainable Power Infrastructure Development in Saudi Arabia

Recommendation:

Accept

Rating	Excel.	Good	Fair	Poor
Originality	Yes			
Techn. Quality		Yes		
Clarity	Yes			
Significance		Yes		

Reviewer's ID: JPR- 015

Detailed Reviewer's Report

Reviewer's Comment for Publication.

Acceptance Comment are mentioned below suitable for the paper titled "Digital Twin-Based Smart Grid Management Framework for Sustainable Power Infrastructure Development in Saudi Arabia "

Reviewer Comments: Accept

Reviewer Comments –

1. Introduction

The introduction clearly establishes the transformation of Saudi Arabia's power sector from a hydrocarbon-dominated system toward a diversified and digitally enabled energy infrastructure. It effectively identifies the limitations of conventional grid expansion in addressing monitoring, prediction, coordination, and lifecycle management requirements. The motivation for adopting Digital Twin technology is clearly articulated. The Saudi Arabian context provides strong practical relevance to the study. The research problem and intended contribution are sufficiently established. Overall, the introduction provides an appropriate foundation for the manuscript.

2. Literature Review

The literature review demonstrates broad and relevant coverage of recent research published between 2020 and 2025. It appropriately integrates Digital Twin architecture with smart-grid operation, renewable energy integration, microgrids, edge intelligence, cybersecurity, and asset management. The distinction between monitoring replicas and operational twins is particularly useful and conceptually meaningful. The review successfully identifies important technical and governance requirements for effective Digital Twin implementation. The connection between international literature and Saudi Arabia's energy-

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transition context is well established. Overall, the literature review is comprehensive and supports the proposed framework effectively.

3. Solution Approach

The proposed six-layer Saudi Digital Twin Smart Grid Management Framework is the major strength of the manuscript. The framework logically connects physical assets, sensing and edge systems, interoperable data services, hybrid grid models, decision intelligence, and governed control. The approach goes beyond a purely visual representation of infrastructure and appropriately emphasizes synchronization, forecasting, scenario analysis, uncertainty validation, cybersecurity, and controlled feedback. The proposed implementation pathway from limited operational twins toward regional federation is practical and logically structured. The framework has both conceptual and managerial relevance for sustainable power infrastructure development. The solution approach is therefore considered appropriate and sufficiently robust.

4. Results and Discussion

The results and discussion effectively synthesize the reviewed evidence and demonstrate the potential contribution of Digital Twins to grid reliability, renewable-energy hosting capacity, asset optimization, and sustainability. The manuscript appropriately emphasizes that Digital Twin value depends on reliable data-model alignment rather than visual sophistication alone. The discussion of uncertainty management, cybersecurity, bidirectional interfaces, and institutional governance adds considerable depth to the analysis. The Saudi-specific implications are clearly connected with the broader energy transition. The proposed implementation stages provide useful practical guidance for utilities and infrastructure stakeholders. Overall, the discussion provides a balanced and meaningful interpretation of the study's findings.

5. Conclusion

The conclusion appropriately summarizes the central argument that Digital Twin technology can significantly support sustainable and resilient power infrastructure when supported by robust technical and institutional capabilities. It reinforces the importance of data governance, cybersecurity, model validation, uncertainty management, and organizational readiness. The conclusion is consistent with the proposed framework and the evidence synthesized throughout the manuscript. It also provides a clear pathway for progressive implementation within Saudi Arabia's evolving energy ecosystem. The study offers useful implications for policymakers, utilities, technology providers, and researchers. Overall, the conclusion effectively captures the academic and practical contributions of the manuscript.