RENEWABLE ENERGY INTEGRATION IN ELECTRICAL POWER NETWORKS: AN ANALYTICAL STUDY OF MODERN GRID PERFORMANCE

Graduation Project Report

Submitted in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical Engineering at the faculty of Engineering, Al-Baha University

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Graduation Project

Submitted to

Electrical Engineering Department

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ABSTRACT

About 250 words maximum. The abstract is a brief statement of the problem, methodology, findings, and conclusions of the project. In other words, it should describe the key challenges or problems, the methodology and approach used, and the major findings or outcomes. The type of font used (Times New Roman 12).

ملخص الدراسة

بما لا يتجاوز 250 كلمة. يُعد الملخص بيانًا موجزًا لمشكلة المشروع، ومنهجيته، ونتائجه، واستنتاجاته. وبعبارة أخرى، يجب أن يصف التحديات أو المشكلات الرئيسة، والمنهجية والأسلوب المستخدمين، إضافة إلى أبرز النتائج أو المخرجات المتحصّل عليها. نوع الخط المستخدم فهو **Times New Roman بحجم 14**.

ACKNOWLEDGEMENT

Even though they are optional, acknowledgments are a polite method for authors to thank those who have given them advice, support, or special assistance. This includes academic advisors, family members, colleagues, and friends. The heading ACKNOWLEDGEMENTS is typed in capital letters without punctuation, centered between the margins, leaving a two-inch top margin. The type of font used (Times New Roman 12).

STATEMENT

This is confirmation that the project is original work. All the analysis, design and system have been accomplished by the project members and it has not been submitted to any other college and university. All the students must sign the undertaking page. The heading STATEMENT is typed in capital letters without punctuation, centered between the margins, leaving a two-inch top margin. The type of font used (Times New Roman 12).

TABLE OF CONTENTS

LIST OF FIGURES

Figures must be prepared as following:

- Figures can include any type of illustration, including photos, graphs, diagrams, and maps.
- Each figure must have a figure caption that is specifically and alone titled.
- After the initial mention of the figure, present it accurately and the figure caption must be below the figure.

LIST OF TABLES

Tables must be prepared as following:

- The table titles should be accurately reflected in the content of the table.
- The information in the table should be presented in a way that makes the textual description clear.
- The table's title is located above the table.

LIST OF ABBREVIATIONS

RES	**Renewable Energy Sources**
MCU	**Master Control Unit**
PWM	**Pulse Width Modulation**
UHV	**Ultra-High Voltage**

CHAPTER 1: INTRODUCTION

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

1.1 Background of Study

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

1.2 Importance of Renewable Energy in Modern Power Systems

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

1.3 Problem Statement

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project

examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

1.4 Project Objectives

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

1.5 Scope and Limitations

Figure 1.1 shows …… - The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

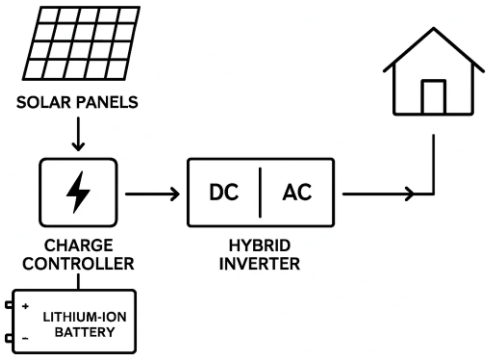

Figure 1.1: Example of figure (....., according to [1])

CHAPTER 2: LITERATURE REVIEW

This chapter provides a comprehensive review of previous research related to renewable energy integration. It highlights the evolution of renewable technologies, their impact on power system dynamics, and the challenges associated with their intermittent nature. The review also identifies gaps in existing studies that this project aims to address

2.1 Overview of Renewable Energy Technologies

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

2.2 Impact of Renewable Energy on Grid Stability

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

2.3 Comparative Study: Control Techniques for Renewable Integration

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance as shown in Table 2.1.

Table 2.1: Example of Table as shown below the table Title

Power Stations	Average Power Output

2.4 Review of Related Studies

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

CHAPTER 3: METHODOLOGY

This chapter outlines the systematic approach adopted to conduct the study. It describes modeling techniques, simulation tools, data sources, and evaluation criteria used to analyze the performance of renewable-integrated power networks.

3.1 System Modeling and Network Design

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance. as shown in Eq. 3.1.

$$P = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} + XM \cos\theta + 2\pi f L\, ABC \qquad \textbf{Eq. 3.1}$$

Where P is active power, θ is impedance angle, f is the power frequency, and L is the inductance of transmission lines.

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3.2 Renewable Energy Source Modeling

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other

renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

3.3 Simulation Tools and Software (e.g., MATLAB/Simulink, DIgSILENT PowerFactory)

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

3.4 Operational Scenarios and Test Cases

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

3.5 Performance Metrics and Evaluation Criteria

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

CHAPTER 4: RESULTS

This chapter presents the outcomes of the simulations and analyses. It evaluates the behavior of the power system under various renewable penetration levels and discusses the implications of the findings on grid performance.

4.1 Baseline System Performance

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

4.2 Impact of Solar Energy Integration

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

4.3 Impact of Wind Energy Integration

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4.4 Comparative Analysis of Scenarios

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

4.5 Discussion of Results

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

CHAPTER 5: CONCLUSION AND FUTURE DIRECTIONS

This chapter summarizes the key findings of the project and reflects on the extent to which the objectives were achieved. It also provides recommendations for future research and practical improvements in renewable energy integration strategies.

7.1 Summary of Findings

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

7.2 Key Conclusions

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

7.1 Recommendations for Future Work

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce

carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

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[1] Author, “Title of Article,” Journal Name, vol. X, no. X, pp. XX–XX, Year.

[2] B. Author and C. Author, Title of Book. Publisher, Year.

[3] D. Author, “Title of Conference Paper,” in Proceedings of the Conference Name, Year, pp. XX–XX.

[4] International Energy Agency, “Renewables 2023,” IEA, 2023.

APPENDIX

This section may support students' need to attach secondary material like source code, user manual, or other relevant information not suitable in the body of the report. Secondary materials which are of the same nature should be gathered under the same appendix heading. For example, students may need to have one appendix for all secondary source codes, one appendix for all secondary forms … etc. The students should use a capital letter numbering style for the appendices, i.e. A, B, C …, as used in writing this document.

APPENDIX A

1.6 TITLE OF APPENDIX A

The global transition toward sustainable energy has accelerated the adoption of renewable energy sources within electrical power networks. As countries seek to reduce carbon emissions and enhance energy security, integrating solar, wind, and other renewable technologies into existing grids has become a strategic priority. This project examines the technical, operational, and economic implications of renewable energy integration, with a focus on grid stability, reliability, and performance.

APPENDIX B

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