



FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING.

FINAL YEAR PROJECT REPORT

**ASSESSING THE IMPACT OF DISTRIBUTING LARGE GRID-TIED PV SYSTEMS ON
NETWORK LOSSES. A case study on the Tororo-Busia 33kv feeder and Busitema solar
plant.**

BY

WAMUTTU EMMANUEL

REG NO: BU/UP/2021/1364

TEL: 256778722316

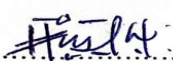
EMAIL: wamuttuemmanuel8@gmail.com

*A final year project report submitted to the Department of Electrical Engineering in partial
fulfilment of the requirements for the award of a Bachelor's Degree of Science in Electrical
Engineering from Busitema University*

MAY 2025

DECLARATION

I, WAMUTTU EMMANUEL, hereby declare that this project report is my original work except where explicit citation has been made and has never been published and/or submitted for any other degree award to any other university or institution of higher learning for any academic award.

Sign: 

Date: 30th May, 2025

APPROVAL

This is to certify that this project report has been compiled by WAMUTTU EMMANUEL Registration Number **BU/UP/2021/1364** under the supervision and guidance of the University supervisors. It is now ready for submission to the Department of Electrical Engineering.

SUPERVISORS

ENG. BUTIME ERIC

Signature 

Date: 28th May, 2025

MR. MBABAALI FRANK

Signature: 

Date: 27th May, 2025

ACKNOWLEDGEMENT

I have taken efforts in this project report. However, it would not have been possible without the kind support and help of many individuals and Staff of Busitema University Electrical engineering department. I would like to extend my sincere thanks to all of them especially Eng. Butime Eric, Eng. Frank Mbabaali, Eng. Jensen Nduhuura and Eng. Kilama George for their continuous and unceasing guidance and support towards the completion of this project.

I take this great opportunity in a special way to thank my beloved parents for financial support and encouragement and above all, I thank Almighty God for the His provision.

DEDICATION

I dedicate all my efforts and hard work towards the implementation of this final year research project towards my loving father MR. KHAUKA GEORGE MOSES WAMUTTU who not only provided tuition and upkeep for all the four years but also all the costs that were incurred during the implementation of the project.

May the almighty God bless him abundantly.

TABLE OF CONTENTS

DECLARATION.....	i
APPROVAL.....	ii
ACKNOLEDGEMENT.....	iii
DEDICATION	iv
TABLE OF CONTENTS.....	v
LIST OF FIGURES	viii
LIST OF TABLES	ix
LIST OF ABBREVIATIONS.....	x
ABSTRACT.....	xi
1.0 CHAPTER ONE: INTRODUCTION.....	1
1.1 INTRODUCTION	1
1.2 BACKGROUND	1
1.3 Problem statement.....	3
1.4 OBJECTIVES.....	3
1.4.1 Main Objective.....	3
1.4.2 Specific Objectives	4
1.5 Significance.....	4
1.6 Justification.....	4
1.7 RESEARCH SCOPE	5
1.7.1 Geographical scope.....	5
1.7.2 Time scope	5
1.7.3 Theoretical coverage	5
1.8 CONCEPTUAL FRAMEWORK	5
2.0 CHAPTER TWO; LITERATURE REVIEW.....	6
2.1 Renewable energy sources	6
2.2 Understanding network losses	7
2.3 Effect of transmission distance on the I^2R losses.....	7
2.3.1 Resistance	7
2.3.2 Effect on the I^2R losses	8
2.4 Solar Power Intermittency	8
2.4.1 Sources of solar intermittency.....	9
2.4.2 Effects of Solar Power Intermittency on Network Losses	10

2.4.3 Okta.....	10
2.5 Residential density	11
2.6 Busitema Solar Power Plant Technical Documentation.....	12
2.6.1 Introduction.....	12
2.6.2 Technical Specifications.....	12
2.6.3 Monitoring and Control	13
2.7 The Tororo-Busia 33 kv feeder	13
2.8 Load flow analysis	13
2.8.1 DigSILENT PowerFactory.....	13
2.8.2 Genetic Algorithm (GA)	13
3.0 CHAPTER THREE: METHODOLOGY	15
Quasi-experimental/simulation:	15
Experimental:	15
3.1 RESEARCH APPROACHES.....	15
3.2 GEOGRAPHICAL AREA OF STUDY.	15
3.3 DATA COLLECTION METHODS.	15
3.3.1 Literature Review.....	15
3.3.2 Surveys.....	16
3.3.3 Field Measurements and Data Acquisition	16
3.3.4 Simulation.....	17
3.3.5 Interviews.....	17
3.4 Graphing	17
3.5 Data quality control.....	18
3.7 Measurements to be used	19
3.6 System design	19
3.7 SUMMARY OF THE METHODOLOGY	20
4.0 CHAPTER 4; RESULTS AND DISCUSSION	22
4.1 AVERAGE LOAD PROFILE ON THE TORORO-BUSIA 33KV LINE.	22
4.1.1 Relevance to the Research Project.	24
4.2 SOLAR IRRADIANCE LEVELS AT THE PLANT (RESULTS 1)	24
4.3 SOLAR PRODUCTION AT BUSITEMA SOLAR PLANT. (RESULTS 1).....	26
4.4 LOSSES ASSOCIATED WITH THE AVERAGE LOAD PROFILE ON THE TORORO-BUSIA 33KV LINE WIT AND WITHOUT BUSITEMA SOLAR PLANT. (RESULT 2)	27

4.5 CONNECTING BUSITEMA SOLAR PLANT TO THE TORORO BUSIA 33KV LINE.	30
4.6 DISTRIBUTING THE SOLAR POWER GENERATION (REFERENCE TO NETMETERING) (RESULT 3)	32
4.7 FINANCIAL ANALYSIS (RESULT 4).....	34
5.0 CHAPTER FIVE; CONCLUSIONS AND RECOMMENDATIONS	36
5.1 CONCLUSIONS.....	36
5.2 CHALLENGES FACED.....	36
5.3 LIMITATIONS OF THE DATA OBTAINED.....	36
5.4 RECOMMENDATIONS	36
REFERENCE LIST AND APPENDICES	38
Works Cited	38
APPENDICES	40

LIST OF FIGURES

Figure 1 Conceptual Framework.....	5
Figure 2 Time of day when solar panels are most efficient	9
Figure 3 Cloud cover	11
Figure 4 Flow chart for genetic algorithm	14
Figure 5 Graph for the average load profile on the tororo-busia 33kv line.	23
Figure 6 Graph for the irradiance levels on the two different days.....	25
Figure 7 Graph for Solar power production at the plant	27
Figure 8 Design of the Busia 33kV line and the point of connection of Busitema Solar Plant (4MW)	30
Figure 9 Graph for the losses before and after connecting Busitema Solar plant.....	31
Figure 10 Graph for the percentage loss reductions through the day	32
Figure 11 Graph showing the losses with, without and after distribution of Busitema solar plant.....	33
Figure 12 Solar irradiation data being obtained from the plant	40
Figure 13 Obtaining power production data using the optical eye	41
Figure 14 Busitema solar Plant	42
Figure 15 A gantt showing all the activities done	42

LIST OF TABLES

Table 1 How Oktas are categorized	11
Table 2 Residential Denstities	12
Table 3 Summary of the methodology	20
Table 4 Average load profile on the tororo-busia 33kv line.	22
Table 5 Solar irradiance levels at the solar plant.....	25
Table 6 Solar power production at the plant	27
Table 7 Resistivity for different metals at 20 ⁰ C	28
Table 8 Losses associated with the average load profile on the tororo-busia 33kv line wit and without busitema solar plant.	29
Table 9 Loss reductions after connecting the plant.....	31
Table 10 Power saved and financial saving due to loss reductions from distributing Busitema Solar plant	34

LIST OF ABBREVIATIONS.

- DigSILENT: Design Intelligent Grid Simulation Integrated Laboratory Engineering Network Technology
- AC: Alternating Current
- DC: Direct Current
- PCU: Power Conditioning Unit
- ECP: Electricity Connection Policy
- MTU: Master Terminal Unit
- UEDCL: Uganda Electricity Distribution Company Limited
- ERA: Electricity Regulatory Authority
- RES: Renewable Energy sources
- KRECS: Kyegegwa Rural Electricity Co-operative Society
- A: Amperes (current)
- V: Volts (voltage)
- REA: Rural Electrification Agency
- PV: Photo-Voltaic
- NDP III: Third National Development Plan
- KIL: Kilembe Infrastructure Limited
- MW: Mega Watts
- KW: Kilo Watts
- UETCL: Uganda Electricity Transmission Company Limited
- I2R: I- Current, R- Resistance
- SCADA: Supervisory Control and Data Acquisition
- RTU: Remote Terminal Unit
- p.a: per annum
- GOU: Government Of Uganda
- MBE: Mean Bias Error
- RMSE: Root Mean Square Error.

ABSTRACT

Various large solar plants have been connected to the grid in the recent years for example the Busitema Solar Plant (4MW), Tororo North solar Plant (10MW) among others with a co-joint role of minimizing losses on transmission lines through distributed generation, hence a reduction in the transmission distance. However, the losses remain significant due to some of the areas distributed to being at a considerable distance from the plant hence a longer transmission distance resulting into higher resistances.

This study aims at how distributing the large grid-tied PV systems will help to minimize the losses further using a case-study of Busitema Solar Plant (4MW) and the Tororo-Busia 33KV feeder.

The study consists of five chapters. Chapter One introduces us to the study, stating and providing a viable explanation for the existing problem, the main objective, specific objectives, research questions, the scope of the study, background, and justification of the study.

Chapter two consists of the literature review with detailed explanations for the literature on network losses, how distributing large grid-tied PV systems helps to reduce losses on transmission and distribution lines by minimizing the I²R losses on the lines. This chapter also describes several factors behind the study which were majorly the increasing technical energy losses (around 16.4% p.a) despite several loss reduction methods available, which would not correlate with the increasing energy demand of Uganda's population and the strategies of GOU to increase electricity access to about 60% by 2040. With the distribution of large grid-tied PV systems, the technical losses would be greatly reduced and the electrical power utilized would have increased.

This chapter also presents the conceptual framework, which shows the inputs into the project to obtain a given set of results.

An extract of the ERA net metering regulations which guide us on the eligibility requirements for the license of net metering in Uganda are also presented, limitations, and the maximum amount of power a prosumer can generate.

Chapter three is the methodology which contains detailed explanations of the research design, research approaches, geographical area of study, measurements, data collection methods, and data analysis among others. This included the use of various data collection techniques such as literature review, surveying, and interviews among others. The research was majorly of a quantitative approach using quasi-experimental/simulation as well as experimental designs to come up with the data.

Surveys were conducted on the Tororo-Busia 33kv line to determine the number and size of the components on the line including the transformers, buses/nodes, switches and circuit breakers, generators, loads,

capacitors, and reactors among others, and then a solar net-metering scheme was carried out using DIGISILENT software to assess the network losses and hence its benefits in a distribution network.

Chapter four consists of the results and discussions of the study. And conclusions which shown that the losses decreased further on distributing large grid-tied Busitema Solar Plant (4MW) along the feeder are presented in chapter five together with the recommendations which were advocating for net metering on a large scale, improved monitoring systems due to changing production levels and leveraging the private sector dealing in Renewable energy. That way more power will be available for utilization by the ever-increasing population in Uganda.

REFERENCE LIST AND APPENDICES

Works Cited

- [1] "Uganda: Power Struggles - Uganda's Uneven Electricity Distribution - allAfrica.com." Accessed: Jan. 16, 2025. [Online]. Available: <https://allafrica.com/stories/202406060045.html>.
- [2] "UGANDA: NEW DEVELOPMENTS IN ELECTRICITY AMENDMENT ACT,," 2023.
- [3] "OFF-GRID SOLAR ENERGY MARKET," 2022, Accessed: Jan. 16, 2025. [Online]. Available: www.statista.com/statistics/447758/gross-domestic-product-gdp-growth-rate-in-uganda/.www.ubos.org/wp-content/uploads/publications/11_2020STATISTICAL__ABSTRACT_2020.pdf".
- [4] F. U. Z. R. A. R. R. S. a. G. A. H. H. Zahid, "Critical Analysis and Application of Net-Metering Practice in MEPCO," International Journal of Photoenergy, vol. 2020, no. 1, p. 4135860, Jan. 2020, doi: 10.1155/2020/4135860."
- [5] ERA, "ELECTRICITY REGULATORY AUTHORITY ANNUAL REPORT-2023".
- [6] "T H E REPUBLIC OF UGANDA THE ELECTRICITY."
- [7] G. BOYLE, RENEWABLE ENERGY: POWER FOR A SUSTAINABLE FUTURE, 1996.
- [8] "What are Losses? - SP Energy Networks." Accessed: Nov. 24, 2024. [Online]. Available: https://www.spenergynetworks.co.uk/pages/what_are_losses.aspx".
- [9] "Non-Technical Losses - SP Energy Networks." Accessed: Nov. 24, 2024. [Online]. Available: https://www.spenergynetworks.co.uk/pages/non_technical_losses.aspx".
- [10] "'Technical Losses - SP Energy Networks." Accessed: Nov. 24, 2024. [Online]. Available: https://www.spenergynetworks.co.uk/pages/technical_losses.aspx".
- [11] F. U. Z. R. A. R. R. S. a. G. A. H. H. Zahid, "Critical Analysis and Application of Net-Metering Practice in MEPCO,International Journal of Photoenergy, vol. 2020, 2020, doi: 10.1155/2020/4135860."
- [12] "What time of day are solar panels most efficient - Tongwei Co., Ltd.,," Accessed: Nov. 24, 2024. [Online]. Available: <https://en.tongwei.com.cn/news/99.html>".
- [13] "S. Shedd et al., "To be presented at the 2nd Annual International Workshop on Integration of Solar Power into Power Systems Conference Lisbon," 2012. [Online]. Available: <http://www.osti.gov/bridge>".
- [14] M. S. F. a. H. A. D. S. Hasan, "Impact of Cloud, Rain, Humidity, and Wind Velocity on PV Panel Performance," *Wasit journal of Engineering Sciences*, vol. 10, pp. 34-43, 2022.

- [15] "Okta - Wikipedia." Accessed: Jan. 08, 2025. [Online]. Available: <https://en.wikipedia.org/wiki/Okta>".
- [16] "What Is Density? | Planetizen Planopedia." Accessed: Jan. 08, 2025. [Online]. Available: <https://www.planetizen.com/definition/density>".
- [17] "Density - Physical Planning Division." Accessed: Jan. 08, 2025. [Online]. Available: <https://physicalplanning.gov.dm/requirements/planning-and-building-guide/density>".
- [18] "DigSilent manual -<https://www.digsilent.de>".
- [19] A. Sawwas, "Optimal placement and sizing of photovoltaics and battery storage in distribution networks," feb 2019.
- [20] C. W. R. Markets, "Optimal Scheduling Strategies of Distributed Energy Storage Aggregator in Energy and Reserve Markets Considering Wind Power Uncertainties," pp. 1-17, 2019.
- [21] L. M. R. I. M. Dewantara, "Optimal placement and sizing of photovolataics and battery energy systems".
- [22] "S. Chandra VEGUNTA Steve STAPLETON Paul JEWELL and D. HAWKINS Rodney BROOK, "Impact on network losses of shorter low-voltage feeders and higher transformer density," 2016".
- [23] "" T H E REPUBLIC OF UGANDA THE ELECTRICITY."
- [24] ""What Is Density? | Planetizen Planopedia." Accessed: Jan. 08, 2025. [Online]. Available: <https://www.planetizen.com/definition/density>".
- [25] ""Density - Physical Planning Division." Accessed: Jan. 08, 2025. [Online]. Available: <https://physicalplanning.gov.dm/requirements/planning-and-building-guide/density>".