

COMPARATIVE PERFORMANCE ANALYSIS OF SENSORLESS VOLTAGE-BASED AND LDR SOLAR TRACKING SYSTEMS

By

Mishael Jehoshua

22452056

MASTER'S DEGREE

in

MASTER OF MECHANICAL ENGINEERING – MECHATRONICS
CONCENTRATION

FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY



SWISS GERMAN UNIVERSITY
The Prominence Tower
Jalan Jalur Sutera Barat No. 15, Alam Sutera
Tangerang, Banten 15143 - Indonesia

Januari, 2026

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

Mishael Jehoshua

Student

Date

Approved by:

Dr. Yunita Umniyati, S.Si., M.Sc

Thesis Advisor

17 February 2026

Date

Prof. Dr. Hendriko, S.T., M.Eng,

Thesis Co-Advisor

19 February 2026

Date

Dr. Maulahikmah Galinium, S.Kom., M.Sc.

Dean

Date

MISHAEL JEHOHUA

ABSTRACT

Comparative Performance Analysis Of Sensorless Voltage-Based And LDR Solar Tracking Systems

By

Mishael Jehoshua

Dr. Yunita Umniyati, S.Si., M.Sc., Advisor

Prof. Dr. Hendriko, S.T., M.Eng., Co-Advisor

SWISS GERMAN UNIVERSITY

The efficiency of solar panels is highly dependent on the angle of incidence of solar radiation, which varies throughout the day due to the apparent motion of the sun. This study proposes and evaluates a single-axis solar tracking system based on the comparison of the solar panel output voltage, eliminating the need for additional light sensors. The developed system utilizes voltage differences measured at several panel positions as the main control parameter to determine the optimal orientation of the panel toward the sun, with a microcontroller responsible for data processing, motor actuation, and real-time data logging. Experimental testing was conducted by comparing the electrical performance of the proposed tracking system with a fixed-position solar panel under identical environmental conditions. The results indicate that the voltage-based solar tracking method is able to maintain the panel orientation close to the optimal angle, leading to an improvement in output voltage and potential daily energy yield compared to the static system. Owing to its simple architecture and reduced sensor dependency, the proposed system offers a cost-effective and practical solution for enhancing solar energy harvesting in small- to medium-scale photovoltaic applications.

Keywords: *solar panel, solar tracking system, output voltage based, reliable tracking system, cost-effective solar tracker*



DEDICATION

I dedicate this work to my beloved family, for their support, endless prayers, and constant encouragement have been my greatest strength throughout my academic journey. I also dedicate this research to Indonesia, my homeland. With its vast potential for solar energy as a tropical nation, I hope this study on cost-effective solar tracking provides a meaningful contribution toward a more sustainable and renewable energy future for our country. Finally, this work is dedicated to the advancement of Mechatronics and Renewable Energy. May the development of this sensorless, voltage-based tracking system serve as a useful reference for creating affordable and reliable technology that can benefit society, particularly in rural and off-grid areas.



ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my primary advisor, Dr. Yunita Umniyati, S.Si., M.Sc., and my co-advisor, Prof. Dr. Hendriko, S.T., M.Eng. for their invaluable guidance, patience, and expert insights throughout the development of this thesis. I also extend my thanks to Dr. Maulahikmah Galinium, S.Kom., M.Sc., Dean of the Faculty of Engineering and Information Technology at Swiss German University, for providing the academic environment necessary to complete this Master's degree. Special thanks to MME Mechatronics Batch 20 for their technical assistance during the prototype construction and outdoor testing phases in Pekanbaru. Finally, I am profoundly grateful to my family for their constant prayers and support, which remained my primary motivation in completing this work.



TABLE OF CONTENTS

	Page
STATEMENT BY THE AUTHOR.....	2
ABSTRACT.....	3
DEDICATION	5
ACKNOWLEDGEMENTS	6
TABLE OF CONTENTS.....	7
LIST OF FIGURES	9
LIST OF TABLES	11
Chapter 1 INTRODUCTION.....	12
1.1 Background.....	12
1.2 Problem Statement.....	18
1.3 Research Questions	18
1.4 Objectives	19
1.5 Scope and Limitations	19
1.6 Hypothesis	20
Chapter 2 LITERATURE REVIEW	21
2.1 Voltage-Based Solar Tracking Concept	21
2.2 Photovoltaic Panel Characteristics	21
2.3 Solar Radiation Spectrum and Sensor Limitations.....	22
2.4 Summary of Literature Review	25
2.5 Previous Studies	25
Chapter 3 RESEARCH METHODS.....	28
3.1 Research Framework	28
3.2 Root Cause Analysis.....	29
3.3 Addressing the Root Cause	31
3.4 Photovoltaic Panel	32
3.5 Energy Storage System and Battery Selection	34
3.6 Microcontroller Selection.....	38
3.7 Voltage Sensor.....	39
3.8 Real Time Clocking DS3231.....	40
3.9 DC Motor for Panel Positioning.....	41
3.10 Linear Motor Mechanism	42
3.11 Mechanical Design Overview	43

3.12 Electrical Design Overview.....	46
3.13 Experimental Procedure	50
3.14 Reference System: LDR-Based Solar Tracker	52
3.15 LDR (Light Dependent Resistor)	53
Chapter 4 RESULTS AND DISCUSSIONS	57
4.1 Pre-Operational Functional Verification	57
4.2 Voltage Sensor Calibration.....	63
4.3 LDR Sensor Calibration for Differential Tracking.....	69
4.4 Hardware Implementation	74
4.5 Experimental Results.....	76
4.6 Output Voltage Performance of Each System.....	79
Chapter 5 RECOMMENDATIONS	86
5.1 Conclusions	86
5.2 Recommendations	87
REFERENCES	91
CURRICULUM VITAE.....	93

LIST OF FIGURES

Figures	Page
Renewable Energy and Fossil Fuels Energy	12
Solar Panel With Fixed Instalation	13
Solar Panel With Tracking System	15
Types of Solar Panel	22
Sunlight Spectrum That can be absorbed by Silicon Solar Cell	23
Research Framework	29
Fishbone Diagram	30
VRLA deep-cycle battery used as the energy storage system in the solar tracking setup.	36
Arduino Mega 2560 and Pin IO Description	38
Voltage Sensor	39
Bottom View Voltage Sensor	40
Voltage Sensor is a Voltage Divider Circuit.....	40
DC Motor	42
Linear Motor Mechanism	42
Isometric View of the Solar Tracker Structure	44
Side View of the Panel Rotation Mechanism	44
Internal Component Layout of the Control Box	45
Schematic Diagram of the Voltage-Based Solar Tracker Circuit.	50
Experimental Procedure Flowchart.....	52
LDR Sensor Mounting	55
Each System RTC Synchronization.....	59
Voltage Based System Battery Capacity Before Tracking	62
LDR Based System Battery Capacity Before Tracking.....	62

Voltage Sensor Calibration Flowchart.....	64
Voltage Sensor Output vs Multimeter Reference (Before Calibration).....	65
Voltage Sensor Output vs Multimeter Reference (After Calibration)	69
Potentiometer	71
LDR Sensor Equalitation	71
LDR Sensor Before Tuning (Equalitation)	72
LDR Sensor After Tuning (Equalitation)	73
Comparison Graphic Voltage Between 2 Different System	78



LIST OF TABLES

Table	Page
Average Voltage and Light Intensity During Observation	14
Comparative Summary of Prior Research	26
Photovoltaic Datasheet.....	34
List Of System Component.....	45
Daily Quantitative Results	81

