



FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL ENGINEERING
FINAL YEAR PROJECT REPORT
DESIGN AND CONSTRUCTION OF A BUCK-BOOST SOLAR
CHARGE REGULATOR FOR CHARGING VARIOUS
BATTERY CAPACITIES

By

OTIMGIU COSMAS

BU/UG/2021/0022

Tel: 0766942943

Email: otimgiucosmas@gmail.com

SUPERVISORS: ENG. GEORGE KILAMA AND ENG. JENSEN
NDUHUURA

A final year project report submitted to the Department of Electrical Engineering, Faculty of Engineering and Technology in partial fulfillment of the requirement for the award of the Bachelor of Science in Electrical Engineering of Busitema University.

MAY, 2025.

DECLARATION

I OTIMGIU COSMAS do declare that this project report is piece of work that has been generated out of my own efforts and has never been presented to any institution or published for any academic award.

OTIMGIU COSMAS

Signature:  . Date ...17.../...11...../...2025

APPROVAL

I OTIMGIU COSMAS, submit this final year project report to the Faculty of Engineering and Technology in the Department of Electrical Engineering for examination with approval of my supervisors.

ENG. JENSEN NDUHUURA

Signature:  Date: 13 / 06 / 2025

DEDICATION

I dedicate this project report to the Almighty God who has always been with me and to my parents for their endless courage and support towards me during this academic journey.

ACKNOWLEDGMENT

I would like to begin by expressing my heartfelt gratitude to the Almighty God for preserving my health and strength throughout this academic journey. I am profoundly thankful for the blessings in my life, recognizing that I could not have successfully completed this project without His unwavering guidance and protection.

My sincere thanks extend to the Electrical Engineering department of Busitema University for their invaluable support and mentorship. I am genuinely honored to have had the opportunity to learn from such seasoned and knowledgeable professionals. Their dedication to imparting various knowledge and skills to us has left an indelible mark, and I am confident that these knowledge and skills will be of immense significance in my future endeavors.

I am also deeply indebted to my dear supervisors, ENG. GEORGE KILAMA and ENG. JENSEN NDUHUURA for their invaluable guidance and support throughout this project.

Special appreciation to my parents, siblings, and friends for their unwavering encouragement and assistance during this academic journey.

TABLE OF CONTENTS

DECLARATION	i
APPROVAL	ii
DEDICATION	iii
ACKNOWLEDGMENT	iv
LIST OF FIGURES	ix

LIST OF TABLES	x
LIST OF ACRONYMS	xi
ABSTRACT	
xii	
CHAPTER	ONE:
	INTRODUCTION
.....	1
1.1 BACKGROUND	1
1.2 PROBLEM STATEMENT	2
1.3 OBJECTIVES	2
1.3.1 Main Objective.....	2
1.3.2 Specific Objectives	2
1.4 JUSTIFICATION	2
1.5 SIGNIFICANCE	2
1.6 SCOPE	3
1.6.1 Technical Scope	3
1.6.2 Geographical scope.	3
1.6.3 Time scope	3
1.6 CONCEPTUAL FRAMEWORK	3
CHAPTER TWO: LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Solar charge controllers	4
2.2.1 PWM (Pulse Width Modulation) Solar charge controller	4
2.2.2 MPPT (Maximum Power Point Tracking) Solar charge controller.	4
2.3 Maximum Power Point Tracking algorithms.	5
2.3.1 Incremental conductance (IC)	5
2.3.2 Constant Voltage (CV)	5
2.3.3 Perturb and observe (P&O)	6

2.3.4 Comparative analysis of the Common MPPT algorithms.	6
2.4 DC-DC Converter topologies	7
2.4.1 Buck Converters.....	8
2.4.2 Boost Converters	8
2.4.3 Buck-Boost Converters.	8
2.5 Existing systems.....	9
2.6 Developed system	9
CHAPTER THREE: METHODOLOGY	10
3.1 Introduction	10
3.1 Design of a DC-DC buck-boost converter based on maximum power point tracking (MPPT)	10
3.1.1 Developing the system's block diagram	10
3.1.2 Developing the system's flow chart	11
3.1.3 Choosing and implementation of a suitable MPPT algorithm with the DC-DC buck boost	12
3.2 Design of the output voltage and current selection circuitry.	13
3.2.1 Designing separate charging channel for each battery	13
3.2.2 Integrating Safety and Protection Features.	13
3.2.2.1 Overcharging protection and over discharging protection	13
3.2.2.2 Reverse flow protection	14
3.2.3 System's simulation and design	14
3.2.3.1 Power Source	15
3.2.3.2 Buck-Boost Converter Circuit	15
3.2.3.3 Voltage Sensing	17
3.2.3.4 Current Sensing	17
3.2.3.5 Microcontroller Unit (ATMEGA328P - U1)	17
3.2.3.6 The channels for the different battery capacities.	18

3.2.3.7 LCD Display (LM016L - LCD1)	19
3.2.4 The System's Prototype	19
3.3 Verification of the performance of the developed system.	20
3.3.1 Testing and Validating MPPT Functionality	20
3.3.2 Evaluating the system's protection mechanisms	21
3.3.2.1 Overcharging protection	21
3.3.2.2 Over discharging protection	21
3.3.3 Evaluating Multi-Battery Charging	21
CHAPTER FOUR: RESULTS AND DISCUSSIONS	22
4.1 Implementation of a DC-DC buck- boost converter based on maximum power point tracking.	22
4.2 Output voltage and current selection circuit design.	22
4.3 Verification of the performance of the developed system.	23
4.3.1 Verification of the MPPT functionality.	23
4.3.2 Verification of the system's protection mechanisms.	25
4.3.2.1 Overcharging protection.	25
4.3.2.2 Over discharging protection	26
4.3.3 Verification of the Multi-Battery Charging	27
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS	28
5.1 Conclusion	28
5.2 Recommendation	28
REFERENCES	30
APPENDICES	34
Appendix 1: Arduino MPPT algorithm code	34
Appendix 2: Overcharge and Over discharge code	35
Appendix 3: The System's circuit diagram	38

LIST OF FIGURES

Figure 1: Conceptual framework	3
Figure 2: The system's block diagram	10
Figure 3: The system's flow chart	11
Figure 4: The voltage divider circuits and the charging channels for the batteries	13
Figure 5: The system's simulation	15
Figure 6: The solar panel	15
Figure 7: Buck boost converter circuit.....	16
Figure 8: The PWM signal for controlling the switching MOSFET	16
Figure 9: ACS712 current sensor	17
Figure 10: The ATmega328p microcontroller	18
Figure 11: LCD display circuit	19
Figure 12: The system's prototype	20
Figure 13: The charging voltages of the batteries	22
Figure 14: The charging voltages of the batteries when the input voltage was increased to test for over discharge protection.	25
Figure 15: The charging voltages when the input voltage was reduced to test for over discharge protection	26

LIST OF TABLES

Table 1: Over charge and Over discharge threshold voltages.	14
Table 2: Test conditions and the corresponding solar panel's voltage and current	23
Table 3: Output voltage and current to different battery channels under different test conditions	24
Table 4: LCD display voltages and Multimeter readings of the battery charging voltages	27

LIST OF ACRONYMS

DC:	Direct Current
SDG:	Sustainable Development Goal
PV:	Photovoltaic System
PWM:	Pulse Width Modulation
MPP:	Maximum Power Point

MPPT:	Maximum Power Point Tracking
P&O:	Perturb and Observe
CV:	Constant Voltage
MOSFET:	Metal Oxide Semiconductor Field Effect Transistor
ADC:	Analog-to-Digital Converter
LCD:	Liquid Crystal Display
EV:	Electrical Vehicle
ACS:	Analog Current Sensor
IC:	Incremental Conductance
O/I:	Output and Input
I-V:	Current-Voltage
P-V:	Power-Voltage

ABSTRACT

The growing demand for renewable and sustainable energy solutions has created a demand for efficient and flexible systems for harnessing solar energy. This project presents the development of an efficient and flexible solar charge regulator capable of charging various batteries with different capacities at the same time using one unit. The system incorporates buck-boost converter topology that step downs and steps up the input voltage to match the requirements of the batteries being charged. The system also integrates Maximum Power Point Tracking (MPPT) algorithm that is Perturb and Observe (P&O) method using an ATmega328P microcontroller to maximize the power extracted from the solar panel under various environmental conditions. The system is equipped with current and voltage sensors to monitor the system's parameters and an LCD display that display charging voltages of the batteries and the current of the load connected to the system.

It also employs Pulse Width Modulation technique (PWM) for efficient control of the power conversion process. Overcharge protection, over-discharge protection, and reverse current flow protection were integrated to ensure safe charging of the batteries. The system was simulated using Proteus software to validate the performance of the system and the design was validated by testing with both lead-acid and lithium-ion batteries. The outcome indicates the ability of the system to charge batteries of different capacities using solar power effectively, making it suitable for offgrid systems, rural electrification, and for applications like Electrical Vehicles (EV) charging.

REFERENCES

- Acharya, P. S., & Aithal, P. S. (2020). A Comparative Study of MPPT and PWM Solar Charge Controllers and their Integrated System. *Journal of Physics: Conference Series*, 1712(1). <https://doi.org/10.1088/1742-6596/1712/1/012023>
- Ahmed Jony, M. J., Baki-Ul-Islam, Roy, K., Lamon, A., Alom, M. S., & Jami, M. R. (2024). Optimizing MPPT for PV Systems: A Combined Study of Constant Voltage and Incremental Conductance Technique. *Proceedings - 6th International Conference on Electrical Engineering and Information and Communication Technology, ICEEICT 2024*, 1072–1076. <https://doi.org/10.1109/ICEEICT62016.2024.10534369>
- Almazrouei, A. (n.d.-a). *Solar Charge Controller*.
- Almazrouei, A. (n.d.-b). *Solar Charge Controller*.
- Ananda-Rao, K., Rosmi, A. S., Tanisellah, S., Baharudin, N. H., Hamid, M., Zhe, L. W., & Sudabattula, S. K. (2025). MPPT Charge Controller using Fuzzy Logic for Battery Integrated with Solar Photovoltaic System. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 47(2), 171–182. <https://doi.org/10.37934/ARASET.47.2.171182>

- Asoh, D. A., Noumsi, B. D., & Mbinkar, E. N. (2022). Maximum Power Point Tracking Using the Incremental Conductance Algorithm for PV Systems Operating in Rapidly Changing Environmental Conditions. *Smart Grid and Renewable Energy*, 13(05), 89–108. <https://doi.org/10.4236/sgre.2022.135006>
- Awan, M. M. A. (2022). Strategic Perturb and Observe Algorithm for Partial Shading Conditions. *Sir Syed University Research Journal of Engineering & Technology*, 12(2), 26–32. <https://doi.org/10.33317/ssurj.497>
- Bahadur, S., Mondol, K., Mohammad, A., Mahjabeen, F., Tamzeed-Al-Alam, M., & Bulbul Ahammed, M. (n.d.). *DESIGN AND IMPLEMENTATION OF LOW COST MPPT SOLAR CHARGE CONTROLLER*.
- Baharudin, N. H., Mansur, T. M. N. T., Hamid, F. A., Ali, R., & Misrun, M. I. (2017). Topologies of DC-DC converter in solar PV applications. *Indonesian Journal of Electrical Engineering and Computer Science*, 8(2), 368–374. <https://doi.org/10.11591/ijeecs.v8.i2.pp368-374>
- Boubaker, O. (2023a). MPPT techniques for photovoltaic systems: a systematic review in current trends and recent advances in artificial intelligence. *Discover Energy*, 3(1). <https://doi.org/10.1007/s43937-023-00024-2>
- Boubaker, O. (2023b). MPPT techniques for photovoltaic systems: a systematic review in current trends and recent advances in artificial intelligence. *Discover Energy*, 3(1). <https://doi.org/10.1007/s43937-023-00024-2>
- Chitransh, A., & Kumar, Mr. S. (2021a). The Different Type of MPPT Techniques for Photovoltaic System. *Indian Journal of Environment Engineering*, 1(2), 1–4. <https://doi.org/10.54105/ijee.A1809.111221>
- Chitransh, A., & Kumar, Mr. S. (2021b). The Different Type of MPPT Techniques for Photovoltaic System. *Indian Journal of Environment Engineering*, 1(2), 1–4. <https://doi.org/10.54105/ijee.A1809.111221>
- Choudhary, D. K., & Gupta, S. K. (2023). *Modelling and Simulation of Solar PV-Powered Buck Boost Converter Battery Charging* (pp. 521–536). https://doi.org/10.1007/978-981-99-41759_42

- Endiz, M. S. (2024). Design and implementation of microcontroller-based solar charge controller using modified incremental conductance MPPT algorithm. *Journal of Radiation Research and Applied Sciences*, 17(2), 100938. <https://doi.org/10.1016/j.jrras.2024.100938>
- Jabbar, R. I., Mekhilef, S., Mubin, M., & Mohammed, K. K. (2023). A Modified Perturb and Observe MPPT for a Fast and Accurate Tracking of MPP Under Varying Weather Conditions. *IEEE Access*, 11, 76166–76176. <https://doi.org/10.1109/ACCESS.2023.3297445>
- Kumar, M., Panda, K. P., Rosas-Caro, J. C., Valderrabano-Gonzalez, A., & Panda, G. (2023). Comprehensive Review of Conventional and Emerging Maximum Power Point Tracking Algorithms for Uniformly and Partially Shaded Solar Photovoltaic Systems. *IEEE Access*, 11, 31778–31812. <https://doi.org/10.1109/ACCESS.2023.3262502>
- Kummara, V. G. R., Zeb, K., Muthusamy, A., Krishna, T. N. V., Prabhudeva Kumar, S. V. S. V., Kim, D. H., Kim, M. S., Cho, H. G., & Kim, H. J. (2020). A comprehensive review of DC–DC converter topologies and modulation strategies with recent advances in solar photovoltaic systems. In *Electronics (Switzerland)* (Vol. 9, Issue 1). MDPI AG. <https://doi.org/10.3390/electronics9010031>
- Majaw, T., Deka, R., Roy, S., & Goswami, B. (2018a). Solar Charge Controllers using MPPT and PWM: A Review. *ADBU Journal of Electrical and Electronics Engineering (AJEEE)*, 2. www.tinyurl.com/ajejee-adbu
- Majaw, T., Deka, R., Roy, S., & Goswami, B. (2018b). Solar Charge Controllers using MPPT and PWM: A Review. *ADBU Journal of Electrical and Electronics Engineering (AJEEE)*, 2. www.tinyurl.com/ajejee-adbu
- McCullough, B. P., Kellison, T., & Melton, E. N. (2022). The Routledge Handbook of Sport and Sustainable Development. In *The Routledge Handbook of Sport and Sustainable Development*. Taylor and Francis. <https://doi.org/10.4324/9781003023968>
- Mishra, D. P., Senapati, R., & Salkuti, S. R. (2022). Comparison of DC-DC converters for solar power conversion system. *Indonesian Journal of Electrical Engineering and Computer Science*, 26(2), 648–655. <https://doi.org/10.11591/ijeecs.v26.i2.pp648-655>
- Osaretin, C. A. (n.d.). *DESIGN AND IMPLEMENTATION OF A SOLAR CHARGE*

CONTROLLER WITH VARIABLE OUTPUT.

<https://www.researchgate.net/publication/303683238>

- S, S. P., Year Student, B.-F., & Professor, A. (2023). *DESIGN OF BUCK-BOOST CONVERTER FOR EV CHARGING APPLICATIONS*. www.ijcrt.org
- Sabir, B., Lu, S. Der, Liu, H. D., Lin, C. H., Sarwar, A., & Huang, L. Y. (2023a). A Novel Isolated Intelligent Adjustable Buck-Boost Converter with Hill Climbing MPPT Algorithm for Solar Power Systems. *Processes*, *11*(4). <https://doi.org/10.3390/pr11041010>
- Sabir, B., Lu, S. Der, Liu, H. D., Lin, C. H., Sarwar, A., & Huang, L. Y. (2023b). A Novel Isolated Intelligent Adjustable Buck-Boost Converter with Hill Climbing MPPT Algorithm for Solar Power Systems. *Processes*, *11*(4). <https://doi.org/10.3390/pr11041010>
- Samosir, A. S., Sutikno, T., & Mardiyah, L. (2023). Simple formula for designing the PID controller of a DC-DC buck converter. *International Journal of Power Electronics and Drive Systems*, *14*(1), 327–336. <https://doi.org/10.11591/ijpeds.v14.i1.pp327-336>
- Yanarates, C., Wang, Y., & Zhou, Z. (2021). Unity Proportional Gain Resonant and Gain Scheduled Proportional (PR-P) Controller-Based Variable Perturbation Size Real-Time Adaptive Perturb and Observe (PO) MPPT Algorithm for PV Systems. *IEEE Access*, *9*, 138468–138482. <https://doi.org/10.1109/ACCESS.2021.3119042>