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Original Article

Design and Analysis of Cascaded Buck Boost Converter Using Solar MPPT Method for Electric Vehicles Charging Applications

S. Venkatesan[1], S. Amirtha[2], M.U. Thirisha[3], S.S. Dharini Subha[4], A. Marimuthu[5], P. Loganthurai[6]
[1,2,3,4,5,6]*Electrical and Electronics Engineering, K.L.N. College of Engineering Sivagangai, Tamil Nadu, India.*

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Abstract: *Charging infrastructure will play a pivotal role in EV application, and in the absence of a proactive plan and schedule, it is a major impediment to mass market adoption. Infrastructure limitations are particularly pertinent to battery-operated EVs due to their sole dependency on electricity The charging infrastructure encompasses all hardware and software necessary to ensure energy transfer from the electric grid to the vehicle. It can be categorized by location, power level, and charging time strategy. Optimizing charging locations along with an acceptable charging time strategy increases BEV functionality while reducing public charging requirements. To address these challenges, the project proposes approximating the Electric Vehicle Supply Equipment (EVSE) needed at different locations (e.g., Home, Work, and Commercial Parking) based on an optimal charging strategy. In this presented project, a Cascaded buck boost DC-DC converter is employed to add additional benefits. This converter reduces stress on diodes and other switching components and offers high voltage transfer gain compared to other converters, thereby saving time. The main aim of this project is to satisfy various battery loads by implementing automatic Cascaded buck boost operation, which senses the voltage source. This new approach has proven accuracy, robustness, and efficiency in energy utilization for standalone charging systems. Unlike conventional boost/buck converters, the Cascaded buck boost converter utilizes an extra pair of diodes and capacitors during energy transmission. Divided inductor stored energy is stored in one capacitor, while another divided inductor stored energy is composed by the other capacitor, resulting in much higher efficiency.*

Keywords: *DC-DC Converter; Solar Panel; Batteries; Pulse Width Modulation; Cascaded Converter; Battery Management System.*

I. INTRODUCTION

Conventional single stage buck or boost converter converts a variable DC voltage to a lower or higher DC voltage either in one topology, here cascaded converter adds additional benefits that simultaneously works in same topology by cascaded buck boost operation. Maximum Power Point Tracking (P&O Algorithm) is needed to extract maximum energy from the solar module. This Algorithm not only increase the system's output power but also give the system a longer lifespan, MPPT algorithms are designed so that the system can adapt to weather changes and achieve optimal power. This project involves theoretical derivations, simulations, and experimental demonstrations. Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. PV modules still have relatively low conversion efficiency due to the nonlinear V-P-V characteristics, and I, which depend on the irradiance, the operating temperature and load condition of the cell. Therefore, high efficiency is required for the power conditioning system (PCS), which transmits power from the PV array to the load. In general, a single-phase PV PCS consists of two conversion stages (i.e., DC-DC conversion stage and DC-AC conversion stage). The DC-DC converter is the first stage and it has to control the variation of the maximum power point of the solar cell output. In other word, modulation of the duty ratio of the DC-DC converter controls maximum power point tracking (MPPT). The most famous one is called P&O based algorithm. However, this method has presents limitations to track maximum power point as fast as possible to reduce oscillations in output power. In order to increase the overall efficiency of PV power conditioning system, cascaded converter is utilized for better efficiency for high power applications, and having low conduction loss (I2R). Therefore, the output power of the PV array boosted with high efficiency. The proposed topology helps us to predict the optimum DC–DC converter duty ratio based on solar irradiation to run the constant load. The Cascaded converter will buck & boost the desired voltage depends upon the Load by manual feedback through Raspberry pi Pico coding. Cascaded converter has reduced output voltage ripple, low switching loss, and faster transient response. Also, the steady-state voltage ripples at the output capacitors were reduced. Although this converter topology has derived from nominal buck & boost operation so, more inductors increasing the complexity of the converter correlated to the classical boost & buck converter it is chosen because of the low ripple content in the input and output sides. In order to decrease this complexity, this work considers the aids of coupling both buck & boost converter. The proper-cascaded converter for photovoltaic module application is suggested. Switching pulses are generated using Raspberry pi Pico Microcontroller.

I. LITERATURE SURVEY

S.no	AUTHOR NAME & YEAR	JOURNAL NAME	DESCRIPTION
1.	C. Rao, A. Hajjiah, M. A. El-Meligy, M. Sharaf, A. T. Soliman and M. A. Mohamed	IEEE Access, vol. 9, pp. 58790-58806, 2021	This paper proposes a novel l gain structure of DC-DC co soft-switching ability for p (PV) applications. A small s inductor with one magnet co to improve the voltage conv in the proposed converter.
2.	O. Abdel-Rahim and H. Wang.	IEEE Explore CPSS Transactions on Power Electronics and Applications, vol. 5, no. 2, pp. 191-200, June 2020.	High step-up DC/DC co maximum power point track control are essential com photovoltaic (PV) systems purpose of utilizing PV modu generation, this manuscript new high step-up DC/DC c model predictive contr maximum power point track MPPT) algorithm
3.	K. O. Sarfo, W. M. Amuna, B. N. Pouliwe and F. B. Effah	***2020 IEEE PES/IAS PowerAfrica*, 2020, pp. 1-5.**	This paper proposes a modified perturb and observe (P&O) maximum power point tracking (MPPT) technique under partial shading conditions for a photovoltaic (PV) system. Two algorithms proposed in the literature are combined and modified for this work. The advantages of the modified technique include accuracy and simplicity of implementation.
4.	N. J, M. NandaKumar and R. K. P,	***2020 International Conference on Power Electronics and Renewable Energy Applications (PEREA), 2020, pp. 1-6.***	In this energy crisis scenario, demand for energy is so high that we are forced to rely on renewable energy resources. DC-DC converter is an intermediate stage in the power conversion. These converters experiences issues like, maximum power point tracking, input current ripple, switching loss etc which affects the power efficiency of entire system. Hence in a PV system, power converter used has a key role in determining system efficiency.

II. PROBLEM STATEMENT

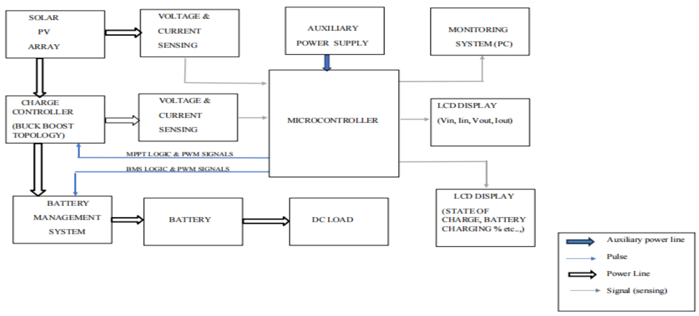
COMPARISON BETWEEN SINGLE STAGE CONVENTIONAL CONVERTER AND CASCADED BUCK-BOOST CONVERTER

S.NO	SINGLE STAGE CONVENTIONAL CONVERTER	CASCADED BUCK-BOOST CONVERTER
1.	Efficiency is low	Improved efficiency
2.	Only step up/step down	Both step up and step down
3.	Slow switching speed as compared with Cascaded Buck-Boost converter	Fast switching speed

III. PROPOSED METHOD

Maximum Power Point Tracking is a technology that can harvest the maximum power from the PV source, by adjusting the PWM Duty through DC-DC converter topology to maintain the constant voltage at the output for charging the battery. The main aim of this project is to satisfy the various battery ratings such as 4V/8V/12V/16V/20V/24V by implementing the automatic buck and boost operation by sensing the Input PV source. The new approach has proven accuracy, robustness and effectiveness of efficient energy utilization for standalone PV system by knowing the various facts & topologies about converters, batteries and PV panel is used as a source and MPPT (P&O Algorithm) is validated through MATLAB/Simulink.

i. BLOCK DIAGRAM



ii. SOLAR PANEL

A 10-watt polycrystalline solar panel is a compact and efficient solar energy solution suitable for various applications. These panels are constructed using silicon cells composed of multiple silicon crystals, which are fused together during manufacturing. While slightly less efficient than

monocrystalline panels, polycrystalline panels offer a cost-effective option for generating renewable electricity. In terms of size, a 10-watt polycrystalline solar panel is relatively small and lightweight, making it easy to install in various settings. Its compact design makes it suitable for portable solar setups, such as charging small electronic devices, powering outdoor lights, or maintaining batteries in off-grid locations like cabins or RVs. Despite their compact size, polycrystalline panels are durable and can withstand different weather conditions. They are resistant to impact and temperature fluctuations, ensuring reliable performance over time. This durability makes them suitable for outdoor use, whether mounted on rooftops, in gardens, or on portable structures. A 10-watt polycrystalline solar panel typically generates enough power to charge batteries or provide supplemental electricity for low-energy devices. It's a practical choice for applications where a small, reliable solar power source is needed without requiring a large-scale solar array. The affordability of polycrystalline panels, combined with their durability and efficiency, makes them a popular choice for small-scale solar projects and off-grid applications. Whether used individually or as part of a larger solar system, a 10-watt polycrystalline solar panel offers a convenient and sustainable way to harness solar energy for various purposes.

Fig 1. SOLAR PANEL

iii. CASCADED BUCK BOOST CONVERTER

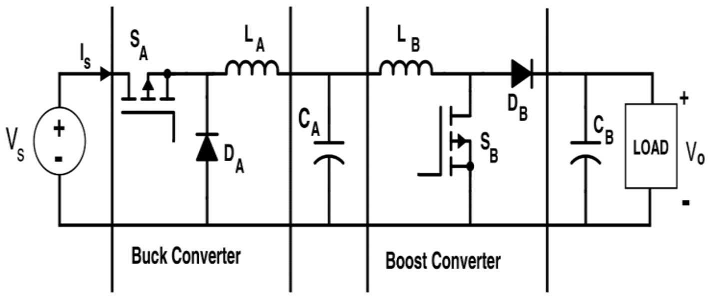
A cascaded buck-boost converter is a type of power converter topology that combines both buck and boost converter stages to achieve a wider range of output voltages compared to a single buck-boost converter

Buck Converter Stage: The input voltage is first stepped down (bucked) to an intermediate voltage level. This is achieved by controlling the duty cycle of a switching element, typically a MOSFET. The output of this stage is typically lower than the input voltage.

Boost Converter Stage: The intermediate voltage from the buck converter stage is then fed into the boost converter stage. Here, the voltage can be further increased (boosted) to achieve the desired output voltage level. This is done by controlling another switching element, usually another MOSFET, and using an inductor and a capacitor to store and transfer energy.

Control and Regulation: The control circuitry monitors the output voltage and adjusts the duty cycles of both the buck and boost converter stages to maintain a stable output voltage regardless of changes in the input voltage or load condition.

Fig 2. Cascaded buck & boost converter



iv. MOSFET IRF840 DRIVER CIRCUIT

The IRF840 is a power MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) widely used in electronic circuits requiring high-power switching applications. It belongs to a class of N-channel enhancement-mode MOSFETs, meaning it operates with a positive voltage applied to the gate terminal to control the flow of current between the drain and source terminals. The IRF840 is characterized by its ability to handle high voltage and current loads, making it suitable for applications such as power supplies, motor control, and amplifier circuits. With its low on-resistance and high switching speed, the IRF840 offers efficient performance in various power electronics designs. However, it's important to properly manage heat dissipation, as excessive temperature can degrade its performance and reliability. Overall, the IRF840 remains a popular choice for engineers seeking robust and high-performance MOSFET solutions in their designs.

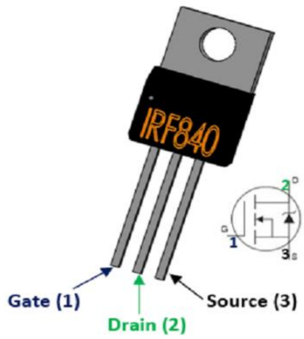


Fig 3. MOSFET IRF840

v. RASPBERRY PI PICO

The Raspberry Pi Pico is a microcontroller board developed by the Raspberry Pi Foundation. It features the RP2040 microcontroller chip, which is designed by Raspberry Pi. The Pico is a versatile and affordable board suitable for a wide range of projects, from simple electronics to more complex applications. It has GPIO pins, SPI, I2C, UART interfaces, and can be programmed using MicroPython, C, and other programming languages. Sure! The Raspberry Pi Pico is a small, low-cost microcontroller board designed by the Raspberry Pi Foundation. It's powered by the RP2040 microcontroller chip, which features a dual-core ARM Cortex M0+ processor running at up to 133MHz. The board includes 26 GPIO pins, which can be used for digital input/output, PWM, SPI, I2C, and UART communication. One of the standout features of the Pico is its flexibility in programming. It can be programmed using a variety of languages, including MicroPython, C, and C++. The Pico also supports USB connectivity, allowing for easy programming and power supply. Overall, the Raspberry Pi Pico is a versatile and affordable option for electronics hobbyists, educators, and professionals looking to explore the world of microcontrollers.

Fig 4. Raspberry pi Pico

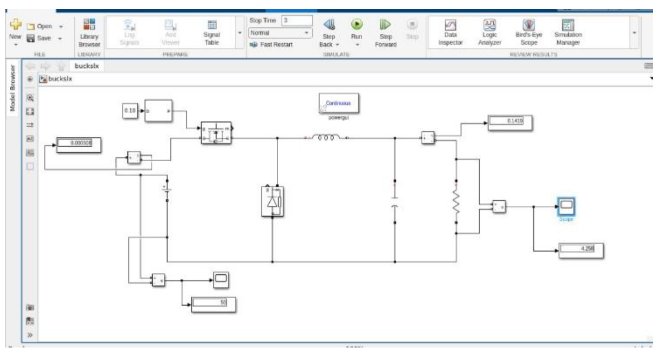
vi. BATTERY

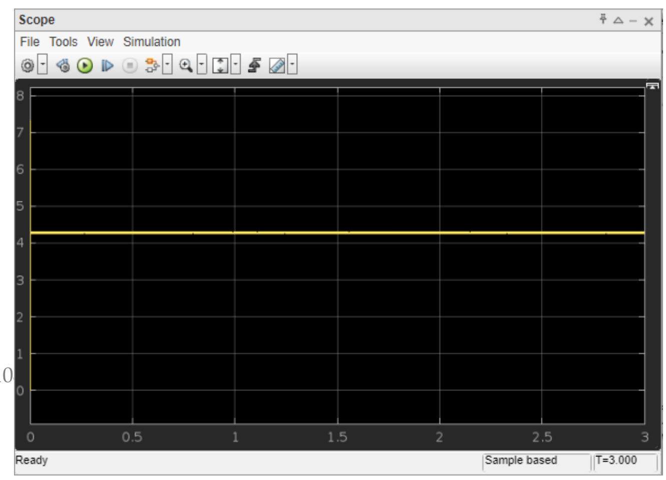
Lead-acid batteries are a type of rechargeable battery that uses a lead oxide and lead plate design immersed in a sulfuric acid solution as its electrolyte. They have been around for more than a century and remain one of the most commonly used types of rechargeable batteries due to their low cost, reliability, and relatively high surge current capability. Here are some key points about lead-acid batteries. Lead-acid batteries typically consist of several lead plates submerged in an electrolyte solution of diluted sulfuric acid. Each cell contains a positive plate made of lead dioxide (PbO2), a negative plate made of sponge lead (Pb), and a separator made of porous material to prevent short circuits. During charging, electrical energy is supplied to the battery, causing a chemical reaction that converts lead sulphate on the plates back into lead dioxide and sponge lead. This process reverses during discharging, with lead dioxide and sponge lead converting back into lead sulphate, releasing electrical energy. The sulfuric acid serves as the electrolyte that facilitates these chemical reactions.

Fig 5. Lead Acid Battery

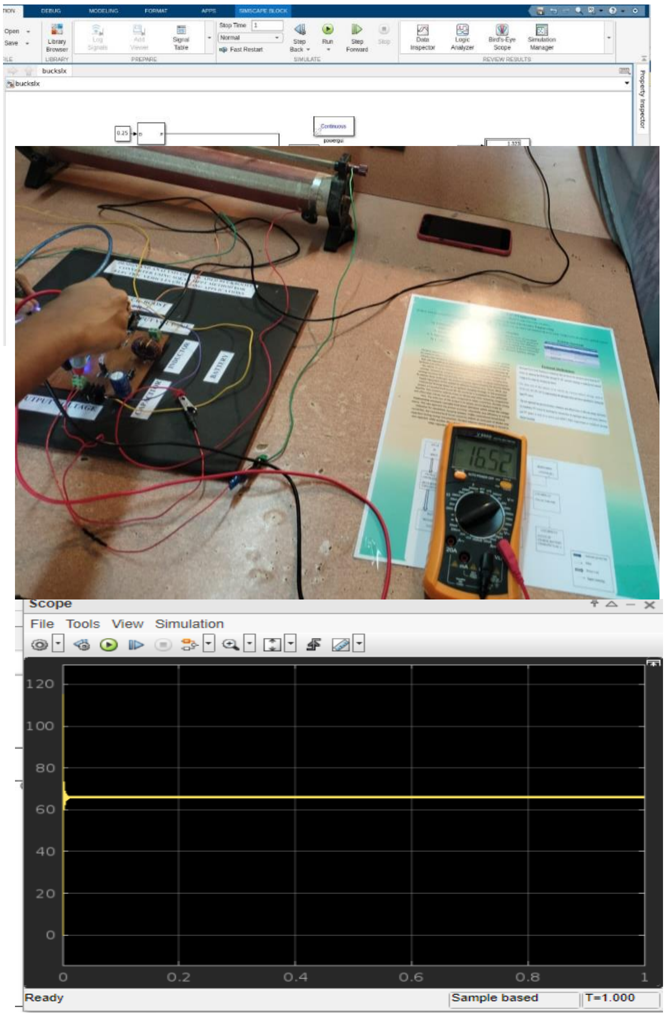
IV. MATLAB SIMULATION

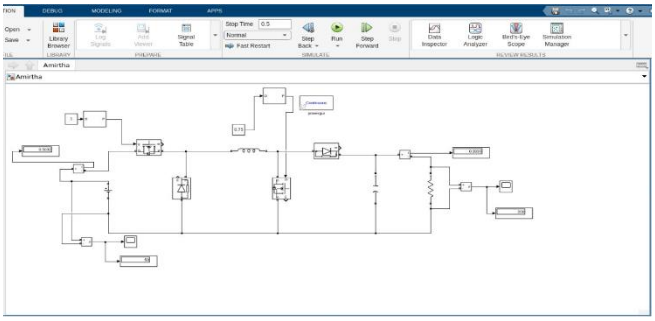
i. **MATLAB SIMULATION OF BUCK CONVERTER**

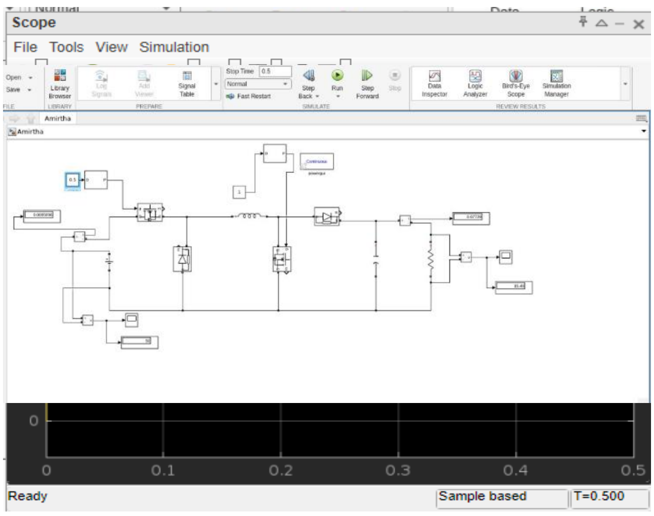




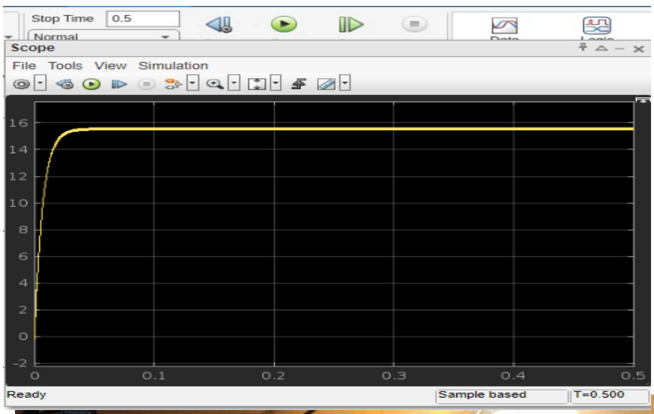
ii. MATLAB SIMULATION OF BOOST CONVERTER







iii. MATLAB SIMULATION OF CASCADED BUCK BOOST CONVERTER



V. HARDWARE WORKING

VI. CONCLUSION

By efficiently managing the power flow from the solar panels to the EV battery, this system optimizes charging efficiency and minimizes energy loss. The cascaded topology enhances voltage conversion capabilities, while MPPT ensures maximum power extraction from the solar source. Overall, this approach presents a promising solution for sustainable EV charging infrastructure, contributing to a cleaner and more efficient transportation ecosystem.

VII. REFERENCES

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