



CONTROL OF SENSORLESS BLDC MOTOR DRIVE IN EVS USING INTERLEAVED LANDSMAN CONVERTER WITH CLASS TOPPER OPTIMIZED PI CONTROLLER

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Abstract: In recent years, there has been a growing focus on the integration of renewable energy sources, particularly solar power, into efficient motor driving systems. The sensor less Brushless DC (BLDC) motor drive is commonly utilized in electric vehicle applications due to its high efficiency and low maintenance requirements. However, conventional converter designs for BLDC motor drives, such as buck-boost or SEPIC converters, tend to be inefficient and bulky, contributing to system losses and diminishing overall efficiency. To address these challenges, this project introduces an innovative energy management system that combines a photovoltaic array with a BLDC motor drive, aimed at improving the efficiency and sustainability of renewable energy applications. The system utilizes a Landsman Converter to enhance power conversion from solar energy, along with a bi-directional converter to facilitate efficient energy transfer between the PV system and battery storage. A Pulse Width Modulation generator produces control signals for a three-phase Voltage Source Inverter that powers the BLDC motor. To maintain stable operation under varying load conditions, a Class Topper Optimized PI Controller regulates the DC voltage output, thereby enhancing the motor's dynamic response and extending battery life. This project is implemented using MATLAB 2021a.

Index Terms - Renewable Energy Sources; Brushless DC Motor; Photovoltaic System; Pulse Width Modulation (PWM); Voltage Source Inverter (VSI); Electric Vehicles (EV)

I. INTRODUCTION

A photovoltaic (PV) system harnesses the photovoltaic effect, first discovered in the 19th century, to convert sunlight directly into electricity. Central to these systems is a solar panel composed of multiple solar cells, predominantly made of silicon. When sunlight strikes the solar cells, it excites electrons, generating an electric current. This electricity can be converted into alternating current (AC) using an inverter, making it suitable for home use or for feeding into the electrical grid. Optoelectronic systems are categorized into three types: line-in, line-out, and hybrid systems. Grid-tied systems connect to the electrical grid, facilitating the transfer of excess energy back to the utility provider. Off-grid systems function autonomously, making them suitable for remote locations, while hybrid systems combine both methods, utilizing battery storage to supply power during outages or at night. The installation of PV systems requires careful planning, including site assessment, design, and installation. Ensuring optimal exposure and orientation of solar panels is essential for maximizing energy capture, considering factors such as shading and geographic location. Once installed, these systems require minimal maintenance, primarily involving regular cleaning and periodic inspections to ensure peak performance.

Grid-tied photovoltaic systems are directly linked to the electrical grid, allowing for the return of surplus electricity, typically managed through metering. These systems are favored in both residential and commercial settings due to their cost efficiency and the capability to draw power from the grid when solar generation is insufficient. However, they do not supply electricity during outages unless paired with storage batteries. By integrating with the existing grid, grid-tied PV systems enable users to generate their own electricity while also facilitating the sale of excess energy back to the grid, effectively providing credits for future energy consumption during peak solar production hours.

Off-grid photovoltaic systems are ideally suited for remote areas lacking grid access, as they operate autonomously. These systems utilize battery storage to provide power during periods without sunlight, such as night-time. Often employed in mobile settings, vacation homes, and rural residences, off-grid systems necessitate meticulous planning to ensure adequate energy generation and storage capabilities. The efficiency of these systems is largely determined by the battery storage, which allows users to accumulate energy produced during daylight hours for later use. While off-grid systems offer independence and reliability, they entail a higher initial investment due to the costs associated with batteries and other essential components. They are prevalent in rural homes,

cabins, and mobile applications, offering sustainable energy solutions that diminish reliance on fossil fuels and enhance energy security in isolated regions.

Hybrid photovoltaic systems integrate both grid-connected and off-grid components. These systems feature battery storage for backup power and can connect to the grid, enabling users to utilize grid electricity when accessible while also managing power during emergencies. They are especially favoured in regions lacking grid access or facing high electricity costs, allowing users to harness solar energy, decrease reliance on the grid, and store surplus energy for future use. This setup enhances energy independence and lowers energy expenses. As advancements in battery technology and solar efficiency continue, hybrid systems are increasingly adopted to fulfil diverse energy requirements and contribute to a sustainable energy future.

CSP systems are especially advantageous in regions with abundant sunlight and are commonly implemented in extensive solar power facilities. Various CSP technologies exist, such as parabolic troughs, solar towers, and dish systems, each characterized by distinct designs and operational methods. A significant advantage of CSP is its ability to store thermal energy, enabling electricity generation even in the absence of sunlight, thereby enhancing grid stability and reliability. Despite the considerable land requirements and initial investment needed, CSP presents a viable and cost-effective solution for harnessing solar energy on a larger scale, contributing significantly to the shift towards renewable energy sources.

II. LITERATURE SURVEY

According to the requirements of EV drive systems, the performance and features of electric motors currently utilized in EV applications are compared and assessed in this study. Conclusions were also drawn in order to identify the generator that performs best for electric cars. Several studies have been conducted on the Landsman converter, focusing on its design, performance, and application in various power electronics systems. Here's a summary of key areas explored in the literature.

Pandav Kiran Maroti et al [2022] have proposed the role of electronic components in electric vehicles is presented and explained. Internal combustion engines (ICEs) are gradually being replaced by electric motors, increasing efficiency and reducing greenhouse gas emissions.

Mohammad Ali Sayed et al [2022] have described to a comprehensive assessment of the EV ecosystem, from inefficiencies to challenges to final solutions. The growing need to cut greenhouse gas emissions and the creation of green cities have promoted the usage of electric vehicles because of their advantages for the environment. To encourage people to switch from gasoline-powered cars to electric ones, nations have established their own goals.

Sai Sudharshan Ravi et al [2022] have demonstrated to discuss the challenges, barriers, and future market penetration of V2G technology. Create a bidirectional charger that allows energy to flow in and out of an electric vehicle.

Jonna Hynynen et al [2023] have proposed six large-scale fire tests were conducted, including three EVs, two EVs in a home, and an EV with its battery removed. Electric cars are making headlines worldwide. Carbon monoxide emissions from electric vehicles and the destruction of lithium-ion batteries are concerns.

Masooma Nazari et al [2023] have described an Application of three-level analytical clustering method to different problems related to electric vehicles. The development of electric vehicles has created many problems for the engine and especially the gearbox, with the emergence of mysterious products.

Abdulgader Alsharif et al [2023] have brief that to analyze the impact of microgrid systems considering electric vehicles. Making the switch to efficient transportation is one of the most difficult tasks in the fight against global climate change. Electric vehicle integration with renewable energy sources (RES) is seen as a way to address the environmental and energy issues needed to meet Climate Action Goal 13 (CAG13) and Sustainable Development Goal 7 (SDG7).

Boris V. Malozyomov et al [2024] have presented a Mathematical models of electric trucks include systems that calculate battery traction, electric traction trucks, and engine traction power to determine the depth of battery discharge during electric operation. Anahita Jannesar Niri et al [2024] have proposed Consider the actions taken by government, regulators, businesses and all stakeholders in the battery industry. The global commitment to decarbonize the transportation industry has led to significant growth in the electric and battery industry.

Continuous innovation in solar technology is increasing efficiency and reducing costs. New solutions such as energy storage systems and smart grids continue to improve the performance of photovoltaic systems. The benefits of photovoltaic systems make them a good choice for individuals, businesses and communities looking for sustainable and cost-effective energy solutions. Technological advancements are revolutionizing various aspects of life, driving innovation, efficiency, and connectivity across multiple sectors. In manufacturing, automation and robotics are streamlining production processes, reducing costs, and increasing output. Furthermore, information technology breakthroughs have revolutionized business operations by facilitating data-driven decision-making and improving client experiences. As technology continues to evolve, it also raises important questions about ethics, privacy, and the future of work.

Objectives:

- To implement an interleaved Landsman converter with Class Topper optimized PI control provides an innovative solution, enhancing the performance.
- To increase the efficiency and response time of sensor less BLDC motor drives by using the interleaved Landsman converter.
- To optimize the performance of the PI controller through Class Topper tuning for reduced overshoot in varying load conditions.
- To ensure the motor runs smoothly under different driving conditions, including changes in speed and load.

III. MODELING AND CONFIGURATION OF THE PROPOSED SYSTEM

The proposed design is suitable for various applications, including electric vehicles and renewable energy systems, promoting a greener and more efficient future.

The Interleaved Landsman Converter with Class Topper Optimized Proportional-Integral (PI) Control in a Sensor less Brushless DC (BLDC) Motor Drive introduces a novel method for enhancing the efficiency and performance of electric vehicles (EVs). BLDC motors are increasingly favoured in EV applications due to their high efficiency, compact size, and low maintenance needs. The Landsman converter, a type of DC-DC converter, provides significant benefits in energy conversion by efficiently adjusting voltage levels within an EV's powertrain.

The proposed system combines a photovoltaic (PV) array with a Brushless DC (BLDC) motor drive to improve energy efficiency and promote sustainability are shown in figure 1. It utilizes a Landsman Converter to enhance solar energy conversion and ensure effective power management. A bi-directional converter manages the energy exchange between the PV system and a battery storage unit, facilitating both charging and discharging as required. The system features a PWM generator that generates control signals for a three-phase Voltage Source Inverter (VSI), which powers the BLDC motor. To optimize performance, a Class Topper Optimized PI Controller regulates the DC voltage, adjusting to load changes and maintaining stability.

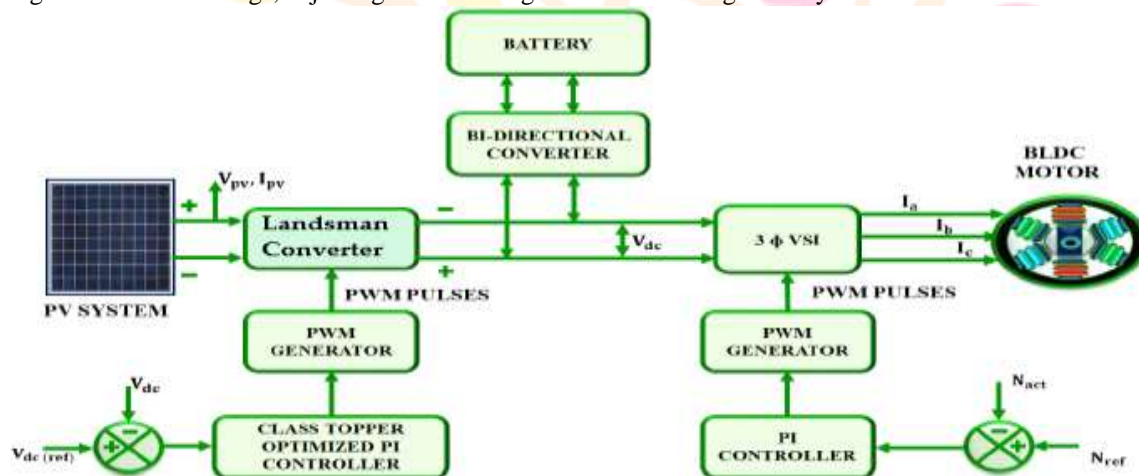


Figure 1. Block Diagram of Proposed system

A. Modeling of the Proposed System

i) PV System:

Solar energy is reliable and environmentally friendly. It can be harnessed directly to generate electricity through photovoltaic power generation. This method, known as photovoltaic (PV) generation, utilizes the photovoltaic effect to convert sunlight into electrical energy. The fundamental unit of photovoltaic systems is the solar cell, which captures light energy to produce electricity via this effect. The efficiency of a photovoltaic module is influenced by the performance of its cells and the integration of sunlight within the module.

The equivalent diode structure of the photovoltaic cell is shown in figure 2. The PV model constitutes current sources, diode Shunt resistance R_{sh} , Series Resistance R_s , Shunt Resistance R_{sh} represent the cell surface leakage through the edges [6].

The total current I is the difference of the light generated current I_{ph} , diode current I_d and current through R_{sh} [7].

$$I = I_{ph} - I_d - I_{sh} \tag{1}$$

Diode current I_d and Shunt Resistance current I_{sh} is presented by Equations (1),

$$I_d = I_0 \{ \exp [q m k T_c (V + I R_s)] - 1 \} \tag{2}$$

$$I_{sh} = V + I R_s R_{sh} \tag{3}$$

- Where, m = Idealizing factor
- K = Boltzmann constant
- T_c = Absolute temperature of cell
- q = Charge of electron
- V = Potential across cell
- I_0 = Cell reverse saturation current

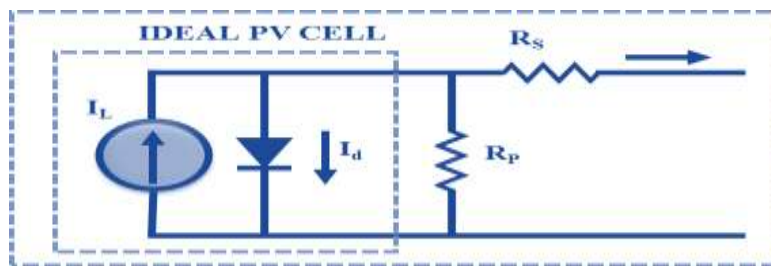


Figure 2. Equivalent Circuit of PV Cell

ii) Landsman Converter

The Interleaved Landsman converter emerges a promising solution for boosting the output voltage from PV array for optimizing the performance of BLDC motor driven EVs [8]. The interleaving technique as represented in Figure 3 helps to minimize the current ripples on the input side and voltage ripple on output side.

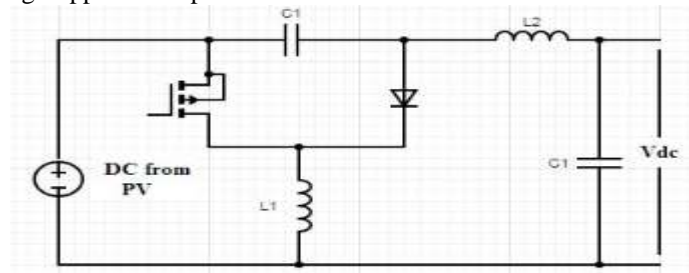


Figure 3. Circuit diagram of designed Landsman converter

iii) Class Topper Optimized PI Controller

The motivation behind the class topper optimization method comes from the school, where students' learning behaviors are evaluated based on their knowledge in a class, and they compete with one another to become the class topper. The student who ranks highest in the class is regarded as the most knowledgeable member of the group. A Meta heuristic population-based approach is used in the class topper optimization process. This algorithm achieves global optima improvement through student learning at every level.

iv) Bidirectional DC-DC Converter

An electronic power converter known as a bidirectional DC-DC converter (BDC) permits energy to move between two DC voltage levels in both directions. Applications such as energy storage systems, electric vehicle (EV) systems, battery charging/discharging systems, and renewable energy systems can benefit from this. Here's the general working process of a bidirectional DC-DC converter.

v) Threes Phase Voltage Source Inverter

Two-phase converters are found in rectifier-fed inverter systems. Inverter side control is taken into consideration in this study. The duty cycle is controlled by the rectifier side. Voltage regulation is necessary for the majority of inverter applications. This control is necessary due to changes in inverter voltage and inverter control. It can be divided into three categories.

- Control the voltage at the inverter
- Control the voltage supplied by the inverter
- Control the voltage supplied by the inverter

vi) Modelling of Battery System

BESS is an important energy storage system to manage the energy balance between the load and renewable energy sources such as solar and wind. Hybrid systems use electrical power to provide more power and energy. There are many types of batteries on the market today.

vii) PI Controller

The PI controller is commonly utilised because they are simple to change and tweak, because BLDC motors are multivariate systems, saturation is conceivable. Speed and current are frequently regulated with the use of PI controller. The Proportional and integral processes to produce output signal and examines discrepancy between speed feedback signal's real value and its reference value.

IV. RESULTS AND DISCUSSIONS

The simulation results were analyzed using the program called MATLAB/SIMULINK. MATLAB is a language that can be used to calculate, visualize and compute in the user environment, where the problem and its solution are expressed using the information method. MATLAB is the best tool for signal analysis. The proposed work is implemented in MATLAB simulation are shown in figure 4.

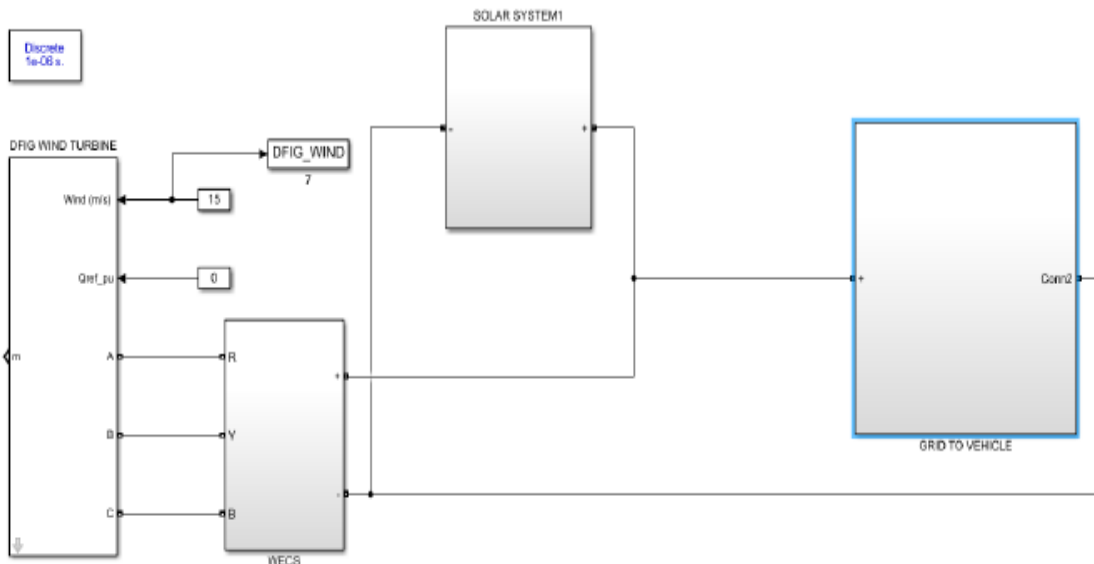


Figure 4. Over All Simulation Diagram

Figure 5 represent as “Solar Temperature Waveform” shows a constant solar temperature of 40°C over a 0.5 second duration. The temperature remains stable, indicating a controlled condition in a solar-related process or experiment. This stability is crucial for maintaining consistent performance in solar energy applications.

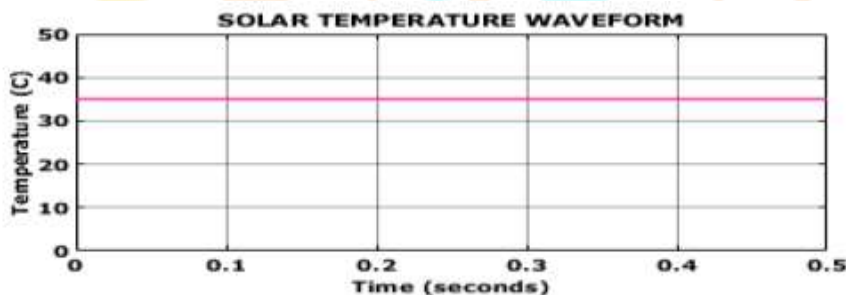


Figure 5. Solar Temperature Waveform

Figure 6 represent as illustrates the input DC voltage waveform of a DCDC converter. Initially, the voltage spikes to nearly 250 volts before rapidly dropping and stabilizing around 50 volts. This behaviour highlights the converter’s initial surge upon activation and its subsequent stabilization, which is crucial for understanding its operational characteristics.

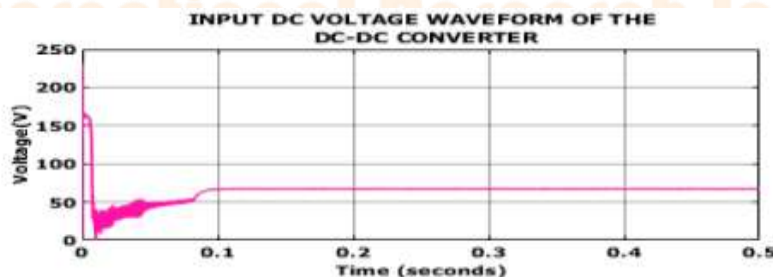


Figure 6. Input DC voltage waveform of a DC-DC converter

Figure 7 represent as “proposed dc-dc converter output voltage waveform” shows the current (A) on the y-axis and time (seconds) on the x-axis. The waveform starts at 0 Amperes, drops sharply to around -600 Amperes, and then stabilizes at approximately -700 Amperes. This illustrates the performance characteristics of the proposed DC-DC converter over a 0.5-second period.

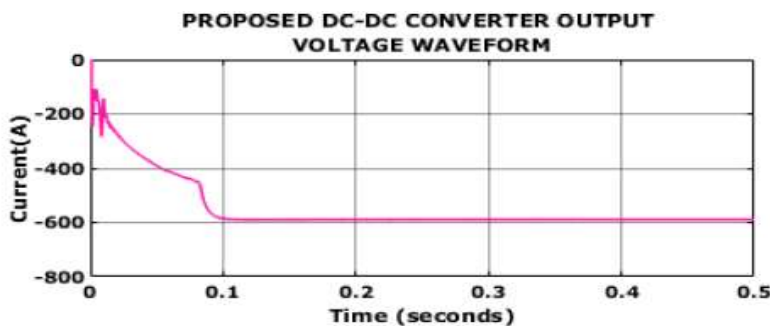


Figure 7. Proposed DC-DC converter output voltage waveform

Figure 8 represent as “output power waveform” illustrates power output over time. The vertical axis, labeled “Power (W),” ranges from -4000 to 4000 watts, while the horizontal axis, labeled “Time (seconds),” spans from 0 to 0.5 seconds. A pink line shows a rapid spike to just below 4000W, then drops back near zero, indicating power output fluctuations within this timeframe.

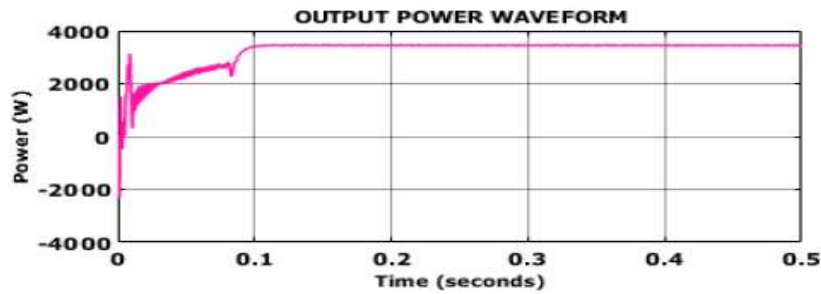


Figure 8. Output power waveform

Figure 9 represent as “Back EMF waveform of the BLDC motor” shows voltage over time. The x-axis, labeled “Time (seconds),” ranges from 0 to 0.2 seconds, and the y-axis, labeled “Voltage (V),” ranges from -200 to 200 volts. The waveform consists of periodic sinusoidal waves oscillating above and below zero, illustrating the alternating nature of the back EMF in BLDC motors.

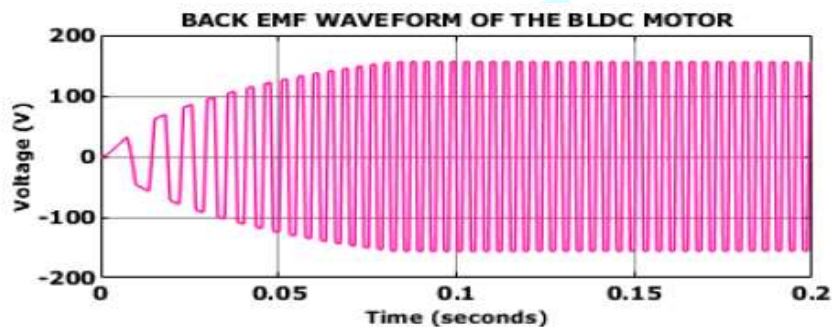


Figure 9. Back EMF waveform of the BLDC motor

Figure 10 represent as “Battery SOC waveform” shows the State of Charge (SOC) percentage over time. The SOC remains constant at 100% from 0 to 0.5 seconds, indicating stable battery performance. This stability is crucial for applications requiring consistent power supply, ensuring reliable operation without fluctuations in battery charge.

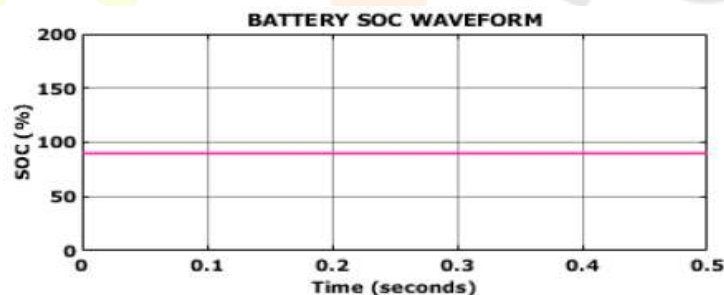


Figure 10. Battery SOC waveform

V. CONCLUSION

This initiative effectively illustrates a cutting-edge and efficient energy management system that combines a photovoltaic (PV) array with a Brushless DC (BLDC) motor drive. Utilizing advanced components such as the Interleaved Landsman Converter, a bi-directional converter, and a Class Topper Optimized PI Controller, the system achieves superior power conversion, stable operation, and improved dynamic response. The incorporation of a Pulse Width Modulation (PWM) generator alongside a three-phase Voltage Source Inverter (VSI) facilitates effective motor control, while optimizing energy use prolongs battery life. Additionally, the modular design provides flexibility for integration with other renewable energy sources, rendering it suitable for a variety of applications. This project, executed in Matlab 2021a Simulink, highlights the potential for enhancing the sustainability and performance of renewable energy systems through innovative control strategies and power management techniques.

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