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SECURITY SYSTEM TO PROTECT VOLTAGE FLUCTUATIONS OF GRID CONNECTED DC POWER SYSTEM

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Abstract: Multiport converters play a significant role in portable electronic and electric vehicle applications. In literature, different configurations of single-input multi-output (SIMO) converters are presented. Most of the SIMO converters generate the outputs with operating constraints on the duty ratio and charging of inductors. The cross-regulation problem is still a challenge in SIMO converters design. A SIMO topology is proposed in this study to overcome the limitations mentioned earlier. It can provide three different output voltages without constraint on the duty cycle and inductor currents. Cross regulation difficulties do not exist in the proposed topology; Hence the load voltages are not affected by the variation of output currents. The loads are isolated from one another during control.

Keywords: Multiport Converters, Single-Input Multi-Output (SIMO), Load Isolation, Output Voltages, Inductor Charging, Energy Management, Portable Electronics, Electric Vehicles (EVs).

I. INTRODUCTION

Multiport converters are improving crucial in the development of portable electronic devices and electric vehicles (EVs), where efficient power management is essential. Among these, Single-Input Multi-Output (SIMO) converters are particularly valued for their ability to distribute power from a single source to several outputs. However, traditional SIMO converters often face challenges such as constraints on the duty cycle and the precise control of inductor currents, which can lead to cross-regulation issues. These challenges occur when changes in one output negatively impact the stability of other outputs, affecting the overall power management. To solve these problems, this research proposes a new SIMO converter topology that provides a three distinct output voltages without imposing constraints on the duty cycle. Importantly, the proposed topology removes cross-regulation issues, ensuring that each output remains stable and independent of other outputs. This technology is particularly for small devices and EVs, where reliable and independent power supply is critical for performance and safety.

II. LITERATURE SURVEY

Heris et al. (2019) described a two-input, single-output converter with high voltage gain and ripple-free input currents, improving efficiency and reduced voltage stress on semiconductors [1]. Farakhor et al. (2019) introduced a multiport DC–DC converter tailored for renewable energy applications, ensuring effective energy management across multiple inputs [2]. Mishra et al. (2019) proposed a multiport converter based on switched-boost action, offering enhanced power conversion capabilities [3]. Similarly, Lu et al. (2016) described a multi-port DC fast-charging system for electric vehicles, significantly increasing efficiency and charging speed [4]. Babaei and Abbasi (2017) proposed a bidirectional multi-input, multi-output buck converter to reach higher efficiency [5]. Rehman et al. (2015) introduced many multi-input DC-DC converters, focusing on their applications in renewable energy systems [6]. Chen et al. (2019) described integrated multi-port converters with less switch count, increasing efficiency and simplifying system complexity [7]. Patra et al. (2012) develops a single-inductor multiple-output switcher capable of delivering simultaneous buck, boost, and inverted outputs [8]. Abbasi et al. (2019) later described enhancements for SIMO switchers to mitigate performance challenges [9]. Finally, Hsu et al. (2020) proposed a SIMO step-down converter with a coupled inductor, aiming to maximize power conversion efficiency [10].

III. PROBLEM IDENTIFICATION

Conventional converter designs face several difficulties that limit their efficiency and performance. One significant issue is component complexity, where a large number of components, such as nC2nC^2 switches, are required, resulting in increased size, cost, and overall system complexity. Another major issue is cross-regulation issues, where energy sharing between outputs causes instability, ripples, and interference in load voltage regulation. Additionally, load isolation remains a challenge, as traditional methods fail to segregate loads during operation, leading to performance challenges and inter-load dependency. Grounding issues further complicate operations, particularly when charging a battery with active loads, potentially causing operational instability. Moreover, converting a negative output voltage in buck-boost mode combined to circuit complexity. Conventional designs also face difficulties from limited independent control, as shared control mechanisms make it difficult to regulate multiple outputs independently. Finally, traditional designs face energy distribution limitations, where inductor energy is shared across multiple outputs, leading to inefficiency and regulation difficulties. These challenges highlight the need for advanced solutions to address these limitations efficiently.

IV. PROPOSED SIMO CONFIGURATION AND MODES OF OPERATION

The Single-Input Multi-Output (SIMO) converter is introduced to efficiently manage power distribution from a single source to multiple outputs while overcoming common issues like cross-regulation and load isolation. The SIMO converter works by using an inductor to store energy, which is then allocated to a specific output without being shared among others. Each output voltage is separately regulated through separate duty cycles, allowing for precise control and ensuring stability, regardless of changes in other outputs. A key innovation in this design is the isolation of loads, meaning that variations in one output do not affect the others, effectively eliminating cross-regulation problems. Additionally, the converter design avoids typical grounding problems, particularly in electric vehicles, by maintaining proper isolation and control, even when multiple loads are active and the battery is being charged. This technique leads a reliable and efficient power management system suitable for applications in portable gadgets and electric vehicles.

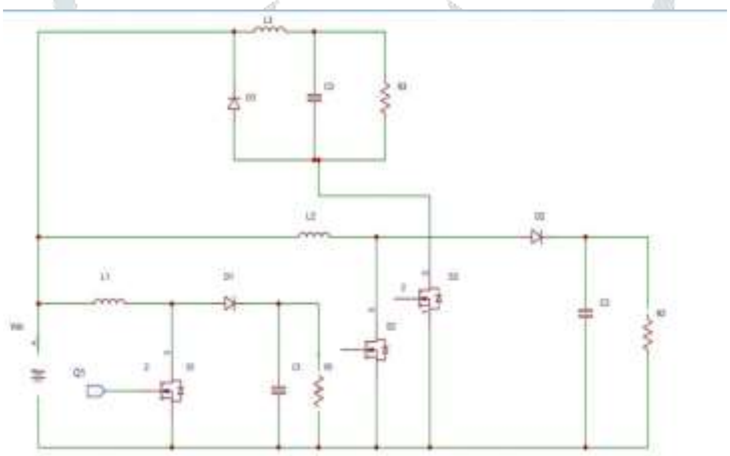


FIGURE 1: Proposed SIMO converter

Modes of Operation in the Proposed SIMO Converter

The proposed single-input multi-output (SIMO) converter operates in three different modes, each corresponding to a different configuration of the switches. These modes are proposed to ensure independent control of three output voltages: boost, buck-boost, and buck. Each mode regulates that the loads are isolated from each other during operation, reducing cross-regulation issues.

Mode 1: switching state 1

Operation:

- In this mode, switch S3 is turned ON while S1 and S2 remain OFF.
- The input voltage vdc is applied to inductor l3, which begins to store energy.
- During this period, capacitor c3 charges, supplying power to load r3.
- Loads r1 and r2 remain isolated, as only s3 is active.

Mode 2: switching state 2

Operation:

- In this mode, switch S1 is turned ON while S2 and S3 are OFF.
- The input voltage vdc is applied to inductor l1, which starts to store energy.
- Capacitor c1discharges to provide power to load r1, creating a boost output.
- Loads r2 and r3 remain isolated during this state.

Mode 3: switching state 3

Operation:

- In this mode, switch S2 is turned ON while S1 and S3 are OFF.
- The input voltage vdc is applied to inductor l2, which stores energy.
- Capacitor c2 discharges, delivering power to load r2 and providing a buck-boost output.
- Loads r1 and r3 remain isolated, ensuring no interference with r2.

Summary of Operation:

- **Independent Control:** Each mode ensures that the selected load is isolated from the others, allowing for independent voltage regulation.
- **Elimination of Cross-Regulation:** By isolating each load during its respective switching state, the design eliminates cross-regulation issues, ensuring stable output voltages.
- **Efficiency:** The proposed operation modes enhance overall efficiency by optimizing the energy transfer process for each output.

V. RESULTS & DISCUSSIONS

a. Hardware Implementation

The multiport converter system combines a number of hardware components to efficiently manage power conversion and regulation for various outputs. The PIC16F877A microcontroller is at the core of the system, controlling the converter's operation by generating Pulse Width Modulated (PWM) signals in response to feedback. It uses a 10 MHz crystal oscillator to ensure exact timing for PWM control, which is required for reliable voltage regulation. The system receives electricity from a 12V supply, which is first conditioned by a bridge rectifier (W10) to convert the AC input into a steady DC voltage. This DC voltage is then controlled to 5V by a 7805 voltage regulator, which supplies continous power to the microcontroller and other low-voltage components. Capacitors with different values ranging from 470 µF and 100 µF, are employed to filter and smooth the voltage, decreasing ripple and stabilizing the power supply.

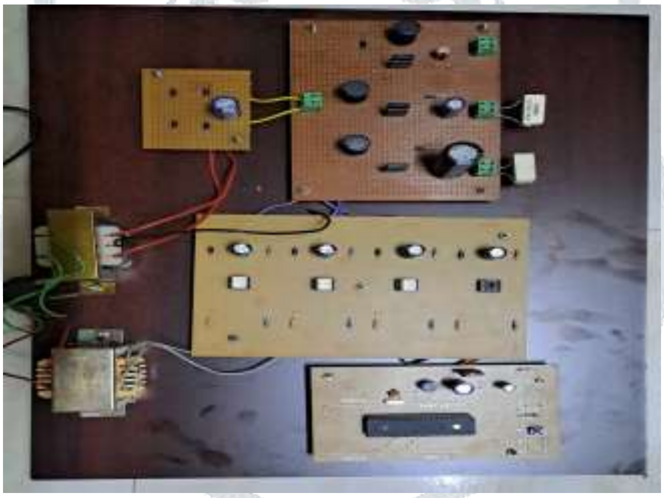


FIGURE 2. Hardware Implementation

The system's control signals are divided from high-power parts by a TLP250 optocoupler, which also drives the MOSFET gate. MOSFETs, especially the IRF840, regulates as switches to regulate power flow in the converter stages. The driver circuit has more capacitors and resistors to provide optimal functioning and protection. The circuit's IN4001 diodes protect reverse current flow, which prevents delicate components from harm. The main board has 1 mH inductors that store and transmit energy throughout the conversion process, which is crucial for stepping up or down the voltage as required. These inductors, combined with a 470 µF capacitor, easy the output voltage and minimize ripple. The diodes and MOSFETs collaborate to control the current and avoid back-current concerns, assuring. In operation, the microcontroller produces PWM signals to regulate the MOSFETs, which adjust the energy transfer through the inductors. The feedback system continuously monitors the output voltages and currents, adjusting the PWM duty cycles to maintain the desired output. This system ensures that the loads are connected to each output are generated with stable and regulated voltages, despite different in load conditions or input power. The output voltage values Vo1, Vo2& Vo3 are shown below tabular column,

Input voltage	Output voltage 1	Output voltage 2	Output voltage 3
34V	115V	50V	13V

1. Tabular column

b. Simulation Results

The simulation results for the proposed multiport DC-DC converter give detailed information on its performance, confirming the theoretical expectations and design objectives. The simulation was designed using a Simulink model, which effectively represents the converter's operation under different conditions. The simulink has been built in MATLAB environment to verify the proposed system with VDC=50 V, frequency is 50 kHz, and the duty ratio is 50%. The output voltages (V01 , V02 , and V03) and inductor currents (iL1 , iL2 , and iL3) are illustrated in below Figures. The output voltages in Figures. The closed-loop control is designed for the proposed configuration, and the dynamic performance of the system is validated for a sudden change in the input voltage.

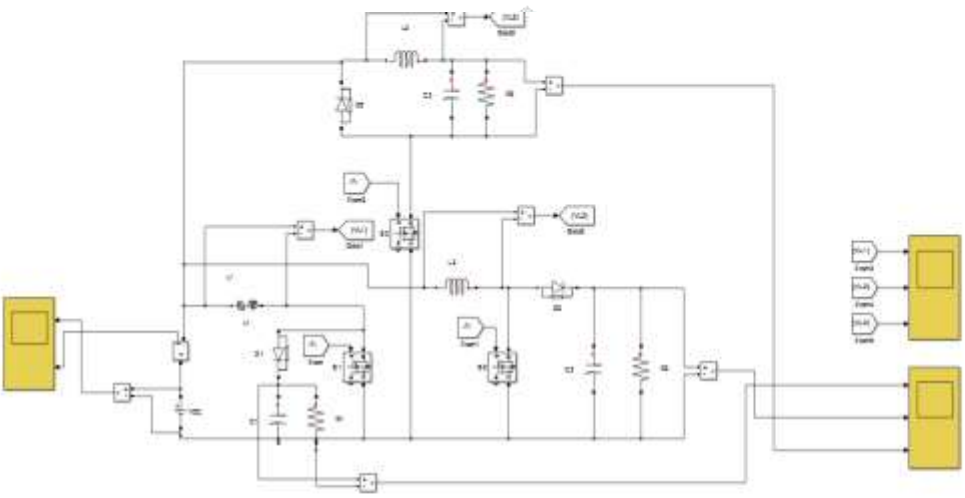
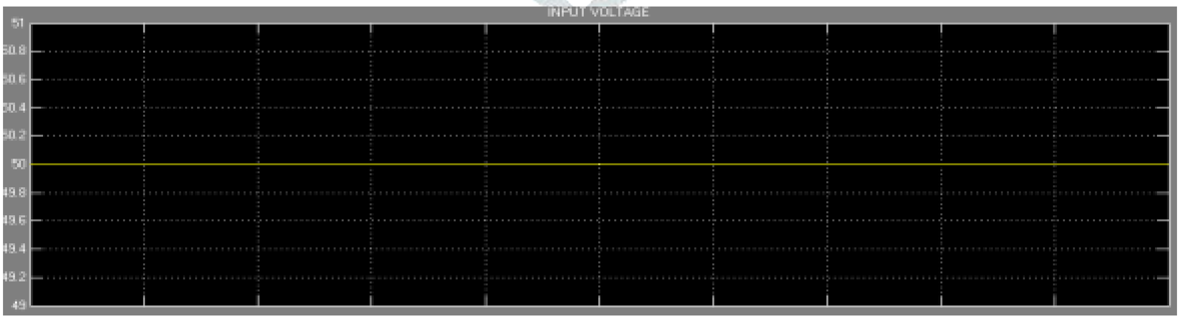


FIGURE 3. Simulink

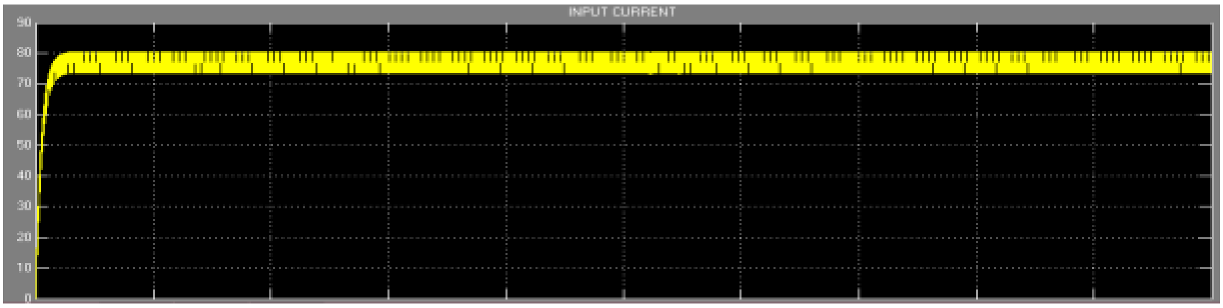
1. INPUT VOLTAGE

The input voltage is a main role in the simulation of the proposed converter, serving as the primary power source for the system. In the simulation, a steady DC voltage, such as 12V, is applied, representing a common power source like a battery used in devices. This fixed input voltage allows the converter to generate multiple output voltages, such as 5V, 12V, and -5V, through controlled switching of MOSFETs and inductor current management. Keeping a continuous input voltage is critical for accurate simulation results, ensuring reliable performance under different loads and during transients. The input voltage is continuously monitored to allow it stays within the expected range, supporting consistent power distribution and stable operation of the converter.



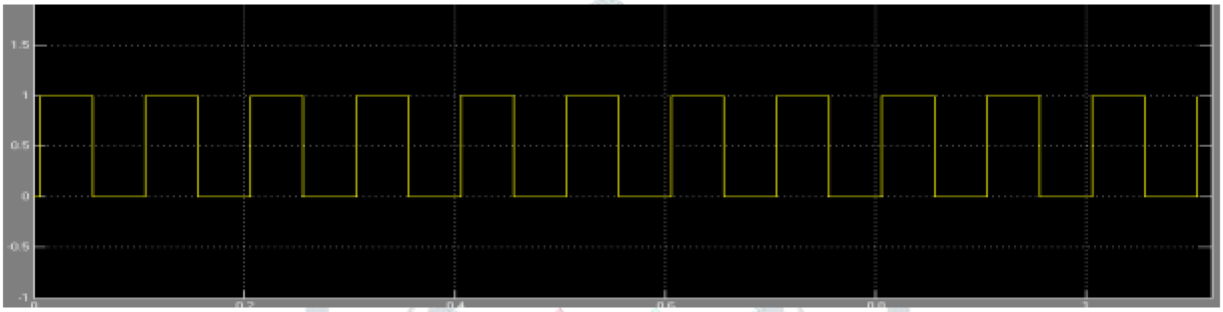
2. INPUT CURRENT

The input current depends on the total load across all outputs and the converter's efficiency. As the converter controls output voltages and supplies power to the loads, the input current changes based on switching cycles and load conditions. When the load increases, the input current rise to meet the demand, and it reduces when the load reduces. Monitoring the input current helps understand the power draw and ensures the converter operates efficiently without overloading the input source. If the converter is effective, the input current will closely match the total output currents, adjusted for system losses.



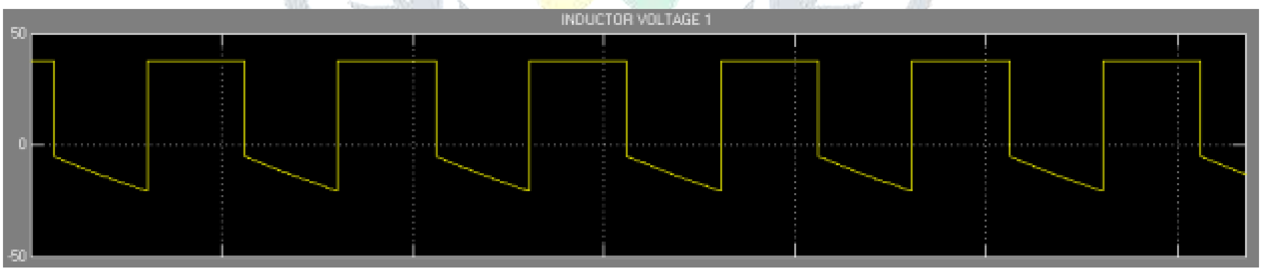
3. GATE PULSE

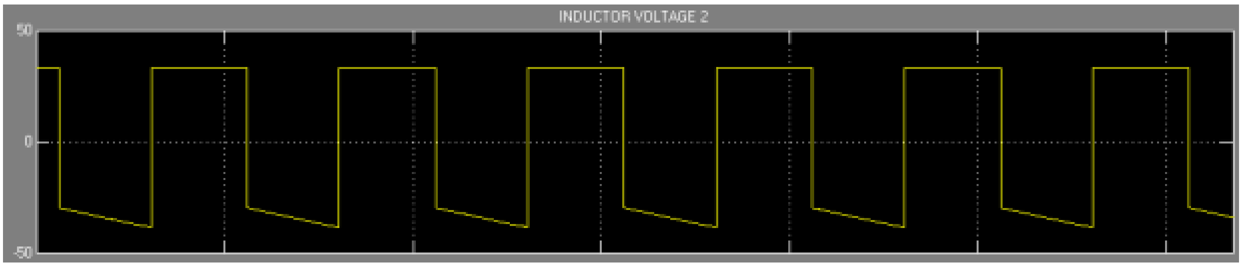
Gate pulses are more essential to control signals that manage the switching of MOSFETs. These pulses are generated using Pulse Width Modulation, where the duty cycle determines each MOSFET stays "on" during a switching cycle. By adjusting the duty cycle, the converter regulates the energy transferred to the outputs, regulating their voltages. Longer duty cycles improve output voltage, while shorter ones reduce it. The gate pulses are square wave signals, typically operating at frequencies from 20 kHz to 100 kHz. Precise timing and control of these pulses ensure independent regulation of each output voltage, avoiding cross-regulation problems.

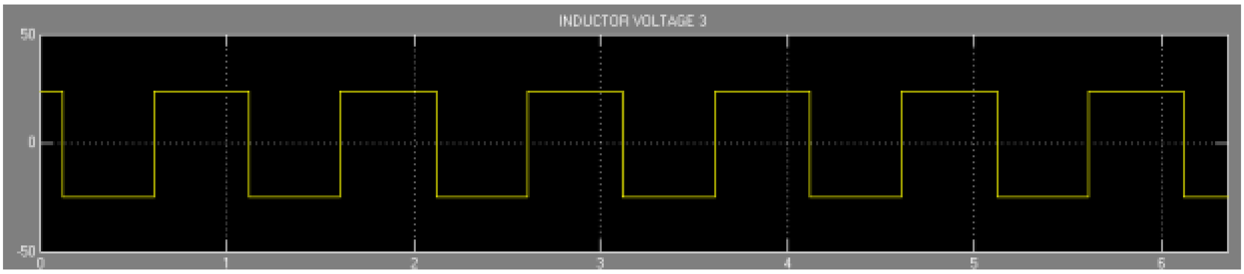


4. INDUCTOR VOLTAGES

Each inductor stores energy during the "on" phase of its respective MOSFET switch and releases it during the "off" phase to maintain the desired output voltage. During the "on" phase, the input voltage gives a positive voltage across the inductor, increasing the current. In the "off" phase, the inductor discharges energy to the output, resulting in a drop in voltage, sometimes turning negative. The voltage waveform for each inductor typically shows a triangular or sawtooth pattern, reflecting the charging and discharging cycles. Monitoring these waveforms allows the outputs are stable, regulated, and free from extra ripples, demonstrating efficient energy transfer and proper converter operation.

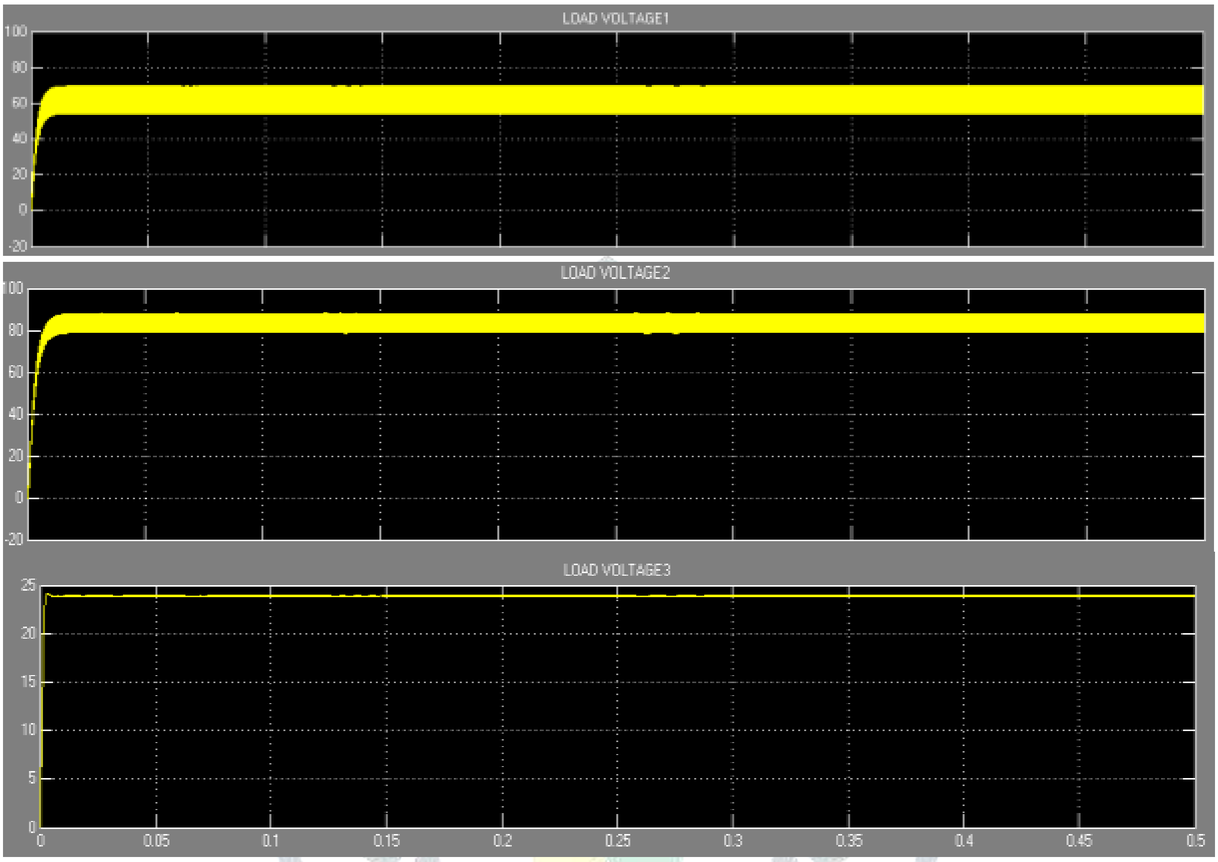






5. LOAD VOLTAGES

The voltage at Load 1, Load 2, and Load 3 is critical for determining the converter's ability to produce stable and regulated power. The voltage at Load 1 remains constant, close to the intended value 5V, even with varying load conditions, demonstrating the converter's capacity to maintain stable output. Similarly, Load 2's voltage remains close to the desired 12V under various loads, with minimum ripple and sudden recovery to changes, ensuring stable power delivery. For Load 3, the voltage remains constant at the intended value -5V, with minimum fluctuations and fast adjustment to load changes. The converter effectively handle power distribution, maintaining stability, reducing cross-regulation issues, and providing clean, noise-free output across all loads.



VI. CONCLUSION

This paper proposed an innovative Single-Input Multi-Output (SIMO) converter with a simplified manner, addressing limitations in conventional designs. The proposed configuration operates without assumptions regarding inductor charging or the duty cycle, ensuring flexibility and adaptability in many applications. It is capable of generating buck, boost, and buck-boost output voltages with individually regulated outputs, enabling improved performance and stability. Unlike standard converters, the proposed design removes cross-regulation problems, ensuring that quick changes in inductor or load currents do not affect output voltages. This feature significantly improves reliability and load isolation, making it suitable for applications requiring stable multi-output power delivery.

FUTURE WORK

- **Improve Efficiency**: Use advanced semiconductors and better control algorithms for various energy-efficient designs.
- **Compact and Reliable Design**: Integrate smaller components and improve thermal management for more reliability in compact applications.
- **Wider Input Voltage Range**: Expand the input voltage range to maximum versatility.
- **Smart Features**: Add digital communication and adaptive load-sharing to boost the system performance.
- **Adaptable to More Applications**: These improvements will give the converter suitable for a longer range of applications.

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