Modified High Gain Dc–Dc Converter With Dual Switch

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***Abstract*—With the increasing adoption of solar energy sys- tems, the need for high-gain DC-DC converters has become more critical. Traditional boost converters operating at high duty cycles often suffer from poor efficiency and elevated voltage stress. To address these issues, a modified converter is proposed that operates at a lower duty cycle, reduces voltage stress, and delivers high voltage gain. This design incorporates a voltage multiplier cell comprising a capacitor and diode at the output stage of a conventional buck-boost converter, effectively minimizing the stress across switching devices. As a result, switches with lower voltage ratings can be employed. The proposed converter is well-suited for solar power applications, offering a wide voltage conversion range, steady input current, and high efficiency. A comprehensive steady-state analysis and operational study are presented. Simulation is performed using MATLAB/SIMULINK R2017b, demonstrating a peak efficiency of 85% and substan- tial voltage gain. Furthermore, a hardware prototype utilizing the TMS320F28027F microcontroller is developed, achieving an output voltage of 8.5V from a 2V input.**

***Index Terms*—Voltage Multiplier, SEPIC, Efficiency, Photo- voltaic (PV).**

I. INTRODUCTION

Concerns such as climate change, increasing energy de- mand, fossil fuel depletion, and global warming have in- tensified the emphasis on renewable energy sources. Power electronic systems are essential for integrating technologies like photovoltaic (PV) systems, wind turbines, and fuel cells into the power grid or other applications. These systems ensure stable load voltage despite large variations in input voltage and are widely used in battery storage systems, elec- tric vehicles, power factor correction, and portable electronic devices. Furthermore, certain applications, such as multifunc- tional switched-mode power supplies, demand multiple output voltage levels while operating with a constant input voltage.

To address the above challenges, a DC–DC converter with a high voltage conversion ratio proves to be an effective solution. Conventional boost and buck converters are well- established due to their simplicity and ease of understanding.

In [2], a novel negative-output (N/O) buck–boost converter is introduced, suitable for applications that demand a wide range of inverted voltages. This modified buck–boost con- verter provides both a wide conversion ratio and an inverted output, with smooth voltage transitions achieved by storing energy in an energy-transfer capacitor. In [3], a transformerless buck–boost converter is proposed, incorporating an additional switching network into the traditional buck–boost design. Its main advantage lies in its ability to operate over a broad output voltage range, with a voltage gain that is quadratic compared to that of a conventional buck–boost converter.

In step-up mode [4], the proposed converter attains a higher voltage gain than conventional non-isolated buck–boost con- figurations, including SEPIC, Cuk, Zeta, and the traditional buck–boost converter. The use of a single power switch reduces switching losses and simplifies the control approach. As noted in [5], its straightforward structure further facili- tates easy control implementation. Because the output voltage surpasses the voltage stress on the main switch and diodes, switching losses are minimized, enhancing overall efficiency. Reference [6] presents a modified buck–boost converter ca- pable of producing a negative output voltage, with a low step-down gain similar to that of the conventional buck–boost

converter. The work in [7] focuses on a novel transistor arrangement and specific switching functions, which greatly reduce input current ripple and enable the use of smaller inductors. In [8], a buck–boost converter design incorporating switched capacitors and a common-ground configuration is introduced for point-of-load applications.

Reference [9] introduces an advanced power converter de- sign that employs a voltage ripple cancellation technique, enabling operation at any desired duty cycle while maintaining zero output voltage ripple, independent of the duty cycle value. In [10], a novel quadratic buck–boost converter is proposed, combining the functions of conventional boost, buck, and buck–boost converters into a single topology using only one

power switch. To address the shortcomings of earlier designs, reference [1] presents an improved dual-switch buck–boost converter, which reduces the component count and lowers volt- age stress across components, thereby enhancing practicality and efficiency.

The proposed converter provides a common ground conection between the input and output and ensures a constant input current. Its control is simplified by operating both switches with a single PWM signal. To overcome the aforementioned challenges, a dual-switch enhanced-gain buck–boost converter with reduced voltage stress is introduced. Incorporating a voltage multiplier circuit substantially increases the voltage gain while significantly lowering the voltage stress across components compared to conventional buck–boost converters. The voltage multiplier cell is central to achieving this gain enhancement. As a result, the converter delivers low stress on switching devices, stable input current without transient spikes, and high voltage gain over a wide duty cycle range. The performance is evaluated in continuous conduction mode, with the converter operating in two distinct modes.

II. METHODOLOGY

The dual switch enhanced gain buck boost converter is de- rived from the conventional buck boost topology by integrating a voltage multiplier stage at the output, consisting of a capacitor diode pair. This arrangement effectively minimizes voltage stress on the switching devices. The converter architecture includes two synchronously operated power switches (S1 and S2), three inductors (L1, L2, L3), four capacitors (C1, C2, C3, C4), three diodes (D1, D2, D3), and a load resistor (R).

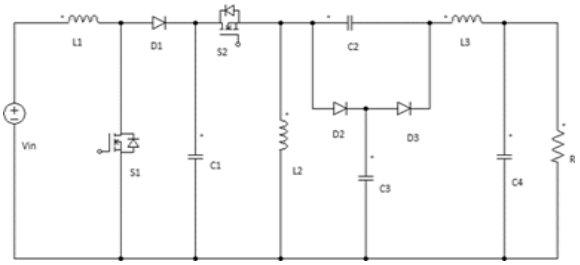


Fig. 1. Modified Dual-Switch Boost DC-DC Converter

A. Modes of Operation

The dual-switch enhanced gain buck-boost converter func- tions in two distinct modes. Both power switches, S1 and S2, operate with an identical duty cycle. Based on their synchronized switching turning ON and OFF simultaneously the converter's operation within a single switching cycle is divided into two modes.

1) Mode 1: During Mode 1, diode D conducts along with switches S and S, while diodes D and D remain in the off state. In this interval, the source supplies energy to charge inductors L, L, and L. Simultaneously, capacitor C is being charged, whereas capacitors C, C, and C are discharging. The current through the inductors increases linearly. The load receives power from the discharging output capacitor C. The corresponding circuit for Mode 1 is illustrated in Figure 2.

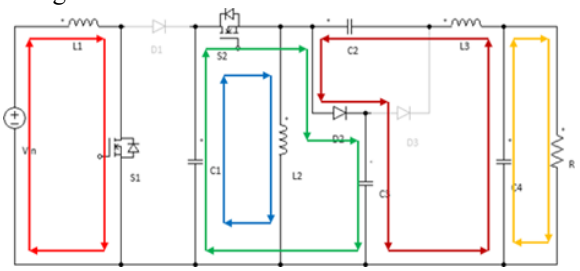


Fig. 2. Operating circuit of of Mode 1

2) Mode 2: In mode 2, diode D_2 is switched off together with switches S_1 & S_2, while diodes D_1, and D_3 are turned on. At this point, the inductors L_1, L_2 & L_3 are now being discharged by the source. Current in inductors falls down linearly. Mode 2 of circuit is depicted in Figure 3

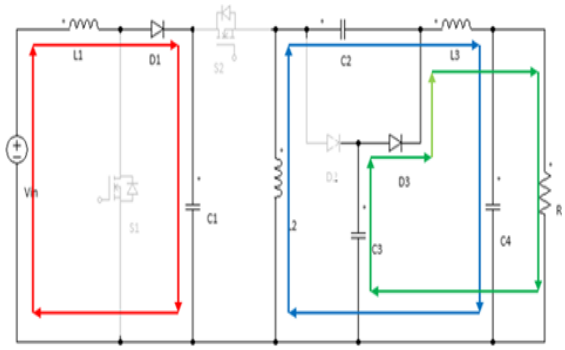


Fig. 3. Operating circuit of of Mode 2

Figure 4 illustrates the theoretical waveforms corresponding to Mode 1 and Mode 2.

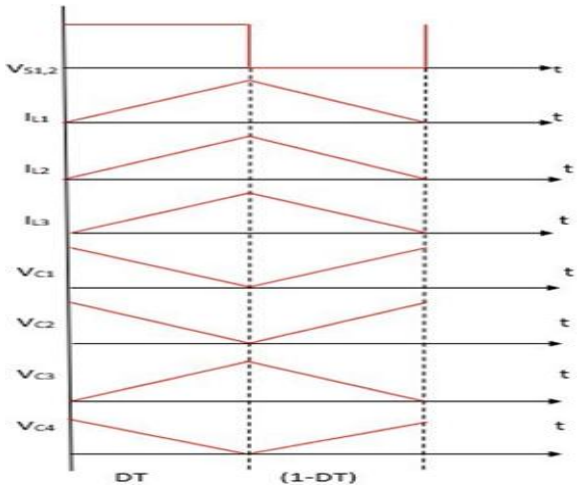


Fig. 4. Theoretical waveform

B. Design of Components

A converter cannot operate properly unless its components are designed appropriately. The design of the buck boost converter makes a few assumptions. It consists of the inductors L_1, L_2, L_3, and L_4, as well as the load resistance design and the capacitors C_1, C_2, C_3, C_4, and C_5. We take 15 V to be the input voltage. It is assumed that the output power is 40W and the output voltage is 75V. The switching frequency is 75 kHz. The output current is equal to 0.53A.

Parameters	Values
Input Voltage V_{IN}	15V
Output Load R	150Ω
Switching Frequency f_s	75 kHz
Inductors L_1 L_2, L_3	1.2mH, 1mH, 1.1mH
Capacitors C_1, C_2C_3 C_4	47 μF, 100 μF, 100 μF,100 μF
Duty Ratio	0.55

Load resistance can be found by the equation,

$$R_o = \frac{V_o^2}{P_o}$$

Voltage Gain,

$$M = \frac{V_o}{V_{in}} = \frac{1}{(1-D)^2}, \quad D = 0.69$$

The inductors L is obtained from the following equations.

$$L1 >= \frac{V_{IN} D}{\Delta I_{L1} \cdot f_s}$$

$$L2 >= \frac{V_{IN} D}{\Delta I_{L2} \cdot f_s * (1-D)^2}$$

$$L3 >= \frac{V_{IN} D^2}{\Delta I_{L3} \cdot f_s * (1-D)^2}$$

$$C_1 \geq \frac{I_0 * D}{\Delta V_{C1} * (1-D)^2 * f_s}$$

$$C_2 \geq \frac{I_0 * D}{\Delta V_{C2} * f_s}$$

C_1 and C_2 is taken as 47 μF

$$C_3 \geq \frac{I_0}{\Delta V_{C3} * (1-D) * f_s}$$

$$C_4 \geq \frac{D * I_0}{\Delta V_{C4} * f_s}$$

C_3, C_4 are taken as 100 μF

III. SIMULATIONS AND RESULTS

The enhanced gain buck boost DC-DC converter is simu- lated using MATLAB/SIMULINK with the settings chosen from Table 1.

The MOSFET switch keeps its switching frequency constant at 75kHz. The power switch is managed using a 0.55 duty ratio.An output of 75V can be obtained with a dc input voltage of 15V. Figure 5 illustrates the display of the source voltage and current. The voltage and current of the converter's output can be observed in Figure 6.

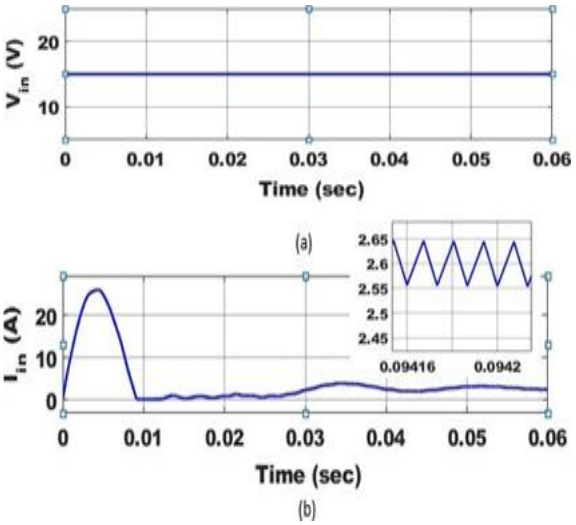
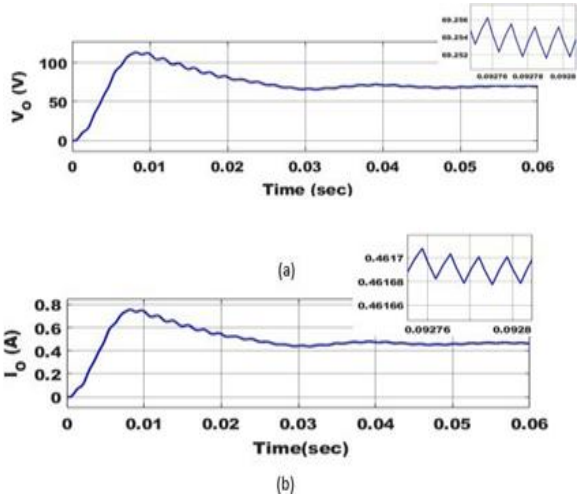


Fig. 6. (a) Output Voltage (V_0) and (b) Output Current (I_0)



The gate pulse and switching voltage across switches are displayed in Figure 7. Switch S_1 & S_2 has a voltage stress of 33V & 71V

The voltage across capacitors V_{C1} is 32V ,V_{C2} is 69V, V_{C3} is 31V and V_{C4} is obtained as 75V as shown in Figure 8.

IV. PERFORMANCE ANALYSIS

The power input to output ratio of a electrical equipment determines its efficiency at various load. The efficiency versus output power for a single switch high gain buck boost DC-DC converter with R and RL loads is presented in Figure 9. For R and RL loads, the maximum converter efficiencies are 85% and 86% respectively.

The graph of Voltage gain VS duty ratio is shown in figure

10. The graph of Output voltage ripple Vs duty ratio is shown in figure 11. The graph of Output voltage ripple Vs Frequency is shown in figure 12.

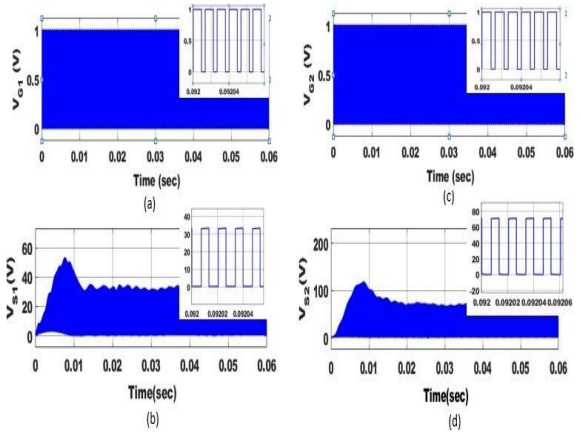


Fig. 7. Gate Pulse of S_1 and S_2 and (b) Voltage Stress of S_1(V_{S1}) and (c) Voltage Stress of S_2(V_{S2})

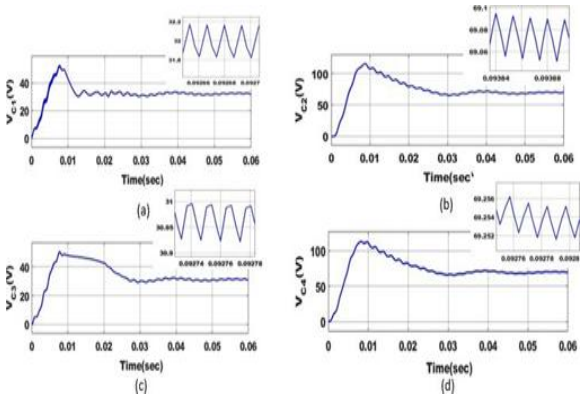


Fig. 8. Voltage across Capacitor (a)V_{C1}, (b)V_{C2}, (c)V_{C3}, (d)V_{C4}

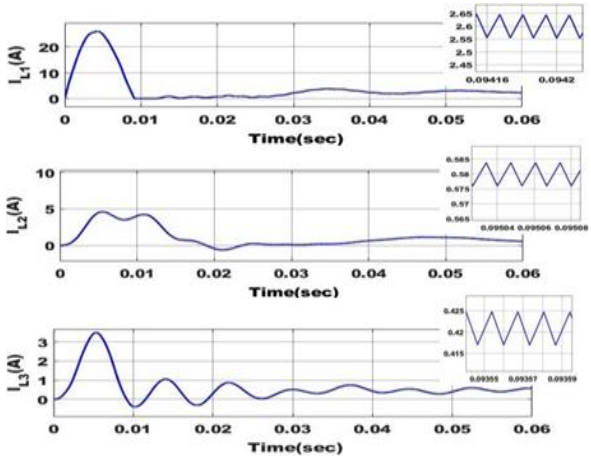


Fig. 9. Current through Inductors L_1, L_2 and L_3

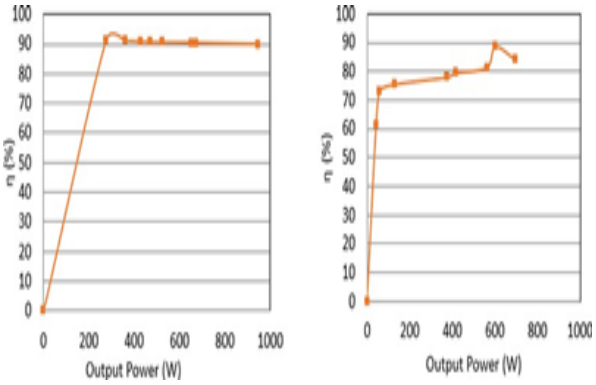


Fig. 10. Efficiency Vs Output Power for (a) R load (b) RL load

The plot of output voltage ripple as a function of duty Ratio for Modified Dual-Switch Boost DC-DC Converter is shown in figure 13.

Figure 14 depicts the variation in output voltage ripple of the modified boost converter as the switching frequency changes. It can be seen that increasing the switching frequency leads to a reduction in the output voltage ripple.

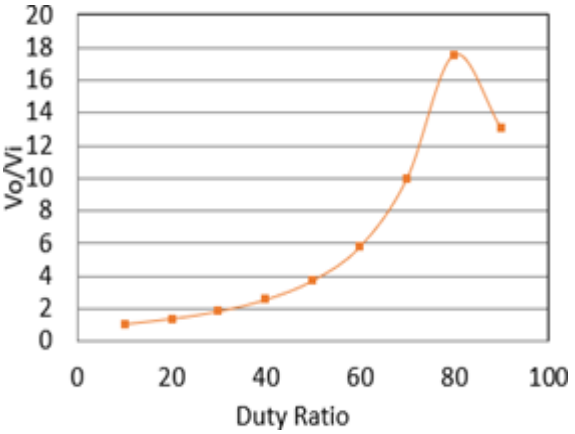


Fig. 11. Voltage gain VS Duty ratio

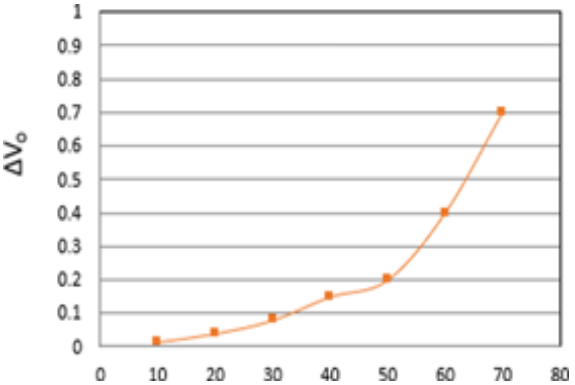


Fig. 12. Output Voltage Ripple VS Duty Ratio

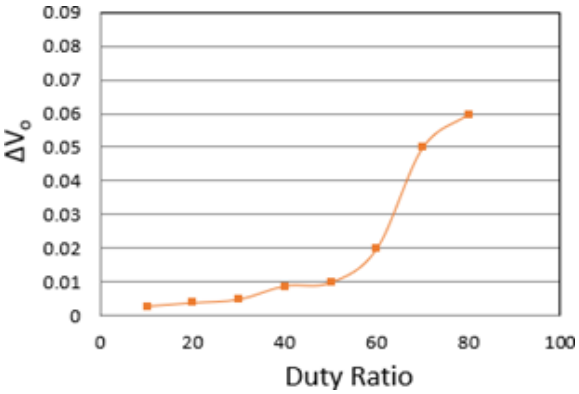


Fig. 13. Output voltage ripple VS frequency

V. COMPARITIVE STUDY

Due to the addition of a voltage multiplier circuit, the high gain buck boost converter has more components. Thus, there was a reduction in stress across the switch. The Comparison between dual switch buck boost converter and enhanced gain buck boost converter is done by keeping the same output power P_O = 40W, input voltage V_{IN} = 15V, switching frequency f_s= 50kHz and the load as constant. The utilization of a high gain converter effectively reduces the ripple exist in both the output voltage and current. Table III presents the results of a com- parative analysis between various buck boost topologies and the suggested converter. After evaluating similar buck boost converters, it can be inferred that the suggested converter has exceptional performance in regards of voltage gain, switching voltage, and efficiency.

Table 3 presents a comprehensive comparison of the com- ponents utilized in the proposed Modified Dual-Switch Boost DC-DC Converter with those employed in alternative converter configurations.

Table II Comparison Between Dual-Switch Boost Dc-Dc Converter& Proposed Modified Dual-Switch Boost Dc-Dc Converter

Parameters	*Dual Switch Buck Boost Converter*	*Enhanced Gain Buck Boost Converter*
Duty Ratio (D)	69%	55%
Output Voltage (*Vo*)	70.8V	69.4V
Output Current (*Io*)	0.47A	0.46A
Input Voltage	15V	15V
Input Current	2.75A	2.66A
Voltage stress across switches	Vs_1 = 48V Vs_2 = 151.8V	Vs_1 = 33.2V Vs_2 = 71.3V
Efficiency	80%	80.6%
Voltage Gain	4.7	4.6
Input Current Ripple	0.1A	0.1A
Output Voltage Ripple	0.01V	0.004V
Output Current Ripple	0.00002A	0.00003A

Table III Comparison between Modified High Gain DC-DC Converter& Other converters

Converters	*Buck Boost Converter in [2]*	*Buck Boost Converter In [3]*	*Dual Switch Buck Boost Converter [1]*	*Enhanced Gain Buck Boost Converter*
Switches	2	2	2	2
Diodes	2	2	2	3
Inductors	2	2	3	3
Capacitors	2	2	3	4
Voltage Gain	$\frac{D(2-D)}{(1-D)^2}$	$\frac{D^2}{(1-D)^2}$	$\frac{D^2}{(1-D)^2}$	$\frac{1}{(1-D)^2}$

VI. EXPERIMENTAL SETUP WITH RESULT

For hardware realization, the input voltage is stepped down to 2 V. Switching pulses are produced using the TMS320F28335 controller. IRF540 MOSFETs are employed as the main power switches, while IN5817 diodes are used within the circuit. The driver stage is implemented with a TLP250H optocoupler, which provides the necessary gate drive voltage for switch operation and ensures isolation and protection for the microcontroller. This device enables the development of an interface circuit to deliver gate signals to the switches. Figure 13(a) shows the experimental setup of the dual-switch enhanced-gain buck–boost converter. In this setup, a 1.57 V DC supply from a DC source is used as the input, and switching pulses for the driver circuit are generated by the TMS320F28027F microcontroller.

Fig. 14. Experimental Setup

VII. CONCLUSION

A high gain buck boost converter with reduced switch stress has been designed, implemented, and tested. The topology is derived from the conventional high-gain buck boost converter by incorporating a voltage multiplier stage at the output,

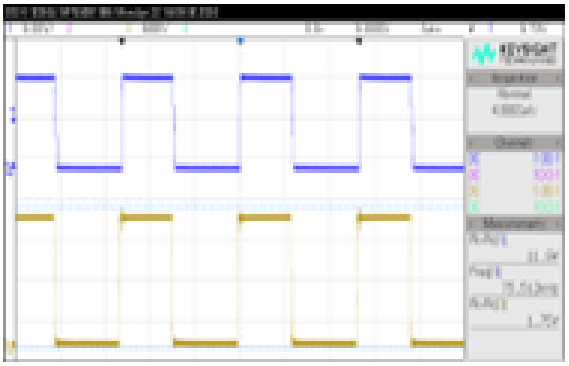


Fig. 15. Output Voltage of Proposed Converter

composed of a capacitor and diode. Compared to other high gain buck boost DC–DC converters, the proposed design delivers higher voltage gain while subjecting the switching devices to lower voltage stress. Simulation and performance analysis indicate an efficiency of 80% at 40 W output power, with a peak efficiency of 85.4% achieved at 140 W out- put. The converter supports a wide duty cycle range and maintains low stress on the switches. Control is realized using a TMS320F28027F microcontroller. A 40 W prototype validates the design, producing an output voltage of 8.5 V even after accounting for voltage drops across components. These features make the converter highly suitable for photovoltaic system applications.

REFERENCES

[1] Mummadi Veerachary and Malay Ranjan Khuntia “Design and analy- sis of two-switch-based enhanced gain buck boost Converters”, IEEE Transactions on Industry Applications, vol. 69, no. 4, April 2022.

[2] S. Ding and F. Wang, “A new negative output buck–boost converter with wide conversion ratio,” IEEE Trans. Ind. Electron., vol. 64, no. 12, pp. 9322–9333, Dec. 2017.

[3] S. Miao, F. Wang, and X. Ma, “A new transformerless buck-boost converter with positive output voltage,” IEEE Trans. Ind. Electron., vol. 63, no. 5, pp. 2965–2975, May 2016.

[4] M. R. Banaei, H. Ardi, and A. Farakhor, "Analysis and implementation of a new single switch buck-boost converter," IET Power Electron., vol. 7, no. 2, pp. 1906–1914, Feb. 2014.

[5] M. R. Banaei and H. A. F. Bonab, "A high efficiency nonisolated buck- boost converter based on ZETA converter," IEEE Trans. Ind. Electron., vol. 67, no. 3, pp. 1991–1998, Mar. 2020.

[6] J. Li and J. Liu, "A novel buck-boost converter with low electric stress on components," IEEE Trans. Ind. Electron., vol. 66, no. 4, pp. 2703–2713, Apr. 2019.

[7] Pedro Mart´ın Garc´ıa-Vite and Julio C. Rosas-Caro, "Quadratic buck–boost converter with reduced input current ripple and wide con-version range," IET Power Electronics, Sept. 2019.