



RESEARCH ARTICLE

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DESIGN AND ANALYSIS OF HIGH GAIN BOOST CONVERTER USING IMPROVED SEEKING OPTIMIZATION ALGORITHM FOR ELECTRIC VEHICLES

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ABSTRACT

This paper seeks to demonstrate a way to optimize a high-gain DC-DC boost converter designed for use in electric vehicle (EV) applications by utilizing the Improved Seeking Optimization Algorithm (ISOA), which is a new method of optimization. The proposed boost converter is designed to have a non-isolated, non-coupled inductor configuration so that it can be built into a high-gain boost converter operating with a low duty cycle, allowing for reduced voltage stress on the power switches. The recommended boost converter design uses only two power switches and one PWM control signal thereby making the system compact, lightweight and inexpensive. The ISOA optimization method is also applied to the design parameters of the boost converter: duty cycle, switching frequency and passive component selection for maximum performance improvement. The optimized boost converter incurs minimal power losses and the output voltage remains constant given that the load varies. The effectiveness of the suggested strategy is proved by performance of the optimized boost converter that can be verified with the help of MATLAB/Simulink simulations. Therefore, the suggested boost converter is applicable to the effective functioning in the present-day EV electric systems.



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I. INTRODUCTION

EVs can be powered through very efficient power conversion interfaces to interface with the low-voltage battery sources with high-voltage DC distribution systems. Auxiliary subsystems are commonly run at 24-48 V in a typical EV architecture, though traction battery pack are run in 200-400 V. Such sources of energy will have to provide traction inverters, onboard chargers, and fast-charging systems with high voltage DC buses [1], [2]. DC-DC boost converters are important in this regard since they serve as a critical intermediary in the power generation to power conditioning processes, hence has a strong impact on total performance of the vehicle, its thermal, and charging efficiency [3], [4]. Modern boost converter circuit topologies, however, are not well adapted to high step-up voltage applications, because high voltage gains are normally obtained by operating at extremely high duty cycles. Such operating condition causes problem of increased conduction loss, higher input current ripple, higher electromagnetic interference (EMI), and high electrical stress on semiconductor devices, which ultimately results in low efficiency and causes low reliability for system. In a possible way to overcome through the limits for the traditional boost can converters a bunch of converters (high gain) DC to DC converter topologies have been presented in literature. These are quadratic high boost converters, switched-inductor and switched-capacitor, coupled-inductor and coupled-capacitor, coupled inductor-capacitor, quasi-Z-source converters [5], [6].

Even though these topologies have the potential to attain high ratios of voltage conversion, they tend to bring practical issues like addition of more components, leakage inductance effects, intricate control schemes, and large circuit layouts. These limitations are especially unwanted when it comes to the use of electric vehicles, when compact size, weight reduction, and high reliability are especially important performance factors. A more recent proposal is that of a connected, integrated-inductor high-gain boost converter which uses two independent inductors with three capacitors, three diodes and two active switches driven by a single PWM signal [7-15]. This topology can produce a large voltage gain at intermediate duty cycles and the voltage stress on the power semiconductor devices is low and at the same time the circuit configuration is relatively simple. Due to these merits, the converter has attracted very much attention in the renewable energy systems and in contemporary power electronic systems. Although it has structural advantages, the non-isolated, non-coupled-inductor high-gain boost converter strongly relies on the choice of important design and operating parameters, including duty cycle, switching frequency, and values of passive components. Depending on the conditions of the practical work of electric vehicles, the efficiency, regulation of the voltage, and the power losses could significantly depend on the changes in the demands of the loads and the input voltage in case these parameters are not selected optimally. Designing traditional methods with set analytical calculations or trial-and-error optimization are not usually adequate to ensure optimal performance over a wide operating range. To address this weakness, the current work uses an Improved Seeking Optimization Algorithm (ISOA) in order to obtain the optimal operating parameters of the converter in a systematic manner. The optimization strategy proposed aims at the minimization of the power losses, the increase in the efficiency, and the stability of the output voltage in different operating conditions, to increase the overall appropriateness of the converter in the electric vehicle context of power electronics.

II. PROPOSED CONVERTER

The connected high-gain DC-DC boost converter that was explored in this paper is based on the topology that is initially introduced in [7]. The converter arrangement has two independent, uncoupled inductors (L_1 and L_2), three capacitors (C_1 , C_2 , and C_3), three diodes (D_1 , D_2 and D_3), and two active power switches (S_1 and S_2). Both switches are excited by a shared PWM gating signal of a switching frequency f_s . The converter is mainly intended to run under a continuous conduction mode (CCM) over the range of its operation. Running in CCM leads to less irregular input current waveforms and less electromagnetic interference (EMI). All these features are quite beneficial in the case of the electric vehicle usage, as they contribute to the battery system protection, enhancement of the general energy conversion efficiency, as well as enhanced compatibility with other onboard power electronic subsystems.

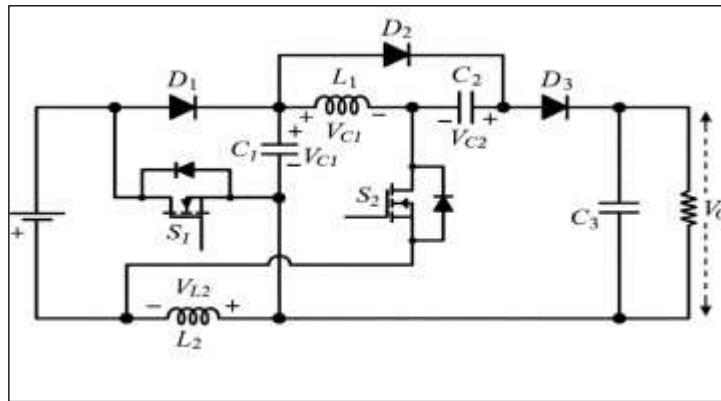


Figure 1: Proposed Converter.
Source: Authors, (2026).

II.1 OPERATING MODES

With a constant conduction mode (CCM), the currents L_1 and L_2 do not drop to zero during the entire switching period. Every switching period is further subdivided into two dissimilar sub-intervals that are the ON and OFF of the power switches.

II.1.1 Continuous Conduction Mode

During continuous conduction mode inductor currents do not go to zero anywhere in the switching period. The switching cycle was hence divided into 2 operating periods, which include a switch ON period and switch OFF period.

Mode I: Switch ON Interval ($0 \leq t \leq DT$)

At this time power switches are S_1 and also S_2 will be switched at same time. As per result, the diodes present are D_1 and D_3 have their reverse-biased, and diode D_2 has its opposite version. The input voltage source in this mode is the source of energy that is stored in the form of inductors L_1 and L_2 .

$$V_{L1} = V_{in} + V_{C1} = V_{C2} \quad (1)$$

$$V_{L2} = V_{in} \quad (2)$$

Where V_{in} is the voltage input, V_{C1} and V_{C2} both are the voltages- across capacitors (C_1) and (C_1), respectively. During this interval, both inductors are energized, and their currents increase linearly.

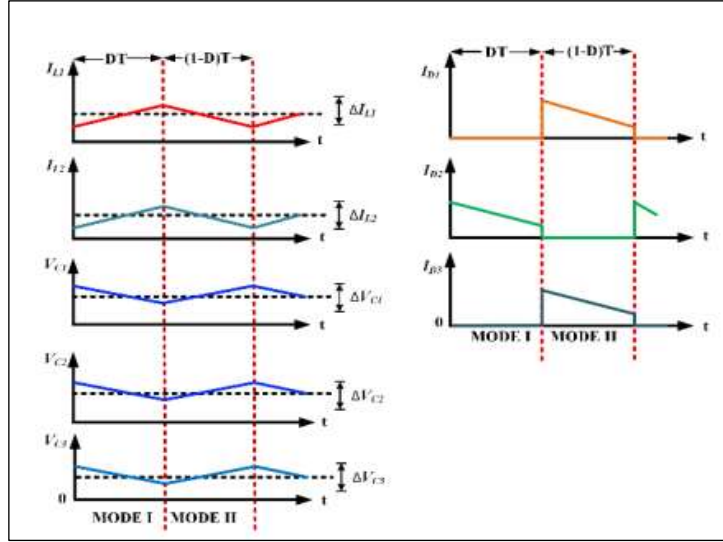


Figure 2: Ideal waveform in CCM mode.

Source: Authors, (2026).

Mode II: Switch OFF Interval ($DT \leq t \leq T$)

At this period, the two switches S1 and S2 are turned OFF. As a result, diodes D1 and D3 become forward biased, where diode D2 is opposite. When this state of operation, energy stored in the capacitors and inductors is emitted and passed on to output load. Using the Voltage-Law (KVL) to the equivalent circuit (when the voltage is switched off) gives:

$$V_{C1} - V_{L1} + V_{C2} - V_o = 0 \quad (3)$$

Rearranging the above expression we have:

$$-V_{L1} = V_o - V_{C1} - V_{C2} \quad (4)$$

Substituting

$$V_{C2} = V_{in} + V_{C1}$$

$$V_{L1} = V_{in} + 2V_{C1} - V_o \quad (5)$$

$$V_{L2} = V_{in} - V_{C1}$$

Steady State Voltage Gain Derivation (CCM)

Applying the volt second balance principle for inductor (L_2):

$$V_{in}D + (V_{in} - V_{C1})(1-D) = 0 \quad (6)$$

$$V_{C1} = \frac{V_{in}}{1-D} \quad (7)$$

$$(V_{in} + V_{C1})D + (2V_{C1} + V_{in} - V_o)(1-D) = 0 \quad (8)$$

Replacing Equation (8) with Equation (9), and simplifying, yields the formula of the output voltage gain:

$$\frac{V_o}{V_{in}} = \frac{(3-2D)}{(1-2D)^2} \quad (9)$$

As shown in the equation (10), the converter that we proposed can attain a large gain in voltage with only a small duty ratio hence the loss due to conduction is minimized and the value of stress voltage placed is reduced on the semiconductor devices.

II.2 OPEN LOOP ANALYSIS

The open circuit performance of proposed high gain DC to DC boost converter was analysed for to evaluate the natural voltage-boosting property of the converter in the scenario when there is no feedback control. In the case of an open-loop connection, the ratio of the duty of the PWM control signal is held constant and changes the output voltage directly in tandem with the changes in the voltage input and load demand. The proposed converter adheres to the steady-state voltage gain relationship at Equation (10) when converter can be operated at continuous conduction mode (CCM). The converter can reach a significant voltage gain even at rather small duty ratios, which is supported by the results of the simulation. Upon a constant duty ratio, a rise in the input voltage would lead to a proportional increase in the voltage output, therefore, confirming the analytical voltage gain expression.

In practice, though, the voltage output is considerably sensitive to changes in voltage input and also the load resistance in case of the absence of feedback control. To be more precise, variations in the voltage input, from 24 V to 30 V, and load resistance variations, from 250 Ω to 500 Ω cause significant changes in the output voltage. The observations above show that the converter has a good step-up capacity when used in an open-loop configuration but cannot sustain a regulated output voltage when the operating conditions change. Consequently, electric vehicle use cannot use an open-loop operation but rather a steady and controlled output voltage will be required in order to guarantee good performance of power electronic modules down the line. This limitation makes it very clear that there is a need to put in place proper closed loop control measures.

II.3 CLOSED LOOP ANALYSIS

II.3.1 Closed loop Analysis with PI Controller

The closed-loop control scheme has a conventional proportional-integral (PI) controller to augment output voltage regulation. In this method, a converter output voltage is constantly measured and analyzed against a reference value which is predetermined. The PI controller then acts on the error signal to adjust the PWM duty ratio to produce the desired control action. This feedback process permits a good control of the output voltage in changing operating conditions.

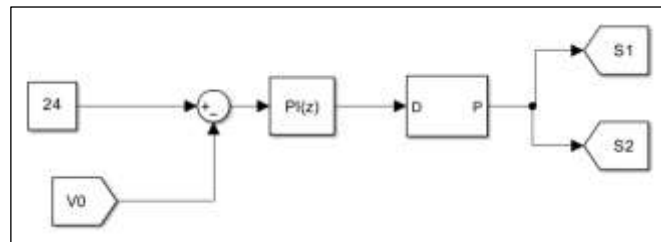


Figure 3: show the control design of used converter that includes a PI controller.

Source: Authors, (2026).

The PI controller can be said to have the control action:

$$u(t) = K_p e(t) + K_i \int e(t) dt$$

Where K_p and K_i denote the proportional and integrating gain constants, respectively and $e(t)$ is an error between reference voltage and the measured output voltage. The proportional term guarantees a rapid reaction to abrupt fluctuations in the output voltage whereas the integral term gets rid of the steady-state error. In the simulation study, it can be shown that the converter with PI control can keep the output voltage constant, at the required reference voltage, when the input voltage varies between 24 V and 30 V and the load resistance varies between 250 Ω and 500 Ω . Nevertheless, the controller gains are constant so the system has transient performance constraints including over shooting, under shooting, and comparatively long settling periods to sudden disturbances in its operations. Moreover, it is found that temporary voltage imbalance is experienced across the capacitors during dynamic transitions. These findings suggest that the PI controller offers good basic voltage regulation, but its operation falls short when faced with the highly dynamic operating environments that are generally found in the use of electric vehicles.

II.3.2 Closed loop Analysis with ISOA Controller

Improved Seeking Optimization Algorithm (ISOA)

The Improved Seeking Optimization Algorithm (ISOA) is an improved version of population-based metaheuristic algorithm that was created out of the traditional Seeker Optimization Algorithm (SOA). This algorithm has been based on the human searching behavior where the searcher moves in a complex search space and continuously changes the direction of movement and size of step so as to get to an optimal target. Although the original SOA has good local search performance, it is not uncommon to apply it to highly nonlinear systems, such as high-gain DC-DC converters, due to slow convergence and a high likelihood of getting stuck in local optimal solutions. To eliminate these drawbacks, ISOA implements two major enhancements, which are chaotic population initialization and Cauchy variation operator. Chaotic initialization enhances the diversity of the population in the initial phases of the optimization process thus minimizing the chances of early convergence. In the meantime, the Cauchy variation operator enhances the global exploration power of the algorithm at an advanced stage so that it is able to overcome the local optima more efficiently. These have made convergence properties and increased robustness. In turn, ISOA is more effectively applied in optimization and control of power electronic converters in dynamic conditions, including battery voltage variations and load changes usually faced in an electric vehicle system.

Detailed ISOA Algorithm Steps

The general execution of the ISOA to regulate the proposed converter is as follows:

Step 1: Chaotic Initialization

To begin with, chaotic logistic mapping is used to form a population of seekers rather than traditional randomization. The approach encourages a more uniform exploration of the search space and would reduce the chances of an early optimum finding.

Step 2: Fitness Evaluation

Every seeker relates to a potential ratio of duty, and its operation is measured with the help of a fitness function that is characterised by the difference among the voltage output and its value that required.

Step 3: Determination of Search Direction Direction of motion of every seeker is calculated by computing three directional values.

- Egoistic direction, based on the seeker's personal best solution
- Altruistic direction, based on the global best solution among all seekers
- Proactive direction, based on historical search information

Step 4: Step Size Calculation

The step figure of every seeker is created with the help of a Gaussian distribution which facilitates the exact local exploration and guaranteed smooth convergence behavior

Step 5: Cauchy Variation Operator

In order to stop stagnation at the local optimum, a Cauchy variation operator is used in the later phases of the optimization. This operator also adds some big leaps to the search space so that it further enhances the global search of the algorithm.

Step 6: Position Update

Each seeker updates its position based on the computed search direction and step size. The updated position corresponds to a new duty ratio value.

Step 7: Constraint Handling

The updated duty ratio is constrained within permissible limits to ensure stable operation of the converter.

Step 8: Iteration and Convergence Check

The optimization procedure includes steps 2-7 that are repeated in an iterative manner until the predetermined stopping criteria is achieved, e.g. the max number of loops is reached or the objective function converges.

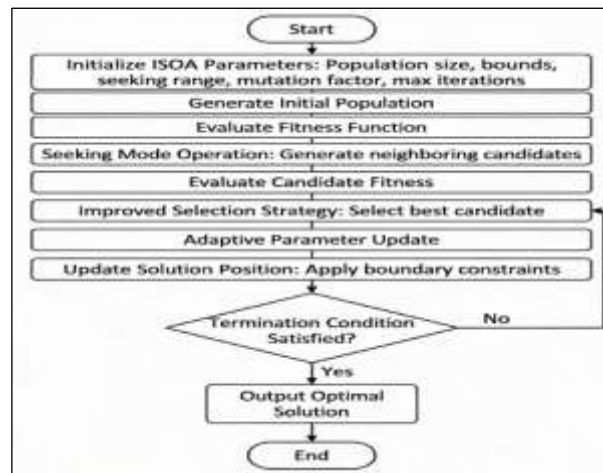


Figure 4: The flowchart of the ISOA algorithm.
Source: Authors, (2026).

Closed Loop Performance with ISOA Controller

The PWM controller of the proposed high-gain DC-DC boost converter is fed with the duty ratio that is optimized by the algorithm used in the ISOA-based closed-loop control scheme.

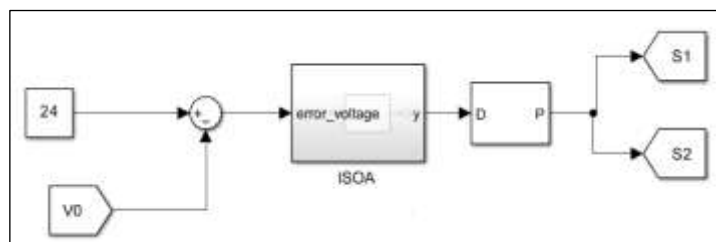


Figure 5: shows the control of the converter with the ISOA-based adaptive control.
Source: Authors, (2026).

It the control of a converter using ISOA-based adaptive control techniques, with the converter's steady state voltage gain for continuous conduction mode defined in equation (10). The ISOA adjusts the duty ratio in an adaptive manner to obtain the appropriate output voltage from using the converter's non-linear voltage gain characteristics. The simulation performance proves that the converter controlled by ISOA can maintain the output voltage of 400 V with an insignificant overshoot and much lower settling time even when voltage input get varies among 24 V and 30 V, and the load resistance varies at 250 Ω to 500 Ω . Moreover, capacitor voltages are well balanced both in the transient and steady-state conditions, and the voltage-lift process does not become unstable.

III. RESULTS AND DISCUSSION

The open-loop simulation results validate the theoretical voltage gain of the proposed high-gain DC-DC boost converter. The results match established high-gain topologies found in previous studies [16-20]. Specifically, with a 24 V input and a 0.4 duty cycle, the converter delivers an output of approximately 140 V. This operational result confirms the step-up capability predicted in the theoretical analysis. Increasing the duty ratio to 0.6 while maintaining the identical input voltage leads to a substantial rise in output voltage. This response explicitly demonstrates that the voltage gain characteristic of the converter is both nonlinear and quadratic. Furthermore, applying a 36 V input at a 0.7 duty ratio generates a simulated output voltage of approximately 610 V. This outcome closely matches the analytical predictions, confirming that the proposed converter is highly suitable for high step-up electric vehicle applications. Under every operating scenario evaluated, the waveform profiles for both the inductor current and capacitor voltage confirm stable operation in the continuous conduction mode (CCM). The current ripple across the inductor remains bounded within acceptable limits, while the capacitor voltages exhibit consistent voltage-voltage lift characteristics. Collectively, these operational trends demonstrate a highly efficient energy transfer mechanism between the system's passive components.

Case 1:

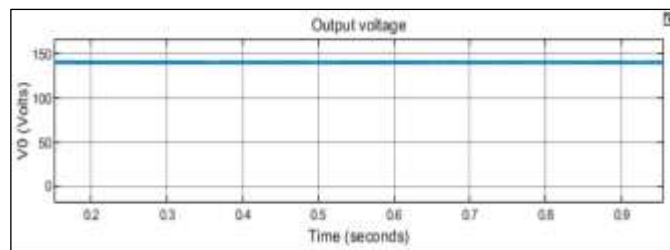


Figure 6: Output waveform at a duty ratio of 0.4.
Source: Authors, (2026).

Case 2:

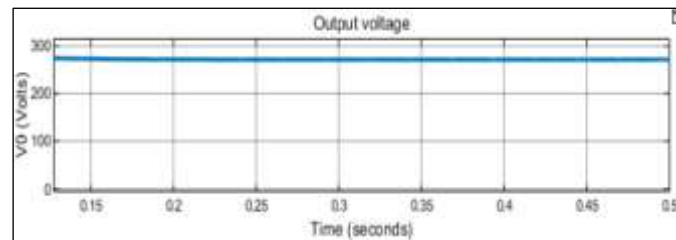


Figure 7: Output waveform at a duty ratio of 0.6.
Source: Authors, (2026).

Case 3:

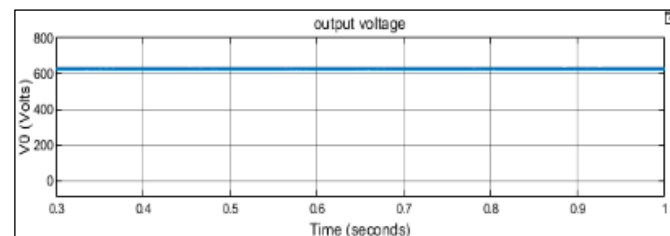


Figure 8: Output waveform at a duty ratio of 0.7.
Source: Authors, (2026).

PI Control of a closed-loop performance.

Under closed-loop operation with a fixed-gain PI controller, the output voltage is regulated to the desired reference value despite variations in input voltage and load resistance, which is consistent with classical PI-controlled DC-DC converter behaviour [21] [22]. When the input voltage is varied from 24 V to 30 V and the load resistance is changed from 250 Ω to 500 Ω , the PI controller maintains the output voltage close to the reference level, demonstrating basic regulation capability.

However, the transient response of the PI-controlled system exhibits noticeable overshoot and longer settling time during sudden changes in input voltage and load conditions. These effects are primarily attributed to the fixed nature of the PI controller gains and integrator wind-up during large disturbances [23]. In addition, temporary voltage imbalance across the capacitors is observed during transient intervals, which slightly degrades the dynamic performance of the converter. Although the PI controller provides acceptable steady-state regulation, its limited adaptability under rapidly changing operating conditions restricts its effectiveness for electric vehicle applications, where fast transient response and robust voltage regulation are critical.

ISOA-Based Control of Closed-Loop Performance.

As the adaptive control implemented is based on ISOA, the above converter has a significant improvement in dynamic performance due to the ongoing online optimization of the duty ratio [24]. The ISOA-controlled converter has a shorter settling time than the traditional PI-controlled system and much less voltage overshoot on both input voltage perturbations and load step changes. The control variable is tuned dynamically to maximize damping in the system and allows the rapid approach to a steady state operation. This means that the ISOA-based controller will be able to control the output voltage at a more accurate reference level at lower steady-state error and higher transient stability. This is especially vital to the electronic systems of the electric vehicle power that the proper voltage regulation is required to make sure that the sensitive downstream components such as the traction inverters, onboard chargers, and battery management systems operate safely and reliably [25].

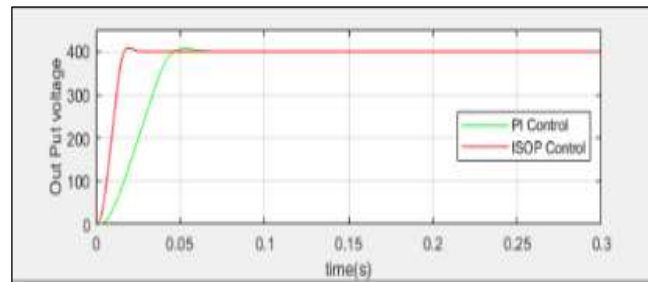


Figure 9: Output voltage under 250–500 Ω load variation.
Source: Authors, (2026).

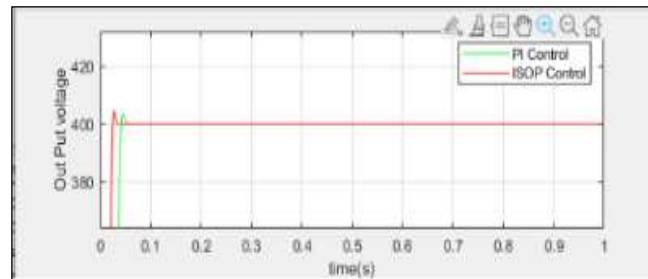


Figure 10: The output voltage response for load variation from 250 Ω to 500 Ω .
Source: Authors, (2026).

IV. CONCLUSION

This paper contains discussed the design, analysis, and performance assessment of high gain and connected and integrated-inductor DC to DC boost converter designed to work in the electric vehicle environment. The given topology utilizes two inductors, three capacitors, three diodes, and two switches that will operate under the influence of one PWM control signal. The structure allows a high ratio of voltage conversion at comparatively low duty cycles and low voltage stress of semiconductor devices. The solution removes coupled inductors to avoid complications with leakage inductance and magnetic saturation, which enhance reliability and makes the converter quite suitable to the compact and lightweight EV power electronic system. The converter was analysed in terms of operating behavior under continuous functioning mode (CCM), and the respective expressions of the voltage gain were obtained based on principle of volt-second balance. The model of analytical voltage gain was confirmed to have the high degree of accuracy through the open-loop simulations, which ensured that the model was stable to high step-up performance over a large range of input voltages and duty ratios.

The generated simulated inductor current, capacitor voltage waveforms also indicated effective transfer of energy amongst passive elements, and acceptable ripple levels, hence justified by the theoretic analysis. In order to operate in a closed-loop, a standard PI controller and an ISOA-based adaptive control plan were compared and contrasted. Although the PI controller could control the voltage output in response to changes in voltage input between 24 V and 30 V and changes in load resistance between 250 Ω to 500 Ω , it had a fixed-gain structure that led to worse overshoot, worse settling times, and short-lived oscillations. Conversely, the control method using the ISOA had better transient behavior, such as lower settling time, low overshoot, and better damping properties and was more accurate in voltage control since the control variable was optimized adaptively. In general, it is possible to note that the combination of proposed high-gain DC to DC boost converter and ISOA-based adaptive control ensures high level of dynamic performance and enhanced robustness of the system. These features render the suggested solution a potential applicant of power conversion to electric vehicles. The next step in the work would be the experimental validation and real-time implementation to evaluate the practical effectiveness and feasibility of the suggested system once more.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Lombada Baya Reddy, Bukke Mamatha Bai, Ampavatina Veera Pranavi, Nallaboina Venkata Ramana and Pinjari Gmmepalli Noor Mahammed.

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Investigation: Lombada Baya Reddy, Bukke Mamatha Bai, Ampavatina Veera Pranavi, Nallaboina Venkata Ramana and Pinjari Gmmepalli Noor Mahammed.

Discussion of results: Lombada Baya Reddy, Bukke Mamatha Bai, Ampavatina Veera Pranavi, Nallaboina Venkata Ramana and Pinjari Gmmepalli Noor Mahammed.

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Approval of the final text: Lombada Baya Reddy, Bukke Mamatha Bai, Ampavatina Veera Pranavi, Nallaboina Venkata Ramana and Pinjari Gmmepalli Noor Mahammed.

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