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Installation of an Electric Car Charger Using the Bald Eagle Optimizer Cascaded PI and LQR Controller

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Abstract: The study paper concentrates on the development and execution of a system for an AC to DC conversion, then followed by an electric vehicle (EV) charger. It enhances the significant power factor of the power source while minimizing distortion from harmonics. The Golden Eagle optimization methods are employed to enhance the setting of Proportional-Integral (PI) and Linear Quadratic Regulator (LQR) controller settings for improved conversion efficiency. The optimal strategy is formulated relying on the eagle's expertise in searching at different angles of circular paths for obtaining prey. The system converters are developed from the state space version using state space averaging, and the simplified model is achieved via the current matched technique to decrease computing overhead. The optimize the KP and KI settings of the PI controller and the weighting matrix Q of the linear quadratic controller. The suggested improvement is executed using MATLAB applications, and the modeling results indicate a reduction in settling duration, rapid recovery from input and output fluctuations, decreased Total Harmonic Distortion (THD), and increased permanency.

Keywords: Bald Eagle Optimizer; electric vehicle; Linear Quadratic Regulator; Power factor;

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1. Introduction

The worldwide transition to electric vehicles (EVs) is motivated by the necessity to mitigate considerable ecological problems linked, such as their exhaustion, increasing expenses, and considerable releases of greenhouse gases. The transport industry significantly contributes to climate change, with carbon dioxide emissions from combustion engines being a principal factor in the ongoing ecological disaster. Electric vehicles (EVs) have emerged as a viable solution to mitigate issues related to carbon dioxide emissions and dependence. Nonetheless, the shift towards extensive electric vehicle adoption encounters several obstacles, including the inadequacy of infrastructure for charging. Aboard steeds are essential in mentioned setting, as they enable the effective and dependable recharging of batteries in electric cars. The prevalent method employed by the Onboard charger's charger involves an AC to DC conversion succeeded by a DC-to-DC converter for battery charging [1, 2].

The adapter is a part of the charging that transforms the AC power from the charging facility into electrical current for car battery charging. A notable AC to DC, converter structure is the sequential arrangement of a rectifier and the DC to DC, succeeded by a diode rectification. The converter has garnered significant attention in solar uses, correction of power factor converters, and fuel cell systems; nonetheless, it has challenges related to large parts, the necessity for result filtering, voltage anxiety, and achieving high effectiveness when the final result exceeds the maximum feed. Buck converters are cost-effective and very effective; yet, they are significantly impacted by blind angle issues in the supply voltage, necessitating the use of a supply voltage filtration [3-5]. The CUK conversion exhibits the disadvantage of reversing productivity and large fatalities at its switch and diode components [6].

The standalone converters utilized in AC to DC conversions experience issues related to dimensions, transducer core the saturation point, and current harmonics [7]. The non-minimum period features of the flyback converter impede the reaction to transients due to circuit the inductance, complicating closed-loop correction [8]. The Forward converting experiences transformer core exhaustion and requires an extra switch to mitigate this issue. Consequently, the system converter is better suited for power factor adjustment in battery power systems owing to its rapid transient reaction, reduced current delivery reverberation that not upsetting results, and capability to execute lowly improvement processes. The utilization of system network topology relied power factor converters in correcting power factors devices is on the rise [9].

The latest advances in optimizing for electrical converters encompass numerous essential methods that enhance dynamic performance [10].

This paper presents an innovative method that combines BEO with PI and LQR controllers for power factor correction in system converters utilized in electric vehicle charging systems. This research's new element is the utilization of BEO to enhance PI and LQR controllers, overcoming the constraints of conventional optimization techniques. BEO has exceptional optimization features, resulting in increased accuracy in variable adjustment and greater system efficiency. The integration of BEO with PI and LQR control techniques enhances the productivity and permanency of system converters while streamlining controller installation. State space be an average of is used for the system converter, while the present corresponding strategy streamlines controller development and diminishes the converter's higher-order move work. To evaluate the reliability and precision of the BEO method, data points such are contrasted with those of PSO and GWO.

2. Materials and Methods

2.1 Decoration, Operation, And Modeling of a System Converter

The system converter depicted in Figure 1 comprises the source voltage, a MOSFET switch, a diode, input and output inductors, a power assignment capacitor, a production filter capacitor, and a resistor for the load. The converter functioning has been evaluated inside the constant conductivity phase. The voltage that results is measured over the load impedance. It possesses several operational says, which are as follows: Activate Switch and Deactivate Diode; Deactivate Switch and Activate Diode.

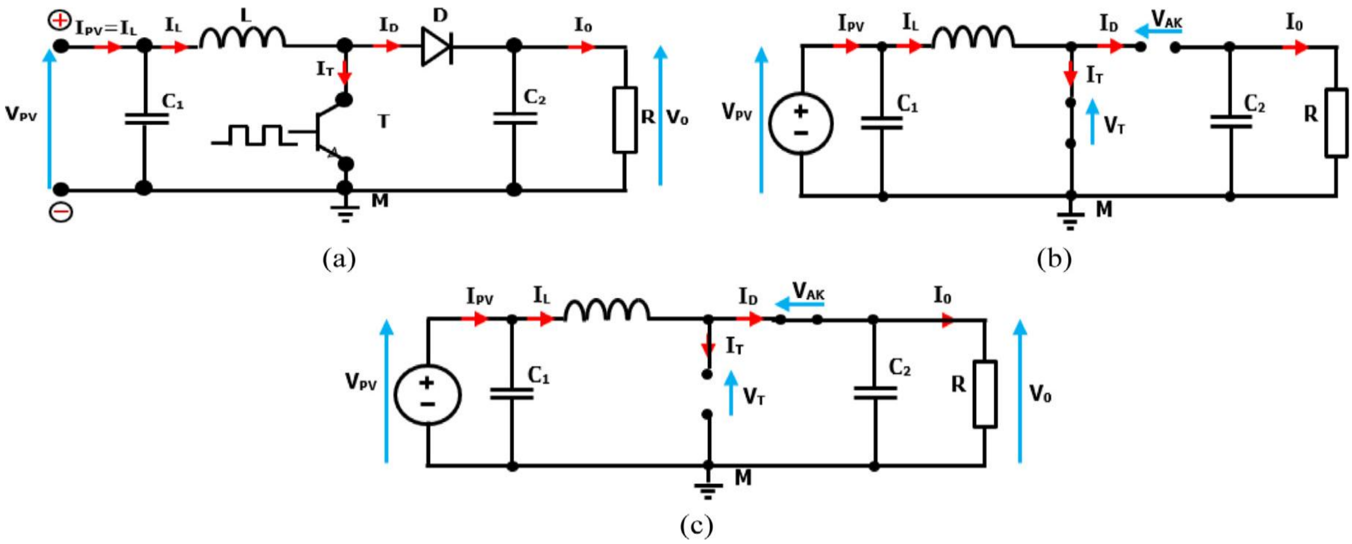

Figure. 1. System converter: (a) wiring schematic, (b) ON condition, (c) OFF condition.

The scientific analysis [11, 12] indicates that an inexpensively conversion chargers' lightweight electric cars. The subsequent formulas are employed to construct the system converter [13], and its parts are detailed in Specifications Table 1. The converter's duty cycles are derived, ripple current, the inductors are computed also, the coupling capacitor's value is determined and the voltage at the input is 240V AC, and the output voltage is 60V. The maximum frequency effort riddle capacitor and inductor are built using two formulas as illustrated in Ref. [14].

2.2 Closed-Loop Control of Converter for Power Factor Correction

The system converter employs a sequential control approach for closed-loop regulation. The outer loops use proportional integral regulator for voltage regulation to achieve the specified electricity, while the inside loop utilizes LQR control for the present controller to enhance the energy ratio on the network lateral. The solitary stage electrical input is transformed into a pulsing DC output using a diode bridge rectifier, resulting in a suboptimal power ratio, reduced effectiveness, and elevated distortion from harmonics. The system converter is employed for power factor alteration, with its final voltage being monitored for comparison to the reference electrical voltage. The incorrect voltage is supplied as a signal to the PI controller, also known as the voltage controller [15].

Traditional techniques for determining PI controller settings, such as the Routh instability criteria, Ziegler-Nichol's technique, and pole assignment, are labor-intensive, may result in increased error in steady-state stability, and carry the risk of system instability. The traditional Ziegler-Nichols approach determines the KP and KI numbers for the upper and lower bounds of PI variables and optimization requirements. replacing these numbers to compute the PI controller. According to Table 2, the proportional increase and the integral gain, the acquired variables exhibit sluggishness in attaining the steady state, resulting in increased errors. The converter's greatest efficiency relies on the controller's activity; hence, the controller settings are established via optimization.

Table 1. Proposal constraint

Parameter	Value
Effort Voltage	220 V
Production Voltage	59 V
Duty cycle ratio	0.19
Inductor	1.9 mH
Capacitor	9.9μF/7900 μF
Substituting frequency	29 kHz
Effort filter capacitor	9.9 μF
Effort filter inductor	2.49 mH
Output Power	459 W

Table 2. Ziegler Nicholas modification.

Methods	Kp	Ti	Td
P	0.49	NA	NA
PI	0.44	1.19	NA
PID	0.59	0.49	1.19

Utilizing the function of fitness J, appropriate PI variables are identified via the BEO process, with Table 3 presenting the variety of optimization value ranges. Analyzing and constructing a great gage prototypical are complex endeavors that necessitate continuous labors to streamline the higher command modeling and mitigate actual computational demands to yield suitable outcomes from conventional research, modeling, control, layout, and computational methodologies [16].

The optimal parameters of KP and KI are determined, and the reaction time of the voltage controller is contrasted with alternative refinements. Furthermore, the results are presented in Table 4.

Table 3. Limitations for PI optimization

Parameter	Value
Inhabitants size	49
No of repetitions	99
Variety of Kp morals	to five
Variety of Ki morals	to five

Table 4. Efficiency parameters of a closed system

Methods	KP $\times 10^{-6}$	KI $\times 10^{-4}$	Tr $\times 10^{-1}$
PSO	313	191	152
GWO	224	1803	140
BEO	9	1600	80

The T-test is presented for the suggested optimization in comparison to PSO and GWO in Table 5, indicating that BEO outperforms the three optimization methods. The statistical variables have been calculated to assess the suggested optimization's correctness and uniformity, and 40 thirty tests are performed.

Traditionally, the price vector of LQR is computed individually, resulting in limited outcomes. The Q vector is selected for improvement according to the fitness function to enhance the controller's efficiency. To determine the ideal weightage quantities for Q in LQR, an optimization technique, namely the Bald Eagle algorithm, is employed to yield optimized Q values. Furthermore, it reduces the alteration variables while enhancing controller efficiency. The fitness function J is defined as the summation of IAE and ISE, with the range of Q matrix values specified in Table 6.

Table 5. T-test for BEO optimization with GWO and PSO

Test method	PSO Vs BEO	GWO Vs BEO
t-Test	2890.57	3869.7

Table 6. Optimization restrictions for LQR

Parameter	Value
Population	To Thousand
Iteration	To Handed
Range of Q matrix	To five Thousand

2.3 Bald Eagle Optimization for Utilized Controller

This algorithm replicates the fishing actions of bald eagles when pursuing food. The formulated optimizer's hunting conduct consists of three separate stages: 1) choosing an area where the eagle identifies a location with a greater likelihood of encountering prey compared to alternatives. 2) Conducting an investigation inside the area traversed by the eagle to the already designated location to execute the discovery procedure. 3) Dive in which the fisherman identifies the optimal location to capture the animal and proceeds directly to it utilizing data gathered in the stage before it. For more information about this matter and how connect employed system with this algorithm search, see Ref. [17]

3. Results

The simulation is conducted using the MATLAB/SIMULINK 2025 software. The subsequent converter settings are taken into account for modeling: The input AC energy voltage is 220 Vrms, the target voltage at the output is 59.9 V, the resultant current is 7.69 A, and the equipment's impedance is 7.9 Ω.

3.1 Closed Loop Reaction

The open-loop modeling outcomes of the conversion, the overall distortion of harmonics is 45%, as seen in Figure. 3, and the power factor is 0.95. The improved PI and LQR cascading closed-loop calculations in Figure. 4 demonstrate that the supplied flow is nearly in sync with the voltage, resulting in the entire harmonic distortion that has decreased to 1.64% with significant scales.

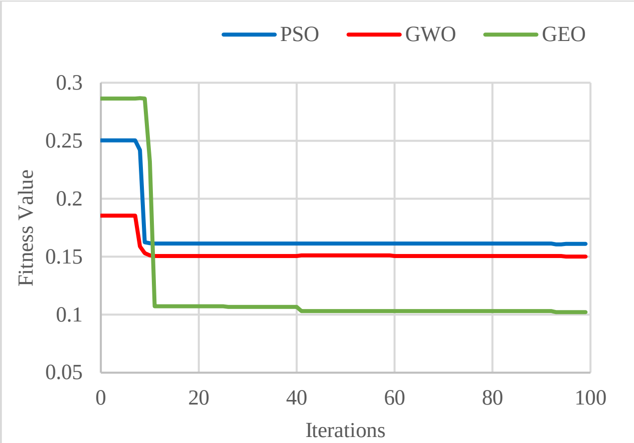

Figure. 2 Convergence curve of GWO, GWO and PSO.

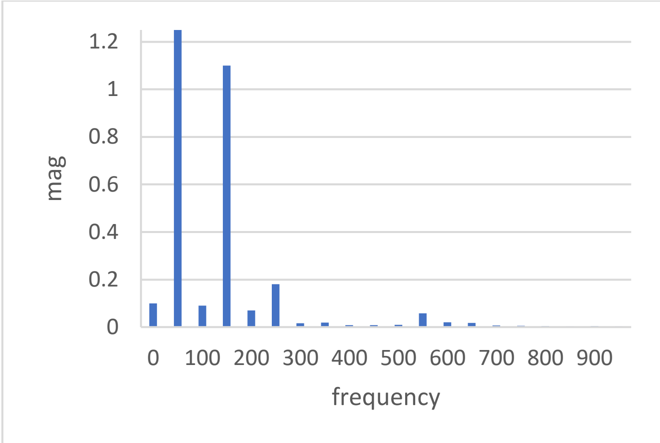

Figure. 3 Open loop reaction of the converter

Figure 5 demonstrates that the converters effectiveness remains relatively stable with varying load, sustaining excellent performance throughout a wide spectrum of results duties, indicative of little losses. Figure 6 illustrates how the converter substantially reduces the total harmonic noise as the load current escalates, with reduced source current harmonic attaining elevated load electrical currents. In Figure. 7, the power factor improves as the load current rises. 5.8 A, resulting in a power factor that approaches unison. In Figure. 5, the total harmonic distortion escalates as the effort voltage rises from 179V to 239V. The Total Harmonic Distortion is Below one percent at 179 V and elevated to 2.5 percent at 220V.

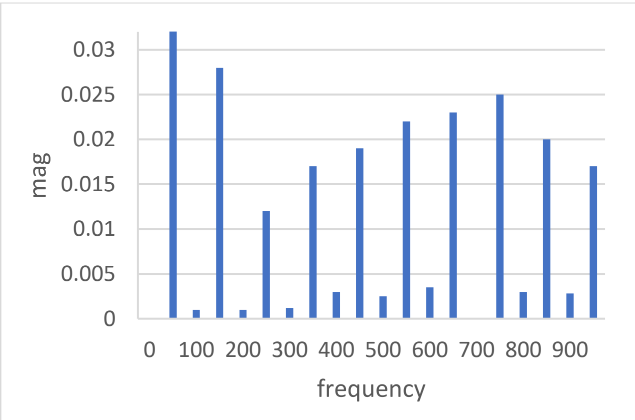

Figure. 4 Closed-loop reaction of the converter in BEO

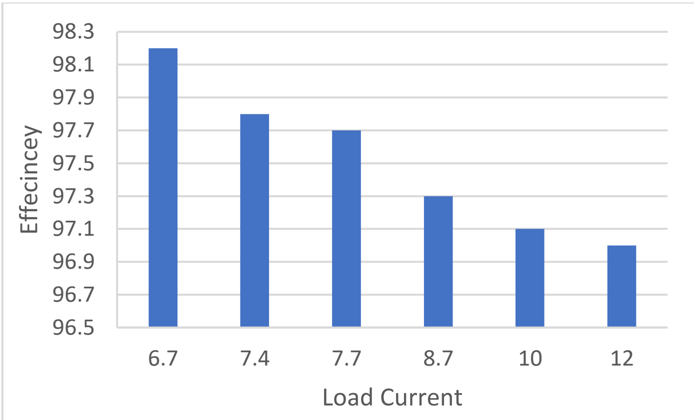

Figure. 5 Load and efficiency relationship

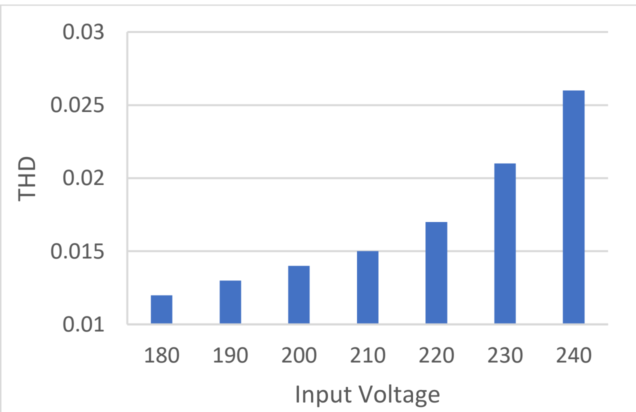

Figure. 6 Load current and THD relationship

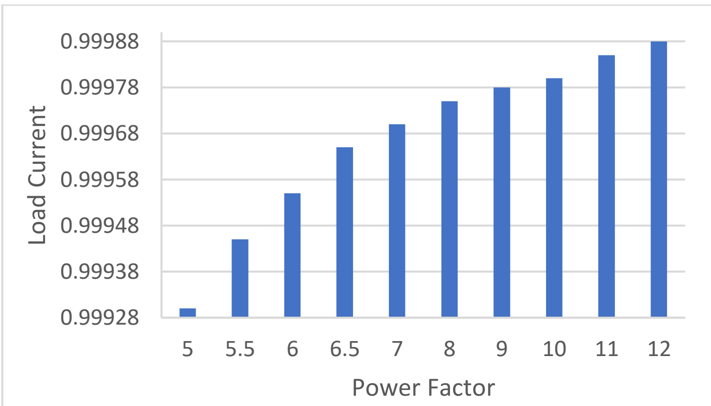

Figure. 7 Power factor and load current relationship

Table 7 illustrates the converter's reaction to the suggested optimization strategies in comparison to the current approach. The BEO outperforms PSO and GWO in criteria like profit border, getting duration, power ratio, and effectiveness.

Table 7. Evaluation of the system converter with current approaches.

Methods	Source Current	PF	η
PSO	2.62	0.995	97.30%
GWO	2.409	0.9983	97.51%
BEO	1.73	0.9984	97.61%

5. Conclusions

This paper employs the BEO method to improve PI and LQR transmitted supervisors for voltage regulation and improvement of power factors in a system converter. The study utilizes a summary instruction concept derived from the instant corresponding approach to alleviate computing requirements. The BEO rely on PI and LQR cascade controllers have been replicated in MATLAB/Simulink, demonstrating substantial enhancements compared to conventional PI controllers. The improved controllers exhibited accelerated static reactions, less overshoot, and attained a power factor, approaching unison. The equipment demonstrated an efficiency and a total harmonic distortion present. In comparison to GWO and PSO, the BEO technique decreased excessive currents in diodes and MOSFETs, facilitating the use of low-current rated and economically viable switches. This adjustment reduces energy loss and total harmonic distortion. It enhances the AC arrangement, fosters energy efficiency, and guarantees steady output voltage amidst fluctuating load and input circumstances. The suggested approach provides actual cost savings and increases in manufacturing excellence, illustrating its significance in boosting converter efficiency and dependability.

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References

1. Yuan, J., et al., *A Review of Bidirectional On-Board Chargers for Electric Vehicles.* IEEE Access, 2021. **9**: p. 51501-51518.
2. Mahmood Khudhur, A., F. Ghazi Saber, and M.A.K. Alsaeedi, *Single-switch PWM converters for DC-to-DC power with reliability tolerance for battery power purposes.* Edison Journal for electrical and electronics engineering, 2024. **2**(1): p. 12-19.
3. Memon, A.H. and K. Yao, *UPC strategy and implementation for buck–buck/boost PF correction converter.* IET Power Electronics, 2018. **11**(5): p. 884-894.
4. Sivakumar, S., et al., *An assessment on performance of DC–DC converters for renewable energy applications.* Renewable and Sustainable Energy Reviews, 2016. **58**: p. 1475-1485.
5. Jaenul, A. and B.N.A. Altameemi, *Triple-Level Single-Ended Main Inductor Converter (SeMLC) with regard to Wind-Solar Hybrid Energies.* Edison Journal for electrical and electronics engineering, 2024. **2**(1): p. 20-26.
6. Khalili, R. and E. Adib, *Soft-switching bridgeless buck PFC with low THD.* IEEE Transactions on Industrial Electronics, 2023. **70**(12): p. 12211-12218.
7. Itoh, K., et al., *Analysis and Design of a Single - Stage Isolated DC/AC Converter for a High - Power - Density Onboard AC Inverter.* IEEJ Transactions on Electrical and Electronic Engineering, 2022. **17**(1): p. 120-131.
8. Goudarzian, A., A. Khosravi, and H.A. Raeisi, *Modeling, design and control of a modified flyback converter with ability of right-half-plane zero alleviation in continuous conduction mode.* Engineering Science and Technology, an International Journal, 2022. **26**: p. 101007.
9. Sarowar, G., et al., *Investigation of a power factor correction converter utilizing SEPIC topology with input current switching.* Results in Engineering, 2024. **22**: p. 102271.
10. Rajendran, G., et al., *Dynamic voltage stability enhancement in electric vehicle battery charger using particle swarm optimization.* IEEE Access, 2022. **10**: p. 97767-97779.
11. Sivaperumal, N. and G. Jothimani, *An energy efficient unidirectional on-board battery charger for power factor correction in electric vehicles.* Electrical Engineering, 2024: p. 1-16.
12. Pandey, R. and B. Singh, *PFC - SEPIC converter - fed half - bridge LLC resonant converter for e - bike charging applications.* IET Electrical Systems in Transportation, 2020. **10**(3): p. 225-233.
13. Vijayakumar, S. and N. Sudhakar. *Design and Implementation of On-Board charger integrated with rooftop Solar PV for e-Rickshaw*. in *2023 Innovations in Power and Advanced Computing Technologies (i-PACT)*. 2023. IEEE.
14. Singh, S., et al., *Power factor corrected zeta converter based improved power quality switched mode power supply.* IEEE Transactions on industrial electronics, 2015. **62**(9): p. 5422-5433.
15. Chakraborty, A., et al., *A Scalable Single-Inductor Multiple-Output DC–DC Converter With Constant Charge-Transfer and Power-Up Sequencing for IoT Applications.* IEEE Transactions on Circuits and Systems I: Regular Papers, 2024.
16. Prajapati, A.K., et al., *A new technique for the reduced-order modelling of linear dynamic systems and design of controller.* Circuits, Systems, and Signal Processing, 2020. **39**: p. 4849-4867.
17. Mohammadi-Balani, A., et al., *Golden eagle optimizer: A nature-inspired metaheuristic algorithm.* Computers & Industrial Engineering, 2021. **152**: p. 107050.