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AI-assisted design and control of a landsman converter for electric vehicle charging applications with advanced power factor correction

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ABSTRACT

The burgeoning electric vehicle (EV) industry necessitates cutting-edge solutions to improve the efficiency and sustainability of EV charging systems. This paper presents an innovative Landsman converter design tailored for EV charging applications, incorporating artificial intelligence (AI) to achieve effective power factor correction (PFC). The integration of AI into the converter's control strategy enhances its ability to optimize operational performance, ensuring a high-power factor, minimizing harmonic distortion, and boosting energy efficiency throughout the charging process. The study develops a sophisticated simulation model of the Landsman converter using MATLAB/Simulink, wherein AI algorithms are employed to dynamically adjust the converter's operation. This approach enables the system to adapt to varying load conditions and input voltages, demonstrating superior performance in terms of power factor correction and overall efficiency. The simulation results underscore the potential of combining AI with power electronics to elevate EV charging technology, offering significant advancements in creating smarter, more reliable, and efficient charging infrastructures. This research highlights the transformative impact of AI on enhancing power electronics designs, paving the way for more sustainable and effective solutions in the rapidly evolving EV sector.

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1. INTRODUCTION

The escalation of global warming and associated climate change has emerged as the most perilous problem the world must now confront. To combat climate change, utilities are increasingly turning to renewable energy sources. Solar energy has the ability to supply the ever-increasing need for electrical power, and it is only one of several renewable energy sources now accessible. Recently, PV system installations have skyrocketed [1]-[5], mostly due to the improving efficiency and decreasing cost of solar cells. To increase the

relatively modest voltage output from a solar panel, the PV system needs a DC-DC converter with high voltage gain and high efficiency [6]. Voltage boosting is a common task, and for this purpose DC-DC converters come in handy. Due to its simplicity, reduced component count, and ease of implementation and production, the standard boost converter is the most popular architecture among these converters for increasing the input voltage [7], [8]. The input inductor is what gives the boost converter its voltage-boosting capacity and lets it switch between continuous and discontinuous conduction modes. On the other hand, the voltage increase of a regular boost converter isn't enough to provide the load. High voltage gain is achieved if this converter is run with a high duty cycle, but this always results in a reverse recovery problem, switching losses, and a decrease in efficiency [9], [10]. With the high voltage gain DC-DC Landsman converter coupled with the PV system, these problems are solved.

Using maximum power point tracking (MPPT) improves a solar PV system's efficiency. Maximum power point (MPP) detection is used to find the optimal time for power harvesting, independent of weather and solar radiation conditions [11]-[15]. Multiple MPPT algorithms, including both traditional and AI approaches, are often utilized to maximize the PV panel output. Perturb and observe (P&O), hill climbing (HC), and incremental conductance (INC). are examples of common MPPT algorithms. In comparison to other MPPT algorithms, INC and P&O are the most often used due to their intuitive and user-friendly layout. These algorithms work well under transient conditions, but in steady state they generate oscillations that degrade the efficiency of the PV array.

In order to solve the problems that have plagued traditional MPPT systems, artificial intelligence algorithms like artificial neural networks (ANN) and fuzzy logic control (FLC) have been developed. Using fuzzy theory and the PV characteristic tangent slope, an FLC-based MPPT algorithm tracks the MPP with high tracking accuracy and minimal oscillations around the MPP, but at the cost of complexity and slower tracking speed. Due to its conditioning for non-linear mapping of PV arrays, ANN based MPPT approaches offer a high converge speed and accuracy even when dealing with rapidly changing meteorological circumstances. Their intricacy makes it difficult to implement them on a microcontroller platform. On top of that, they need to be reconditioned to accommodate any shift in the photovoltaic system's underlying characteristics. Inconsistent tracking near the MPP, slow tracking speeds, and other problems are experienced by all of the aforementioned methods [10]-[19]. The inverter's primary responsibility is to convert DC electricity into AC power and control the output before feeding it into the electrical grid. As a result of its lower price, higher efficiency, and smaller footprint, the voltage source inverter (VSI) is the inverter of choice for most PV systems [20], [21]. The VSI's functionality is regulated by a proportional integral controller (PI). The PI controller is a widely sought-after feedback compensation controller due to its many appealing qualities (easiness to build, install, and comprehend). PI controllers are used to keep the grid current and DC-link voltage stable [22]-[25] due to their capacity to guarantee resilience and reject abrupt disturbances.

In this study, a Landsman converter based MPPT method using a radial basis function neural network (RBFNN) is developed for a grid-connected PV system. In this work, a PV-side power conversion stage for EV charging applications, while detailed battery charging and SOC control are beyond the scope of the present study. The present work also focuses on PV power extraction, voltage boosting, and grid-side power-quality performance; an explicit EV battery charging model and state-of-charge analysis are outside the scope of the present study. Tracking the MPP of the solar PV panel is suggested using the RBFNN based MPPT algorithm. Reduced total harmonic distortion (THD) and synchronized grid voltage were achieved with the help of the PI controller.

The selection of RBFNN is motivated by its localized function approximation structure and its suitability for implementing a compact nonlinear mapping for the considered MPPT task. Unlike an FLC, the proposed controller does not require an explicitly defined fuzzy-rule base. Unlike ANFIS, it does not employ a combined fuzzy-inference and neural-learning structure. Compared with a conventional multilayer ANN, the RBFNN uses a radial-basis hidden layer whose responses are determined by the distance between the input vector and the centers of the basis functions.

It is important to emphasize that RBFNN is not inherently superior to ANN, FLC, or ANFIS for every PV application. Its relative performance depends on the network configuration, training dataset, operating conditions, and implementation requirements. Accordingly, the present study focuses on evaluating the RBFNN-based MPPT controller within the proposed Landsman converter and grid-connected VSI architecture, rather than establishing universal superiority over all existing intelligent MPPT methods.

Recent studies provide a useful basis for the present RBFNN-controlled Landsman-converter approach. AI-based MPPT surveys compare neural-network, fuzzy, and optimization-based techniques, while RBFNN implementations have been investigated for PV systems and high step-up converter interfaces. Research on grid-connected PV inverters further examines inverter topologies, grid-code requirements, current-control strategies, and ancillary services relevant to power quality and synchronization [26], [27]. In the EV domain, reviews of charging infrastructure and vehicle-to-grid power electronics identify the role of

power-conversion stages and power-factor management in grid-connected charging systems [28]-[30]. A recent study specifically combines a high-gain Landsman converter with ANFIS-based MPPT, making it a close comparator for the present RBFNN-based implementation [30].

Existing MPPT methods such as P&O, INC, FLC, and ANN-based techniques have limitations in terms of oscillations, tracking speed, and computational complexity. To address these limitations, this work integrates an RBFNN-based MPPT controller with a high-gain Landsman converter for a grid-connected PV system. The RBFNN uses PV voltage and current to generate the converter duty cycle, enabling nonlinear MPPT operation under varying PV conditions. The proposed combination improves voltage regulation, MPPT tracking, dynamic response, and power-factor performance compared with the conventional PI-based approach.

2. SYSTEM DESCRIPTION

The low DC voltage output of the PV panel may be increased with the help of a DC-DC Landsman converter, which is a high voltage gain converter. The quantity of electricity generated by a solar PV system is sensitive to the amount of sunshine reaching the PV panels and the temperature of the surrounding air. This is why a very effective MPPT controller based on an RBFNN is used to draw out the most power possible from solar panels under any given set of circumstances. Block schematic of the proposed 3 phase grid-tied PV system is shown in Figure 1. Recent reviews of EV charging infrastructure and grid integration emphasize the importance of coordinated converter control and grid-compatible power conversion. Reviews of EV charging infrastructure and grid integration emphasize the importance of coordinated converter control and grid-compatible power conversion.

This controller tracks V_{PV} and I_{PV} for the sake of detecting V_{MPP}, which is the operating voltage at which the maximum power is harnessed. Based on the output of the controller, the PWM generator generates PWM pulses that adjust the duty cycle of the Landsman converter and produce a controlled output voltage without any fluctuations. The controlled output thus obtained from the Landsman converter is fed to the 3φ VSI, which is connected to the 3φ grid via an LC filter. The inverter converts the DC voltage to AC voltage and the LC filter reduces the harmonics in order to deliver a distortion free AC supply to the grid. Effective grid voltage synchronization is achieved by using a PI controller with the grid-tied inverter. The actual active power P_{act} is compared with the reference active power P_{ref}, in the same way the actual reactive power Q_{act} is compared with the reference reactive power Q_{ref} to find the errors. Based on the real and reactive power errors, the PI controller produces control signal, which is fed to the PWM generator in order to generate PWM pulses. The resultant pulses control the switching operation of the inverter by adjusting its duty cycle for reducing the total harmonic distortion in the inverter output voltage and attain grid voltage synchronization.

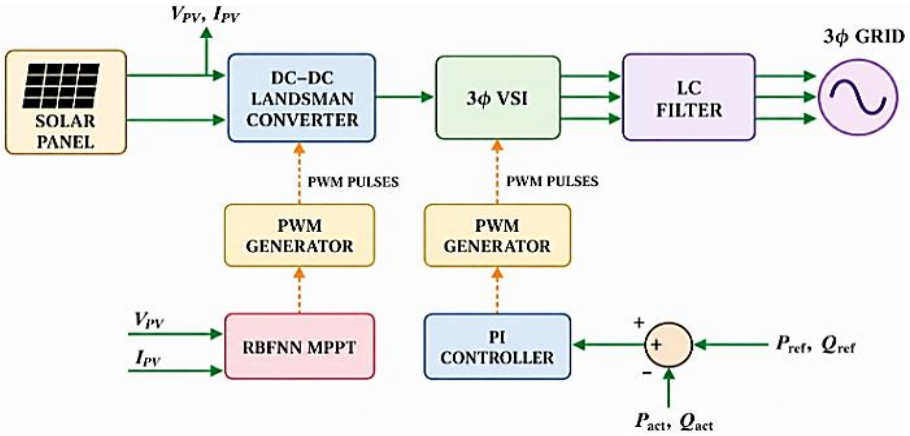

Figure 1. Proposed 3 Φ grid tied PV system

3. MODELLING OF THE PROPOSED SYSTEM

3.1. Solar PV modeling

The photovoltaic (PV) cell absorbs sunlight and turns it into electrical current using a PN junction structure. When these solar cells are wired in series and in parallel, they create a PV panel. Figure 2 depicts a solar panel's rudimentary equivalent circuit diagram.

The output current of the solar panel is:

$$I_{PV} = I_{ph} - I_O\left[exp\left(\frac{V_{PV}+I_{PV}R_S}{nv_t}\right) - 1\right] - \frac{V_{PV}+I_{PV}R_S}{R_{sh}} \quad (1)$$

here, I_{Ph} is the current produced from the incident light, I_d denotes the diode saturation current, V_{PV} represents the PV output voltage, v_t denotes the diode thermal voltage, series resistance is represented as R_s, shunt resistance is denoted as R_{sh} and n stands for number of series connected cells. The voltage obtained from the PV system is inadequate to meet the requirement, so it is boosted by using a Landsman converter.

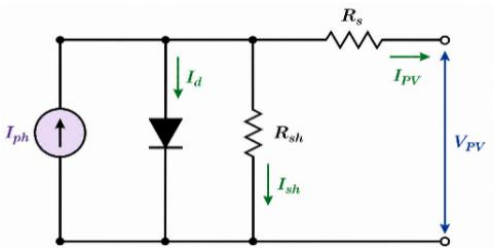

Figure 2. Equivalent circuit diagram of solar panel

3.2. Landsman converter

Regardless of changes in the available light, the Landsman converter will continue to function in continuous conduction mode (CCM) because of its high voltage gain. Figure 3 is a schematic depicting the Landsman converter's internal workings. There are two main operating modes for this converter, both of which are shown in Figure 4.

– Mode 1 operation

During Mode 1 operation, as shown in Figure 4(a), the power switch S_1 is turned ON, allowing the input current I_{PV} to flow through the circuit while the diode D becomes reverse-biased. In this interval, the capacitor C_1 and the inductors $L_1$and L_2 store energy from the input voltage V_{PV}.

– Mode 2 operation

During Mode 2 operation, as illustrated in Figure 4(b), the power switch S_1 is turned OFF, causing the diode D to become biased forward. The stored energy in capacitor $C_1$and inductors L_1 and L_2 is released to the output side. Consequently, current flows through capacitor C_2 and the load resistance R, thereby supplying power to the load.

The peak-to-peak current ripple of inductor L_1 is (2).

$$\Delta I_{L_1} = \frac{\Delta\Phi}{L_1} = \frac{1}{L_1}.\frac{1}{2}.\frac{\Delta V_{C_1}}{2}.\frac{T}{2} \quad (2)$$

The current flowing through the capacitor C_1 is (3).

$$I_{C_1} = I_{L_1} = C_1\frac{\Delta V_{C_1}}{(1-D)T} \quad (3)$$

Here, the duty cycle is denoted as D and the switching time period is represented as T. The voltage ripple in $V_{C_1}$is (4).

$$\Delta V_{C_1} = \frac{I_{L_1}}{C_1}(1-D)T \quad (4)$$

By substituting the value of ΔV_{C_1}in (2), we get (5).

$$\Delta I_{L_1} = \frac{1}{L_1}.\frac{1}{2}.\frac{I_{L_1}}{2C_1}(1-D)T.\frac{T}{2} \quad (5)$$

$$\Delta I_{L_1} = \frac{1}{8L_1C_1}.\frac{I_{L_1}(1-D)}{f^2} \quad (6)$$

$$\frac{\Delta I_{L_1}}{I_{L_1}} = \frac{1}{8L_1C_1}.\frac{(1-D)}{f^2} \quad (7)$$

Here, $f = \frac{1}{T}$ represents the switching frequency of the converter. The input-output relationship of the converter is given in (8).

$$\frac{I_{L_1}}{I_{dc}} = \frac{D}{1-D} \tag{8}$$

By substituting the value of I_{L_1} from (8) into (6), we obtain in (9).

$$L_1 = \frac{DI_{dc}}{8f^2 C_1 \Delta I_{L_1}} \tag{9}$$

Here, the output current of the converter is denoted as I_{dc}. The inductor L_2 value is (10).

$$L_2 = \frac{DV_{dc}}{f\Delta I_{L_2}} \tag{10}$$

Here, V_{dc} represents the output voltage of the Landsman converter.

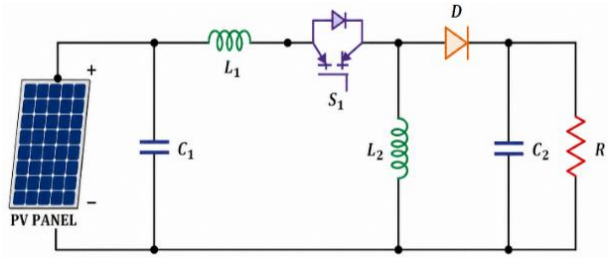

Figure 3. Circuit diagram of landsman converter

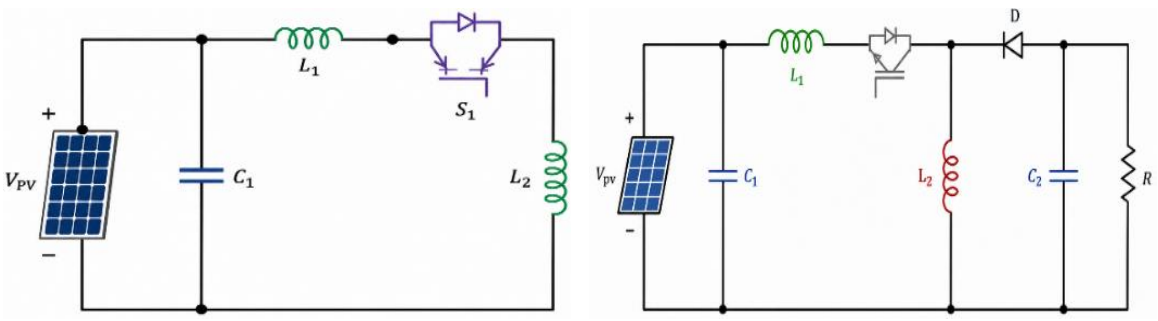

Figure 4. Operating modes of the proposed PV-fed DC–DC converter:
(a) Mode 1 (ON state) and (b) Mode 2 (OFF state)

3.3. RBFNN based MPPT controller

In order to get the most out of a PV system's solar panels in a wide range of climates and levels of sunlight, an MPPT controller is crucial. Here, the PV panel output voltage and current are utilized by the RBFNN-based MPPT controller to calculate an estimate of the MPP. The RBFNN is a kind of feedforward neural network model that uses both unsupervised and supervised learning. As can be seen in Figure 5, RBFNN consists of a basic structure with three layers: an input layer, a hidden layer, and an output layer. Both the hidden and output layers employ radial basis activation functions, while the one in the hidden layer is non-linear.

The operation of RBFNN is highly influenced by the interconnection pattern, activation function and weights. The input neuron's net input and output are specified as (11) and (12).

$$x_i^{(1)}(n) = net_i^{(1)} \tag{11}$$

$$y_i^{(1)}(n) = f_i^{(1)}\left[net_i^{(1)}(n)\right] = net_i^{(1)}(n), i = 1,2 \tag{12}$$

Here, the input layer and hidden layer are denoted by the terms $x_i^{(1)}$and $y_i^{(1)}$respectively. The sum of the input layer is denoted as $net_i^{(1)}$. In the hidden layer, every node behaves like a Gaussian function. In the RBFN, the Gaussian function is used as a membership function.

$$net_j^{(2)}(n) = -(X - M_j)^T \sum_j (X - M_j) \tag{13}$$

$$y_j^{(2)}(n) = f_j^{(2)}\left[net_j^{(2)}(n)\right] exp\left[net_j^{(2)}(n)\right], j = 1,2, \ldots \tag{14}$$

Here, the mean and standard deviation of the Gaussian function are specified by the terms M_j and $\sum_j$ respectively. The linear control signal (D) is generated by the output layer, which has a single node k.

$$net_k^{(3)} = \sum_j w_j y_j^{(2)} \tag{15}$$

$$y_k^{(3)} = f_k^{(3)}\left[net_k^{(3)}(n)\right] = net_k^{(3)}(n) \tag{16}$$

The connective weight matrix between both the output and hidden layer is denoted as w_j. Based on the output of the controller, the PWM generator generates PWM pulses, which adjust the duty cycle D of the Landsman converter and produce a controlled output voltage without any fluctuations.

The proposed RBFNN consists of an input layer, hidden radial-basis layer, and output layer. PV voltage (V_{PV}) and current (I_{PV}) are used as inputs, while the duty cycle (D) of the Landsman converter is generated at the output. Gaussian radial basis functions are employed in the hidden layer to represent the nonlinear relationship between the PV operating point and the required duty cycle. The network is trained using PV operating data obtained under different irradiation and temperature conditions. After training, the network weights are fixed and the trained RBFNN is implemented in MATLAB/Simulink. During operation, the measured PV voltage and current are supplied to the network, which generates the duty-cycle command for the PWM generator. This process enables the Landsman converter to continuously track the maximum-power operating region.

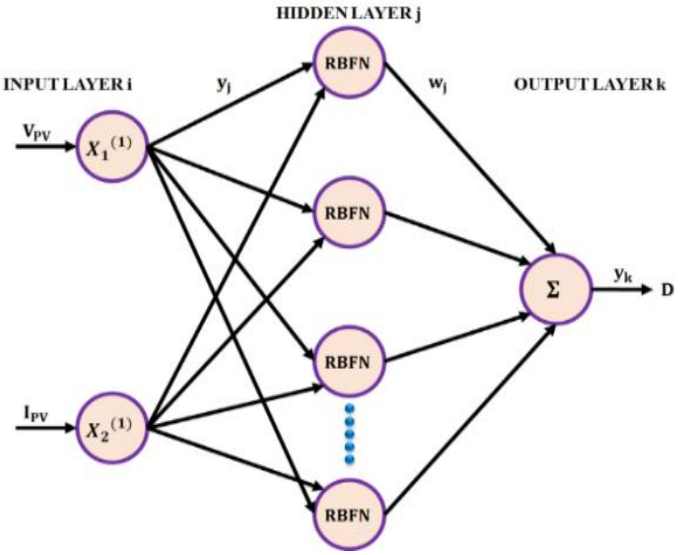

Figure 5. RBFNN based MPPT controller

3.4. Grid voltage synchronization using PI controller

The actual active power P_{act} and the reference active power P_{ref} are compared and an error is generated. Likewise, the actual reactive power Q_{act} is compared with the reference reactive power Q_{ref} for error calculation. The real and reactive power errors are given as input to the PI controller. The steady state error is eliminated by the proportional and integral action that takes place in a PI controller. Based on the error, this controller produces control signal, which is fed to the PWM generator in order to generate PWM pulses.

The resultant pulses control the switching operation of the inverter by adjusting its duty cycle. Hence, the inverter output voltage is controlled and made equal to the grid voltage, which is known as grid voltage synchronization.

4. RESULTS AND DISCUSSION

The simulation performance of the proposed Landsman converter integrated with PI and RBFNN-based MPPT controllers was analyzed in MATLAB/Simulink. The comparative analysis was carried out in terms of grid voltage and current characteristics, converter output voltage, source power factor, and active/reactive power response. The obtained results validate the effectiveness of the proposed control strategy in improving the dynamic and steady-state performance of the grid-connected PV system.

To further position the proposed method within recent developments, a comparison with representative AI-assisted PV and EV charging converter approaches is presented in Table 1. The comparison considers the converter architecture, intelligent control technique, MPPT capability, validation method, and primary application. Unlike approaches that mainly focus on intelligent MPPT or EV charging control independently, the proposed method combines an RBFNN-based MPPT controller with a high-gain Landsman converter and a grid-connected VSI. This combination provides high voltage conversion and intelligent MPPT control within a single PV power-conversion structure. Therefore, the main contribution of the proposed approach is the coordinated integration of intelligent MPPT and high-gain conversion for PV-based EV charging applications.

As observed from Table 1, the proposed method differs from conventional and intelligent approaches through the combined use of an RBFNN-based MPPT controller and a high-gain Landsman converter. The RBFNN generates the converter duty-cycle command from the PV voltage and current, while the grid-side PI controller maintains grid synchronization. The proposed system therefore provides an integrated solution for PV power extraction and high-voltage DC conversion. However, unlike some recent EV charging studies, the present work does not include an explicit battery charging model or experimental hardware validation. These aspects will be addressed in future work.

Table 1. Comparison of the proposed method with recent AI-assisted EV charging and PV converter studies

Study/approach	Converter/architecture	Intelligent method	MPPT	Validation	Main focus
Conventional PI	Grid-connected PV converter	PI	Conventional	Simulation	Voltage/grid control
Recent AI-MPPT studies	DC–DC/PV converters	ANN/FLC/ANFIS	Yes	Simulation/Experimental	MPPT improvement
Intelligent EV charger studies	EV charging converter	AI/Adaptive control	Application dependent	Simulation/Experimental	Charging and power quality
Proposed method	Landsman + VSI	RBFNN + PI	RBFNN	MATLAB/Simulink	High-gain conversion and intelligent MPPT

4.1. Performance with PI controller

Figure 6 illustrates the grid voltage and grid current waveforms obtained using the conventional PI controller. The waveforms indicate synchronization between voltage and current; however, small oscillations and transient distortions are observed during the initial operating period. Figure 7 shows the output voltage response of the Landsman converter under PI control. The converter output reaches the desired steady-state value after a short transient interval with noticeable overshoot. Figure 8 presents the source power factor obtained using the PI controller. Although the power factor approaches unity during steady-state operation, slight ripples are observed because of switching and control variations. Figure 9 depicts the active and reactive power characteristics of the system using PI control. The active power exhibits oscillatory behavior before attaining stability, while the reactive power remains comparatively low.

4.2. Performance with proposed RBFNN controller

Figure 10 shows the grid voltage and current waveforms obtained with the proposed RBFNN-based MPPT controller. Compared with the PI controller, the voltage and current waveforms exhibit improved synchronization and reduced harmonic distortion. Figure 11 illustrates the output voltage response of the Landsman converter using the proposed RBFNN controller. The converter achieves faster settling time with reduced overshoot and improved voltage stability compared to the conventional PI controller. Figure 12 presents the source power factor achieved with the proposed RBFNN control strategy. The power factor rapidly reaches near-unity operation with minimal oscillations, demonstrating superior power quality enhancement

capability. Figure 13 illustrates the active and reactive power characteristics under the proposed RBFNN controller. The active power response becomes more stable with reduced fluctuations, whereas the reactive power is significantly minimized, confirming improved dynamic performance and efficient grid integration.

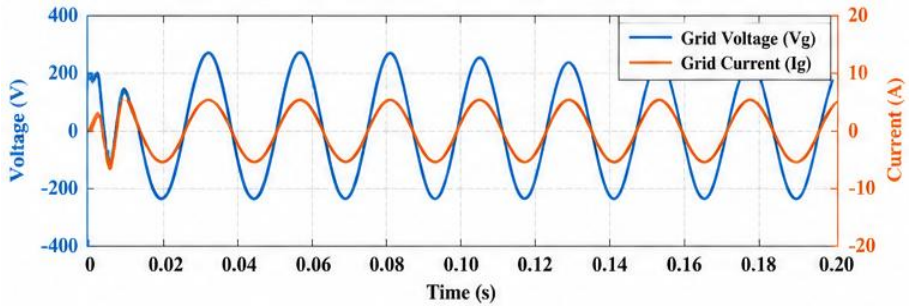

Figure 6. Grid voltage and grid current response using PI controller

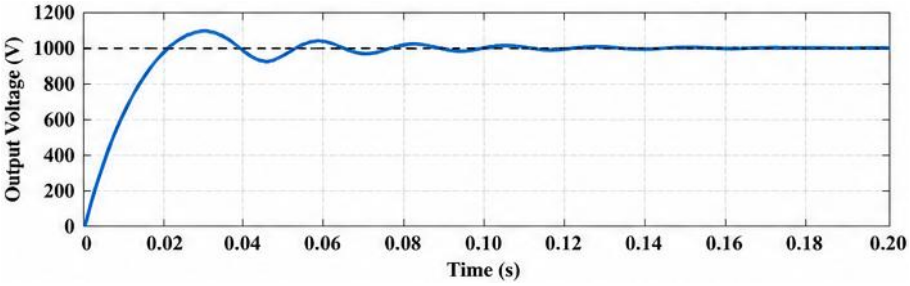

Figure 7. Output voltage response of Landsman converter using PI controller

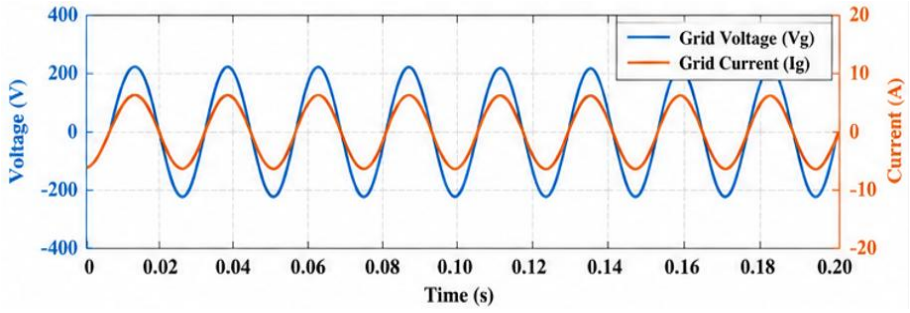

Figure 10. Grid voltage and grid current response using proposed RBFNN controller

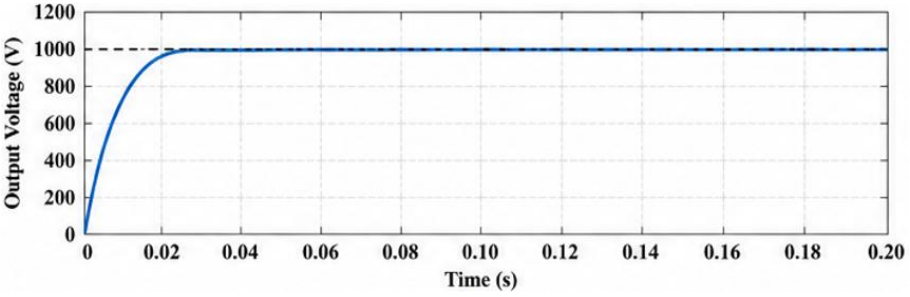

Figure 11. Output voltage response of Landsman converter using proposed RBFNN controller

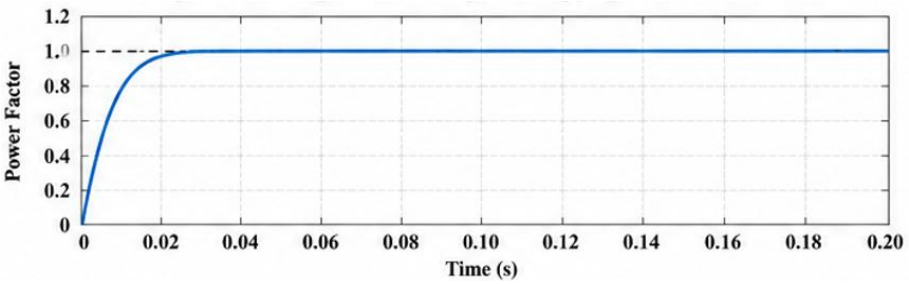

Figure 12. Source power factor response using proposed RBFNN controller

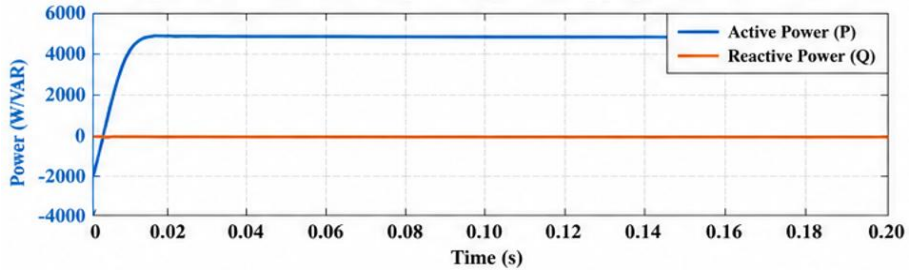

Figure 13. Active and reactive power response using proposed RBFNN controller

The comparative results indicate that the proposed RBFNN controller provides a faster and more stable response than the conventional PI controller. The settling time is reduced from 0.08 s to 0.02 s, while the output-voltage overshoot decreases from 10% to 2%. The source power factor improves from 0.96 to 0.999, indicating improved utilization of the generated PV power at the grid interface. The MPPT tracking accuracy also increases from 94% to 99%. These improvements demonstrate the ability of the RBFNN to provide a more effective nonlinear mapping between the PV operating condition and the converter duty cycle. However, quantitative THD and converter-efficiency comparisons are not included because these parameters were not directly calculated in the present simulation study.

The presented results mainly evaluate voltage regulation, settling time, power factor, active and reactive power, and MPPT tracking performance. Since a detailed THD spectrum and converter efficiency calculation are not included in the present simulation, claims regarding quantitative harmonic reduction and efficiency improvement are not considered as primary performance measures. The results therefore focus on the demonstrated electrical and dynamic performance of the proposed RBFNN-controlled Landsman converter.

Table 2 presents the comparative performance analysis of the conventional PI controller and the proposed RBFNN-based MPPT controller for the Landsman converter-fed grid-connected PV system. The comparison is carried out in terms of output voltage regulation, settling time, power factor improvement, active and reactive power response, harmonic reduction, MPPT tracking accuracy, and overall converter efficiency. From the obtained simulation results, it is observed that the proposed RBFNN controller provides superior dynamic response, reduced oscillations, improved voltage stability, near-unity power factor, and enhanced power quality compared to the conventional PI controller. These improvements confirm the effectiveness of the proposed intelligent control strategy for EV charging and renewable energy integration applications.

The present simulation primarily evaluates the controller under the selected PV and grid-connected operating conditions. A detailed sensitivity analysis considering wide variations in PV irradiance, battery charging conditions, converter parameters, and load uncertainty has not been performed. Such analysis is important for assessing controller robustness and will be considered in future work using an extended EV battery charging model and varied converter and load conditions.

For practical implementation, the trained RBFNN can be deployed on digital controllers such as DSPs or FPGAs. Since the network uses only the measured PV voltage and current to generate the duty-cycle command, the online computation is mainly associated with the radial-basis function evaluation and output-weight calculation. However, the Gaussian functions and network operations introduce additional computational and memory requirements compared with a conventional PI controller. Real-time implementation therefore requires appropriate selection of the number of hidden neurons, sampling frequency, processor capability, and memory resources. FPGA implementation can provide parallel processing of the hidden-layer operations,

whereas DSP implementation offers a simpler programmable platform. These hardware considerations will be investigated further during experimental implementation of the proposed controller.

Table 2. Comparative performance analysis of PI controller and proposed RBFNN controller for the Landsman converter-based grid-connected PV system

Parameters	PI controller	Proposed RBFNN controller	Improvement achieved
Input PV voltage	200 V	200 V	—
Output voltage of Landsman converter	1000 V	1000 V	Stable regulation achieved
Output voltage overshoot	10 %	2 %	Reduced overshoot
Settling time	0.08 s	0.02 s	Faster dynamic response
Source power factor	0.96	0.999	Near-unity power factor
Power factor ripple	Moderate	Very Low	Improved stability
Active power output	4.5 kW	5 kW	Increased output power
MPPT tracking accuracy	94 %	99 %	Better tracking capability
Converter gain	5	5	

5. CONCLUSION

In this work, an RBFNN-based MPPT controlled Landsman converter for grid-connected PV-fed EV charging applications was presented and validated using MATLAB/Simulink. The proposed converter successfully boosted the PV output voltage from 200 V to nearly 1000 V with improved voltage stability and continuous conduction mode operation. The simulation results demonstrate that the proposed RBFNN controller outperforms the conventional PI controller by achieving a near-unity power factor of 0.999, reduced overshoot below 2%, faster settling time of 0.02 s, and minimized reactive power close to 0 VAR. In addition, the proposed method improved active power response, reduced oscillations, and enhanced grid synchronization and overall system efficiency.

Therefore, the proposed RBFNN-based Landsman converter provides an efficient and reliable solution for advanced EV charging and renewable energy integration applications. The main limitation of the present study is the absence of experimental validation. Future work will include comprehensive sensitivity analysis under varying solar irradiance, EV battery charging conditions, converter parameter variations, and load uncertainty. This analysis will provide further insight into the robustness and practical applicability of the proposed RBFNN-based control strategy.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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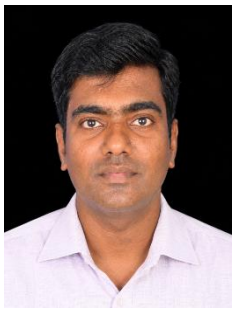

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