Journal of Information Systems Engineering and Management
2025, 10(8s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Hermit Crab Optimizer Approach: Harmonics Reduction of Hybrid Renewable Energy Sources

Mr. G. Balram[1*], Dr. Peddapalli Satish Kumar[2]
[1]Research Scholar, Department of Electrical Engineering, Osmania University, Hyderabad, India*
[1]Email: balramgyadari@gmail.com*
[2]Professor, Department of Electrical Engineering, University College of Engineering, Osmania University, Hyderabad, India

ARTICLE INFO

Received: 20 Oct 2024

Revised: 15 Dec 2024

Accepted: 28 Dec 2024

ABSTRACT

Micro Grids (MGs) have gained a lot of popularity recently because of their benefits in terms of high transmission efficiency and efficient power conversion. However, the nonlinear properties of renewable energy sources (RESs), the increased usage of power electronic devices, and unanticipated fluctuations in load are what lead to the formation of stability issues in the MG. This manuscript presents the optimization approach to improve the performance of microgrid with renewable energy sources (RES). The proposed method is the Hermit Crab Optimizer (HCO) Algorithm. Here, Solar PV and Wind Turbine is utilized as power sources, supported by DC/DC and AC/DC converters for efficient energy conversion. The main objective of proposed technique is to minimize the THD and maximize the efficiency of system. The HCO algorithm is used to optimize the duty cycle of the DC to DC converters within the system. By then, the proposed method's performance is put into practice using the MATLAB platform, and it is contrasted with a number of existing methods, including Salp Swarm Algorithm (SSA), Ant Lion Optimizer (ALO), and Particle Swarm Optimization (PSO). From the result, the THD of proposed method is -17.75. The THD of existing PSO is 17.81465, ALO is -17.81469 and SSA is -17.81545.

Keywords: Hybrid Renewable Energy Source System, Total Harmonic Distortion, Photovoltaic, Wind Turbine, Battery, Hermit Crab Optimizer.

INTRODUCTION

(a) Background

With advancements in energy technology, producing, transferring, and storing electricity can be done more easily, efficiently, and economically. In the recently liberalized setting of smart cities, effective management of electricity generation and supply depends on knowing and anticipating how environmental conditions will impact energy demand [1, 2]. The idea of microgrids is becoming more and more popular. They can be found in modular arrangements within larger grids as well as on small islands and isolated communities. This allows various districts and facilities to function independently and more resiliently in the event of a network outage. The two most crucial parts of a microgrid are regulation and power administration [3]. Maintaining the DC bus voltage is the primary priority, followed by keeping the input sources and loads' power balance. When a photovoltaic (PV) source is connected to a microgrid through a variety of devices and equipment and is dependent on the environment, power fluctuations in the microgrid system occur [4]. Because the generation of renewable energy sources is unpredictable, energy storage techniques must be used to lessen output swings. In order to compensate for the unpredictable nature of different energy sources, an efficient hybrid energy system converter is primarily used in conjunction with an efficient battery storage system to integrate multiple renewable energy sources. Energy storage systems support continuous power generation by satisfying load demand [5-7]. Additionally, inertial and synchronization issues are raised by the use of converters with fault-tolerant capacity, which restrict current fault in the system and guarantee system security [8, 9]. Power disparity is an issue that appears prior to micro grid supplying energy to a utility grid and while transitioning from grid-linked to islanded mode [10–12]. A new balanced phase transition method uses nominal peak load conditions to calculate energy consumption over the current demand period. Then, using triangular functions to compare power demand to the target value, the load factor and reactive power of the converter are calculated [13–15]. This technique addresses the problem of power discrepancy in transition.

(b) Challenges

There are many different issues associated with reducing harmonics in hybrid renewable energy source systems. These include the inherent uncertainty of renewable energy generation and the intricate relationships between power electronic converters and grid infrastructure. Power converters and other non-linear loads cause harmonic distortions that amplify anomalies in the voltage and current waveforms. These harmonics not only reduce the system's effectiveness but also increase the possibility of equipment damage and communication network interference. Furthermore, during times of low power output, harmonic problems may become more severe because RES is sporadic in nature. Complex control algorithms and filtering methods are needed to mitigate harmonics, which increases the complexity and cost of system design and operation. The task is made more difficult by having to adhere to strict grid norms and standards, which calls for a careful balancing act between cost-effectiveness and harmonic reduction. Innovative ways that include hardware solutions that are durable, dynamic control strategies and regulatory compliance are necessary to address these issues and guarantee the dependability and effectiveness of hybrid renewable energy systems.

(c) Literature Review

Various research works are introduced based on renewable energy system for microgrid employing a variety of methods and approaches, some of which are detailed here,

Coordination of power management and control strategies (PMCS) based on BES is presented by Al Sumarmad et al., [16] to enable the MG system to efficiently utilize RE sources while preserving the stability and dependability of the MG. A battery management system (BMS) that incorporates an improved BES control method is used to ensure the safe and efficient use of BES. To improve overall performance in terms of control response and voltage regulation, it is recommended that Direct Current (DC) networks use optimized FOPI controllers in the BES control system in conjunction with the hybrid optimization technique of Atom Search Optimization and Particle Swarm Optimization (ASO-PSO).

According to Kanagaraj et al., [17], biomass, fuel cells, PV, and wind farms are the key players in the renewable energy producing sector. Especially in regions where wind energy potential is modest to high, wind-driven stand-alone systems are a dependable energy source that have shown their ability to provide power to a large number of rural consumers globally. This research presents a novel power system operation smart grid application. Static compensators, or STATCOMs, balance reactive power in the power sources, lessen undesired harmonics, and enhance power flow and quality in the distribution system.

According to Mohammad et al., [18], More distributed generating units are being used in remote locations, and the need for these systems to function dependably and flexible has spurred the development of microgrid technology. An optimal control mechanism needs to be in place to maintain the stability of the system. The best control schemes for self-governing micro grids are presented in this study. Using optimization techniques, the voltage and current controllers' gain settings are changed. The best gain values are obtained in this study by implementing PSO and HHO optimization strategies.

According to Salehirad et al., [19], In a Multi-Agent System (MAS), the Mealy machine is the cornerstone of the energy management strategy. It generates coordination signals and sends them to the RES. Reverse of hill-climbing (RHC) or maximum power point tracking (MPPT) is used in RES to limit the exchange power between the grid and the MG based on these received coordination signals.

The harmonic quality control technique for an islanded microgrid's single distributed resource at low switching frequency operation has been proposed by Qi et al., [20]. A weight factor tuner that automatically adjusts weight factors according to the harmonic component is also suggested by this study, addressing the challenge of altering the weight factors.

(d) Research Gap and Motivation

Enhancing the performance of a microgrid system with renewable energy sources is a crucial issue, as indicated by a general assessment of recent studies. The power system's harmonics were reduced by a variety of tactics, but it was impossible to identify which harmonics were caused by high impedance flaws. In addition, the system's current fault is limited by converters with fault-tolerant capacity, which guarantees system security but raises synchronization and inertial issues. Numerous scholars address issues related to various technologies in literature, such as the "Fuzzy Logic Controller (FLC), Harris Hawks Optimization (HHO), and Particle Swarm Optimization (PSO) Algorithm". While PSO has been proposed as a means of enhancing the functionality of BES systems and distributed generating units, these methods still need to be refined for real-world use.

(e) Contribution

The contributions were summarized as follows,

- This manuscript contributes an optimizing approach to improve the performance of microgrid with renewable energy sources.
- The proposed method is Hermit Crab Optimizer to optimize the duty cycle of the system's DC to DC converters.
- The proposed technique's primary goals are to reduce THD and increase system efficiency.
- Simulation results indicate that the proposed HCO approach outperforms other methods currently in use, including PSO, ALO, and SSA.
- By minimizing harmonic distortion and improving the efficiency of renewable energy systems, efforts in harmonics reduction contribute to advancing sustainable energy solutions

(f) Organization

The remainder of the document is written as: sector 2 gives the Configuration of Hybrid wind-solar system Sources for Harmonic Reduction. Sector 3 presents the proposed methodology. Sector 4 presents the result and discussion and sector 5 concludes the paper.

CONFIGURATION OF HYBRID RENEWABLE ENERGY SOURCES FOR HARMONIC REDUCTION

As industrialization and urbanization pick up speed, more distribution companies are needed to keep up with the demand for electricity. Fossil fuel-based electricity generation is insufficient to meet the necessary demand. Warming is being caused by these conventional sources and is seriously harming the ecosystem. Renewable energy sources have been urged to produce the energy needed to meet load demand in order to solve these issues [21]. The distribution system makes extensive use of a variety of renewable energy sources, including wind, solar, and batteries. Figure 1 shows the construction of a hybrid renewable energy source using the recommended approach. Figure 1 illustrates how the combination of PV and WT is interfaced with the grid in the proposed HRES system. Since the sources under consideration are intermittent, BESS is built to satisfy load demands under extreme environmental circumstances. Combining PV and WT is thought to maximize system reliability and efficiency, and HRES is the best option. The HCO method, an optimization methodology, is used to govern the system's operation. This technique is utilized to gather both the solution efficiency and fast relatively resolution.

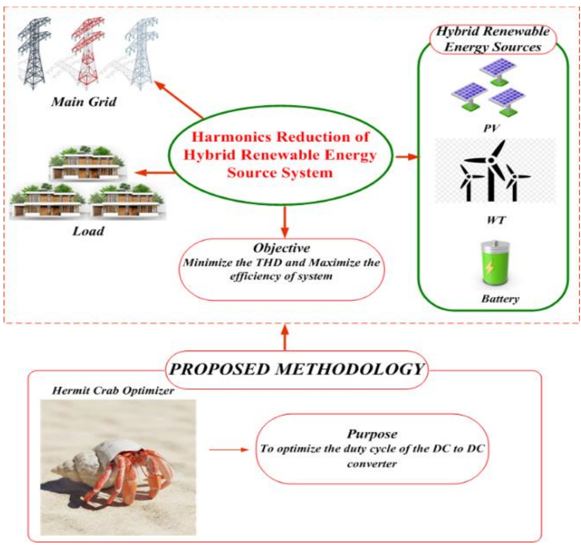

Figure 1: Structure of Hybrid Renewable Energy Source using proposed method

Mathematical Modelling of HRES

Eco-friendly, safe, and less expensive renewable energy sources are made possible by the smart grid AC/DC power system. Batteries, wind turbines, and solar photovoltaic arrays are examples of renewable energy sources. The deterministic technique validates the modeling's overall performance and makes it easy to identify all of the component properties. The solar photovoltaic system, battery, and wind turbine performance validation is provided below.

Mathematical Formulation of Solar Photovoltaic system

In this section, solar PV systems are so widely available, they are essential to renewable energy sources [21]. The greatest power was achieved because of variations in the sun's irradiation level. The solar PV system's modeling is shown in eqn (1) as follows:

$$v_{OC} = \frac{v_{DC}}{Ckt/Q} \tag{1}$$

$$p_{Max} = \frac{\dfrac{v_{OC}}{Ck\dfrac{t}{Q} - \ln\left(\dfrac{v_{OC}}{ck\dfrac{t}{Q}} + 0.72\right)}}{(1+\dfrac{v_{OC}}{Nk\dfrac{t}{Q}}} \tag{2}$$

$$\left(1 - \frac{r_S}{v_{OC}/i_{SC}}\right)\left(\frac{v_{\alpha c0}}{1+\beta \ln g_0/g}\right)\left(\frac{t_0}{t}\right)^{\gamma} i_{SC0}$$

$$v_T = \eta k \frac{t}{Q} \tag{3}$$

The equation above indicates the open-circuit voltage (v_{OC}), the ideality factor (η), and the Boltzmann constant (k). The PV module's temperature, t, is expressed in kelvin, and the electron charge, q. Photocurrent-causing factor α is indicated, and the dimensionless coefficient of the PV module β. γ as the factor that takes into account all non-linear voltage-temperature effects.

Mathematical Formulation of Wind Turbine System

The wind energy system computes WT's output power using the following formulas:

$$p_{wt} = \begin{cases} 0 & if \quad W_S \le W_{S\,CI} \\ \alpha \times W_S^{\;3} - \beta \times P_r & if \quad W_{S\,CI} < W_S < W_{S\,R} \\ P_r & if \quad W_{S\,R} \le W_S < W_{S\,CO} \\ 0 & if \quad W_S \ge W_{S\,CO} \end{cases} \tag{4}$$

The wind speed is represented as Ws in this instance, the cut-in wind speed as Ws_{CI}, the cut-off wind speed as Ws_{CO}, the rated wind speed as Ws_R, and the rated power as P_r [22]. The α and β parameters are displayed in the following equation and are represented as follows:

$$\alpha = P_r / \left(Ws_R^{\,3} - Ws_{CI}^{\,3}\right) \tag{5}$$

$$\beta = Ws_{CI}^{3} / \left(Ws_{R}^{3} - Ws_{CI}^{3}\right) \quad (6)$$

$$P_r = \frac{a_{wt}.c_p.\rho_a.E_r E_{wt}.v_r^3}{2} \quad (7)$$

In this case, c_p stands for power coefficient, E_r for efficiency reducer, E_{wt} for WT efficiency, and ρ_a for air density.

Mathematical Formulation of Battery Storage Modelling

Energy from the battery must flow both ways in order to increase the hybrid power system's requirements. In the event that there is an urgent need for electricity, the battery also lessens the load on the grid [23]. Through a DC-DC converter, the battery is connected to the matching structure and is charged in accordance with the control structure and power requirements. Battery life depends on carefully managing battery charging and discharging as well as preventing further discharges. The battery is modeled mathematically in equations (8) and (9).

$$v_{op} = e + r_B I_B \quad (8)$$

$$soc = 100\left(1 - \frac{1}{q}\int_o^t I d\theta\right) \quad (9)$$

In this case, e for battery terminal voltage, v_{op} stands for open circuit voltage, r_B for internal resistance, I for charging current, q for total energy capacity, and soc for state of charge at percentages of time.

Objective function

Reducing the mistake is the primary means of minimizing the THD, which is the main goal of this study [21]. Equation (10) displays the mathematical formula for the research's goal function.

$$Obj = Min\ (Err) \quad (10)$$

PROPOSED METHODOLOGY OF HERMIT CRAB OPTIMIZER APPROACH USING HYBRID RENEWABLE ENERGY SOURCE SYSTEM

The optimization strategy to enhance the microgrid's performance using renewable energy sources is presented in this section. The Hermit Crab Optimizer (HCO) Algorithm is the proposed technique. The system's DC to DC converters' duty cycle is optimized via the HCO algorithm. The HCO approach mimics the collective intelligence of hermit crabs seen in the wild, which helps them locate shells that shelter them and allow them to grow over time. HCO uses novel solitary and sociable search operators to lead search agents in parallel and individually. The steps involved in the HCO process are listed below:

Step 1: Initialization

Zero out the input settings on the system. Consider the factors like voltage and current in this situation.

Step 2: Random generation

Random generation is used to construct the initialized populations at random. It is explained by,

$$X = \begin{bmatrix} X_1 \\ \vdots \\ X_i \\ \vdots \\ X_N \end{bmatrix}_{N\times m} = \begin{bmatrix} x_{1,1} & \cdots & x_{1,d} & \cdots & x_{1,m} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{i,1} & \cdots & x_{i,d} & \cdots & x_{i,m} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{N,1} & \cdots & x_{N,d} & \cdots & x_{N,m} \end{bmatrix}_{N\times m} \quad (11)$$

here, X is denoted as the HCO population matrix, X_i indicates the i^{th} crab, $x_{i,d}$ denotes its d^{th} dimension in the search space, m is the quantity of decision variables, N gives the number of crab.

Step 3: Fitness Function

The goal function determines the fitness of the system. In order to ascertain the fitness function,

$$fitness\ \ function = Min\,(Err) \tag{12}$$

where, $Min\,(Err)$ denotes the minimization of THD error.

Step 4: Evaluation

Vector $\vec{x}$ is encoded (or mapped) into the solution space, assigning each search agent a value. Consequently, take into consideration that the decoder function is g, which yields a significant answer to the optimization issue. p is combined with a new feature during the assessment phase, which represents the objective values that search agents have acquired:

$$\Pi(i) = |p(i), r(i)| = \begin{bmatrix} \vec{x}_1(i) & g(\vec{x}_1(i)) \\ \vec{x}_n(i) & g(\vec{x}_n(i)) \end{bmatrix}_{n\times(1+1)} \tag{13}$$

where p is denoted as the state matrix showing the search agents' placements, r is indicated as the reward matrix that has been given to each agent, and Π is the state-reward matrix. Figure 2 shows the flowchart of HCO.

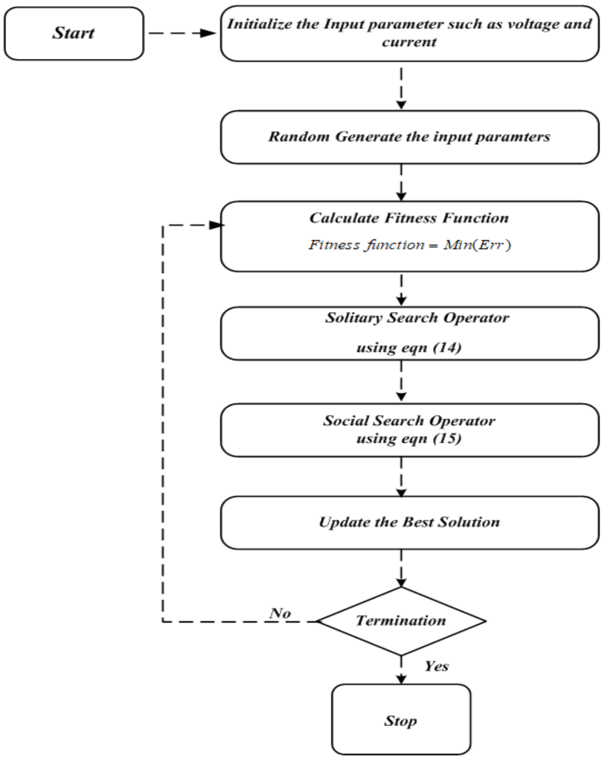

Figure 2: Flowchart of HCO

Step 5: Solitary Search Operator

Only search agents who have successfully completed their label are pursued to this level. As previously noted, in their lonely pursuit of shells, hermit crabs are induced to respond to potent chemical cues in their environment. It is necessary to create an operator that emulates this behavior by accounting for the diffusion of smell molecules from one position within the environment to another.

$$\vec{x}_n(i+1)=\frac{1}{e}\sum_{E=1}^{e}\left(\vec{x}'_e(i)+\gamma_e\left|\delta_1\vec{x}'_e(i)-\vec{x}_n(i)\right|\right) \tag{14}$$

where, $\vec{x}_n(i+1)$ is denoted as the condition (location) of the n-th effective search agent in two consecutive rounds, $\vec{x}'_e(i)$ as e perceived position of the E, γ_e as particular rate at which the e-th odor source distracts.

Step 6: Social search operator

Only search agents with a failing label go to this level. a transition matrix that shows the likelihood that a hermit crab will exchange its shell with another hermit crab in the vacancy chain, taking into account that each hermit crab would only choose to mate with the closest-fitting shell size.

$$w=\begin{bmatrix} I & O \\ R & Q \end{bmatrix} \tag{15}$$

where I is a 2 × 2 matrix that represents the fixing locations in the greatest and smallest hermit crabs' vacant chain. In the vacancy chain, Q is equivalent to the hermit crabs' exchanges of shells. O is denoted as a matrix of zeros and R represents the shifts from temporary hermit crab states to states of absorption.

Step 7: Termination

If the solution is the best, the procedure terminates; if not, it loops back to the step 3 fitness calculation and continue processing the subsequent levels until a solution is found.

RESULT AND DISCUSSION

This sector presents the performance of the proposed technique based on the simulation results. The HCO method approach was presented in this study as a way to reduce THD and enhance microgrid performance while using renewable energy sources. Existing techniques like PSO, ALO, and SSA are contrasted with the proposed strategy. The simulation results are presented as follows;

Figure 3 displays the analyses of PV current, voltage and power. In subplot 3(a) the analyses of PV current is presented. The current flows from 320A to 180A at the time period of 0 to 0.3sec and then it increased up to 210A at the time period of 0.3 to 0.5sec then it increased up to 300A at the time period of 0.5 to 0.7sec and then it decreased up 0A at the time period of 0.9sec. In subplot 3(b) the analyses of PV voltage is presented. The voltage flows from 230V at the time period of 0 to 0.3sec and then it increased up to 280V at the time period of 0.3 to 0.5sec then it increased up to 360V at the time period of 0.5 to 0.7sec and then it decreased up to 150V at the time period of 0.9sec. The PV power analysis is shown in subplot 3(c). The power flows from 2.5W at the time period of 0 to 0.3sec and then it increased up to 6W at the time period of 0.3 to 0.5sec then it increased up to 11W at the time period of 0.5 to 0.7sec and then it decreased up to 0W at the time period of 0.9sec. Figure 4 displays the analyses of WT current, voltage and power. The study of PV current is shown in subplot 4(a). In this instance, the current changes from -70 to 70A within a span of 0 to 0.9 seconds. The study of PV voltage is shown in subplot 4(b). In this case, the voltage changes from -1500 to 1500A during a 0.9-second span. The study of PV power is shown in subplot 4(c). In this instance, the power increases to 2W for a duration of 0 to 0.1 seconds before decreasing to 1.6W for a duration of 1 second. Figure 5 shows the analyses of Battery current, voltage and power. The battery current analysis is shown in subplot 5(a). In this instance, the battery current changes from 0 to 58A during a span of 0 to 1 second. The battery voltage analysis is shown in subplot 5(b). In this case, the battery voltage decreases from 17.50 to 17.38V in 0 seconds, then reaches 17.35V in 1 second. The battery power analysis is shown in subplot 5(c). In this case, the battery power fluctuates between 0 and 1000W for a duration of 0 seconds, and then it stays at 1000W for a duration of 1 second. Figure 6 shows the analyses of grid power. Here, the grid power fluctuates between 0 and 15.9 W for a duration of 0 seconds, then stays at 15.9 W for a duration of 0.1 to 1 seconds.

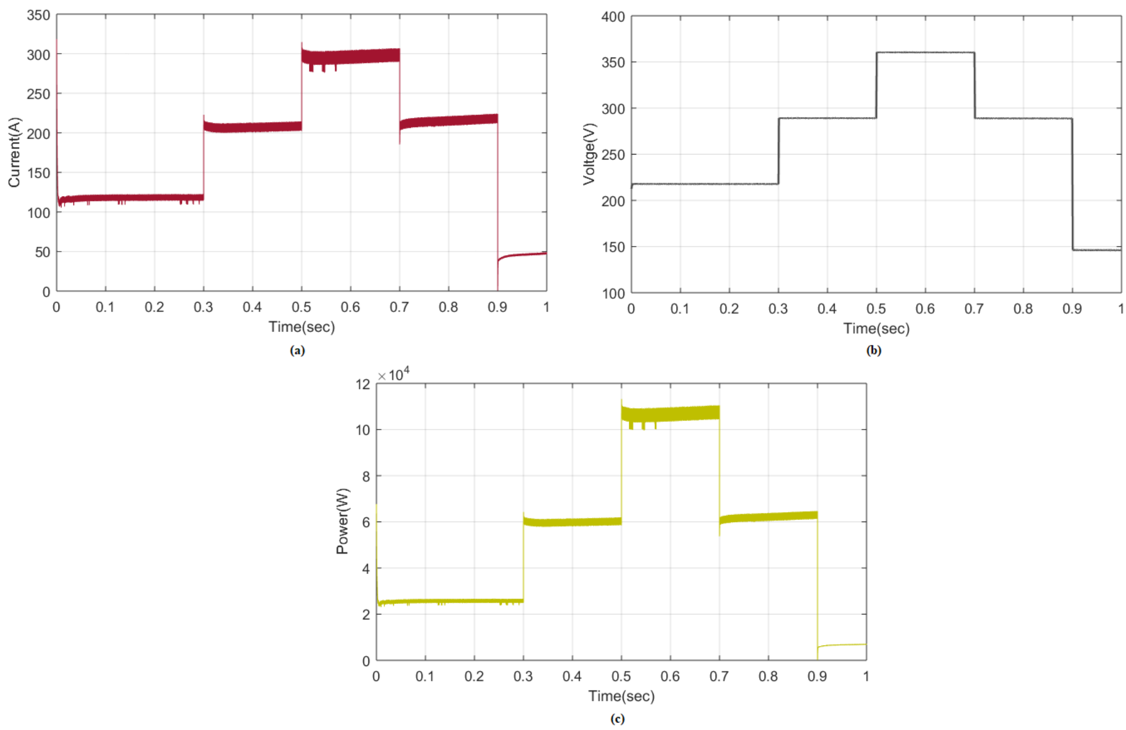

Figure 3: Analyses of PV (a) Current (b) Voltage (c) Power

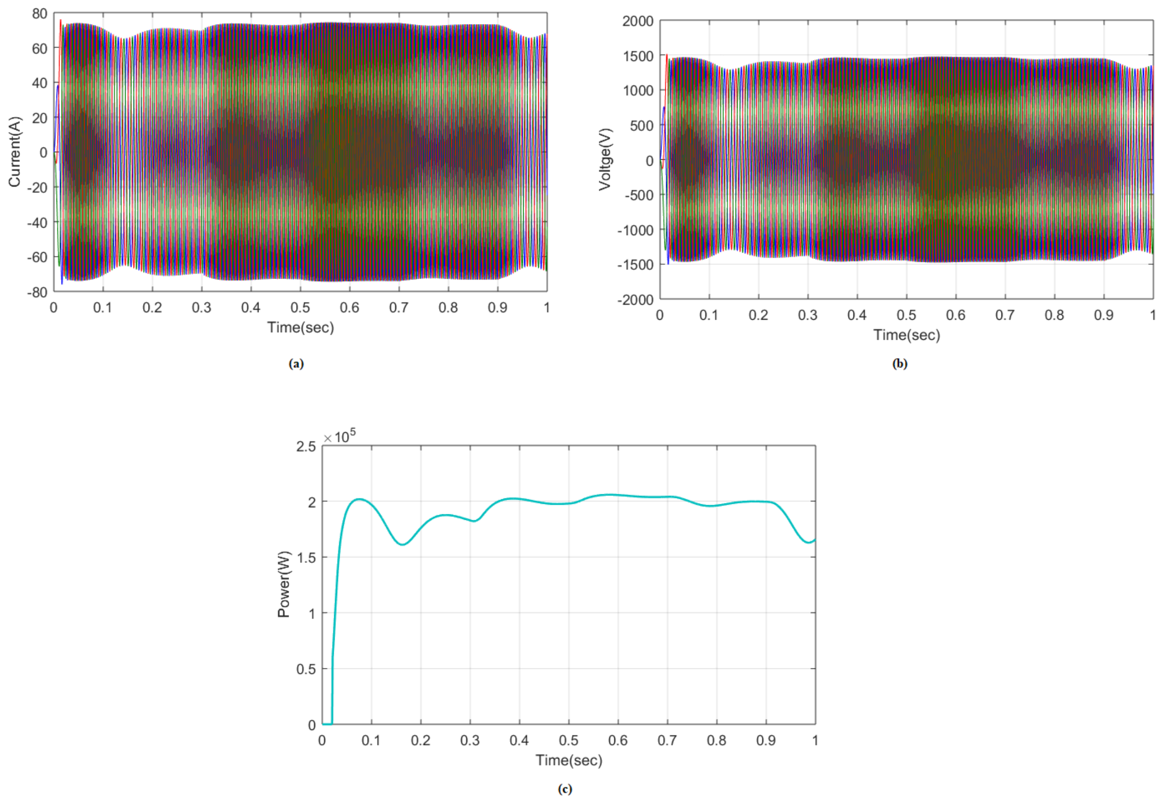

Figure 4: Analyses of WT (a) Current (b) Voltage (c) Power

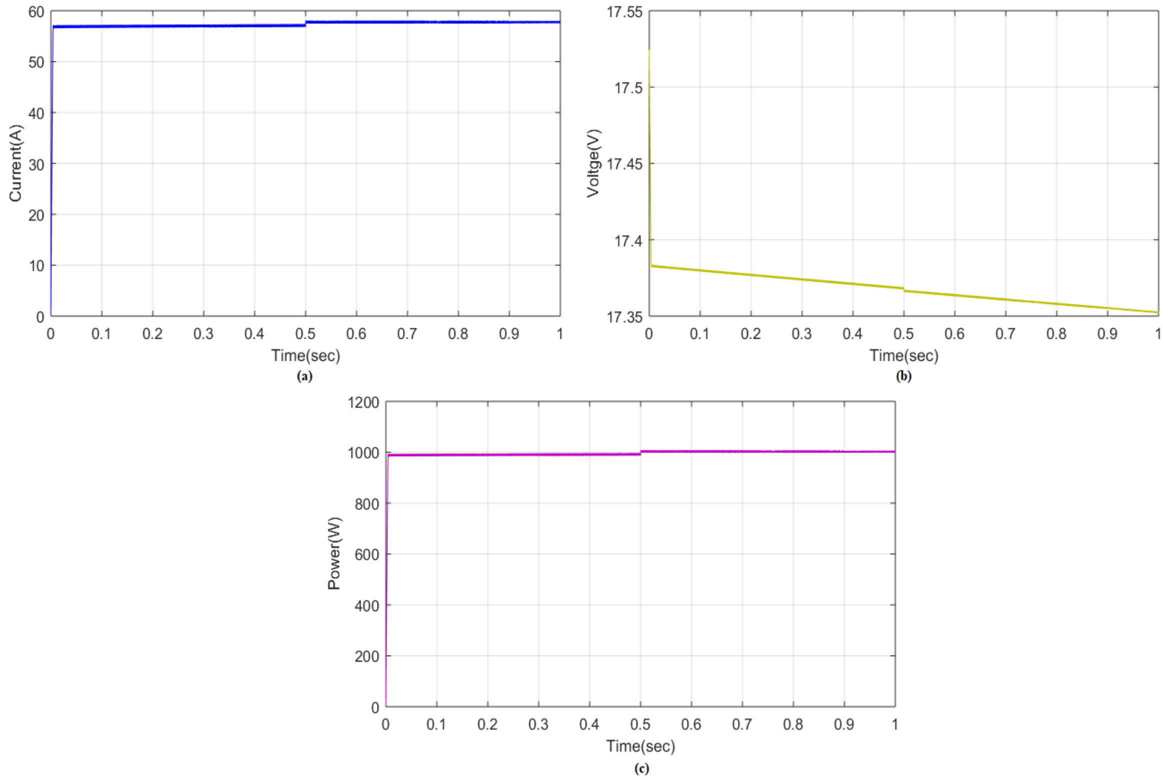

Figure 5: Analyses of Battery (a) Current (b) Voltage (c) Power

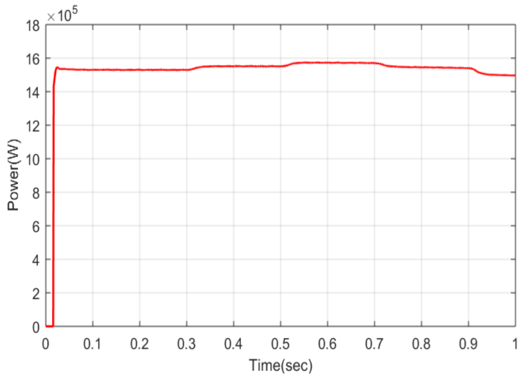

Figure 6: Analyses of Grid power

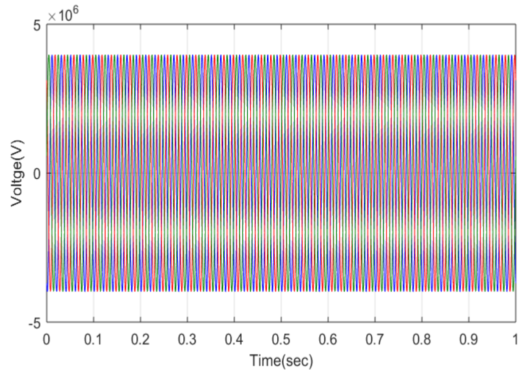

Figure 7: Analyses of Grid voltage

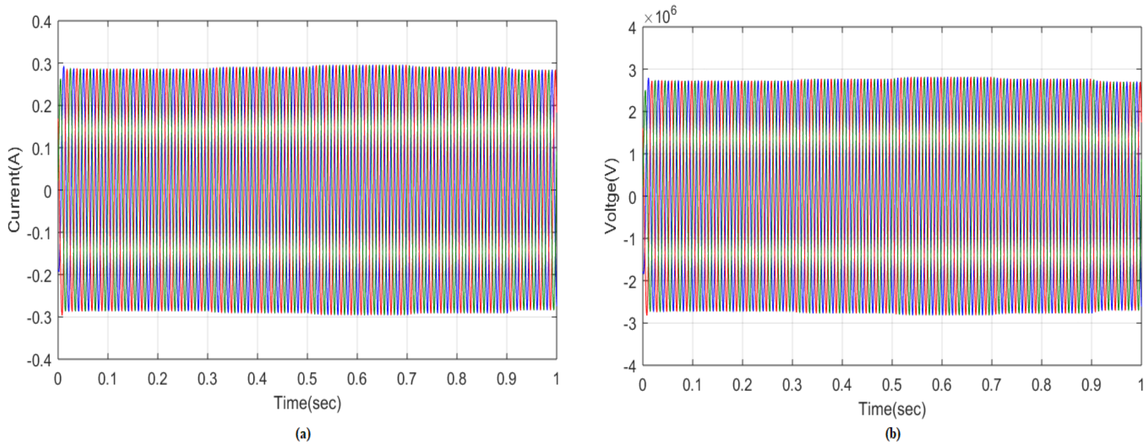

Figure 8: Analyses of Load (a) Current (b).

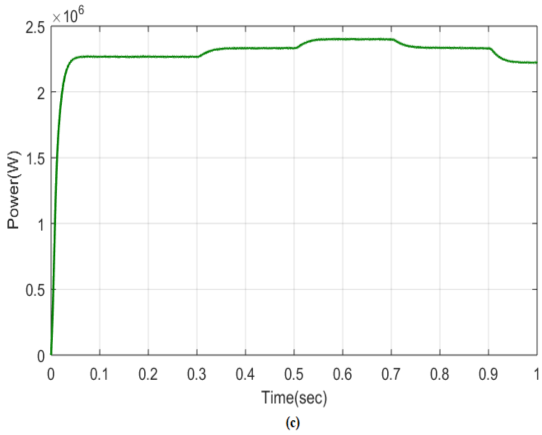

Figure 8: Voltage (c) Power

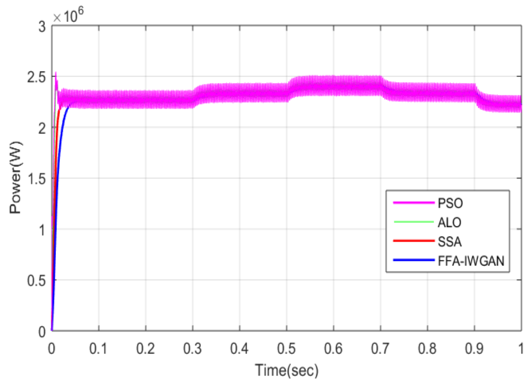

Figure 9: Comparison of load with proposed and existing method

Figure 7 shows the analyses of grid voltage. Here the grid voltage flows from -4 to 4V at the time period of 0sec then it remains constant at 15.9W at the time period of 0.1 to 1sec. In figure 8 the analyses of load of current, voltage and power are presented. The load current analysis is shown in subplot 8(a). In this instance, the load current changes from -0.3 to 0.3A during the course of 0–1 seconds. The study of the load voltage is shown in subplot 8(b). In this instance, the load voltage changes from -2.5 to 2.5V during the course of 0–1 seconds. The study of load power is shown in subplot 8(c). In this case, the power increases from 0 to 2.3 W in 0 seconds and subsequently from 0.1 to 1 W in 0.1 seconds. Figure 9 shows the comparison of load with proposed and existing method. Here, the proposed method's load power increases from 0 to 2.3 W in a span of 0 seconds. The load power range for the present PSO approach is 0 to 2.5 W. The load power range for the present ALO technique is 0 to 2.5 W. The load power of the present SSA approach varies from 0 to 2.4 W. The load power of the proposed approach is less than that of the existing one.

Table 1: Comparison of THD with proposed and existing method

Methods	THD load voltage	Error
PSO	-17.81465634	0.71228073
ALO	-17.81469052	0.70458388
SSA	-17.81545989	0.70579385
Proposed	-17.75689594	0.53284949

Table 1 indicates the comparison of THD with proposed and existing method. Compared to exiting method, the THD of proposed method is low.

Discussion

In this section, discussing the results of harmonics reduction efforts in hybrid renewable energy source systems is presented. The Hermit Crab Optimizer (HCO) Algorithm is the proposed approach for maximizing the duty cycle of the system's DC to DC converters. By then, the effectiveness of this proposed approach is tested on the MATLAB platform and compared with several other approaches, such as PSO, ALO, and SSA. Here, power, current, and voltage analyses for PV, WT, batteries, loads, and the grid are examined. From the result, the load power of proposed method is 2.3W and the existing PSO is 2.5W, ALO is 2.5W and SSA is 2.4W. Overall, the discussion of harmonics reduction results in hybrid renewable energy source systems should provide a comprehensive evaluation of the effectiveness, performance impact, adaptability, and regulatory compliance of the proposed technique. Finally, from the result and discussion it concludes that compared to the existing approach the THD of proposed approach is low.

CONCLUSION

In this manuscript, an optimization approach for improve the performance of microgrid with RES is presented. The proposed approach is the Hermit Crab Optimizer (HCO) Algorithm. Here, Solar PV and Wind Turbine is utilized as power sources, supported by DC/DC and AC/DC converters for efficient energy conversion. The main objective of proposed technique is used to minimize the THD and to maximize the efficiency of system. The HCO algorithm is used to optimize the duty cycle of the DC to DC converters within the system. By then, the effectiveness of the proposed approach is evaluated against other approaches that are currently in use utilizing the MATLAB platform. By addressing these challenges and leveraging emerging technologies, the future of harmonics reduction in hybrid renewable energy source systems holds great potential for advancing sustainable energy solutions and mitigating environmental impacts.

Limitation

- Accurately modeling the behavior of hybrid renewable energy systems, including the interactions between various RES, ESS, and power electronics converters, can be challenging.
- The dynamic nature of renewable energy sources results in variable operating conditions, including fluctuations in power output and load demand.
- Harmonic reduction techniques designed for specific operating conditions may not perform optimally under varying scenarios, necessitating adaptive control strategies that can dynamically adjust to changing conditions.

Future Scope

- Developing more sophisticated control algorithms that can adapt to variable operating conditions and optimize harmonic reduction in real-time is a key area for future research.
- Advancing system modeling techniques to accurately capture the complex interactions between RES, ESS, power converters, and grid infrastructure is essential.
- Developing strategies for grid-friendly operation of hybrid renewable energy systems that minimize harmonic injection and ensure compliance with grid codes and standards is crucial.

Data Availability Declaration

Because no fresh information was produced or analysed in the present research, the sharing of data is not relevant to this publication.

Funding Specifics

This study received no particular financing from financial institutions in the public, commercial, or non-profit areas.

Conflict Statement: The authors declare that they have no conflict of interest.

Declaration of interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have seemed to influence the work reported on this paper.

REFERENCE

[1] Fazal, S., Haque, M. E., Arif, M. T., Gargoom, A., & Oo, A. M. T. (2023). Grid integration impacts and control strategies for renewable based microgrid. *Sustainable Energy Technologies and Assessments*, *56*, 103069.

[2] Qi, X., Wang, C., Holtz, J., Yang, K., Pacas, M., & Xu, D. (2024). Harmonic quality control strategy for single distributed resource of islanded microgrid at low switching frequency operation. *International Journal of Electrical Power & Energy Systems*, *158*, 109969.

[3] Monteiro, V., Moreira, C., Lopes, J. A. P., Antunes, C. H., Osório, G. J., Catalão, J. P., & Afonso, J. L. (2023). A novel three-phase multiobjective unified power quality conditioner. *IEEE Transactions on Industrial Electronics*, *71*(1), 59-70.

[4] Sahoo, B., Alhaider, M. M., & Rout, P. K. (2023). Power quality and stability improvement of microgrid through shunt active filter control application: An overview. *Renewable Energy Focus*, *44*, 139-173.

[5] Shahroudi, M. M., Faghihi, F., & Mozafari, B. (2023). A novel control scheme for load current components sharing improvement, and unbalanced and harmonic voltage compensation, in islanded provisional-microgrids. *Electric Power Systems Research*, *223*, 109560.

[6] Yadav, V., Singh, B., & Verma, A. (2024). Robust control for improving performance of grid-synchronized solar PV-BES-wind based microgrid. *Sustainable Energy Technologies and Assessments*, *64*, 103677.

[7] Nguyen, H. T., Al Hosani, K., Al-Sumaiti, A. S., Nguyen, T. H., Al Jaafari, K. A., Alsawalhi, J. Y., & El Moursi, M. S. (2023). Fast harmonic rejecting control design to enable active support of charging stations to micro-grids under distortion. *IEEE Transactions on Transportation Electrification*, *9*(3), 4132-4146.

[8] Khalid, M., & Panigrahi, B. K. (2023). Decentralized Power Management in Multi BESS-PV Based Charging Infrastructure for EV With SoC Balancing. *IEEE Transactions on Industry Applications*.

[9] Samoon, F. A., Hussain, I., & Iqbal, S. J. (2024). Multi-objective optimal control of renewable energy based autonomous AC microgrid using dandelion optimisation. *Renewable Energy Focus*, *49*, 100563.

[10] Gali, V., Jamwal, P. K., Gupta, N., & Kumar, A. (2023). An adaptive dynamic power management approach for enhancing operation of microgrid with grid ancillary services. *Renewable Energy*, *219*, 119413.

[11] Rajesh, C. R., Meenalochini, P., Kannaiah, S. K., & Bindu, A. (2024). A hybrid control topology for cascaded H-bridge multilevel inverter to improve the power quality of smart grid connected system: NBO-RERNN approach. *Expert Systems with Applications*, *238*, 122054.

[12] Baltacı, K., Ertekin, D., & Bayrak, G. (2024). Design and experimental validation of an artificial neural network-SVPWM controller for a novel micro grid-tied fuel cell-based 3-phase boost inverter. *International Journal of Hydrogen Energy*, *52*, 1247-1265.

[13] Dhara, S., Shrivastav, A. K., & Sadhu, P. K. (2024). Power quality enhancement of microgrid using fuzzy logic controlled inverter and SFCL. *Microsystem Technologies*, 1-24.

[14] Pathak, G., Singh, B., & Panigrahi, B. K. (2023). Multi-operational solar photovoltaic microgrid with synchronization, backup and power quality enhancement ability. *e-Prime-Advances in Electrical Engineering, Electronics and Energy*, *5*, 100256.

[15] Kavitha, P., & Karuvelam, P. S. (2023). An highly efficient optimized pi controller fed sepic converter for hybrid renewable sources based microgrid system. *Microprocessors and Microsystems*, 104797.

[16] Al Sumarmad, K., Sulaiman, N., Abdul Wahab, N. I., & Hizam, H. (2023). Implementation of hybrid optimized battery controller and advanced power management control strategy in a renewable energy integrated DC microgrid. *Plos one*, *18*(6), e0287136.

[17] Kanagaraj, N., Vijayakumar, M., Ramasamy, M., & Aldosari, O. (2023). Energy management and power quality improvement of hybrid renewable energy generation system using coordinated control scheme. *IEEE Access*.

[18] Mohammad, K. S., & Kumar, C. R. (2023). Optimal control strategy of photovoltaic system based autonomous micro grid for power quality improvement. *Indonesian Journal of Electrical Engineering and Computer Science*, *32*(2), 598-611.

[19] Salehirad, M., & Mollaie Emamzadeh, M. (2023). Energy management and harmonic compensation of micro-grids via multi-agent systems based on decentralized control architecture. *IET Renewable Power Generation*, *17*(5), 1267-1285.

[20] Qi, X., Wang, C., Holtz, J., Yang, K., Pacas, M., & Xu, D. (2024). Harmonic quality control strategy for single distributed resource of islanded microgrid at low switching frequency operation. *International Journal of Electrical Power & Energy Systems*, *158*, 109969.

[21] Roy, K., Mandal, K. K., & Mandal, A. C. (2020). Energy management of the energy storage-based micro-grid-connected system: an SOGSNN strategy. *Soft Computing*, *24*(11), 8481-8494.

[22] Cao, T., Hwang, Y., & Radermacher, R. (2017). Development of an optimization based design framework for microgrid energy systems. *Energy*, *140*, 340-351.

[23] Tafakkori, K., & Tavakkoli-Moghaddam, R. (2022). Hermit crab optimizer (HCO): a novel meta-heuristic algorithm. *IFAC-PapersOnLine*, *55*(10), 702-707.