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Modelled and Designed Efficient Controller for Grid-Connected Solar PV System: The AGOA Approach

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Abstract: Modelled and designed an efficient controller with an effective control method for a connected solar PV system. The proposed model is created by combining an integrated converter, a maximum power point tracker (MPPT), and an efficient controller with an effective control scheme. The proposed controller is designed using the adaptive grasshopper optimization algorithm (AGOA). The proposed controller delivers precise control signals for optimal switching in the system and creates a database of control signals for optimal power flow in the system. The proposed model is run in the MATLAB/Simulink environment, and the efficiency of the system is compared with other existing methods.

Keywords: *Solar Energy, PV System, Microgrid, Integrated Converter, AGOA-Based Controller.*

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I. INTRODUCTION

This template, Solar power has the ability to supply inexpensive, endless electricity. These are more environmentally friendly as they are more potent, dependable, and pollution-free [1]. The increased demand on the electrical infrastructure has resulted in a sharp increase in the use of electricity in recent times. Power demands can only be met by renewable energy sources. Wind and photovoltaics, for instance, are two of the most significant energy sources [2]. Microgrid-connected PV systems [3] can provide sufficient electricity to fulfil load demands. Because PV systems are sporadic [4], inclement weather is interfering with the production of solar electricity. Along with its intermittency, matching PV power to a load that changes constantly is the most difficult [5]. Nighttime is the busiest time of day, especially in the city's residential and commercial areas. PV is therefore frequently paired with energy storage technologies like batteries. Maintaining power delivery to the load during periods of high consumption, particularly during night, is crucial. As power backup devices, batteries are crucial to ensuring a steady power supply [6]. They are charged with a lot of energy during off-peak hours, which are usually throughout the day, and then utilised to generate electricity during peak hours [7]. In recent years, traditional generation has grown more expensive, less effective, and even unavailable. Non-traditional power generation is therefore becoming more and more common [8]. In order to maintain the duty ratio of switches in the integrated DC/DC converter and enable the PV module to generate the greatest amount of power, the greatest PowerPoint tracker (MPPT) is used to deliver exact signals to the PWM unit [9]. A list of strategies to mitigate the impact on the public grid was developed by researchers. The most effective strategy to lessen the burden on the public grid is to install electric car charging stations that are powered by solar, wind, and fuel cells [10]. One of the planet's most plentiful energy sources is solar energy. Unlimited, inexpensive power might be produced with solar energy. Because they are more dependable, powerful, and pollution-free, they are better for the environment [11]. Microgrid-connected PV systems can supply sufficient electricity to satisfy load requirements [12]. It is challenging to generate electricity from the sun due to the PV system's intermittent nature, which is brought on by inclement weather [13]. To provide optimal switching of the dc/dc converter to monitor maximum power from solar energy, the Maximum PowerPoint Tracker (MPPT) provides precise signals to the PWM unit [14]. Research was done on the design and modelling of POSLLC converters [15]. The converter's modes of operation, average DC input current, and voltage transfer gain are all analysed for modelling purposes. The converter was modelled using the state space averaging technique [16]. The performance and dynamic responsiveness of the converter are investigated using small signal analysis. An efficient controller with an effective control strategy is needed to create and track the PV system's robust, optimal power with the least amount of converter switching power loss. Based on the adaptive grasshopper optimization approach (AGOA), we

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proposed an efficient controller in this work. Crossover and mutation alter the grasshopper's hunting behavior [17]. The AGOA algorithm was inspired by grasshopper hunting behavior. The AGOA control strategy was used to adjust the PI Controller's gains. In a MATLAB/Simulink environment, the effectiveness of the AGOA control approach is contrasted with other existing methods. Investigations are conducted into both changing solar irradiance at constant load and constant solar irradiance at varying load. The current, voltage, and power responses were examined for both scenarios and contrasted with established methods such FFA [19] and GWO [18].

The following is a description of the current work's part. Section 2 describes how to set up the grid-connected PV system with AGOA controller. The POSLL converter's architecture and modelling, including its operating modes, are covered in Section 3. A brief explanation of the current work's control mechanism is provided in Section 4. The Simulink and MATLAB findings are examined in Section 5. In Section 6, the current work has come to an end.

II. THE SYSTEM CONFIGURATION

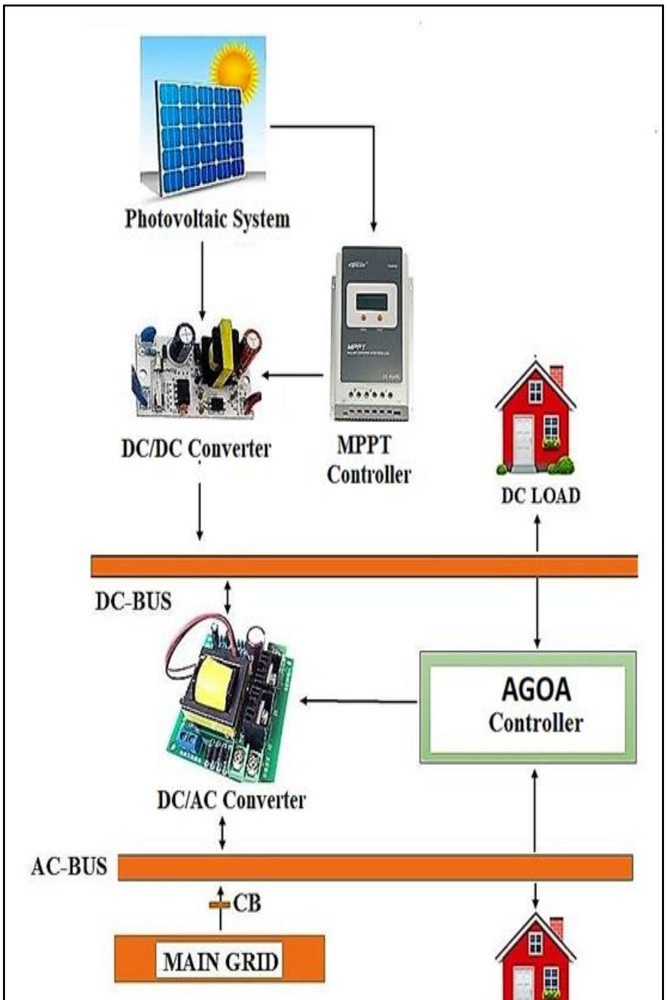

Fig 1 The System Configuration of the Grid-Connected PV System with AGOA Controller.

The grid-connected PV System setup associated with the microgrid, the POSLL Converter, and the chosen AGOA controller is shown in Fig. 1. Positive output self-lift Luo converters (POSLLCs), maximum power point trackers (MPPTs), controllers with AGOA, DC-Microgrid, the grid, and electrical loads are all connected in the suggested model. Initially, the photovoltaic cell harnesses light energy through a solar module to produce electricity, which is subsequently sent to the DC microgrid using the DC-DC Converter. The standard MPPT device modifies the pulse widths of the PWM unit to regulate the converter output using PV-Voltage and PV-Currents as reference values. Power is transferred from the battery to the DC-Microgrid and from the DC-microgrid to the battery using a bi-directional DC/DC converter. The DC-Bus is linked to the AC-Bus via a DC to AC converter. The solar system provides electricity to charge the batteries if there is solar energy available and the charging station's load is kept to a minimum. Net metering is used to feed excess energy into the grid. The batteries attempt to power the charging station in the absence of sunlight, particularly at night. If not, the main grid provides electricity to system.

III. MODELLING AND DESIGN OF DC-DC POSLL CONVERTER

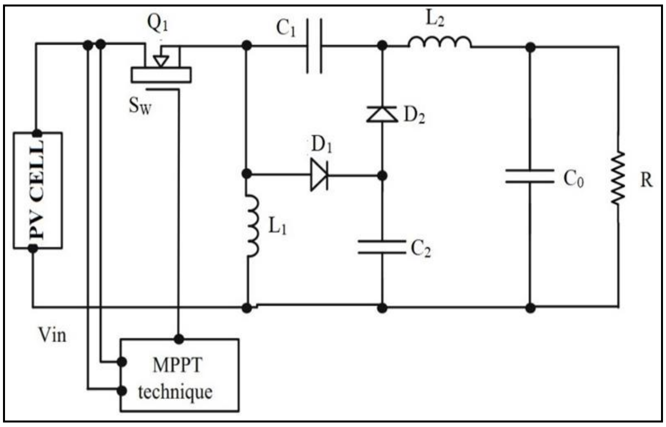

Fig 2 Circuit Diagram of POSLLC

PV systems' intermittent nature makes it very difficult to track their maximum power. For measuring the maximum power from a PV system, conventional converters such as buck, boost, and buck-boost are completely useless in inclement weather. We addressed the drawbacks of conventional converters by utilizing a popular and very effective POSLL converter [18]. To model and develop the proposed POSLLC, the state space averaging approach is used. The suggested converter is built with two inductors and three capacitors, as seen in figure 2. The load and the output capacitor are connected in parallel. When the power demand is low, the output capacitor is charged; when the need is high, it is discharged and supplies power to the load. The voltage across the output capacitor equals the load voltage. The load resistance has a direct relationship with the voltage transfer gain (V_{TG}).

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➢ *Modes of Operation*

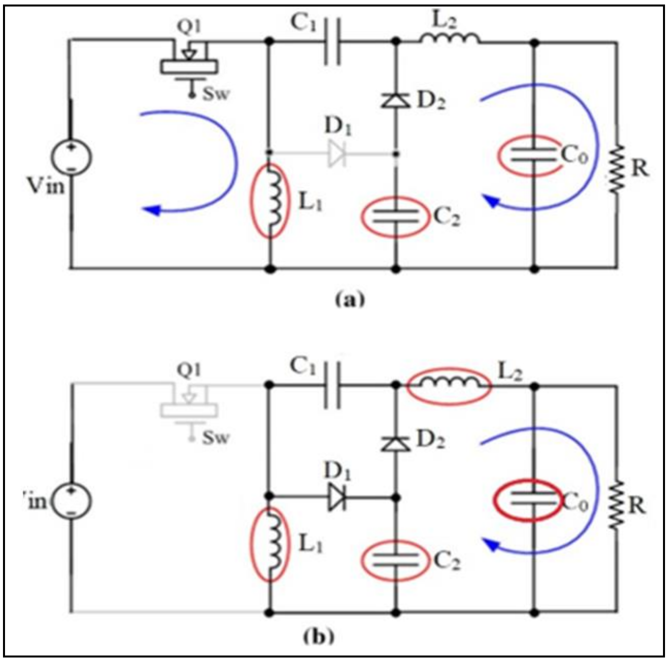

Fig 3 Operational Modes of POSLLC.

This section provides an explanation of the operational modes represented in figure3. When the switch is turned ON, mode 1 starts, the PV source current flows through the inductor (L_1), inductor (L_2), and Capacitor (C_2) which is $I_{in} = I_{L1} + I_{L2} + I_{C2}$. Energy from the PV source is absorbed by the inductor. Meanwhile, energy is absorbed by inductor L_2 from source and capacitor C_1. The inductor currents are raised and the capacitor C_2 is charged to $V_{C2} = V_{in}$. Mode 2 begins when the switch is off, meaning that no source enters the circuit with $I_{in} = 0$. Capacitor C_1 is charged by current passing via diode D_2 and capacitor C_2. The output circuit is where the current I_{L2} flows. The capacitor is continually discharged through the free-wheeling diode D_2. Both currents are reduced in this mode. The following equation shows the average output voltage of DC.

$$v_o = \frac{d}{1-d} vin \tag{5}$$

The average DC input current is expressed from below,

$$I_{in} = \frac{d}{1-d} I_o \tag{6}$$

The transfer voltage gain is articulated from below,

$$V_{Tg} = \frac{d}{1-d} \tag{7}$$

IV. IMPLEMENTATION OF PROPOSED AGOA APPROACH

This section offers a novel control method for the MG connected system's optimal solar energy consumption. In this study, the proposed control method is implemented using the adaptive grasshopper optimisation algorithm (AGOA). In this research, we apply the AGOA algorithm to construct the optimal dataset of the control signal for the offline method based on the power variation between the source and load sides. Crossover and mutation have changed the grasshopper's hunting habits. For the online route, the AGOA forecasts the optimal signal in a reduced execution time. A comprehensive description of the suggested method is given in the section that follows.

➢ *Procedural Steps of AGOA for Getting Optimal Control Signal*

The AGOA is a conceptual method for solving optimization problems that mathematically models and replicates the behaviour of grasshoppers in nature [24]. The grasshopper's searching behaviour is altered here by employing efficient neighbourhood search methods such as crossover and mutation. The algorithm's step-by-step approach for building an optimal dataset is as follows.

- *Step 1: Initialization*

The input proportional and integral gain parameters, such as Kp and Ki, are randomly generated during the initialization process and are as follows.

- *Step 2: Generation at Random*

The random behavior of gain parameters is generated based on the start-up step. The following equation yields the random solutions.

$$Z_i = \begin{bmatrix} k_p^{11}k_i^{11} & k_p^{12}k_i^{12} & \cdots & k_p^{1n}k_i^{1n} \\ k_p^{21}k_i^{21} & k_p^{22}k_i^{22} & \cdots & k_p^{2n}k_i^{2n} \\ \vdots & \vdots & \cdots & \vdots \\ k_p^{m1}k_i^{m1} & k_p^{m2}k_i^{m2} & \cdots & k_p^{mn}k_i^{mn} \end{bmatrix} \tag{9}$$

The gain parameters are kp and ki, respectively.

- *Step 3: Objective Function*

The position of the grasshoppers is used to assess the population's fitness. The required objective function can be found in the equation below:

$$U = \min \{e(t)\} \tag{10}$$

Where “U” is the objective function, “e” error signal, “t” time period of signal

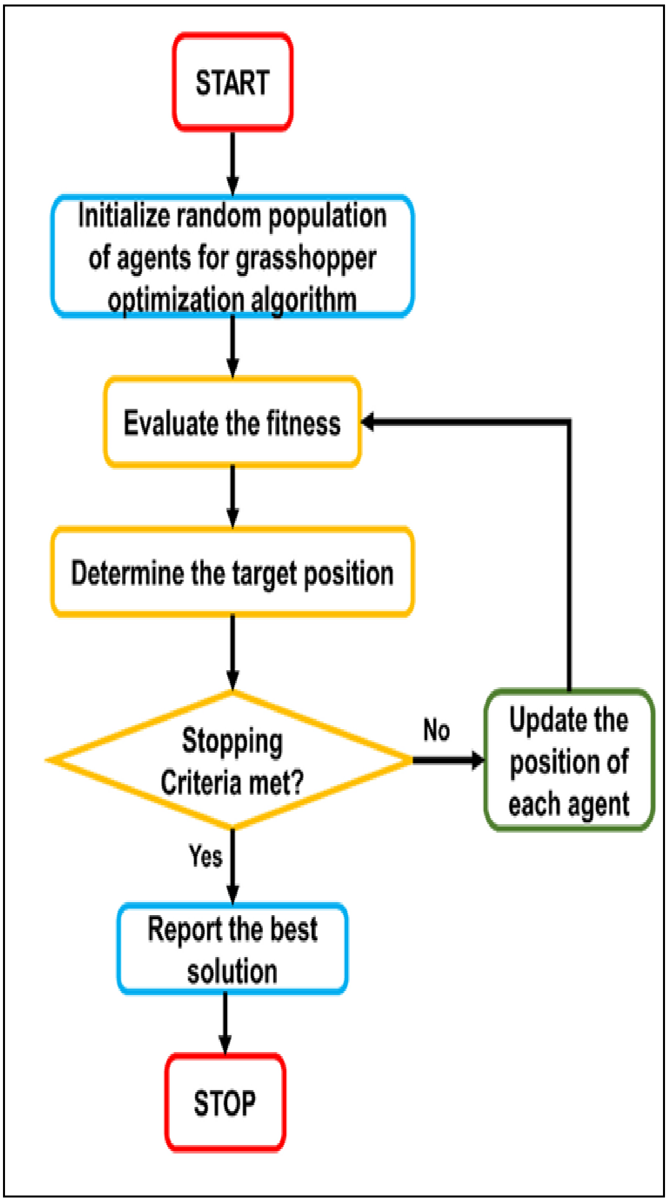

Fig 4 Flowchart of AGOA Algorithm

- *Step 4: Upgraded Position*

Following each individual's fitness computation, the best optimal solution is updated based on the value of the Objective function.

- *Step 5: Crossover and Mutation*

The crossover is established between the two individuals, and the individuals are mutated randomly based on the provided fitness function during the mutation process. The crossover and mutation are calculated in the following way [25, 26].

$$\text{Crossover} = \frac{\alpha_{gc}}{d_c}$$

$$\text{Mutation} = \frac{\beta_{gc}}{d_c}$$

where is the "α_{gc}" gene crossover number and is the "d_c" distance of the individual grasshoppers, "β_{gc}" is the mutation point. Find the fitness and check the objective function using the updated movement.

- *Step 6: Termination*

Examine the condition for stopping. If it is not satisfied, proceed to step 3; otherwise, end the search. Finally, these are the most recent optimal solutions: After the algorithms above stages are done, the system may choose the best HRES use based on the best gain settings and the least amount of error.

V. MATLAB/SIMULINK MODEL OUTCOMES AND ANALYSIS

This section illustrates the power flow management in each segment of the grid-connected PV-based EV charging station linked to the DC-DC POSLL converter. The MATLAB/Simulink environment is used to implement the AGOA control system model. For the best power management in this application, a precise control signal is generated by the AGOA controller. The system is analyzed under a variety of control schemes, and the efficiency of the suggested system with the AGOA control scheme is evaluated based on system output.

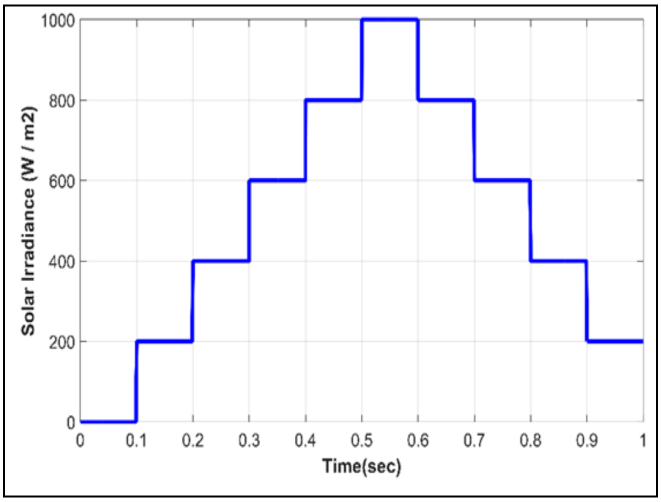

Fig 5 Changing of PV Irradiance with Respect to Time

Figure 5 represents a grid-connected PV system with a POSLL converter operated at a changing solar irradiance and constant load condition. This will be investigated when the solar irradiation is changed while the load taken remains constant for analyzing the system in deep. Here one sunny day taken as one second. When the day is starting the solar irradiance will be 0 W/m^2 it is increased to 1000 W/m^2 later on it will be reduced to zero.

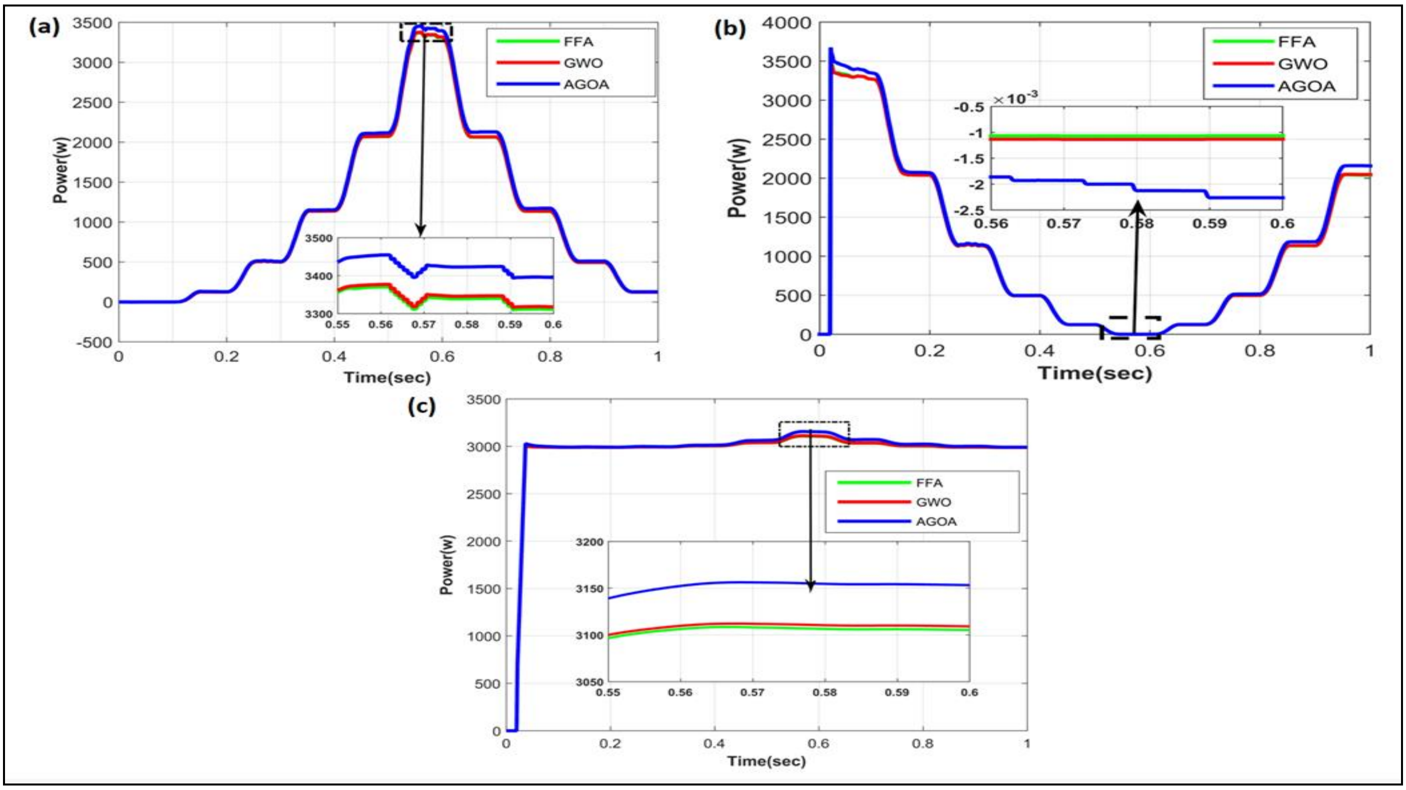

Fig 6 Comparison of Powers Under Case-1 (a) PV Power (b) Grid Power (c) Load Power

Figure 6 demonstrates the comparison of the converter and load power using a proposed controller designed by approaching the AGOA technique with the other existing techniques like GWO, FFA under case1. Figure 6(a) represents the comparison of PV Converter power. The system with FFA approach has produced the maximum power of 3370 W at solar irradiance is 1000 W/m^2. The system with GWO approach has produced the maximum power of 3380 W at solar irradiance is 1000 W/m^2. The system with proposed AGOA technique has produced the maximum power of 3450 W at solar irradiance is 1000 W/m^2. In this observation, the output power of the proposed system with proposed AGOA controller is high means proposed system tracked high power than other existing controllers. Figure 6(b) represents a comparison of power drawn from the utility grid with existing and proposed controllers. In this observation system with proposed AGOA controller drawn low power from the grid than other systems with existing controller. Figure 6(c) represents a comparison of load power with existing and proposed approaches. The system with FFA approach has produced the maximum power of 3050 W. The system with GWO approach has produced the maximum power of 3100 W. The system with proposed AGOA technique has produced the maximum power 3160 W at solar irradiance is 1000 W/m^2. the utilizing power with the proposed approach is high compared with other existing approaches. In this observed that power available at load, utilization of power in a system with the proposed AGOA approach is higher than other existing methods.

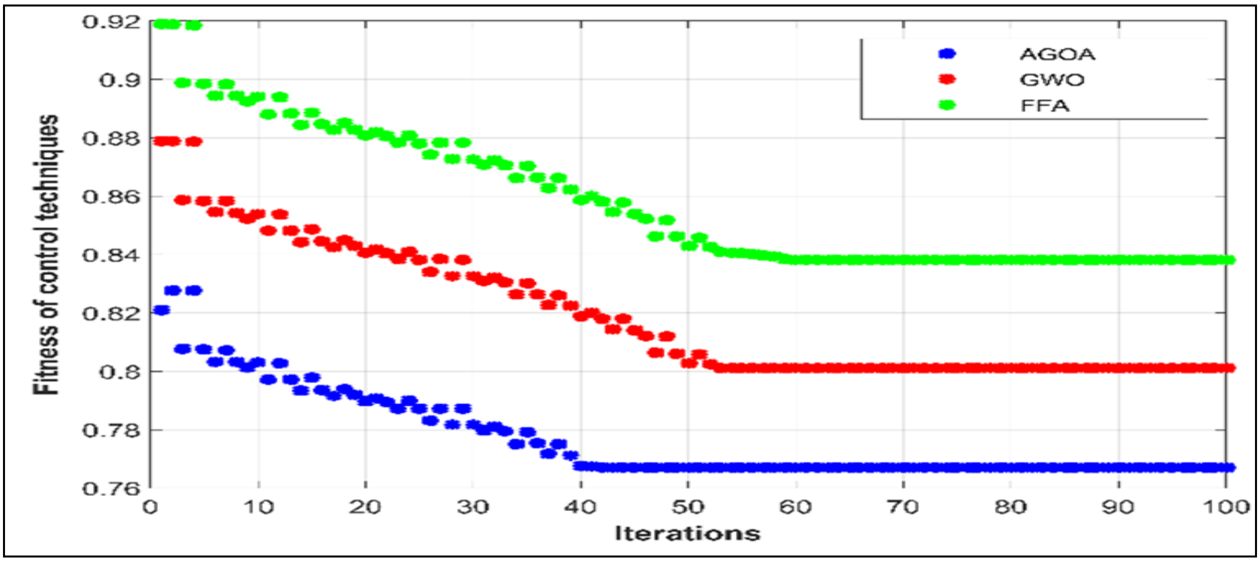

Fig 7 Convergence Characteristics Using Proposed and the Existing Control Techniques

The convergence characteristics of the control methods utilized in this model for system optimality are shown in Figure 6. Plot 12 compares the efficacy and convergence properties of the proposed AGOA control approach with those of GWO and FFA. We deduced from this plot that the AGOA control approach is superior to the other two strategies and converged earlier. The fitness values for the AGOA, GWO, and FFA are 0.7671, 0.8011, and 0.8382 respectively.

VI. CONCLUSION

This work modelled and designed grid-connected solar PV system for the purpose of optimal switching to the converters to achieve optimal power management in the system. An efficient controller is designed with an effective control method, the adaptive grasshopper optimization algorithm (AGOA). The proposed controller achieves robust and optimal power utilisation at the terminal of the system by delivering accurate control signals for the optimal switching of converters. The recommended model is executed on the MATLAB/Simulink working platform, and the efficiency of the system is examined based on the existing methods. In terms of both accuracy and execution time, the AGOA has proven to be a very competitive and promising control approach for optimizing the recommended power system model. While the GWO control approach is competitive, it has a long execution time. The accuracy scores of the FFA control approach were not very good in some of the test functions. This system model was put to the test in two scenarios: PV irradiance fluctuation at constant load and load variation at constant PV irradiance. The AGOA control approach increased the system model's responsiveness during load in both cases. The proposed model's simulation results show that system efficiency has improved. As a consequence, the suggested strategy for energy management is effective and efficient.

REFERENCE

[1]. O Alsayegh, S Alhajraf, and H Albusairi, Grid-connected renewable energy source systems: Challenges and proposed management schemes. Energy Conversion and Management, 2010., 51(8), 16901693. https://doi.org/10.1016/j.enconman.2009.11.042
[2]. A Q Al-Shetwi, M A Hannan, K P Jern, M Mansur, and T M I Mahlia. Grid-connected renewable energy sources: Review of the recent integration requirements and control methods. Journal of Cleaner Production, pages 119831–119831, 2019. https://doi.org/10.1016/j.jclepro.2019.119831
[3]. R Abdelhady. Modelling and simulation of a micro grid-connected solar PV system. Water Science, 31, 2017. https://doi.org/10.1016/j.wsj.2017.04.001
[4]. H Choi and J Jung. Enhanced power line communication strategy for DC microgrids using switching frequency modulation of power converters. IEEE Transactions on Power Electronics, 32(6):4140–4144, 2017. https://doi.org/10.1109/TPEL.2017.2648848.
[5]. M Nasir, H A Khan, I Khan, N Hassan, N A Zaffar, A Mehmood, and S M Muyeen. Grid Load Reduction through Optimized PV Power Utilization in Intermittent Grids Using a Low-Cost Hardware Platform. Energies, 12(9):1764–1764, 2019. https://doi.org/10.3390/en12091764
[6]. X Wu, X Hu, and S Moura. Stochastic control of smart home energy management with plug-in electric vehicle battery energy storage and photovoltaic array. J Power Sources, 333:203–212, 2016. https://doi.org/10.1016/j.jpowsour.2016.09.157
[7]. M Adly and K Strunz. Irradiance-Adaptive PV Module Integrated Converter for High Efficiency and Power Quality in Standalone and DC Microgrid Applications. IEEE Transactions on Industrial Electronics, 65(1):436–446, 2018. https://doi.org/10.1109/tie.2017.2723860
[8]. Mule Sai Krishna Reddy, SK Rasool Ahemmed, Non-Conventional Methods of Power Generation for Future Power Outage Problems, International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064
[9]. Vázquez, N., Azaf, Y., Cervantes, I., Vázquez, E., & Hernández, C. (2015). Maximum Power Point Tracking Based on Sliding Mode Control. International Journal of Photoenergy, 2015, 1–8. doi:10.1155/2015/380684
[10]. Venkatakrishnan, Giri Rajanbabu, Ramasubbu Rengaraj, and Nattamai Balasubramanian Prakash. "Optimally manage the energy between electric vehicle charging stations and electricity distribution system: A hybrid technique." International Journal of Numerical Modelling: Electronic Networks, Devices and Fields 35.1 (2022): e2944.
[11]. Priyadarshi, Neeraj, et al. "Dynamic operation of grid-connected photovoltaic power system." Advances in Greener Energy Technologies. Springer, Singapore, 2020. 211-218.
[12]. Goel, Sonali, and Renu Sharma. "Analysis of measured and simulated performance of a grid-connected PV system in eastern India." Environment, Development and Sustainability 23.1 (2021): 451-476.
[13]. Ogunjuyigbe, A. S. O., T. R. Ayodele, and O. E. Oladimeji. "Management of loads in residential buildings installed with PV system under intermittent solar irradiation using mixed integer linear programming." Energy and buildings 130 (2016): 253-271.
[14]. Verma, Deepak, et al. "Maximum power point tracking (MPPT) techniques: Recapitulation in solar photovoltaic systems." Renewable and Sustainable Energy Reviews 54 (2016): 1018-1034.
[15]. ME, Mr M. Chilambarasan, M. Ramesh Babu, and Ms R. Sujatha. "Design and simulation of LUO converter topologies for photovoltaic applications." International Journal of Applied Engineering Research 9.23 (2014): 21553-21560.
[16]. Mahdavi, J., A. Emadi, and H. A. Toliyat. "Application of state space averaging method to sliding mode control of PWM DC/DC converters." In IAS'97. Conference Record of the 1997 IEEE Industry

ISSN No: 2456-2165 https://doi.org/10.38124/ijisrt/25jul1583

Applications Conference Thirty-Second IAS Annual Meeting, vol. 2, pp. 820-827. IEEE, 1997.

[17]. Rani, P. Sobha, M. S. Giridhar, K. Radha Rani, and Varaprasad Janamala. "Adaptive Grasshopper Optimization Algorithm for Multi-Objective Dynamic Optimal Power Flow in Renewable Energy Integrated Microgrid."

[18]. Davoodkhani, Faraji, et al. "A new hybrid method based on gray wolf optimizer-crow search algorithm for maximum power point tracking of photovoltaic energy system." Modern Maximum Power Point Tracking Techniques for Photovoltaic Energy Systems. Springer, Cham, 2020. 421-438.

[19]. Albert, Johny Renoald, and Albert Alexander Stonier. "Design and development of symmetrical super-lift DC–AC converter using firefly algorithm for solar-photovoltaic applications." IET Circuits, Devices & Systems 14, no. 3 (2020): 261-269.