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Lightning Search Algorithm Controlled Grid Integrated Hybrid Distributed Generation System

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Abstract— **This paper elucidates the optimal control strategy for Hybrid Renewable Energy Systems (HRES), employing the Parallel Execution of Lightning Search Algorithm combined with Artificial Neural Network and Recurrent Neural Network (PLSANN). The control strategy of HRES addresses issues related to power quality (PQ) disturbances. The envisioned system integrates Photovoltaic (PV), Wind Turbine (WT), Fuel Cell (FC), and Battery components, interconnected via a DC link to effectively manage both the powers (real & reactive). The integration of wind/PV power into the grid is identified as a source of PQ disturbances, prompting the investigation into compensation policies for DC/DC converters using PLSANN/RNN techniques for optimal power flow management. The Lightning Search Algorithm (LSA) optimizes real power based on controller gain parameters, while the Recurrent Neural Network (RNN) facilitates the optimization of reactive power management. The proposed approach identifies the optimal control signals for DC/DC converters, considering both source and load constraints. This system not only injects active power into the grid but also improves PQ conditions. Through precise control mechanisms, HRES significantly enhances the dynamic security of the power system. By using MATLAB/Simulink the proposed methodology is implemented & evaluated, with performance analysis conducted based on statistical metrics such as mean, median, and standard deviation. A comparative analysis with existing methods including CMBSNN, Particle Swarm Optimization (PSO), Genetic Algorithm (GA), and PI controller is performed to validate the effectiveness of the proposed approach.**

Keywords— *Battery, FC, WT, PV, HRES, ANN, RNN, LSA, CMBSANN, power flow, active and reactive power control strategy*

I. INTRODUCTION

In the future, the role of power generation technologies will be pivotal in meeting the growing global demand for energy while addressing environmental concerns & fossil fuels dependency. The non-conventional energy usage increasing & on-site generators demands innovative strategies for managing the power grid. These strategies are crucial to maintaining, or even improving, the reliability & quality of electricity delivery. A primary challenge with renewable energy is its intermittency, which underscores the need for innovative grid management strategies. One solution to this challenge is the concept of advanced utility integration. This approach utilizes power electronic inverters to manage the grid power (active & reactive). Additionally, these inverters can help regulate frequency and even provide support for grid voltage during unexpected events like faults or fluctuations. Given the variable and unpredictable nature of renewable resources, energy storage devices become indispensable, particularly at the DC link, ensuring smooth power dispatch and balance. Furthermore, sufficient reactive power control from inverters is vital to guarantee continuous operation during voltage dips. This is especially important for non-conventional sources (like wind & solar), which can be unpredictable due to constant changes in sunlight and wind speed. To improve wind energy transfer efficiency and reduce mechanical strain on turbines, many large-scale wind farms now utilize variable-speed operation with doubly fed induction generators. This approach is complemented by integrating smaller-scale solar, wind, hydro, and energy storage systems. This combined system allows for effective control of generator voltage, power factor, and torque to better match the characteristics of wind turbine systems.

A. *Working*

Core concept behind the optimization algorithm draws inspiration from lightning (natural phenomenon), specifically the propagation of step leaders. However, it introduces a novel element: fast-moving particles called projectiles. Within the step leader, these projectiles contribute to the formation of a distinct binary tree structure. Unlike conventional mechanisms, this approach allows for the creation of two leader tips at branching points, potentially accelerating the search process. It's important to note that this analogy doesn't directly translate to the physical properties of thunderclouds. While real thunderclouds contain oxygen, hydrogen, and nitrogen molecules, the concept of projectiles in the algorithm doesn't represent the physical processes of freezing water or ejection of atoms.

Similar to how lightning creates anionization path as it travels through the air, these projectiles in the algorithm explore the search space for potential solutions. Each projectile initiates a path, representing an initial solution within the population. The term 'projectile' here functions similarly to the 'particle' concept in PSO. These projectiles propose random solutions to the problem, analogous to the leading edge of the current search path. Exploratory projectiles will form the initial population size (N), which can be categorized into three types: space projectiles, transition projectiles, & lead projectiles. The specific characteristics of each type are explained in more detail below.

This paper describes Lightning Search Algorithm & optimisation of controller (PI) gain parameters. The LSA requires two inputs: frequency fluctuations and values for the PI gains that are generated at random. Figure 3.4 presents a flowchart outlining the LSA procedure. Based on minimizing an error function, the algorithm's output gives the ideal gain values. Selection of fitness function plays an important role on algorithm's effectiveness. Real & reactive power issues of ideal PI controller is addressed by designing of proper fitness function. Ideally, the fitness function value should approach zero when the algorithm finds the exact values for the real & reactive power parameters. In real-world applications, however, a small difference between calculated and measured values is expected. Therefore, a lower fitness function value signifies a closer match between calculated and desired power outputs. The following steps summarize the implementation of the LSA method for determining the optimal gain values.

B. *Algorithm*

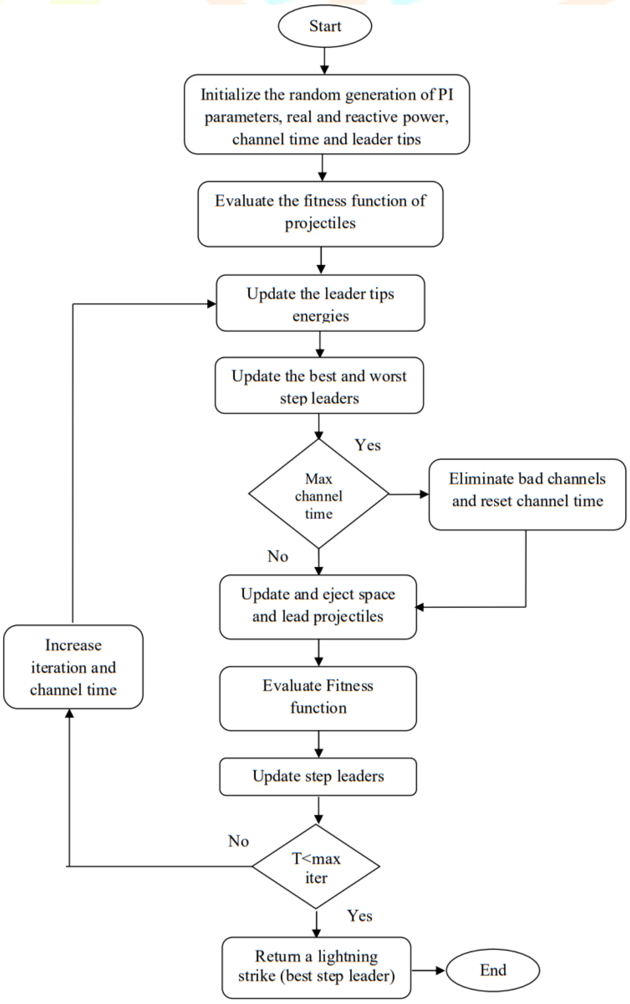


Figure 1: Working flow chart of LSA

II. Results And Discussion

This chapter introduces a PI controller based on the PLSANN/RNN technique, implemented in MATLAB/Simulink. The primary objective of this method is to minimize deviations in generated power while ensuring ideal flow of power within the unit of HRES. The foundation of this approach lies in selecting and organizing signals indicating orientation for HRES (DC/DC converter). Optimized power (real) is achieved with PLSANN method, while PLSRNN method controls power (reactive). Subsequently, controlling signal produced by this method are utilized to formulate pulses aimed at enhancing the performance of converter (DC/DC). As a result, this approach contributes to improving the converter's performance and addressing power quality (PQ) issues. MATLAB/Simulink model shows the efficiency of proposed method presented in performance evaluation of the suggested controller for tuning involves comparing simulation outcomes with those derived from CMBSNN, GA, PSO, & PI controllers.

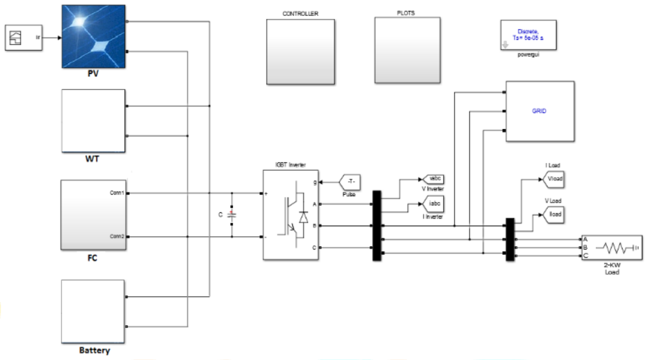


Figure 2: Simulink diagram of proposed method with HRES unit

A. *Performance analysis*

The suggested RNN/PLSANN approach being assessed for its capacity to mitigate variations are produced due to changes in both load and Hybrid Renewable Energy Systems inside a grid link. Furthermore, the design seeks to optimize controllers for both active & reactive power of the HRES. PV, wind, fuel cells, and batteries are examples of HRES. Three case studies are done to assess the suggested method's efficacy.

Case A: Balance supply with unbalanced load condition
Case B: Step variation in PV with balanced load condition
Case C: Zero response in PV with balanced load condition

In this case studies show how different approaches— CMBSNN, GA, PSO, PI, & recently introduced approach are used to regulate microgrid system's power (real & reactive), and the recommended controllers are employed to maximize performance, as indicated under.

Case A: Balance supply with unbalance load condition

Initially, scenario involves analyzing domain of time response of a stable power supplied under unbalance load conditions, examined across various source. The power controller performance analyzing & assessing is the main objective when faced with unbalanced load demands. Typically, various Hybrid Renewable Energy Systems (HRES) are interconnected either to the grid or loads via the DC bus system.

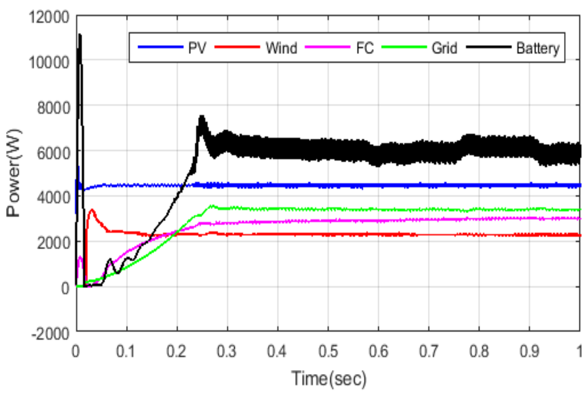
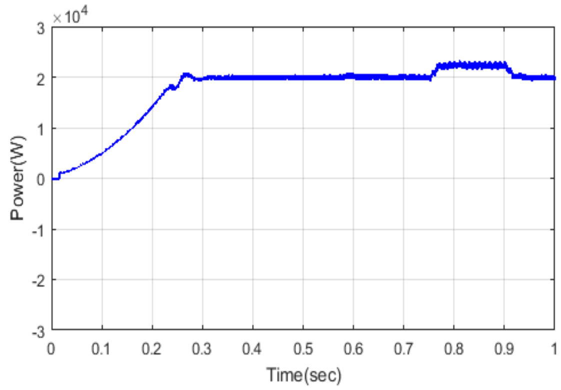


Figure 3: Individual power analysis of HRES

Goal is for the power generated by PV, wind, FC, and battery sources to fulfill load requirements while also contributing surplus active power to the grid. Fig 3 indicates the unique performance of each power source. Initially, irradiance enters the

PV system. Wind power begins to grow at t=0.02 seconds, peaks at 3400 W, and then stabilizes about t=0.4 seconds. However, there are minor variations seen between t=0.25 and t=0.4 seconds.



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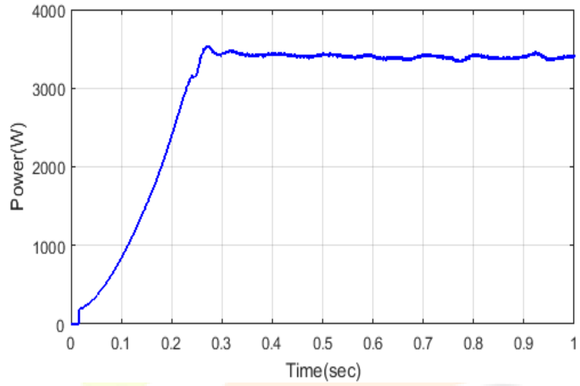

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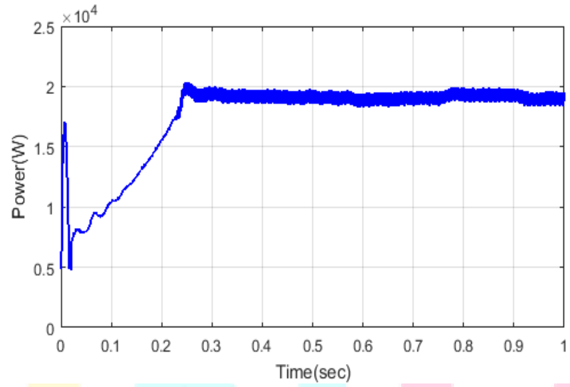


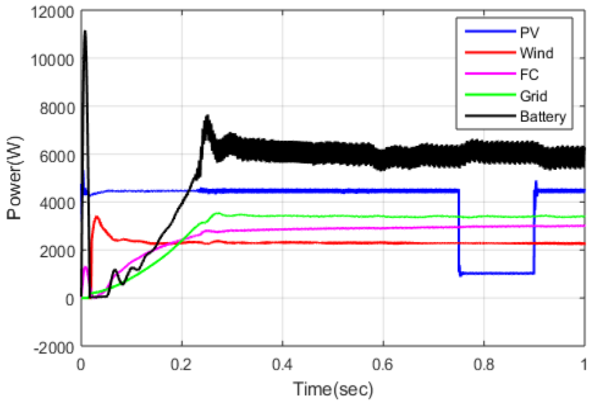
(c)

Figure 4: Analysis of (a) Load power (b) grid power and (c) total power

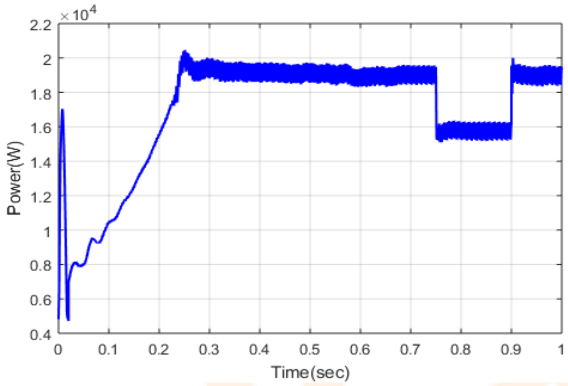
Figure 4 depicts an analyzing of total power (load, grid) under various deviations of power. During a defined timeframe, Hybrid renewable energy storage connected to mains and begins operation in grid-connected mode. The load distribution is supposed to coincide with the HRES system's designated control processes. Fig 4 examines the imbalance situations of grid & load. Load power varies between t sec (0.02 & 0.28), as shown in Fig 4 (a). Following this period, the load power stabilizes. Figures 4 (b) and (c) provide an examination of grid power and total power. The suggested approach demonstrates rapid stability and distortion reduction, resulting in the desired power output values.

Case B: Step variation in PV with balance load condition

Under evaluation, system being exposed to a step response under balanced load circumstances. Furthermore, power variations caused by various sources such as grid, wind, load, and PV irradiance are explored. Degree of distortion is also examined using power graphs.



(a)



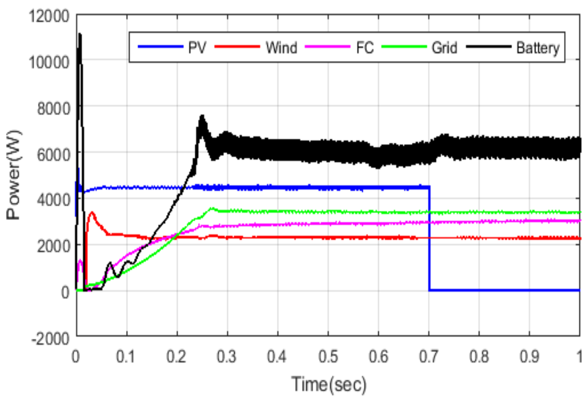
(b)

Figure 5: (a) Individual power and (b) total power

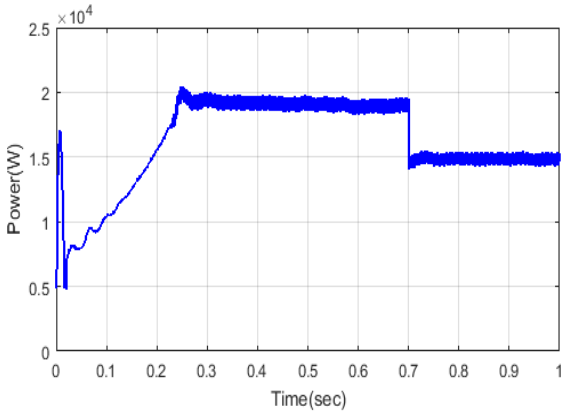
These findings indicate that the control system performs satisfactorily in terms of disturbance rejection, with low peak overshoot while monitoring the command signals. Specifically, power (individual & total) response of output is assessed between t = 0 and 1 second. Figures 5 (a) and (b) show the disturbances discovered during the analysis. Furthermore, distortions of the system are reduced by proposed control, as shown below. After t seconds (0.285), the graph regularly stabilizes. As a result, certain disturbances are created & successfully attenuated utilizing the suggested controller when compared to other strategies.

Case C: Zero response in PV with balance load condition

Here, ideal flow of power HRES is found by setting all source devices to an unbalanced situation and seeing no reaction from PV. Controllers such as PI, GA, PSO, and CMBSN require lengthy setup periods to accommodate power variations.



(a)



(b)

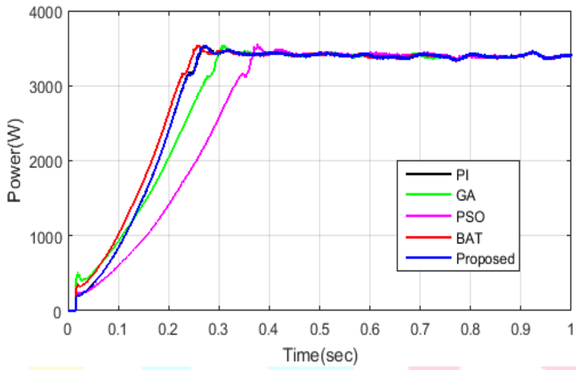
Figure 6: Analysis of (a) Individual power and (b) total power

Suggested controllers are setup in 0.25 seconds. The PI controller's increased setup time has an influence on both control area error and tie line power, resulting in undesirable oscillations and delays in system stability. However, when compared to existing controllers, the suggested PI controller significantly improves power system damping characteristics. Furthermore, it achieves stability and minimizes power system noise, allowing for faster achievement of enhanced transient steady-state levels. The following figures depict the results of a performance analysis that included load power, DC bus voltage, total power, individual power, grid power, irradiance & source power.

The PV irradiance is measured between t=0.7 and 1 second, demonstrating no reaction at this time. Following that, the power outputs of the Battery, WT, FC, and PV are evaluated independently, indicating that these devices work exceptionally well, particularly when the battery is functioning at peak levels. Furthermore, investigation of power (grid & load) is done. A full comparison for proposed and existing approaches is presented under.

B. *Comparison Analysis*

Under the section compares suggested technique's functionality to those other well-established approaches. The system output is assessed using metrics such as time (rising, peak overshoot & settling). The power action of control first recognized, followed by the use of several tools to examine the control signal.



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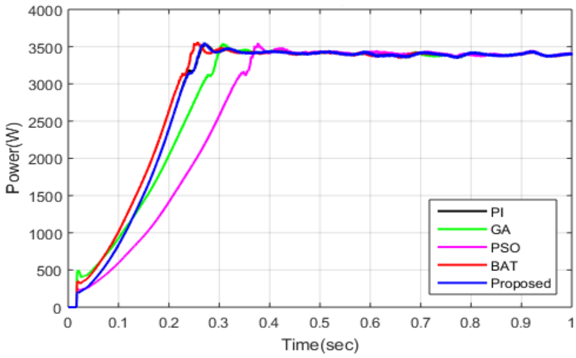

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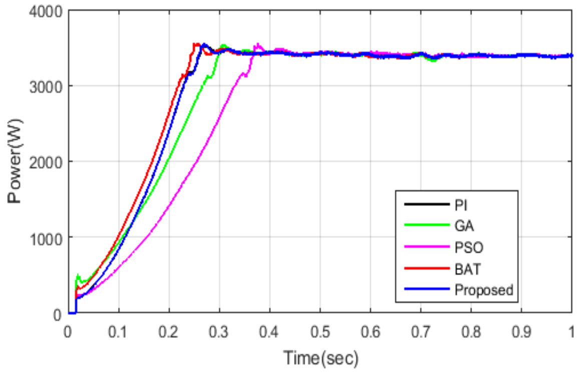
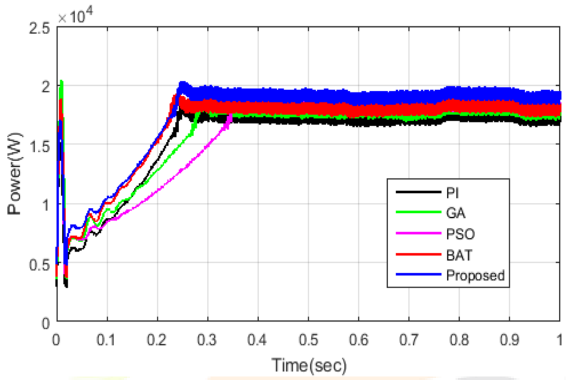


(c)

Figure 7: Power Analysis of Battery in (a) Case A (b) Case B and (c) Case C



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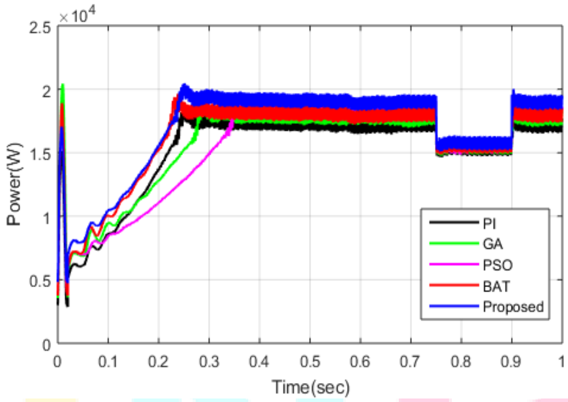

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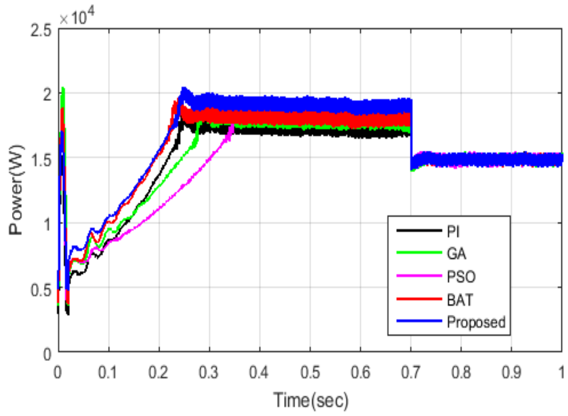


(c)

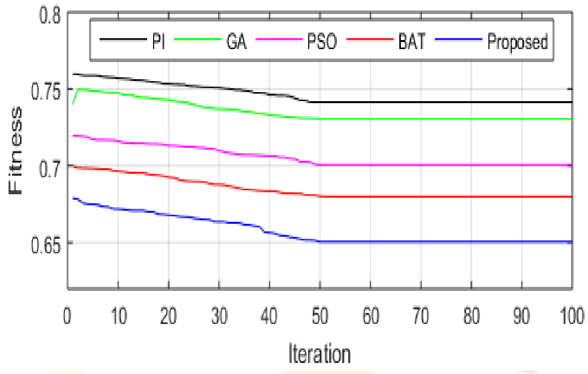
Figure 8: Comparison Analysis of total power in (a) Case A (b) Case B and (c) Case C

The suggested technique's efficacy is evaluated in contrast to existing approaches for outpower & battery. This section gives the results of power output in three scenarios using various methodologies. Figure 7 shows a comparison of battery power between examples A, B, and C. Management flow of power is examined using a variety of methodologies and compared over domain of time periods. The study of example A, done within domain of t sec (0-1), focuses on time (rising, settling & peak overshoot). The discussion begins with an overview action of proposed controller, with first step reaction shown on the x-axis from 0 to 1 second.

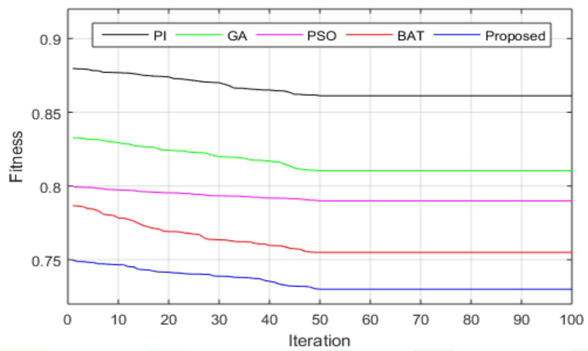
The graph shows that the suggested technique at time (peak overshoot) has zero response, which contrasts with growing range found in conventional methods. Furthermore, the settling times for the proposed approach and other techniques (BAT, GA, PSO, and PI) were reported as t seconds (0.38, 0.34, 0.41 & 0.28). Regarding rising time, the suggested approach and other techniques (BAT, PSO, PI) show t seconds (0.02, 0.032, 0.028 & 0.025). When compared to existing approaches, the suggested method clearly reduces time (rising, settling & peak overshoot). Similarly, in examples B and C, comparisons are made regarding battery power.

Figure 8 displays the total power for several case situations, including rising time, settling time, & peak overshoot time. In Figure 8 for scenario A, the suggested method's rising time, settling time & peak overshoot time are reported as t sec (0, 0.25 & 0.01). These numbers are greater in comparison to other available approaches. Similar analyses are carried out for examples B & C, as shown in Fig 8 (b) & (c). Overall, the suggested controller outperforms previous techniques in terms of distortion minimization.

Figure 9 illustrates the system actual & reactive output power. The convergence analysis is provided as a graph that plots fitness vs iterations. To address the need, several strategies are considered, including BAT, PI, GA, PSO, and the proposed method. In Fig 9 (a), which depicts analysis of real power, the suggested technique has a brief transitory in the first stage, resulting in a fitness score of 0.68.



(a)



(b)

Figure 9: Convergence Analysis in Case A (a) real power and (b) reactive power

As the iterations rises, the suggested strategy rapidly stabilizes, achieving a stable state by iterations 50 and outperforming other known methods in terms of convergence speed. Figure 9 (b) depicts the results of the reactive power analysis. Notably, the suggested strategy reaches stability by iteration 50, although starting with a lower fitness value (0.75) than other methods such as BAT, GA, PSO, & PI, which have fitness values of 0.88, 0.84, 0.8, and 0.78, respectively. The suggested approach is resilient to uncertainties of system & diverse disturbances, including faults & conditions for loading, as proven by extensive test analysis.

Within the Hybrid Renewable Energy System architecture, a variety of control mechanisms have been rigorously tested, with their performance measured against several reliability measures such as settlement time, peak overshoot time, & rise time. The appropriate selection of speed gain characteristics, such as integral and proportional gain, has substantially aided system stability. The suggested technique has helped achieve the appropriate gain settings by reducing differences in both real &

reactive power between the tested HRES frameworks and the actual output response. Throughout this procedure, viable gain parameters were systematically created within defined limitations and applied to the testing HRES framework to ensure the system's resilience and dependability.

III. Conclusion

This paper describes an innovative PLSANN/RNN-based Proportional-Integral controller for optimum flow of power regulation in Hybrid Renewable Energy System units. This controller is designed to reduce variations in actual & reactive power across the system. The suggested approach uses PLSANN/RNN & In the MATLAB/Simulink platform model is implemented by fine-tune of PI controller. The PI controller's gain settings are then modified to produce appropriate control signals for controlling the DC/DC converter within the HRES units. The functionality of this suggested approach is carefully evaluated under a variety of load circumstances, including balanced and imbalanced supply. A thorough comparison study is performed, comparing the proposed PLSANN/RNN-based PI controller to current controllers such as CMBSNN, GA, PSO & PI. The suggested controller's efficacy is assessed using parameters such as overshoot time, rising time, & settling time. Furthermore, a statistical analysis of the HRES unit is performed, accounting for parameters such as standard deviations, median, & mean. The results are then compared to those achieved by controllers (GA, CMBSNN, & PSO). The suggested controller reduces settling time & overshoot, which contributes to improved system stability. Performance study shows that the suggested model's simulation results outperform existing methodologies.

References

[1] M. Kabir, Y. Mishra, G. Ledwich, Z. Dong and K. Wong, "Coordinated Control of Grid-Connected Photovoltaic Reactive Power and Battery Energy Storage Systems to Improve the Voltage Profile of a Residential Distribution Feeder", IEEE Transactions on Industrial Informatics, vol. 10, no. 2, pp. 967-977, 2014.

[2] W. Al-Saedi, S. Lachowicz, D. Habibi and O. Bass, "Power flow control in grid-connected microgrid operation using Particle Swarm Optimization under variable load conditions", International Journal of Electrical Power & Energy Systems, vol. 49, pp. 76-85, 2013.

[3] M. Kermadi and E. Berkouk, "Artificial intelligence-based maximum power point tracking controllers for Photovoltaic systems: Comparative study", Renewable and Sustainable Energy Reviews, vol. 69, pp. 369-386, 2017.

[4] S. Ko, S. Lee, H. Dehbonei and C. Nayar, "Application of Voltage- and Current-Controlled Voltage Source Inverters for Distributed Generation Systems", IEEE Transactions on Energy Conversion, vol. 21, no. 3, pp. 782-792, 2006.

[5] T.Praveen Kumar, Y. Chandrashekar, N. Subrahmanyam and M. Sydulu, "Control Strategies of a Fuzzy Controlled Grid Connected Hybrid PV/PEMFC/Battery Distributed Generation System", In proceedings of IEEE Conference on Power and Energy, pp. 1-6, 2015

[6] H. Shareef, A. Ibrahim and A. Mutlag, "Lightning search algorithm", Applied Soft Computing, vol. 36, pp. 315-333, 2015.

[7] Mandal JK, Sinha AK, Parthasarathy G., "Application of recurrent neural network for short term load forecasting in electric power system", In proceedings of IEEE International Conference on Neural Networks, Vol. 5, pp. 2694-2698, 1995

[8] Ngan MS, Tan CW., "Photovoltaic Multiple Peaks Power Tracking Using Particle Swarm Optimization with Artificial Neural Network Algorithm", In Advances in Solar Photovoltaic Power Plants, Springer, pp. 107-138, 2016