Cloud-Computing and Fuzzy-PI Based Maximum Power Point Tracking for Optimizing Photovoltaic System Performance

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Abstract

A fluffy PI consolidated control calculation for the greatest power point following (MPPT) of photovoltaic (PV) exhibit is proposed with inclusion of cloud computing in this paper. Focusing on the impediment of single PI or fluffy control calculation for MPPT, conventional PI and fluffy control calculation is joined to the fluffy PI calculation. In the joined calculation, while the following blunder is perfect, a fluffy regulator is utilized to change rapidly and acknowledge control power, and while the following mistake is little, the regulator is changed to a PI calculation to reduce the consistent state blunder. Reenactment results show the fast and accuracy of MPPT are accomplished with the fluffy PI joined calculation. In the meantime, in the event that the natural condition changes, the PV with the joined calculation can arrive at another greatest power point with better following execution and steadiness, which is checked by recreation brings about this paper.

Keywords:-PV arrays; Fuzzy controller; MPPT; PI controller.

I INTRODUCTION

Photovoltaic (PV) arrays play a crucial role in solar power generation systems, and their output characteristics, being nonlinear, necessitate effective Maximum Power Point Tracking (MPPT) methods. While conventional techniques like constant voltage tracking, perturb & observe algorithms, and incremental conductance have been widely employed, recent research has explored more sophisticated approaches, including fuzzy logic, sliding mode control, particle swarm optimization, and their combinations. This paper addresses the limitations of single Proportional-Integral (PI) or fuzzy control algorithms for MPPT by proposing a hybrid Fuzzy-PI algorithm. The combination of traditional PI and fuzzy control is designed to achieve high tracking speed, accuracy, and minimal steady-state fluctuation. The study employs modeling and simulation in MATLAB/Simulink, verifying the algorithm's effectiveness in maintaining optimal PV system performance. The research contributes to the growing body of knowledge in intelligent MPPT approaches, showcasing the benefits of a Fuzzy-PI hybrid control strategy.

The photovoltaic (PV) cell, at the heart of solar energy conversion, operates based on the semiconductor P-N junction. This cell absorbs solar radiation and directly transforms it into electrical energy through the photovoltaic (PV) effect. The equivalent circuit of a PV cell, as depicted in Fig. 1, consists of several components. Iph represents the photogenerated current and is modeled as a current source, while ID signifies the forward current of the P-N junction. Additionally, Ish accounts for the leakage current, Rsh denotes the parallel resistance, Rs indicates the series resistance of PV cells, RL represents the equivalent load resistance, Uo signifies the PV cell's output voltage, and IL characterizes the PV cell's output current.

The primary objective of Maximum Power Point Tracking (MPPT) is to continuously optimize the PV output power. This is achieved through specific control algorithms that predict the potential maximum output power under the current conditions, allowing the system to reach the maximum power point by dynamically adjusting the impedance. Consequently, even as the output power fluctuates with changes in ambient conditions, the system can operate in its optimal state. MPPT is crucial for ensuring efficient energy harvesting from the PV cells, maximizing the overall performance of the solar energy conversion system

II. RELATED WORKS

Temperature and irradiance are the two main variables that affect a PV system's output power. This work employs a fuzzy control technique to regulate the system due to the nonlinear output characteristic of the photovoltaic array. With reference to the previously discussed P&O algorithm, the output power deviation (dP/dU) with regard to the PV array voltage over the course of two consecutive control periods is selected as the fuzzy controller's input, with the goal of optimizing the PV array model created in MATLAB/Simulink. The second input is chosen to be ‘dP/dU, which is the second order of the derivation. The output voltage fluctuation is the interference [14]. The result of the MPPT algorithm during the current control period is the disturbance step. The symbol e indicates the divergence dP/dU.

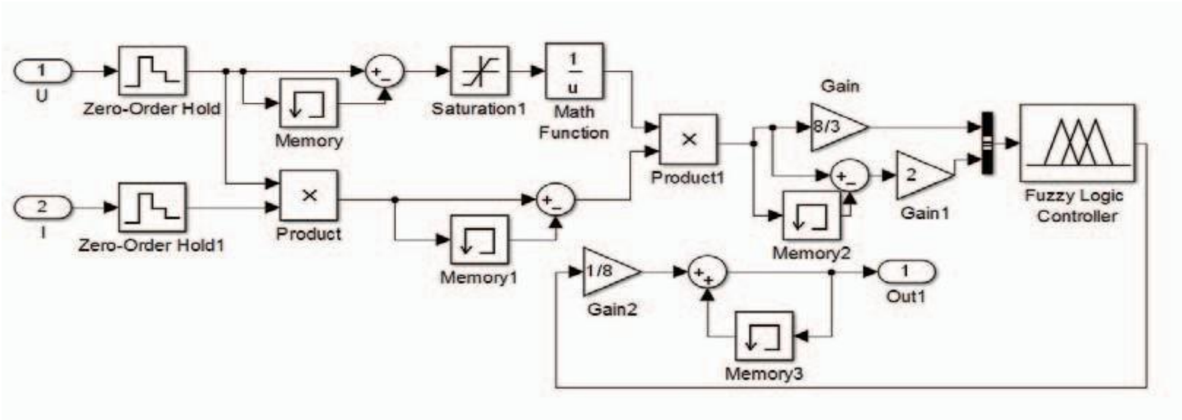

Fig 1: The model of fuzzy controller

In this model, the Mamdani method is selected for fuzzy deduction. The defuzzification method is the centroid method. The final model established in MATLAB/Simulink.

III.Proposed Fuzzy-PI Control Algorithm:

In the proposed control strategy, a Fuzzy-PI controller is employed to enhance the performance of the Maximum Power Point Tracking (MPPT) system. The fuzzy controller, essentially a nonlinear Proportional-Derivative (PD) controller without an integral element, is known for its susceptibility to steady-state error and system oscillations. To mitigate these issues, a traditional Proportional-Integral (PI) control method is integrated to improve control accuracy and minimize errors.

In this hybrid approach, the fuzzy control component is tasked with rapid and accurate adjustments when there is a substantial difference, while the PI control fine-tunes the system when the difference is small. The combined Fuzzy-PI control method ensures a dynamic and responsive MPPT system. To prevent the power point from shifting beyond the maximum power point to its right on the P-U curve (dP < 0), an absolute value is added to the selection condition.

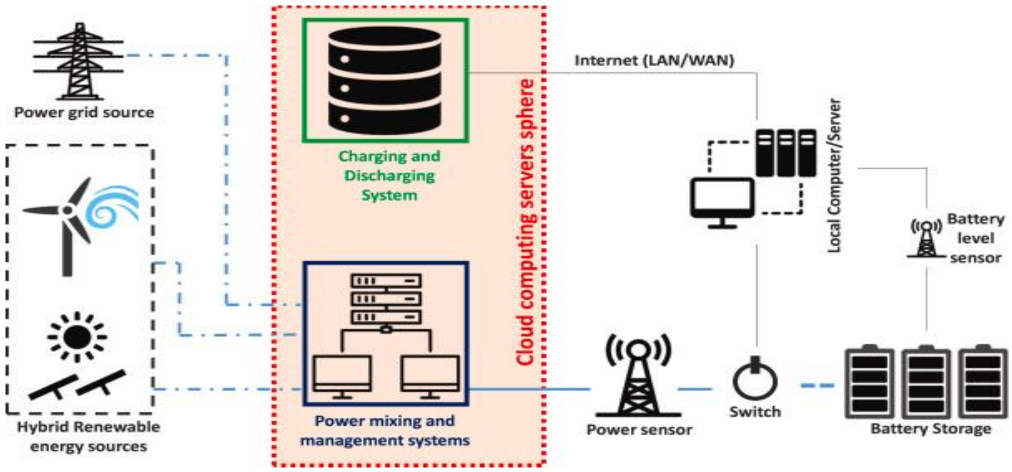

Fig.2.Proposed System

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The improved MPPT model, as illustrated in Fig. 9, incorporates this Fuzzy-PI control strategy. Specifically, when the difference (dU, chosen as the difference in this paper) exceeds 0.6, the fuzzy control is engaged to track the maximum power point. Conversely, when the difference is less than or equal to 0.6, the PI control takes charge of the adjustment.

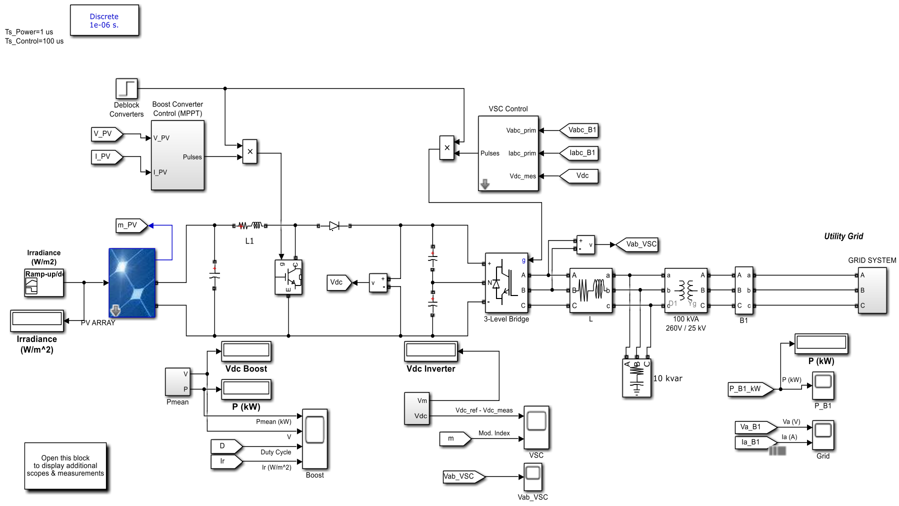

Fig.3.Simulation Circuit Diagram For Fuzzy And PI

During the parameter adjustment of the PI controller, careful consideration is given to the integral effect. The integral element is crucial for eliminating steady-state error during step changes in inputs. Adjusting the scale factor appropriately is essential to strike a balance. Excessive integral effect can lead to deteriorating dynamic performance, increased overshoot, and system instability, while insufficient integral effect results in slow elimination of steady-state error. The integration time value is carefully chosen to achieve a moderate and effective balance. The combined MPPT model, presented in Figure 2, embodies the synergistic application of Fuzzy-PI control, offering an advanced and adaptable approach to optimizing the photovoltaic system's performance.

The comparative analysis reveals that, in response to slight temperature variations, both controllers enable the PV system to swiftly reach a new maximum power point. However, the Fuzzy-PI controller demonstrates a faster tracking speed, particularly when faced with sudden temperature changes. Despite this advantage, it's noteworthy that the Fuzzy-PI controller exhibits some reverse overshoot.

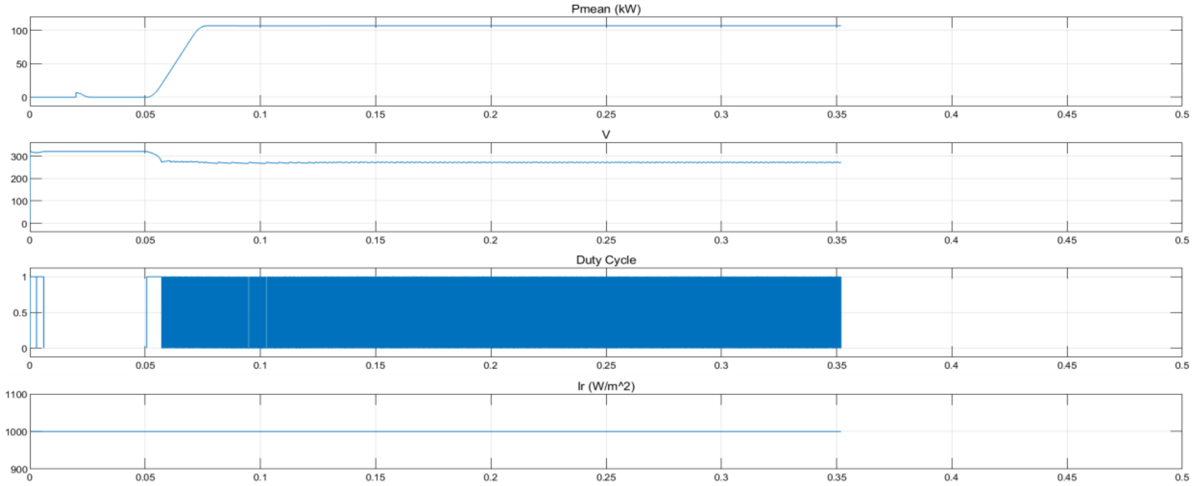

Fig.4. output of boost converter

In summary, the Fuzzy-PI controller excels in several aspects. It exhibits a small steady-state error, showcasing its effectiveness in maintaining accuracy even under varying conditions. Furthermore, the controller demonstrates high speed and precision, particularly beneficial for quickly adapting to abrupt changes in temperature. The findings suggest that the Fuzzy-PI controller is a more effective choice for Maximum Power Point Tracking (MPPT) in PV systems, offering a balance of accuracy, speed, and adaptability.

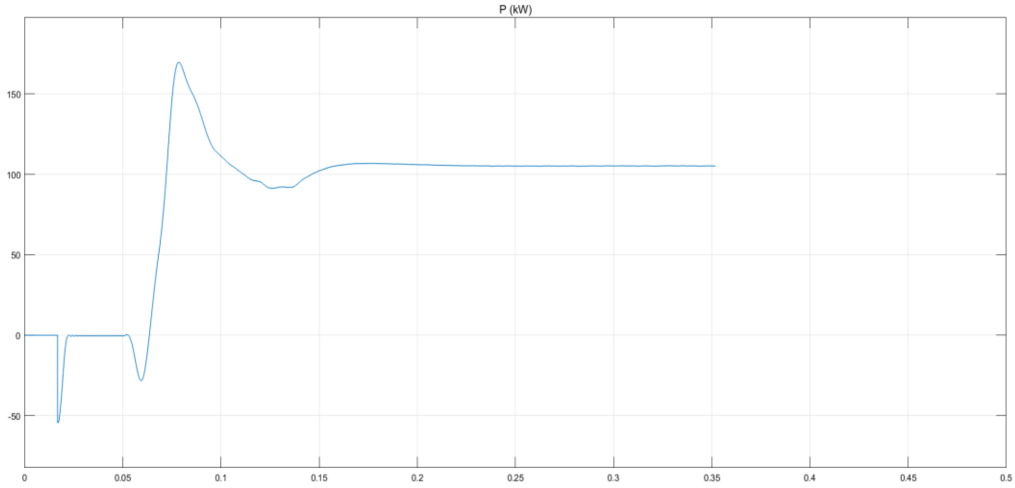

Fig.5.PB1 OUTPUT

Under varying temperature conditions, both controllers efficiently guide the PV system to a new maximum power point, with the Fuzzy-PI controller showcasing a superior tracking speed, particularly in response to sudden temperature changes. Despite the slight reverse overshoot observed in the Fuzzy-PI controller, its overall performance is commendable. It exhibits a small steady-state error, high speed, and precision, making it a more effective choice for MPPT in PV systems.

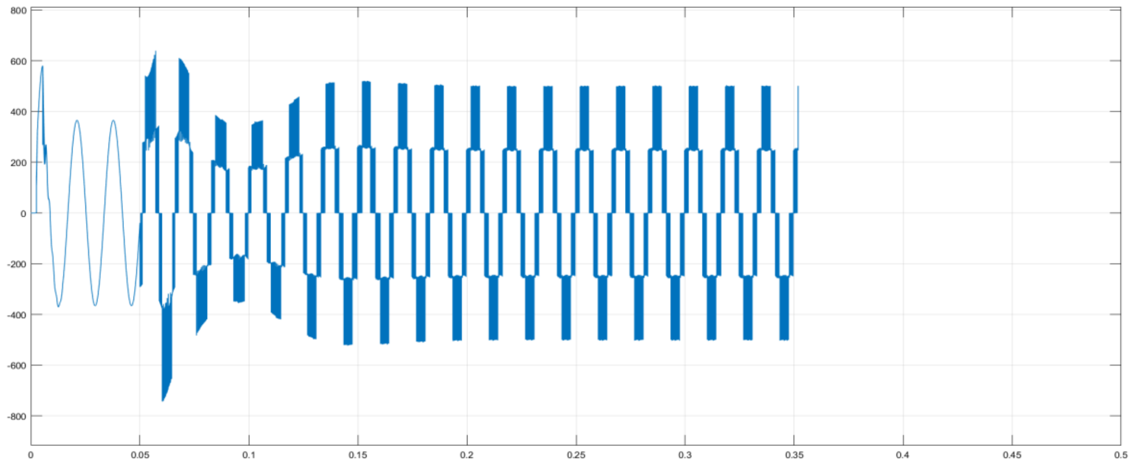

Fig.6. Vab-Vsc Output

When the temperature slightly changes, the PV system can reach a new maximum power point quickly under the both controllers. The tracking speed of fuzzy-PI controller is faster when the temperature suddenly changes. However, some reverse overshoot exists in fuzzy-PI controller as well. In summary, the fuzzy-PI controller has small steady-state error, high speed and precision. And it is more effective in MPPT of PV systems.

V CONCLUSION

In conclusion, this study has investigated and compared the performance of a cloud computing and Fuzzy-PI controller and a traditional PI controller for Maximum Power Point Tracking (MPPT) in photovoltaic (PV) systems. The PV system, being inherently nonlinear with output characteristics affected by temperature variations, demands sophisticated control mechanisms to optimize power generation. The Fuzzy-PI controller, designed to overcome the limitations of a pure Fuzzy controller, has demonstrated notable advantages. The findings highlight the adaptability and efficacy of the Fuzzy-PI controller in dynamically adjusting to environmental changes and ensuring optimal power output. As the demand for efficient and reliable renewable energy systems continues to grow, the Fuzzy-PI controller offers a promising solution for enhancing the performance of PV systems, contributing to the overall sustainability of clean energy solutions. Further research and practical implementation of this controller can provide valuable insights and contribute to the ongoing advancements in renewable energy technology.

REFERENCES

[1] K. A. Aganah and A. W. Leedy, "A constant voltage maximum power point tracking method for solar powered systems," 2011 IEEE 43rd Southeastern Symposium on System Theory, Auburn, AL, 2011, pp. 125- 130.

[2] A. Nigam and A. Kumar Gupta, "Performance and simulation between conventional and improved perturb & observe MPPT algorithm for solar PVcell using MATLAB/Simulink," 2016 International Conference on Control, Computing, Communication and Materials (ICCCCM), Allahbad, 2016, pp. 1-4.

[3] K. Saidi, M. Maamoun and M. Bounekhla, "Simulation and implementation of incremental conductance MPPT algorithm with indirect control method using buck converter," 2017 6th International Conference on Systems and Control (ICSC), Batna, 2017, pp. 199-204.

[4] X.Sun, W.Wu, Xin Li and Q.Zhao, A Research on Photovoltaic Energy Controlling System with Maximum Power Point Tracking, Power Conversion Conference, 2002, pp. 822-826.

[5] A. El Jouni, R. El-Bachtiri and J. Boumhidi, "Sliding Mode Controller for the Maximum Power Point Tracking of a Photovoltaic Pumping System," WSEAS Transactions on Power Systems, vol.1, no.10, pp. 1675-1680, 2006.

[6] Y. Qin, C. M. Pun, H. Hu and H. Gao, "Logistic quantum-behaved particle swarm optimization based MPPT for PV systems," 2017 Seventh International Conference on Information Science and Technology (ICIST), Da Nang, 2017, pp. 154-160.

[7] Z. Cheng, H. Yang and Y. Liu, "Self-Adjusting Fuzzy MPPT PV System Control by FPGA Design," 2011 Asia-Pacific Power and Energy Engineering Conference, Wuhan, 2011, pp. 1-4.

[8] B. R. Peng; K. C. Ho; Y. H. Liu, "A novel and fast MPPT method suitable for both fast changing and partially shaded conditions," in IEEE Transactions on Industrial Electronics , vol.PP, no.99, pp.1-1

[9] X. Liu; K. Ravichandran; E. Sánchez-Sinencio, "A Switched Capacitor Energy Harvester Based on a Single-Cycle Criterion for MPPT to Eliminate Storage Capacitor," in IEEE Transactions on Circuits and Systems I: Regular Papers , vol.PP, no.99, pp.1-11

[10] Y. S. Joel, H. V. Saikumar and S. S. R. Patange, "Design & performance analysis of Fuzzy based MPPT control using two-switch non inverting Buck-Boost converter," 2016 International Conference on Electrical Power and Energy Systems (ICEPES), Bhopal, 2016, pp. 414-419.

[11] S. Tang, Y. Sun, Y. Chen, Y. Zhao, Y. Yang and W. Szeto, "An Enhanced MPPT Method Combining Fractional-Order and Fuzzy Logic Control," in IEEE Journal of Photovoltaics, vol. 7, no. 2, pp. 640-650, March 2017.

[12] B. Bendib, F. Krim, H. Belmili, M. F. Almi and S. Bolouma, "An intelligent MPPT approach based on neural-network voltage estimator and fuzzy controller, applied to a stand-alone PV system," 2014 IEEE 23rd International Symposium on Industrial Electronics (ISIE), Istanbul, 2014, pp. 404-409.

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[13] Ikegami, T., et al. "Estimation of equivalent circuit parameters of PV module and its application to optimal operation of PV system," Solar Energy Materials & Solar Cells 67.1(2001):389-395.

[14] C. Bhattacharjee and B. K. Roy, "Performance analysis of fuzzyproportional integral (PI) control for improvement in quality and magnitude of dispatched power for a weak grid-tied hybrid system," 2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES), Paralakhemundi, 2016, pp. 882-887.

[15] T. A. Brasil, L. F. Crispino and W. Suemitsu, "Fuzzy MPPT control of grid-connected three-phase induction machine for wind power generation," 2015 IEEE 24th International Symposium on Industrial Electronics (ISIE), Buzios, 2015, pp. 803-807.

[16] Tianheng Ni, Bo Zhou, Bing Liu and Long Wang, "A rotor position estimation method based on fuzzy PI for SPMSM sensorless control," 2017 IEEE 3rd International Future Energy Electronics Conference and ECCE Asia (IFEEC 2017 - ECCE Asia), Kaohsiung, Taiwan, 2017, pp. 2148-2152.