Analysis of Maximum Power Tracking and Battery SoC in Grid Integrated Microgrid Using Fuzzy Logic Controller

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Abstract: Conventional power systems are currently undergoing significant change as a result of development of modern micro grids, which include interconnected microgrids with high levels of energy storage, increasing penetration of renewable energy in contemporary distribution networks. An integrated grid with many dispersed sources is developed to provide dependable, effective solution for generation, distribution of electricity. This manuscript focuses on energy management strategy for a hybrid renewable micro-grid system. This kind of control strategies are employed for grid reliability, resiliency voltage regulation. Because renewable energy sources are intermittent, predictive strategy explains energy availability, modifies system operation is required. In this proposed work the main objectives are to improve maximum power, battery charge/discharge by adopting intelligent controllers which can handle complex uncertainties-linear behaviour by MATLAB/SIMULINK. The outcome proposed research which could be in form of results are improving PV voltage, current with P&O method by applying PI, FLC controllers are compared

1 INTRODUCTION

Modern energy demands, developing nations, electrical generation like fossil fuels with sustainable energy(Sarkar, Minai, et al. , 2024), (Rao, Reddy, et al. , 2021). In need of energy every day, world is quickly becoming into global village for human economic development (Nair, Gopika, et al. , 2024), (Seedadan, Wongsathan, et al. , 2024). One important tactic being used to address energy crisis, environmental degradation is utilization of renewable energy sources (RES) (Amirullah and Adiananda, 2024), (Nair, Gopika, et al. , 2024). Similar to solar, wind, and biomass, using RES won't reduce their availability. The ever-growing need for energy is met by using sunlight, a steady source of energy (Rishikesh, Kumar, et al. , 2024).

A viable way to sustain power supply, demand response is to incorporate RES into the power system. Integration of RES to utility grid depends on scale of power generation. Integrating renewable energy into grid poses challenges (Eluri and Naik, 2022). The integration of distributed sources (DER's) with grids throws different kinds of challenges like uncertainties, power quality, voltage stability, frequency stability (Ajit and Agrawal, 2024), (Shi, Liu, et al. , 2024). Distribution System Operators(DSOs) are responsible for efficient management of DER's, optimization of grid operations. A viable option for a modernized electric infrastructure is microgrid (MG), which is notion of DER. coupled to single power subsystem combines conventional, renewable resources (Padmaja, Tammali, et al. , 2022). The MG is operated in grid-connected, islanded mode of operation (Hema, Maheshprabhu, et al. , 2023), (Asnil, Nazir, et al. , 2024). The hybrid MG is to reduce quantity of conversion phases. Interface components where system dependability and overall efficiency might be increased (Eluri, and, Naik, 2023), (Sivakumar, Selvaraj, et al. , 2024). Hybrid MGs may combine both AC. DC loads (Reddy, and, Kumar, 2019). The basic structure basic grid consisting of solar, wind

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energies, battery, 3-phase rectifier, non-linear loads and an Energy management system (EMS) which is used to monitor, control grid connected MG (Aldosary, 2024). The basic structure of grid is depicted is in Figure 1.

This manuscript focuses on various MPPT techniques, battery management system by adopting various intelligent controllers like Fuzzy Logic Controllers (FLC), Adaptive FLC and Fractional order (FOFLC).

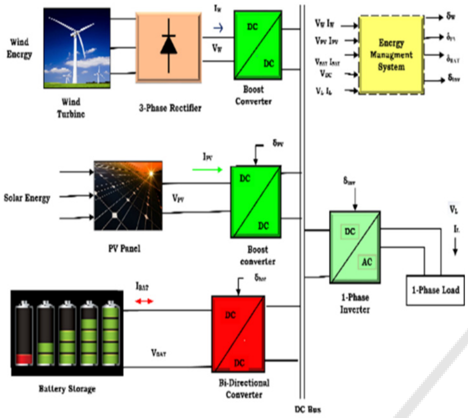

Figure 1: Basic Structure of Microgrid with EMS

This manuscript is structured as follows: Section II includes MPPT techniques, Section III is Battery Management Systems (BEMS) & Energy Management Systems (EMS), Section IV includes proposed controllers, Section V is results & discussions, section VI is conclusion.

2 RELATED WORKS

By continuously adjusting solar panels' operating point to their maximum power point, MPPT enables system to maximize amount of energy can be extracted from available sunshine. MPPT, is an algorithm built into charge controllers that, under specific circumstances, extracts the highest amount of power possible from photovoltaic modules (Mamatha, Neelima, et al. , 2020). A solar charge controller utilizes MPPT to optimize current flowing into battery from photovoltaic modules is known MPPT solar charge controller (Boubaker, 2023).

2.1 P & O MPPT Algorithm

P&O method is change in power(dP),PV voltage(dV) is verified. This leads to changes in duty cycle(D) (Masry, Mohammed, et al. , 2023). The real point is positioned on left side of power curve for positive gradient, on right side of power curve for negative gradient. (Jabbar, Mekhilef, et al. , 2023). P&O is very popular because of simplicity (Messaoudi, Farhani, et al. , 2024). The flow chart of P & O is presented in Figure 2. The equations involved in P&O are.

$$P(t) = V(t) * I(t) \quad (1)$$

$$\Delta P = P(t) - P(t-1) \quad (2)$$

$$V(t) = V(t-1) \pm \Delta V \quad (3)$$

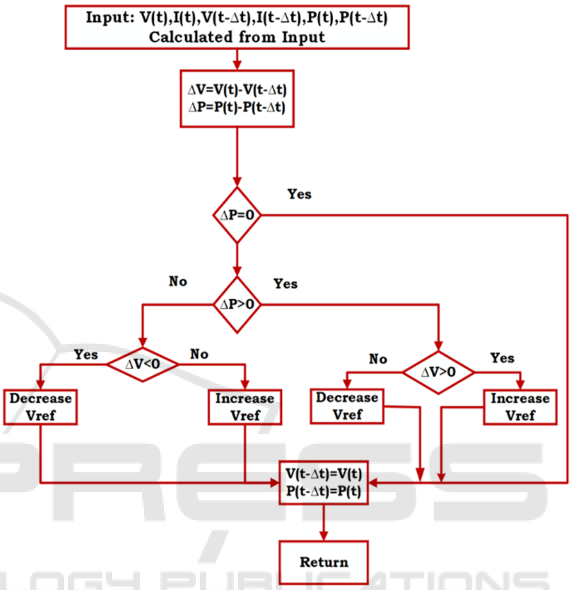

Figure 2: Flow chart of Perturb & Observe(P&O) method

2.2 Incremental Conductance (IC) MPPT Algorithm

MPPT is a useful for raising PV power output. IC tracks peak power under varying atmospheric condition (Singh, Singh, et al. , 2022). IC regulates if MPPT is reached MPP, stops perturbing operating point. The equations involved in IC are.

$$\frac{dp}{dv} = \frac{d(VI)}{dv} = I + V\frac{di}{dv} \quad (4)$$

The IC is defined as follows

$$Gd = \frac{di}{dv} \quad (5)$$

When operating within operational limitations, output power rises as PV module terminal voltage increases (dP/dV >0), output power decreases as PV terminal voltage increases (dP/dV <0)[17]. The IC flow chart of IC is shown in Figure 3.

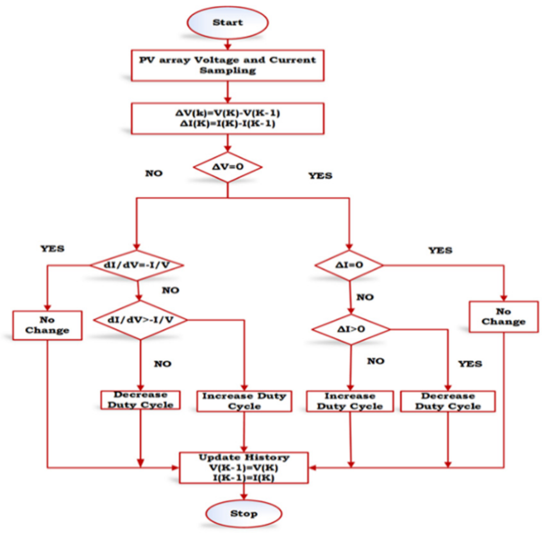

Figure 3: Flow chart of IC method

3 BATTERY MANAGEMENT SYSTEM & EMS

The BMS's is to make sure battery operates safely by managing charging, discharge procedure, cell balancing, estimating state of charge (SoC), providing over-temperature protection. When a cell or module is fully charged, SOC is proportionate to entire amount of charge available. The EMS has been included into BMS of hybrid energy systems to guarantee effective power supply. EMS involves coordination of sources, loads for maximum

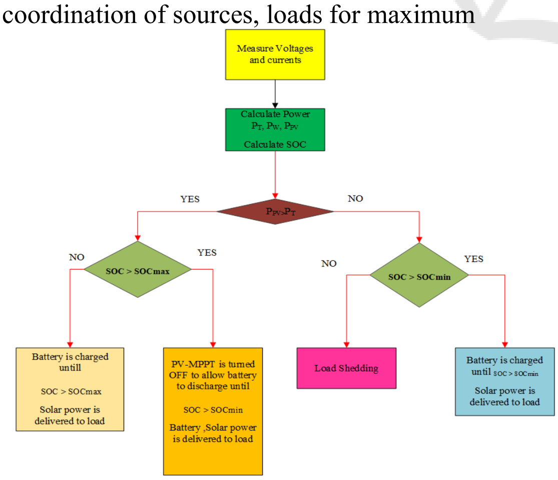

Figure 4: Flow chart of EM

utilization of available power. EMS is crucial for optimal power balance in hybrid PV/Wind turbine systems. The objective of EMS is for improving transients, MPPT, EMS for grid. The flow chart for an EMS is shown in Figure 4.

4 PROPOSED METHODS

4.1 PI Controllers

To achieve objectives like MPPT, Battery performance in grids a conventional controller is used which is nothing but Proportional controller (PI). PI controllers eliminate steady state faults, oscillations caused by closing of controller action. PI controllers are frequently used in electrical systems due to simple form, implementation is frequently used in AC, DC applications in combination with coordinate transformations to regulate slowly changing or constant quantities. The design of PI controllers to reduce impact of load disruptions using a process model. maximizing integral gain is goal of several works. Researchers have increasingly incorporated intelligent optimization algorithms into PI for parameter tweaking as result of advances in intelligent control theory. The proposed PI reduces grid energy consumption by an equivalent amount while maintaining battery SoCs in an optimal operating range. The applications of PI Controller are speed control, liquid flow control, HVAC systems. The proposed PI with MPPT is depicted in Figure 5.

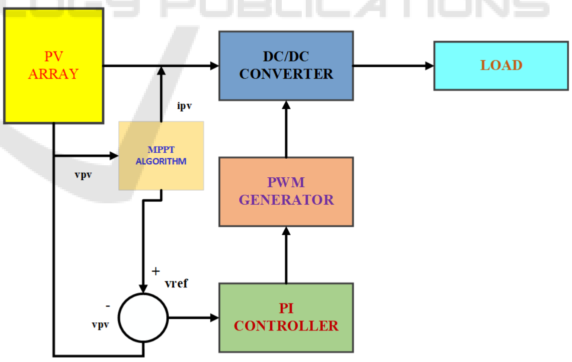

Figure 5: PI controller

4.2 FLC Controllers

Fuzzy logic is frequently employed to regulate a system's numerous parameters. The ability of FLC to handle nonlinearities, uncertainties in variety of technological environments is highlighted via review of most recent advancements in FL applications across crucial domains, like energy harvesting (EH), ambient conditioning systems (ACS), robotics, autonomous systems (RAS). FLC is not exclusively dependent on a mathematical model of plant, in contrast to conventional control theory, an approximate mathematical model aids in FLC fine tuning. The FLC is examined in different loading situations compared with PI controller. The three fundamental building blocks of FLC are defuzzification block, inference engine, fuzzification block. Here, the power is determined by solar panel's voltage, current. The use of essential fuzzy rules, which offer semantic interpretability reasoning process's understandability, is a fundamental component of Fuzzy interference system (FIS). The proposed FLC with MPPT is presented in Figure 6.

FIS is depicted in Figure 7.

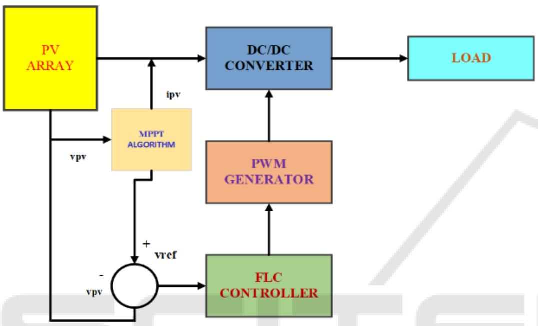

Figure 6: FLC controller

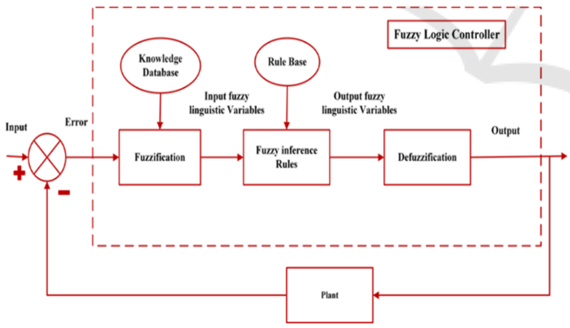

Figure 7: Fuzzy Interference System

The membership functions for input1, input2 and input1is explored in Figure 8., Figure 9., Figure 10.

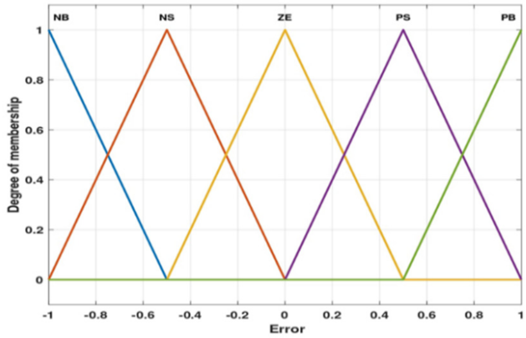

Figure 8: Membership Functions for Input1

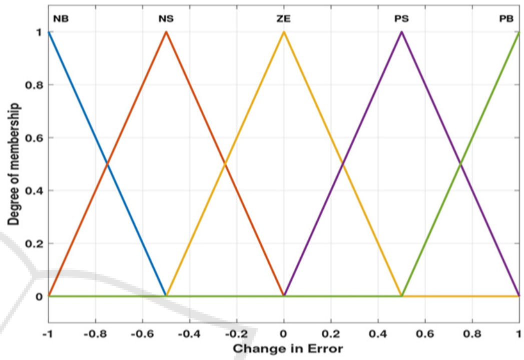

Figure 9: Membership Functions for Input2

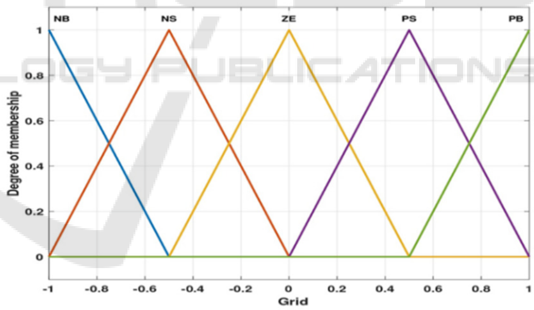

Figure 10: Membership Functions for Output

The rule table FLC is depicted in TABLE1 which explains the relationship between error and change in error.

Table 1 Rule Table

E(K)/DE(K)	NL	NS	ZE	PS	PL
NL	NL	NL	NL	NS	ZE
NS	NL	NL	NS	ZE	PS
ZE	NL	NS	ZE	PS	PL
PS	NS	ZE	PS	PL	PL
PL	ZE	PS	PL	PL	PL

5 RESULTS AND DISCUSSIONS

The results of proposed hybrid system by adopting PI, FLC using P&O, IC method are explored in Figure11-Figure 14.

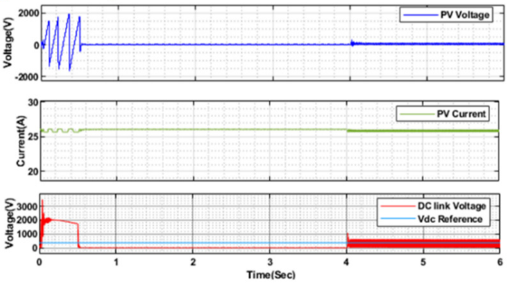

Figure 11: V_{PV}, I_{PV}, V_{DC} with PI using P & O method

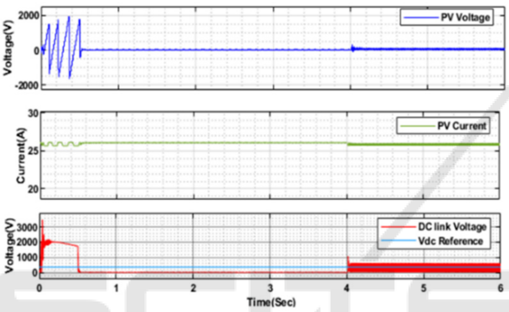

Figure 12: V_{PV}, I_{PV}, V_{DC} with PI using IC method

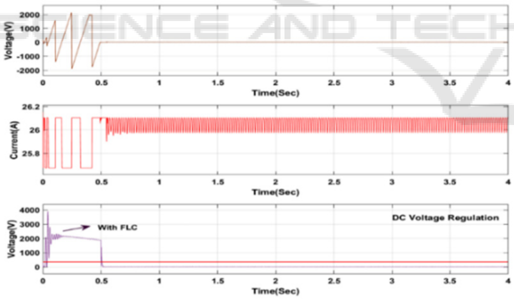

Figure13: V_{PV}, I_{PV}, V_{DC} with FLC using P & O method

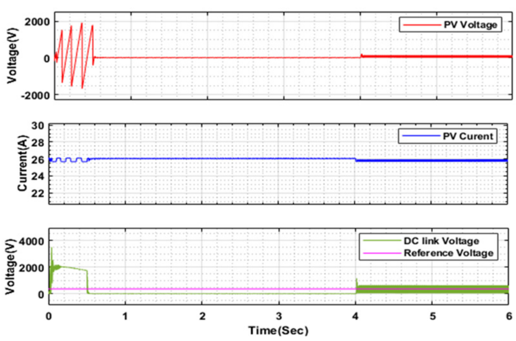

Figure 14: V_{PV}, I_{PV}, V_{DC} with FLC using P & O method

The battery results of PI, FLC controllers are resulted in Figure 15, Figure 16.

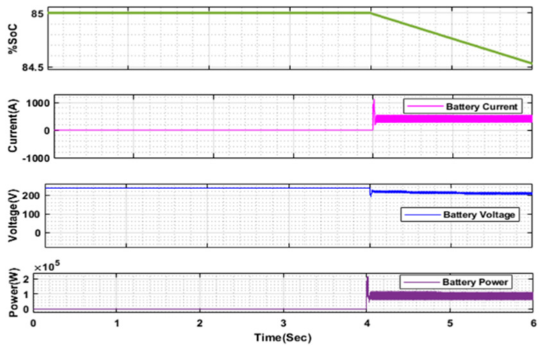

Figure 15: Power, Voltage, Currents with PI Controller

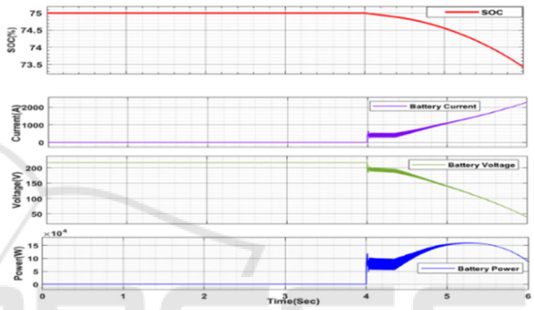

Figure 16: Power, Voltage, Currents with FLC Controller

6 CONCLUSIONS

This paper investigated solutions for Hybrid Micro grid systems comprising various distributed energy resources by using MATLAB/SIMULINK. The proposed work focuses on various MPPT methods, Battery results by adopting PI, FLC controllers. To improve grid reliability, to increase maximum power comparison with intelligent controller and PI is done by simulation. FLC is multi-objective optimization technique that is applied to identify optimal capacity of EMS, schedule optimal power generation. The proposed EMS is designed for smooth fluctuation of grid. Researchers can extend this kind of work to more intelligent controllers.

7 FUTURE SCOPE

By concentrating mostly on electric mobility, stationary applications, it further investigates existing gaps regarding the performance requirements of BMS. This work can be expanded to assess the best method for regulating DC bus voltage: an intelligent controller that makes use of adaptive FLC. innovative supervisory power management technique for battery-powered PV systems. Additionally, the research offers a framework for creating a new BMS standard, with a focus on operational risk and BMS safety. Future battery management systems will face a number of general regulatory hurdles in addition to application-specific safety requirements unique tasks that a BMS must perform. A FLC-based approach for coordinated BESS control with a modified AC coupling topology can be developed from this suggested study. Overshoot, settling time, total harmonic distortion (THD) are factors that can be adjusted in this regard.

REFERENCES

Sarkar, P. R., Minai, A. F., Ahmad, I., Bakhsh, F. I., Khan, A. A., & Pachauri, R. K. (2024). Power Quality Assessment and Enhancement using FLC based SPV Supported Cascaded H-Bridge Multilevel Inverter. e-Prime-Advances in Electrical Engineering, Electronics and Energy, 7, 100465.

Rao, A. P., Reddy, K. S., & Sathiyamoorthi, V. (2021). Automated Soil Residue Levels Detecting Device With IoT Interface. In *Challenges and Applications of Data Analytics in Social Perspectives* (pp. 123-135). IGI Global.

Nair, D. R., Gopika, N. P., & Nair, M. G. (2024). Arduino Interfacing of FLC-based Power Flow Management in Smart Microgrid Systems. IETE Journal of Research, 70(1), 875-889.

Seedadan, I., Wongsathan, R., & Puangmanee, W. (2024). Grid-Connected PV Inverter System using the IPSO-based FLCs and NFCs for Enhancing PV Energy Utilizing Efficiency and Power Quality. *International Journal on Electrical Engineering & Informatics*, *16*(1).

Amirullah, A., & Adiananda, A. (2024). Distributed Generation Integrated by a Photovoltaic System Using Single-to Three-Phase UPQC with Sugeno FIS Method for Power Quality Improvement. *International Journal of Intelligent Engineering & Systems*, *17*(6).

Nair, D. R., Gopika, N. P., & Nair, M. G. (2024). Arduino Interfacing of FLC-based Power Flow Management in Smart Microgrid Systems. *IETE Journal of Research*, *70*(1), 875-889.

Rishikesh, N., & Kumar, J. S. (2024). Integrated PV energy generation system with high-gain converter and CHHO-FLC-based MPPT for grid integration. *Electrical Engineering*, 1-24.

Eluri, H., & Naik, M. G. (2022). Energy management system and enhancement of power quality with grid integrated micro-grid using fuzzy logic controller. *IJEER*, *10*(2), 256-263.

Ajit, & Agrawal, S. (2024). Power Quality Improvement Using a Novel Simplified Adaptive Control of Solar PV Integrated Shunt Active Power Filter. *International Journal of Circuit Theory and Applications*.

Shi, J., Liu, H., & Yang, X. (2024). Precision Control for Room Temperature of Variable Air Volume Air-Conditioning Systems with Large Input Delay. *Energies*, *17*(17), 4227.

Padmaja, D. L., Tammali, S., Gajavelly, N., & Reddy, K. S. (2022, May). A comparative study on natural disasters. In *2022 international conference on applied artificial intelligence and computing (ICAAIC)* (pp. 1704-1709). IEEE.

Hema, M. S., Maheshprabhu, R., Reddy, K. S., Guptha, M. N., & Pandimurugan, V. (2023). Prediction analysis for Parkinson disease using multiple feature selection & classification methods. *Multimedia Tools and Applications*, *82*(27), 42995-43012.

Asnil, A., Nazir, R., Krismadinata, K., & Sonni, M. N. (2024). Performance Analysis of an Incremental Conductance MPPT Algorithm for Photovoltaic Systems Under Rapid Irradiance Changes. *TEM Journal*, *13*(2).

Eluri, H. B., & Naik, M. G. (2023). Energy management system and enhancement of power quality with grid integrated micro-grid using adaptive fuzzy logic controller. *International Journal of Renewable Energy Research (IJRER)*, *13*(1), 144-154.

Sivakumar, N., Selvaraj, J., Jayaprakash, K., & Fante, K. A. (2024). Optimized DBN-based control scheme for power quality enhancement in a microgrid cluster connected with renewable energy system. *IET Renewable Power Generation*, *18*(12), 1926-1947.

Reddy, K. S., & Santhosh Kumar, C. H. N. (2019). Effective data analytics on opinion mining. *International Journal of Innovative Technology and Exploring Engineering*, *8*(10), 2073-2078.

Rai, S., Kumar, Y., Patidar, N. P., Kirar, M., & Agrawal, R. Unified Power Quality Conditioner for Improving Power Quality of Distribution System Integrated with Solar. *Available at SSRN 4717466*.

Aldosary, A. (2024). Power Quality Conditioners-Based Fractional-Order PID Controllers Using Hybrid Jellyfish Search and Particle Swarm Algorithm for Power Quality Enhancement. *Fractal and Fractional*, *8*(3), 140.

Mamatha, K., Neelima, S., & Reddy, K. S. (2020). Fostering Employability-Synergy between Industry and Academia. *Journal of Engineering Education Transformations*, *33*(Special Issue).

Himabindu, E., Krishna, D., Venkateshwarlu, S., & Reddy, K. C. Solar PV Fed DC Link Voltage For Fuzzy Logic Sliding Mode Controller Based UPQC To Improve The Dynamic Performance In Power Grid. *Journal of Applied Science and Engineering*, *28*(5), 969-978.

Boubaker, O. (2023). MPPT techniques for photovoltaic systems: a systematic review in current trends and recent advances in artificial intelligence. *Discover Energy*, *3*(1), 9.

Masry, M. Z. E., Mohammed, A., Amer, F., & Mubarak, R. (2023). New hybrid MPPT technique including artificial intelligence and traditional techniques for extracting the global maximum power from partially shaded PV systems. *Sustainability*, *15*(14), 10884.

Jabbar, R. I., Mekhilef, S., Mubin, M., & Mohammed, K. K. (2023). A modified perturb and observe MPPT for a fast and accurate tracking of MPP under varying weather conditions. *IEEE Access*, *11*, 76166-76176.

Messaoudi, F., Farhani, F., & Zaafouri, A. (2024). A new approach to MPPT hybrid incremental conductance-sliding mode control for PV grid-connected. *Measurement and Control*, 00202940241240666.

Singh, J., Singh, S. P., Verma, K. S., & Kumar, B. (2022). Comparative analysis of MPPT control techniques to enhance solar energy utilization and convergence time under varying meteorological conditions and loads. *Frontiers in Energy Research*, *10*, 856702.