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Improving Power Quality in a Grid-Connected Hybrid Power System through the Implementation of a Fuzzy Logic Controller

Abstract: - The examination of modeling and designing grid-connected hybrid power systems with efficient control strategies is the focus of this study. Integration of wind and photovoltaic systems into the ac-bus bar system is a common practice in enhancing operational performance. Utilization of Matlab Simulink software is employed for the design of this hybrid system, incorporating efficient MPPT control algorithms to optimize power generation from solar and wind sources under varying climatic conditions. Analysis of the maximum power point tracking mechanism and control methods of the hybrid power system is conducted, particularly in response to changes in weather conditions such as wind speed and solar radiation. Maintaining grid voltages and Unity Power Factor (UPF) while feeding currents into the grid is essential for the hybrid system. The employment of Proportional Integral (PI) control instead of Fuzzy Logic Controller (FLC) in the voltage-oriented control approach is explored to enhance power quality.

Keywords: Solar/Wind; MPPT control, pi controller, smart grid, fuzzy logic controller.

I. INTRODUCTION

In the past decade, it has been raising development in distributed electrical power. The present situation the entire world is facing the challenge is that no permanent solution to reach the maximum power demand and also day to day the conventional energy sources are very rapid depletion to reserve the conventional source of energies for the next use must be approached the non-conventional energy it is only the alternative source of energy to meet the power demand. However, every system has merits and demerits; therefore, the wind and PV system have some disadvantages depend on environmental conditions such as in photovoltaic system deviation of solar radiation also in wind system the variation is wind speed. So, merge of photovoltaic and wind systems as hybrid power system uses for overcome the disadvantages as well as produce most effective electrical power along with the good quality to the local grid and remote places [1]. A hybrid renewable energy system, often known as a solar and wind energy system, combines the power generation capabilities of wind turbines and solar photovoltaic (PV) panels to provide electricity. Since solar and wind energy sources frequently provide power at different times of the day and in varied weather conditions, these systems are made to take advantage of their complementing nature [2].

The general operation of such a system is as follows:

1. Solar Photovoltaic (PV) Panels: Using the photovoltaic effect, solar panels directly transform sunlight into electricity. These panels produce electricity when they are exposed to sunlight during the day. If the system is grid-connected, this electricity can be sent into the grid or consumed right away. If not, it can be stored in batteries for later use.
2. Wind Turbines: Using a generator, wind turbines transform wind energy from kinetic energy into mechanical power and ultimately electrical power. As long as there is enough wind, wind turbines can produce electricity day or night. They work best in regions with regular wind patterns.
3. Hybrid Controller and Inverter: These devices control the electricity that moves between batteries, solar panels, wind turbines, and electrical loads. It balances the power output of the system and guarantees effective use of the energy produced.
4. Optional Battery Storage System: Batteries are frequently utilized in hybrid systems to store extra energy produced at times when solar or wind availability is high, for usage during times when generation is low. In the event of a grid failure, batteries can also offer backup power.

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5. Grid Connection (Optional): Hybrid systems have the option to connect to the grid, which enables them to export excess energy to the grid when demand outpaces generation and to take electricity
from it when generation is insufficient.
6.Monitoring and Control System: To keep an eye on energy output, battery storage levels, and overall system performance, a monitoring and control system is usually integrated into a hybrid renewable energy system. This makes it possible to optimize system efficiency through remote monitoring and control. Reduced reliance on fossil fuels, cheaper electricity costs (particularly in isolated places with limited grid connection), and a smaller carbon footprint are some advantages of a solar and wind energy system. These systems' efficacy is contingent upon a number of elements, including the climate in the location, the amount of land available, and the initial investment expenditures. To get the most out of hybrid renewable energy systems, proper design, installation, and maintenance are essential.

II. THE PLANNED HYBRID POWER SYSTEM (PV/WIND)

Figure 1 depicts the suggested configuration of the planned wind and PV system. This system includes a 1-megawatt photovoltaic system and a 9-megawatt wind form system that are built in different locations [2]. The photovoltaic system is made up of multiple solar arrays that are electrically coupled in series and parallel to generate more power when needed. Aside from the photovoltaic system configuration, a dc-ac power electronics converter is used to convert the generated direct current into alternating current and a dc-dc step-up power electronics converter can be used to increase the intended voltage. To track the peak power output from a photovoltaic system and a wind system during variations in solar irradiation and wind speed, several MPPT techniques are available.

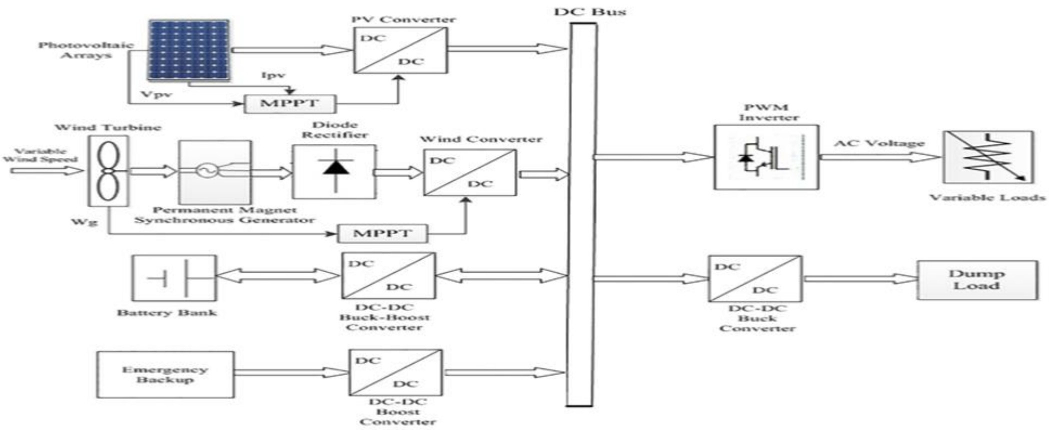

Fig. 1. Functional Block Diagram of Proposed Model

III. PV SYSTEM CONFIGURATION DESIGN

The photovoltaic system is designed and its characteristics are analyzed and also implement the one of the types MPPT technique i.e. incremental conductance technique is analyzed and inverter controller studied

a) Photovoltaic System Model

The solar panels are connected in string to achieve the required voltage rating as well as many photovoltaic strings are parallel combination to gain the desire energy capability. Every photovoltaic module is integrated dc-dc step up power electronics to tract the highest amount energy during the difference in the sun's radiation, afterwards the photo voltaic modules are linked together in the parallel mode of the dc-ac converter to monitor the forced active power integrate grid to attain the required reactive power. This arrange consist of more benefits in stable dc-link voltage losses are less, great efficiency and less in cost. The entire design of the photovoltaic system connected in electrically with the Shockley diode. Voltage and current correlation of photovoltaic system expressions are below.

$$I = N_P\, I_{Ph} - N_P I_S \left\{ exp\left[\frac{q\left(\frac{V}{N_S}+\frac{R_S\, I}{N_P}\right)}{KTA}\right] - 1 \right\} - \left[\frac{\frac{N_P\, V}{N_S} + R_S\ I}{R_{sh}}\right] \quad (1)$$

$$I_{ph} = \frac{G}{1000}\left[I_{SC} + K_i\left(T - T_{ref}\right)\right] \quad (2)$$

$$I_S = I_{rs}\ \left(\frac{T}{T_{ref}}\right)^3 \text{Exp}\left[\frac{qE_g}{K\ A}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right] \quad (3)$$

b) Examination of Gradual Conductance Maximum power point tracking technique

The MPPT control technique is most important for PV system; the MPPT technique plays an essential role to track the maximum amount of solar energy even under variable solar radiation. Therefore, the aim of the control strategy to manage the controller of step-up converter so photovoltaic system can works on the maximum amount power [6]. To track maximum amount power under the variation of solar radiation the IC (Incremental Conductance) MPPT technique is used for good performance of the system and better efficiency. This MPPT method is designed in the simulink software. The incremental conductance MPPT method mathematical expressions are below.

$$P_{pv} = V_{pv} * I_{pv} \quad (4)$$

$$\frac{dP_{pv}}{dV_{pv}} = \frac{d}{dV_{pv}}\left[V_{pv} * I_{pv}\right] = I_{pv} + V_{pv}\,\frac{dI_{pv}}{dV_{pv}} \quad (5)$$

$$\frac{dP_{pv}}{dV_{pv}} = 0\,,\frac{dI_{pv}}{dV_{pv}} = -\frac{I_{pv}}{V_{pv}} \text{ at the MPP } \Delta V_n = 0 \quad (6)$$

$$\frac{dI_{pv}}{dV_{pv}} > -\frac{I_{pv}}{V_{pv}} \qquad \text{Left of the MPP, increment } V_{pv} \quad (7)$$

$$\frac{dI_{pv}}{dV_{pv}} < -\frac{I_{pv}}{V_{pv}} \qquad \text{Right of the MPP, decrement } V_{pv} \quad (8)$$

IV. System Design For Wind Energy

The rotor side controller and grid side controllers are controlled by MPPT control strategy and mechanical design of the wind turbine and the performance characteristics are analyzed [4][5].

a) Wind turbine mechanical model

To operate doubly fed induction generator as produce aerodynamic input torque developed from the wind turbine under the variable wind speeds. The wind turbine performance co efficiency (cp) is based on aerodynamic blade system and wind turbine efficiency is expressed. Estimated mechanical power by wind turbine as below.

$$P_m = \frac{1}{2}\rho\; A_t\; C_p\;(\lambda,\beta)\, V_w{}^3 \quad (9)$$

The performance coefficient (Cp) of the WT based on the blade aerodynamics and indicates the efficiency of the WT. The performance coefficient (Cp) equations are below

$$C_p\;(\lambda,\beta) = 0.5176\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)e^{\left(\frac{-21}{\lambda_i}\right)} + 0.0068\lambda \quad (10)$$

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.008\beta} - \frac{0.035}{\beta^3 + 1} \quad (11)$$

b) Controller for Rotor Side Converters

The primary function of the RSC is to monitor the maximum energy output from the wind turbine system and control the reactive power that is injected by the doubly fed induction generator to sustain the stator voltages at unity power factor, or UPF. The D-Q axis of stator voltage and currents is achieved using the SFOC (Stator Flux Oriented Control) technique as follows.

$$i_{qs} = -(L_m/L_s)i_{qr} \quad and\; i_{ds} = (1/L_s)\,\lambda_{ds} - (L_m/L_s)\,i_{dr} \quad (12)$$

$$V_{ds} \approx 0 \;\; and \;\; V_{qs} \approx \omega_e\lambda_{ds} \quad (13)$$

Working of d-q axis with reference rotor for synchronous reference frame as below

$$V_{dr}{}^* = (V_{dr})' - (\omega_{slip})\sigma L_r i_{qr} \quad (14)$$

$$V_{qr}{}^* = \left(V_{qr}\right)' - (\omega_{slip})\left(\left(L_m{}^2/L_s\right)i_{ms} + \sigma L_r i_{dr}\right) \quad (15)$$

Active power of the stator (ps), reactive power (qs) and electromagnetic torque are below

$$P_s = \frac{3}{2}\left[-V_{qs}i_{qs}\right] = \frac{3L_m}{2L_s}\left[\omega_e\lambda_{ds}i_{qr}\right] \quad (16)$$

$$Q_s = \frac{3}{2}\left[V_{qs}i_{ds}\right] = \frac{3\omega_e}{2}\left[\lambda_{ds}i_{ds}\right] \quad (17)$$

$$T_e = \frac{3}{2}\,\frac{P}{2}\frac{L_m}{L_s}\left[\lambda_{ds}i_{qr}\right] \quad (18)$$

c) Controller for Grid-Side Converter

The D-Q axis value for GSC voltages is represented in the SRF technique (synchronous reference frame), which is described below. The grid's interchanging reactive power is regulated by the GSC in addition to its crucial role in maintaining a constant DC voltage.

$$V_d = V_{d1} + Ri_d - \omega_e L i_q + L\frac{di_d}{dt} \quad (19)$$

$$V_q = Ri_q + L\frac{di_q}{dt} + \omega_e L i_d + V_{q1} \quad (20)$$

$$P_g = \frac{3}{2} V_d i_d \quad (21)$$

$$Q_g = -\frac{3}{2} V_d i_q \quad (22)$$

$$C\,\frac{dV_{dc2}}{dt} = \frac{3m}{4\sqrt{2}} i_{d-i_{or}} \quad (23)$$

$$V_{d\,1}{}^{*} = -(V_d)' + (\omega_e L i_q) + V_d \quad (24)$$

$$V_{q\,1}{}^{*} = -(V_q)' - (\omega_e L i_d) \quad (25)$$

d) Mechanical calculation design using an adapted MPPT technique

When the rotor rotates at its ideal speeds, the wind turbine (WRF) can collect the maximum amount of energy under conditions of wind speed variation [11][12]. The upgraded MPPT control technique can effectively measure the wind's actual velocity to extract the majority of the energy without requiring wind speed computations.

$$\omega_{ref} = \{1.2 \; 1 \geq P_{m-pu} \geq 0.75 \; -0.67(P_{m-pu})^2 + 1.42(P_{m-pu}) + 0.51 \; P_{m-pu} < 0.75 \quad (26)$$

V. Hybrid Grid Technology Analysis

Traditional grid systems function by connecting different power generating units; they have a one-way power flow capacity. Smart grids, on the other hand, are electrical networks with two-way power flow and data communication capabilities. They use digital technology to sense, react, and suggest solutions to various problems and changes in usage [2][3]. Customers connect to the smart grid and feel secure since it has the power to heal itself. Every piece of equipment has a digital metering system that allows for speedy self-healing in the event of a system malfunction, ensuring high-quality, safe, and intelligent service for customers. Analyzing hybrid grid technology entails evaluating a number of factors related to its performance, operation, design, and influence on the electrical grid.

These are some crucial points to take into account when examining hybrid grid technology:

a. Technical Performance: Assess the hybrid grid technology's technical performance, including its capacity to reliably and efficiently integrate a variety of energy sources, including conventional energy sources like hydro and fossil fuels as well as renewable energy sources like solar and wind.

Examine how well management and control systems work to maximize the performance of various energy sources, storage systems, and grid links to guarantee a steady and dependable supply of electricity.

b. Power Quality: Evaluate how hybrid grid technology affects transient response, harmonics, frequency regulation, voltage stability, and harmonics. Examine how well power conditioning and control systems mitigate power quality problems and guarantee adherence to pertinent standards and laws.

c. Reliability and Resilience: Assess the hybrid grid technology's ability to withstand and recover from grid disruptions, such as faults, in grid connectivity. Examine how well fault isolation, restoration, and detection systems work to save downtime and keep essential loads powered variations in the energy supply, and interruptions continuously.

d. Economic Viability: To determine whether implementing hybrid grid technology is more financially feasible than using alternative energy sources or traditional grid infrastructure, perform a cost-benefit analysis. Take into account elements including initial investment costs, ongoing operating costs, fuel prices, upkeep needs, and prospective sources of income from energy trading or supplementary services.

e. Environmental Impact: Assess how hybrid grid technology affects the environment, taking into account how it helps to lower greenhouse gas emissions, enhance air quality, and lessen the environmental risks connected to traditional energy sources.

Examine the environmental impact of the energy generation, storage, and grid infrastructure life cycle components of hybrid grids. Examine how well hybrid grid technology integrates and works with the current grid infrastructure, taking into account grid codes, communication protocols, and grid management systems. Examine the benefits and difficulties of incorporating hybrid grid technology into the larger energy ecosystem, taking into account the interactions with new grid technologies and other distributed energy resources. g. Policy and Regulatory Considerations: Assess the policies and regulations, including as tariffs, standards, and grid interconnection requirements, that control the installation and use of hybrid grid technologies. Examine the possibilities and obstacles for changing regulations or implementing new policies to help hybrid grid technology become more widely used. Stakeholders can learn a great deal about the performance, viability, and possible effects of hybrid grid technologies on the electrical grid and the larger energy landscape by undertaking a thorough analysis across these important domains.

VI. Fuzzy Logic Controller

A control system that uses fuzzy logic, a mathematical method of computing with words or linguistic phrases rather than exact numerical values, is known as a fuzzy logic controller (FLC). In decision-making processes, fuzzy logic enables a more adaptable and natural depiction of ambiguity and uncertainty [14].

An outline of a fuzzy logic controller's operation is provided below:

a. Fuzzy Sets and Membership Functions. In fuzzy logic systems, input and output variables are defined as fuzzy sets, with membership degrees varying from 0 to 1. The degree to which an input or output value belongs to a fuzzy set is expressed by membership functions.

b. Rule Base: A collection of fuzzy if-then rules, sometimes referred to as fuzzy inference rules, serve as the foundation for the FLC's operation. Each rule uses linguistic phrases to explain a link between input and output variables.

c. Fuzzy Inference Engine: To identify the proper output values, the fuzzy inference engine applies the fuzzy rules to the input variables. Fuzzification, rule evaluation, aggregation, and defuzzification are steps in this process.

d. Fuzzification: Fuzzification uses membership functions to transform sharp (numerical) input values into fuzzy values.

e. Rule Evaluation: - Based on the degree of membership of the input variables, each fuzzy rule's degree of satisfaction (or firing strength) is ascertained when it is applied to the fuzzy input values.

f. Aggregation: Aggregation creates a combined fuzzy result by combining the outputs of individual rules.

g. Defuzzification: Using techniques like centroid, mean of maximum (MOM), or weighted average, defuzzification transforms the combined fuzzy output into a clear (numerical) output value. FLCs are especially helpful in situations where obtaining precise mathematical models is challenging or if decision-making heavily relies on human expertise and heuristics.

They have been used in a number of industries, such as industrial automation, consumer electronics, automotive systems, and control systems. The following are a few benefits of fuzzy logic controllers:

Robustness to Uncertainty: Compared to conventional control systems, FLCs are more able to manage imprecise or uncertain information. Ease of Implementation: Fuzzy logic enables human-understandable, rule-based control systems that are simple to adjust.

Adaptability: Compared to fixed rule-based systems, FLCs are more flexible in responding to modifications in operating conditions or system dynamics. But FLCs also have certain drawbacks, such as:

Computational Complexity: Fuzzy inference can be computationally demanding and require several phases, especially for intricate systems with lots of variables and rules.

Difficulty in Tuning: Expert expertise and experience may be necessary for the design and tuning of FLCs' rule bases and membership functions.

Restricted Formal Analysis: Analysis and optimization of fuzzy logic systems are more difficult since they lack the formal mathematical foundation of conventional control theory.

The fuzzy logic controller is move towards changeable processing that considered for several principle it is most accurate controller to control the system with effectively and intelligent performance. It can solve the system problems very quickly through accurate control strategy. fuzzyfication is numerical input process for the system to fuzzy sets with prior membership function. The membership faction within the limit [0 1]. If it is 0 the value does not belong to given fuzzy set and if it is 1 the value completely belongs with the fuzzy set.

VII. Examined Simulation Outcomes

In order to quantify the performance of the maximum power point tracing control system and to determine which control strategies can be applied in unstable natural settings, the solar and wind energy system is constructed and simulated using Matlab simulation software [19]. In addition to analyzing the wind form system performance under wind speed conditions, this section examines how to improve the photo voltaic system's operational performance under variations in solar radiation [21], [22]. The hybrid power system performance simulation results were successfully examined using the maximum power point tracking method and other I intelligent control strategies. The necessary results for the system's operational performance were obtained, and a fuzzy logic controller was also implemented for improved output results.

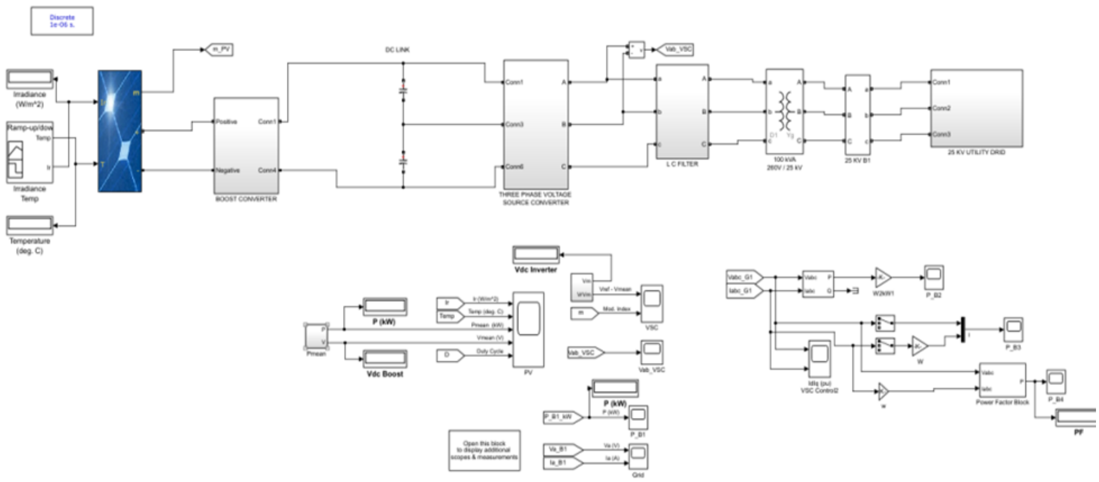

Fig. 2. Proposed System Simulink Model

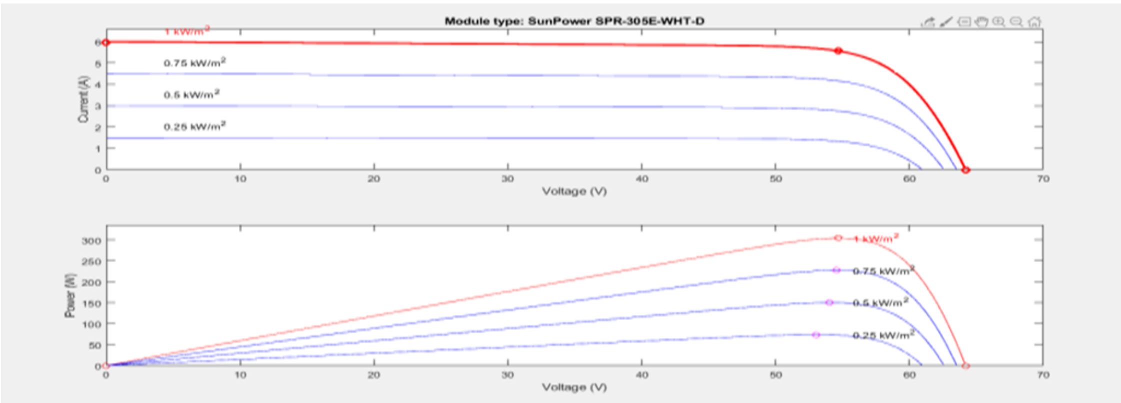

Fig. 3. V-I Characteristics of Photovoltaic System

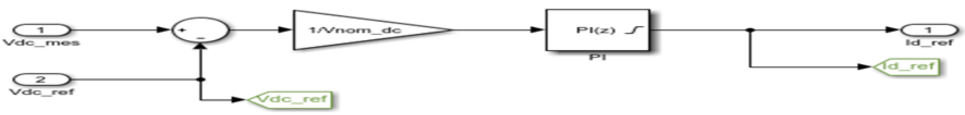

Fig. 7. Simulink PI controller

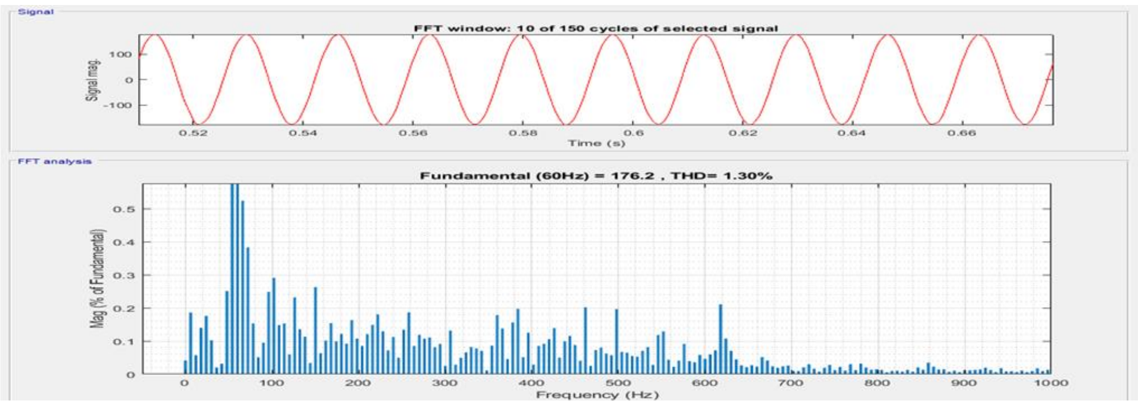

Fig. 8. PI Controller wave form and THD analysis wave form

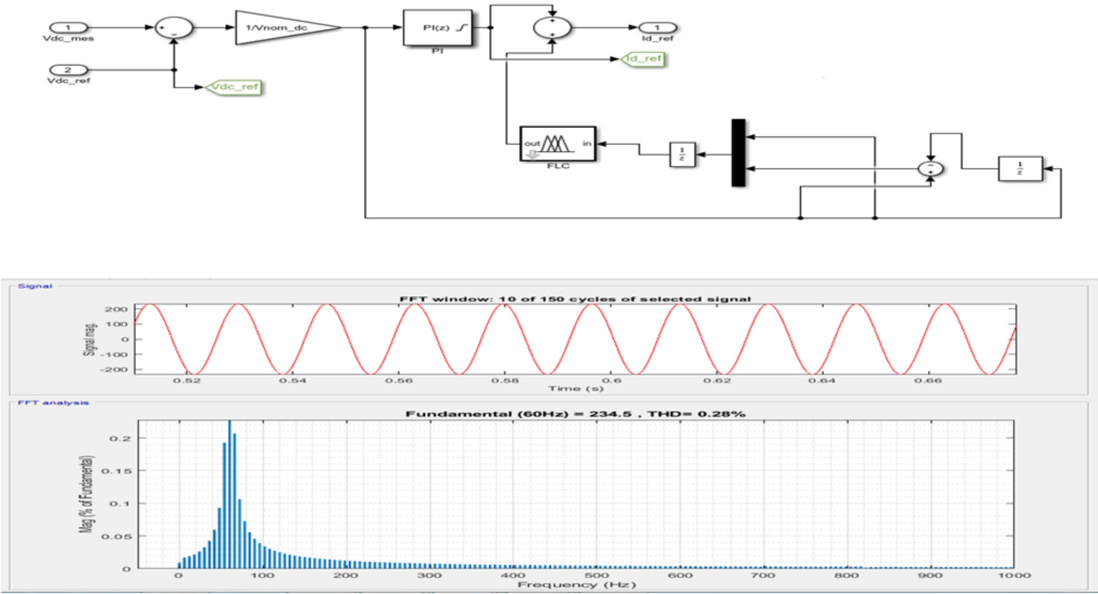

Fig. 9. Fuzzy logic Controller wave form and THD analysis wave form

VIII. CONCLUSION

The maximum power point tracking technique, fuzzy logic controller, hybrid system, and modeling of the hybrid photo voltaic wind system are implemented to investigate the simulation results. The system conflagration of the PV system rated at 1 megawatt and wind system rated at 9 megawatts successfully developed and connected grid through AC bus. With fluctuations in solar radiation, the photo voltaic system is managed using the MPPT incremental conduction method, which tracks the maximum quantity of solar electricity. The modified maximum power point tracking technique is used to operate the wind system in order to extract the highest amount of wind energy under conditions of changeable wind speed. Additionally, since produced reactive power in the hybrid power system equals zero, the PV/wind systems function at UPF. Grid voltages are intelligently controlled to remain steady under climatically changeable conditions.

REFERENCES

[1] H. Laabidi and A. Mami, "Grid connected Wind-Photovoltaic hybrid system," in 2015 5th International Youth Conference on Energy (IYCE), pp. 1-8, 2015. 568

[2] A. B. Oskouei, M. R. Banaei, and M. Sabahi, "Hybrid PV/wind system with quinary asymmetric inverter without increasing DC-link number," Ain Shams Engineering Journal, vol. 7, pp. 579-592, 2016.

[3] R. Benadli and A. Sellami, "Sliding mode control of a photovoltaic-wind hybrid system," in 2014 International Conference on Electrical Sciences and Technologies in Maghreb (CISTEM), pp. 1-8, 2014.

[4] A. Parida and D. Chatterjee, "Cogeneration topology for wind energy conversion system using doubly-fed induction generator," IET Power Electronics, vol. 9, pp. 1406-1415, 2016.

[5] B. Singh, S. K. Aggarwal, and T. C. Kandpal, "Performance of wind energy conversion system using a doubly fed induction generator for maximum power point tracking," in Industry Applications Society Annual Meeting (IAS), 2010 IEEE, 2010, pp. 1-7.

[6] Rahul, Immadisetty, and Raju Hariharan. "Enhancement of Solar PV Panel Efficiency Using Double Integral Sliding Mode MPPT Control." Tsinghua Science and Technology 29.1 (2023): 271-283.

[7] Vignesh, T., and R. Hariharan. "Design and performance analysis of three phase solar PV integrated UPQC." AIP Conference Proceedings. Vol. 2426. No. 1. AIP Publishing, 2022.

[8] Kumar, MVNR Pavan, and R. Hariharan. "Improved trustworthy, speed, and energy-efficient GPSR routing algorithm in large-scale WSN." Measurement: Sensors 24 (2022): 100576.

[9] Rajesh, S., R. Hariharan, and T. Yuvaraj. "Cuckoo search algorithm based critical load restoration with dgr using virtual instrumentation." Int. J. Innov. Technol. Explor. Eng (2019). Sukraj, K., et al. "Simultaneous allocation of shunt capacitor and distributed generator in radial distribution network using modified firefly algorithm." 2019 International Conference on Smart Structures and Systems (ICSSS). IEEE, 2019.

[10] Hariharan, R., P. Usha Rani, and P. Muthu Kannan. "Sustain the critical load in blackout using virtual instrumentation." Intelligent and Efficient Electrical Systems: Selected Proceedings of ICIEES’17. Springer Singapore, 2018.

[11] Hariharan, R., and P. Usha Rani. "Blackout restoration process by PHEV charging station integrated system using virtual instrumentation." 2017 Fourth International Conference on Signal Processing, Communication and Networking (ICSCN). IEEE, 2017.

[12] [Gowtham, S., M. Hemanth, and R. Hari Haran. "A Review on Power System Stability Analysis & Control by Intelligence System." Indian Journal of Public Health Research & Development 8.4 (2017).

[13] Hariharan, R., and P. Usha Rani. "Optimal Generation Start-Up strategy for Blackout Restoration Using Virtual Instrumentation." Indian Journal of Public Health Research & Development 8.4 (2017).

[14] Sowmiya, N., P. Nandhini Devi, and R. Hariharan. "Review on Challenges Facing on Smartd grid Overcome by Intelligence System." Indian Journal of Public Health Research & Development 8.4 (2017): 1111-1117.

[15] D. Sera, L. Mathe, T. Kerekes, S. V. Spataru, and R. Teodorescu, "On the perturb-and-observe and incremental conductance MPPT methods for PV systems," IEEE journal of photovoltaics, vol. 3, pp. 1070-1078, 2013.

[16] M. Brenna, R. Faranda, and S. Leva, "Dynamic analysis of a new network topology for high power grid connected PV systems,"in 2010 IEEE Power and Energy Society General Meeting, pp. 1-7, 2010.

[17] B. E. Strand, "Voltage Support in Distributed Generation by Power Electronics," Master of Science in Energy and Environment, pp. 1-87, June 2008.

[18] A. Althobaiti, M. Armstrong, and M. Elgendy, "Current control of three phase grid-connected PV inverters using adaptive PR controller," in2016 7th Renewable Energy Congress (IREC), International, pp. 1-6,2016.

[19] T. R. Ayodele, A.-G. A. Jimoh, J. Munda, and J. Agee, "Dynamic Response of a Wind Farm Consisting of Doubly-Fed Induction Generators to Network Disturbance," in Simulation and Modeling Methodologies, Technologies and Applications, ed: Springer, pp. 131- 150, 2013.

[20] M. Zhou, G. Bao, and Y. Gong, "Maximum power point tracking strategy for direct driven PMSG," in 2011 Asia-Pacific Power and Energy Engineering Conference (APPEEC), pp. 1-4, 2011.

[21] N. W. Miller, W. W. Price, and J. J. Sanchez-Gasca, "Dynamic modeling of GE 1.5 and 3.6 wind turbine-generators," GE-Power systems energy consulting, 2003.

[22] V. Rajasekaran, "Modeling, simulation and development of supervision control system for hybrid wind diesel system," Thesis for the degree of master of science in applied science, pp. 1-123, 2013.