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ANFIS Controller for Hybrid Power Generation with Bidirectional VSC

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This research propose the design and execution of an Adaptive Neuro-Fuzzy Inference System (ANFIS) controller for a hybrid power generating system that combines solar and wind energy sources with a bidirectional Voltage Source Converter (VSC). The suggested system seeks to improve power quality, optimize energy usage, and provide uninterrupted bidirectional power flow among renewable sources, the load, and the grid. The ANFIS controller integrates the learning abilities of neural networks with the decision-making skills of fuzzy logic, allowing it to dynamically adjust to changing renewable energy inputs and diverse load circumstances. The bidirectional VSC enables efficient energy transfer with the grid, provides reactive power correction, and maintains voltage stability. The simulation findings illustrate the efficacy of the ANFIS controller in attaining rapid response, little harmonic distortion, and stable operation, establishing it as a formidable option for contemporary renewable energy systems. Below, we propose the ANFIS controller for regulating generation and grid. The primary purpose is integrated application of renewable energy concepts and control systems for the qualitative and measurable improvement of electrical power generated from solar and wind resources. The power produced from basic solar and wind resources is typically at a particular level. Yet the addition of solar and wind sources and control systems will definitely be extra in quantity and by the application of power digital converters, the power generated will be a lot more efficient.

Keywords: ANFIS, PV, Wind, Dc-Dc converter, Grid, BtB.

1. Introduction

1) The importance of renewable resource sources is growing rapidly in the modern world. Since these sources will undoubtedly produce much less air pollution than other conventional (non-renewable) energy sources, their use is generally encouraged. When weighed against traditional energy sources, non-conventional ones consistently come out on top when it comes to cost savings, reduced contamination levels, fuel preservation, maintenance requirements, and simple disposal of old gas. But because of their cyclical nature, they can't be there whenever you need them. The use of such resources to meet the need for energy supply

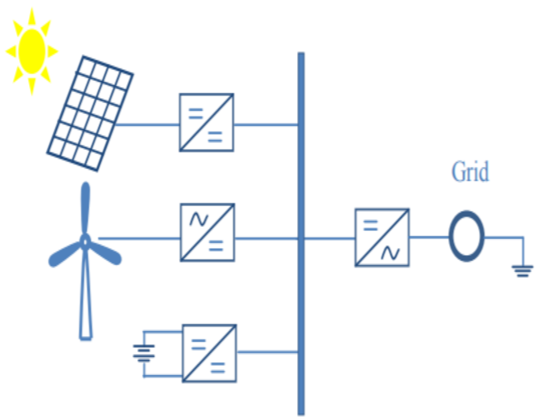
becomes problematic in light of this characteristic. To sidestep the complication of connecting to the power grid, we are just using two of these sources here, although combining them is one way to encounter this difficulty. To ensure that the provided environmentally friendly sources are fully used. Renewable energy sources that are widely accessible include wind and solar power. Presently existing ways exist for removing power and transforming it into electrical energy. Using these two resources to produce electricity will therefore undoubtedly be less complicated. Besides the previously mentioned last points, the price of both power sources has been rising sharply over the last few days. Additionally, two resources are used: wind and solar energy, which have periodic properties and an uncontrolled high quality. Power digital converters are utilized as interface devices with the load incurable or the current grid. Distributed generation devices are manufactured at this stage. Dispersed generation is typically reserved for a single kind of renewable energy.

1)Incorporating both wind and solar electricity boosts the overall functional efficiency since their availability is generally correlated.

2)Wind and solar co-generators work together to make better use of land sources, which in turn makes capital investments better.

3) Due to the moment of inertia in the mechanical system of the wind generators, wind-solar co-generation systems are much more capable of dynamically supporting the utility-grid than stationary PV generators.

4) The reliability of generating is enhanced by having two power supplies. There has been little maintenance on the wind-PV regeneration systems that are linked to the grid. However, for independent off-grid use, there are a variety of wind-PV co-generation systems that come highly recommended.



Main Objective of research:

Compared to the one described in [5], a new geography for connecting renewable energy sources like wind and solar to the power grid is simpler and more dependable. The necessary information for the document is as follows: The integrated BtB VSCs might be used to connect linked wind and solar power plants to the power grid and, as they do not want any additional electrical switches, Energy grids can only achieve optimum power factor tracking (MPPT) by regulating the dc-link voltage with the help of an ANFIS controller and a voltage-source rectifier (VSR). A small-signal state-space variant is used to describe the complete security of the suggested system. Using time-domain simulations in a range of practical scenarios, including utility-grid outages, the suggested hybrid system's efficiency has been examined.

2. SURVEY OF RESEARCH

Authors: Vaibhav J. Babrekar and colleagues. [1] Today, energy is a need for the twenty-first century. Because they are abundant, non-polluting, and easily accessible, renewable resource sources are put to good use. However, hybrid energy systems may overcome the drawbacks of these capabilities in their solo versions, such as changability and schedule inconsistency. They often include a variety of renewable resource sources put together. They provide efficient defense against power issues, harmonic actions, voltage and frequency variations, and standalone systems. By using an appropriate layout, sophisticated rapid feedback, excellent optimization, control feasibility, and reducing complexity, hybrid power systems are able to preserve the most cheap unit cost and handle power variations caused by DPSP (deficiency of power supply probability). Testimonials of solar and wind power systems that combine the two are provided in this article. The technical feasibility of a PV wind hybrid system in the given tonnage range was examined, and the model was used to construct an economical evaluation of PV wind hybrid systems, freestanding PV systems, and standalone wind systems. According to R. Chedid (2017) [2] in In order to help decision makers investigate the factors impacting the design of a grid-linked hybrid solar-wind power system (HSWPS), this study provides a decision-support tool. These factors are mostly related to issues of politics and society, as well as technological developments and economics. To quantify the many different approaches, methods, and occurrences that lead to uncertainty and disarray in HSWPS planning, the Analytic Hierarchy Process (AHP) is used. The relevant compromise outlines are acquired by developing multiple tactics under 16 different futures using the trade-off danger technique. The knee set is constructed using the least distance approach in this novel three-dimensional model of a trade-off surface, which differs from the conventional two-dimensional simulation. The frequency with which each future's conditional choice collection occurs distinguishes robust methods from poor ones, and a hedging assessment is carried out to decrease danger in order to assign other options in the event that high-risk futures arise. V. K. Gajbhiye and colleagues (2017) the third Any nation's economy and society can't develop without reliable energy sources. The production of electricity is a global problem. There needs to be responsible use of the finite fossil fuel supplies. Increased pollution is a result of this power generation. Utilizing a combined solar and wind power system may provide several benefits, allowing it to be used all year round. The proposed research study is based on the testimonials of various types of solar and wind linked hybrid systems.

In 2017, Yazhini et al. [4] This study takes a look at how renewable energy sources can be integrated into the grid using some of the latest interface technologies. It is a big undertaking to include a substantial portion of renewable resource resources into the power grid architecture, since power circulation typically occurs in a single direction from centralized plants to users, because many renewable energy resources are inherent to the system. Renewable energy facilities are smaller in size compared to traditional power plants. However, renewable resources should be taken into account as new sources.

M In 2018, SASHILAL became an associate teacher. [5] While there are many problems affecting our planet today, everyone agrees that emissions of greenhouse gases

(GHGs) are the most detrimental. Carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, and perfluorocarbons are all examples of greenhouse gases. Reducing these gases would cause the Earth's temperature to drop below what humans can sustain, as they help keep the world at a comfortable level for microbes. But, since greenhouse gases (GHGs) let sunlight into the atmosphere but retain the heat radiated from the Earth's surface, an increase in these emissions would cause global warming, which might be deadly to living microbes. For the same reason that meteorological and nautical patterns change as the Earth's temperature rises, many scientists believe that climate change is maintaining the growth in natural disasters.

Using a level-sensitivity analysis of life-process expenditure calculation, Mohanlal Kolhe et al. [6] compared the cost-effectiveness of a standalone solar photovoltaic (pv) system to that of a diesel-powered system, which is one of the most common traditional alternatives for meeting power demand. Many important elements have been included in the energy demand assessment, including diesel fuel price, diesel system lifespan, fuel increase rate, solar isolation, PV selection expense, and reliability, as well as price cuts and diesel fuel prices. With an average daily energy demand of around 15 kWh, even in the face of negative financial conditions, the results demonstrated that PV powered systems may be a cost-effective solution.

A design was developed by Usha Bajpai et al. [7] for a freestanding solar powered system that maximizes the dimensions of the PV panel and battery. Area, performance, cell power, and selection bias were the determinants of PV system optimization. Thus, this kind of PV power system may be more reliable, practical, and palatable on its own. Philip(2003) also conducted research on the design, installation, and operation of a standalone wind-diesel power supply system for off-grid uses. The outcome shows that the mechanism worked as expected. A research on wind power use in a residence in Izmir, Turkey, was evaluated and provided by Aydogan Ozdamar et al. [8]. With an eye on cost-effectiveness, the standard version determines how many batteries are needed for a constant flow of electricity from each wind generator. At low wind capacity sites, the wind battery hybrid system did not seem to be cost-effective.

The potential availability of wind energy resources in central Asia has been discussed by Kanat A. Baigarin et al. [9]. An extensive discussion has taken place about the formulae that are used to ascertain the distribution of wind power production, energy thickness, energy price, and effectiveness.

Based on the website and the kind of wind turbine, Suresh H. et al. [10] have created a design to investigate the optimal seating of wind turbine generators. The methodology relied on precise assessments of the wind power potential of many locations. Using the waybill analytical version that takes the cubic mean cube of the wind speeds as its starting point, the logical calculation of the annual and monthly ability factors has been completed. Using the suggested methodology, one may cautiously choose possible locations for wind turbine generating systems and websites.
In his discussion of storing extra wind power for later use in power production, Wen-jei Yang [11] used the same approach to determine how much electricity a wind turbine was producing. The experimental style requirements for a medium-sized wind generator for remote and hybrid power systems were explored by Rogers et al. (2002). The practical challenges of setting up tool and big wind turbines in inconvenient locations have also been resolved.

3. PROPOSED RESEARCH

Below is the schematic illustrating the proposed system. A voltage source rectifier connects the wind generator to the grid, while a voltage source inverter couples the hybrid co-generation system to the wind generator. The dc-link capacitor of the BtB VSCs is directly connected to the PV generator using a dc wire. Each of the six cells that make up the VSR and VSI contains an in-gate bipolar transistor (IGBT) connected to a diode. Modeling and control of the suggested system are described in depth in the section that follows. An external circuit on the machine-side-VSC regulates the dc-link voltage to the PV panel's maximum power-point monitoring (MPPT) value. AC voltage regulator with a proportional-and-integral (PI) loop. Using a hysteresis existing controller as the law, the recommended values of the machine-side currents are found using the simultaneous discovery approach. A hysteresis grid-current controller is used to inject all currents into the utility-grid on the grid-side VSC. Consistent with the benefits of the proposed approach, the following considerations are made:
1) In many circumstances, the process of both VSCs is included in the MPPT of either PV or wind power, which might lessen system dependability and raise losses. In the event that the wind generator's cut-off rate is met—that is, no wind power the machine-side VSC may not be able to follow the solar PV MPPT dc-link voltage.
2) The machine side regulates the dc-link voltage, and the wind turbine's rate is not directly proportional to it (i.e., a solution operation).
thirdly, hysteresis controllers are used to manage the maker and grid-side currents, which results in a changeable changing frequency and higher harmonic materials. This study presents a novel, user-friendly, and efficient geography for integrating wind and solar generators into the utility-grid. It is motivated by the promising benefits of hybrid wind and solar power systems as well as the obstacles to implementing such a system. This paper conforms with the following contributions:
1) The knowledge that BtB VSCs may be used by grid-connected wind and solar generators in conjunction with one another, eliminating the need for electrical power control buttons.
2) In this system, the VSR is responsible for maximum power point tracking (MPPT) of the wind generator, while the VSI controls the dc-link voltage to capture as much PV power as possible and feed it into the utility grid.
3) Building the full small-signal state-space implementation of the proposed system to define the overall security of the system.
4) Using time-domain simulations, we have tested the suggested hybrid system's efficiency under various operational conditions, including utility-grid failures.

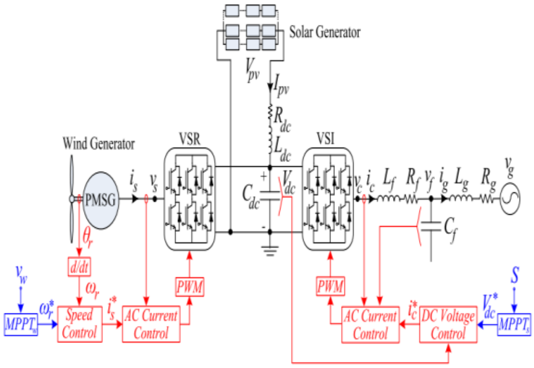


Fig.1. Model diagram

4. WORKING METHODOLOGY

1) The efficient integration of renewable energy sources with little use of power digital conversion stages is shown by hybrid wind-solar systems. However, these devices are only meant for use in isolated areas away from the power grid. The authors are aware that, to the best of their knowledge, grid-connected wind-solar systems have already been extensively discussed. An BtB VSC serves as the user interface between the utility-grid and the solar and wind producers in the system. An external loop Proportional-and-Integral (PI) dc voltage controller on the machine-side-VSC regulates the dc-link voltage to the optimal power-point tracking (MPPT) value of the PV panel. Using the concurrent discovery technique, we calculate the recommended values of the machine-side currents and utilize a hysteresis current controller as the guideline. The full currents are injected into the utility grid by means of a hysteresis grid-current controller on the grid-side VSC.
We keep the compliance hurdles in mind notwithstanding the possible advantages of the suggested method.
1)In certain circumstances, the operation of both VSCs is required for MPPT of PV and wind generation, which might reduce system reliability and increase losses. For example, the machine-side VSC may fail to monitor the solar PV MPPT dc-link voltage if the wind speed is below the wind turbine's cut-off rate, meaning there is no wind power.
2)The machine side controls the dc-link voltage, and a solution operation does not provide a direct guideline for the wind generator's speed.
Higher harmonic materials and changeable changing regularity are the outcomes of hysteresis controller regulation of machine and grid-side currents.

5. SIMULATION RESULTS

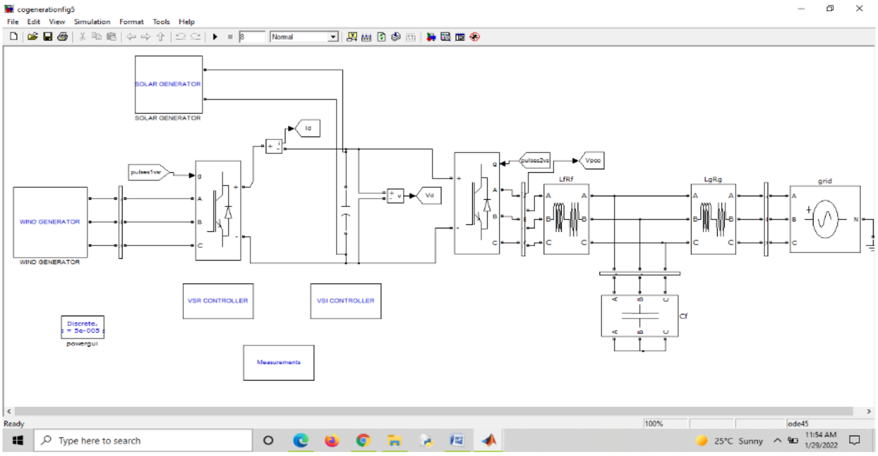


Fig.2. Simulation circuit.

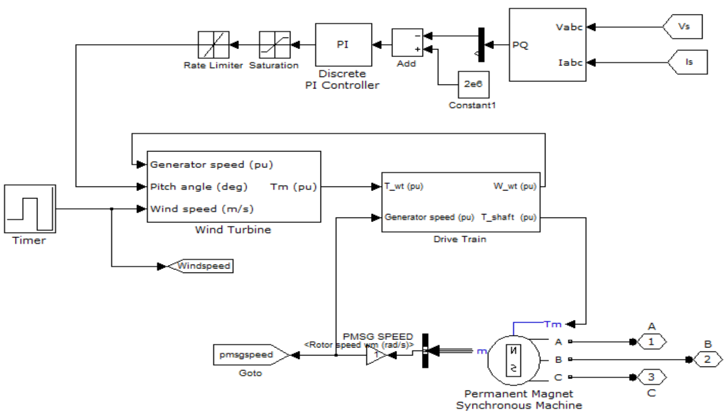


Fig.2. Wind power generation.

In the hybrid solar and wind power generation system, the total power generated (Ptotal) is the sum of the power contributions from the solar photovoltaic (PV) array (Psolar) and the wind turbine (Pwind). The equations governing power generation can be expressed as:

Ptotal=Psolar+Pwind

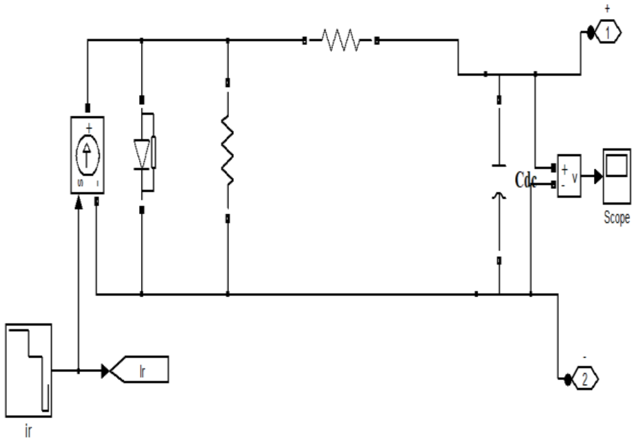


Fig.3. Solar PV system generation unit.

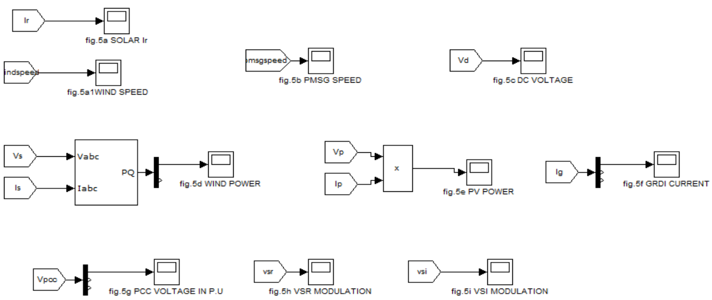


Fig.4. Simulation results.

For solar power, the output is given by:

$P_{solar}=\eta_{solar}\cdot A\cdot G\cdot \cos(\theta)$

where η_{solar} is the efficiency of the solar panel, A is the panel area, G is the solar irradiance, and θ\thetaθ is the angle of incidence. For wind power, the output is:

$$P_{\text{wind}} = \frac{1}{2} \cdot \rho \cdot A_{\text{rotor}} \cdot v^3 \cdot C_p$$

where ρ is the air density, A_{rotor} is the rotor swept area, v is the wind speed, and C_p is the power coefficient of the turbine. These sources are integrated using a bidirectional Voltage Source Converter (VSC) to manage power flow efficiently between the hybrid system, the load, and the grid.

Performance of the wind and solar generators:

The performance of wind and solar generators operating in conjunction with the grid is characterized by their complementary nature and ability to enhance overall energy reliability and efficiency. Wind generators typically produce more energy during windy periods, which often occur at night or during storms, while solar generators are most effective during sunny days. When integrated with the grid, these renewable sources can provide a more stable and continuous power supply, compensating for each other's variability. This synergy helps reduce the reliance on fossil fuels, lowers greenhouse gas emissions, and improves energy security. Advanced grid management systems and energy storage solutions further enhance this performance by balancing supply and demand, storing excess energy during peak production, and ensuring a consistent and reliable power output.

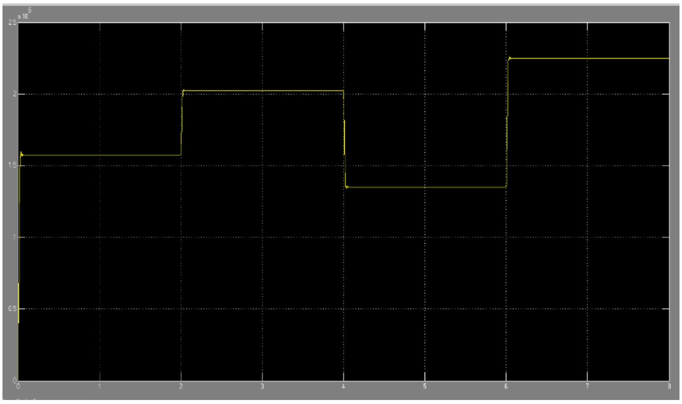


Fig.5. Wind power generation.

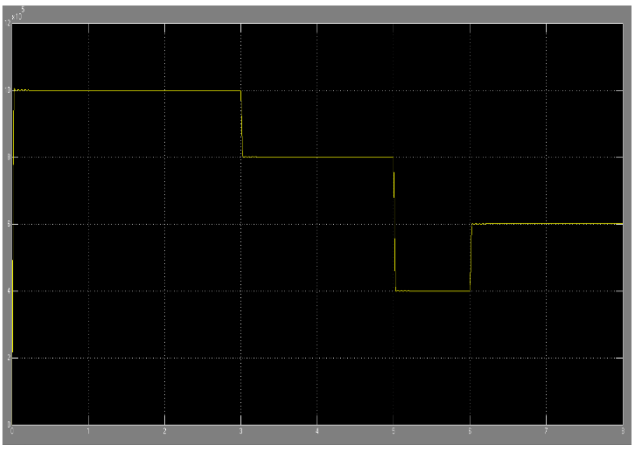


Fig.6. Solar panel generation.

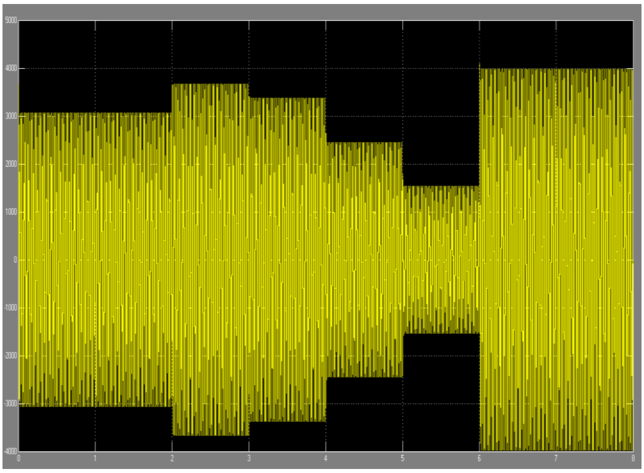


Fig.8. Grid current.

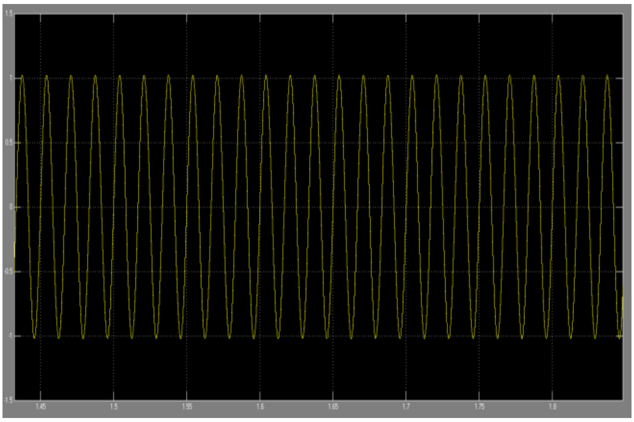


Fig.9. Voltage across the PCC.

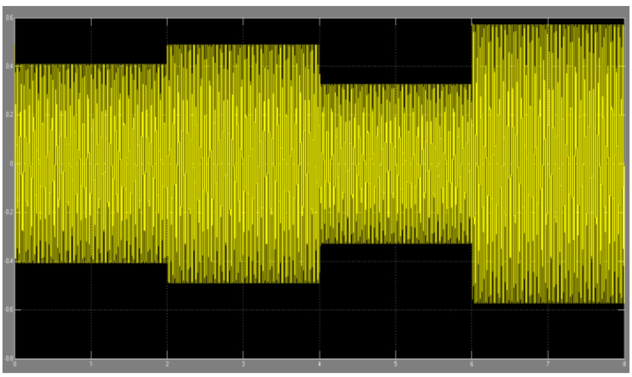


Fig.10. Output across the VSR.

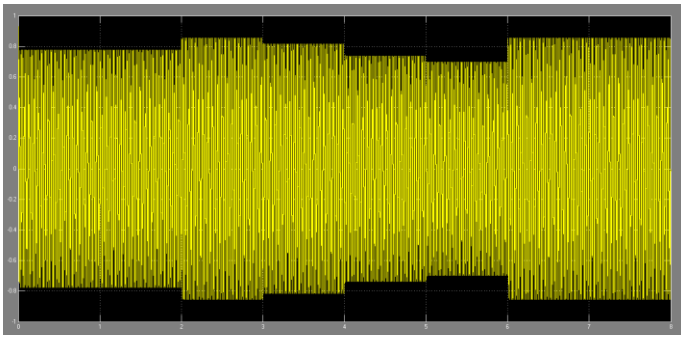


Fig.11. Output across the VSI.

Performance of the wind generator only:

The performance of wind generators in a hybrid circuit with the grid is characterized by their ability to produce electricity efficiently during windy conditions, often complementing other renewable sources like solar. Wind generators, when connected to the grid, provide a consistent and renewable energy supply, particularly during nighttime or stormy weather when wind speeds are typically higher. This integration enhances grid stability by supplying additional power during peak demand times and reducing reliance on fossil fuels. The hybrid setup ensures that any fluctuations in wind power generation are balanced by the grid, maintaining a steady and reliable energy output. Advanced energy storage solutions can further optimize this performance by storing excess wind energy, thus improving overall energy reliability and supporting continuous power availability even when wind conditions are not favorable.

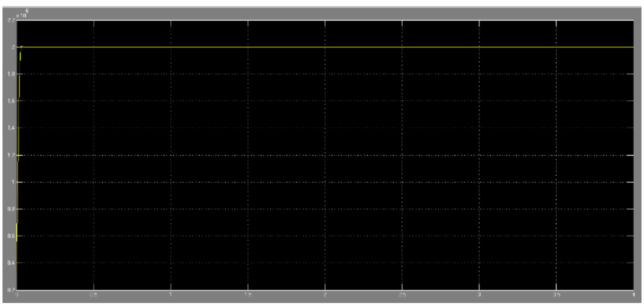


Fig.10. Wind power.

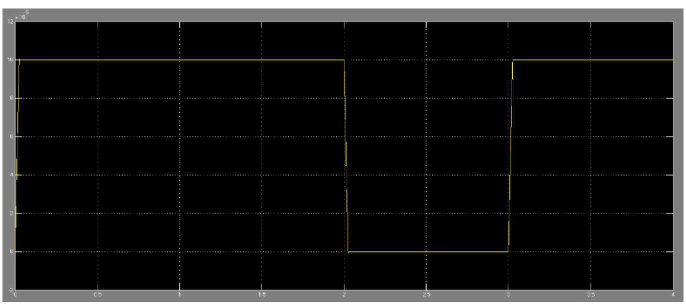


Fig.11. PV power generation.

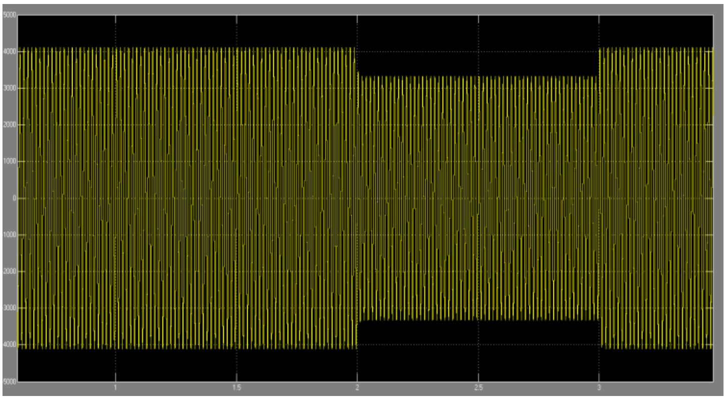


Fig.12. Grid current.

Performance of the PV generator only:

The performance of solar generators in a hybrid circuit with the grid is marked by efficient daytime energy production, directly harnessing sunlight to generate electricity. Solar generators, integrated with the grid, offer substantial benefits by providing renewable energy during peak sunlight hours, reducing the grid's dependence on non-renewable sources. The hybrid system ensures a reliable power supply by compensating for fluctuations in solar output with grid support, especially during cloudy periods or at night when solar production ceases. Energy storage systems like batteries can store excess solar energy, enhancing the system's reliability and allowing for energy use during low production times. This integration not only helps in reducing electricity costs but also contributes to lowering carbon footprints, promoting sustainable energy practices.

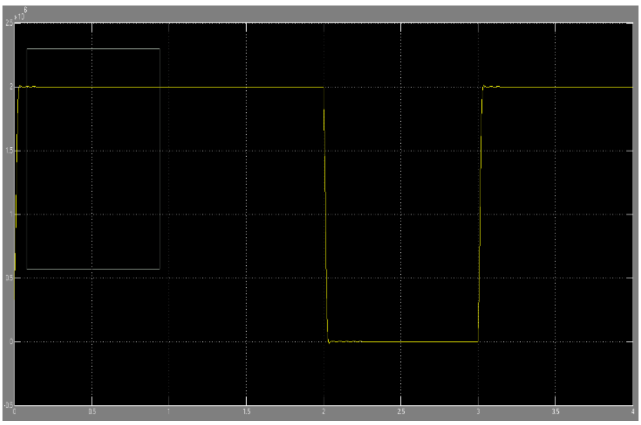


Fig.13. Wind power output.

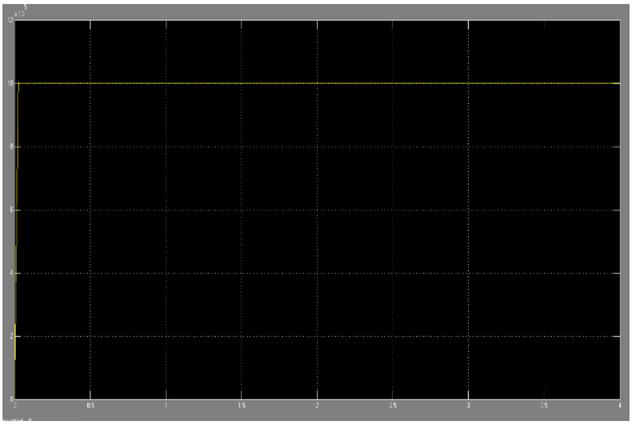


Fig.14. PV power output.

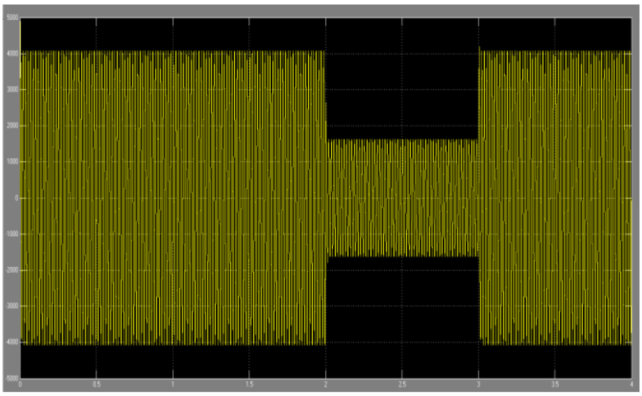


Fig.15. Grid current.

Response to a 3PG fault at t = 4.0 s for 4.0 cycles – 1.0 and 0.5 p.u. wind power generation with 1.0 p.u. solar power.

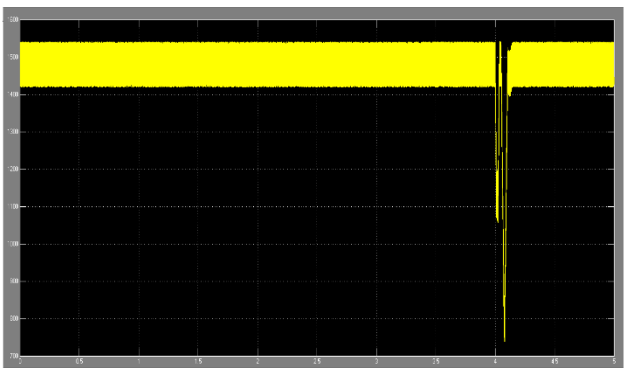


Fig.16. Output of DC voltage.

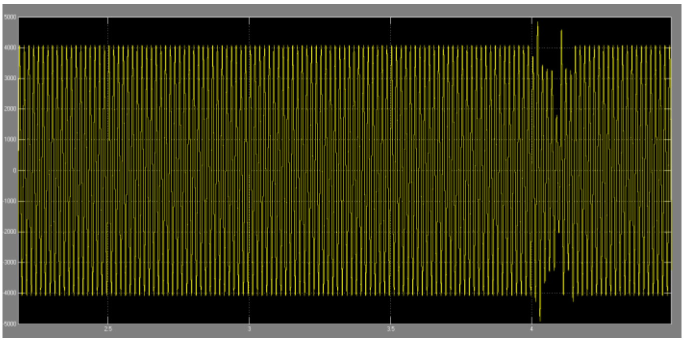


Fig.17. Grid current values.

Response to a 3PG fault at t = 4.0 s for 4.0 cycles – 1.0 p.u. wind and solar power generation with implemented fault protection schemes.

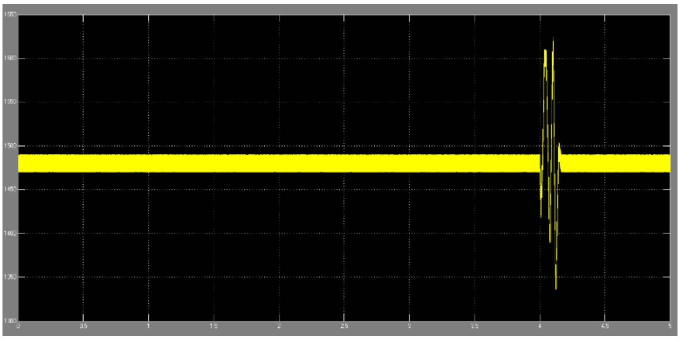


Fig.18. Output of DC voltage.

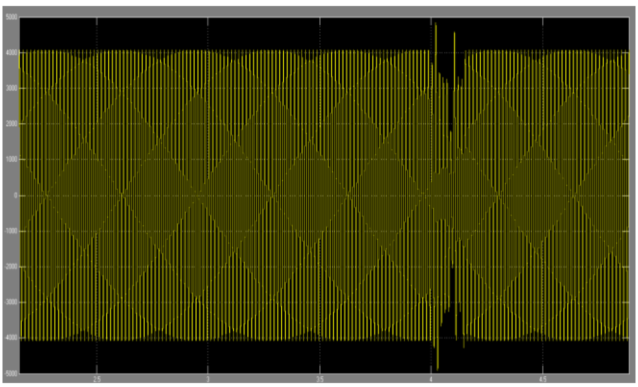


Fig.19. Grid current output.

Response to a 1PG fault at t = 4.0 s for 4.0 cycles – 1.0 p.u. wind and solar power generation with and without the fault protection schemes.

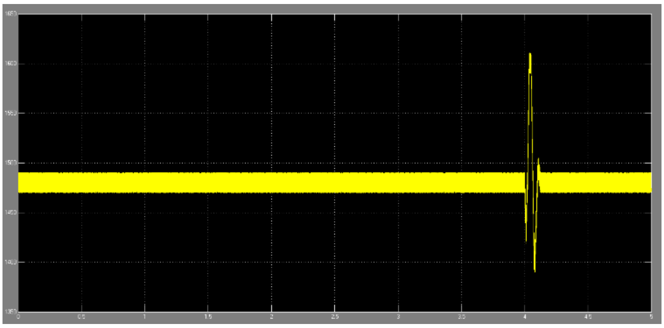


Fig.20. Output of Dc voltage.

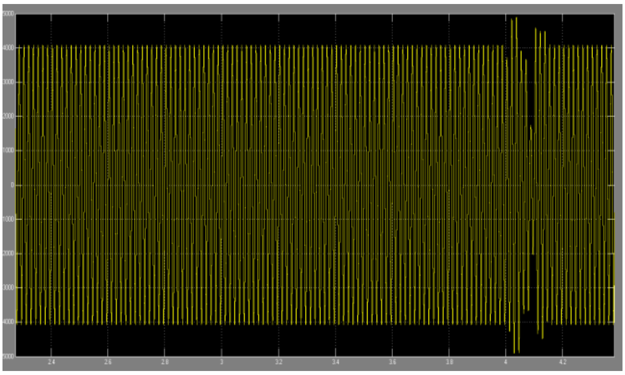


Fig.21. Grid voltage Output.

WITH ANFIS CONTROLLER:

An Adaptive Neuro-Fuzzy Inference System (ANFIS) controller, integrated with solar and wind power generation in a grid-connected setup, optimizes the overall performance and reliability of the hybrid energy system. ANFIS combines the learning capabilities of neural networks with the fuzzy logic approach to handle the nonlinear and dynamic nature of renewable energy sources. This controller effectively manages the intermittency and variability of solar and wind power by adjusting control parameters in real time based on input data, such as weather conditions and power demand. By continuously learning and adapting, ANFIS ensures optimal energy distribution, enhances grid stability, and improves the efficiency of power generation. This intelligent control system minimizes energy losses, balances load demand, and ensures a reliable and consistent power supply, making the integration of renewable sources more efficient and sustainable.

The Adaptive Neuro-Fuzzy Inference System (ANFIS) controller is central to ensuring efficient operation by dynamically managing power distribution and maintaining power quality. The controller takes input parameters such as solar irradiance, wind speed, load demand, and grid conditions. It uses fuzzy logic rules to infer control actions and neural network learning to adapt to varying conditions. The bidirectional VSC performs dual functions: it converts DC power from the hybrid system to AC for grid compatibility and facilitates bidirectional power flow, enabling energy export to or import from the grid. The ANFIS controller adjusts the reference voltage and current for the VSC to regulate reactive power (Q) and active power (P) based on the following relationships:

$$P = V \cdot I \cdot \cos(\phi), \quad Q = V \cdot I \cdot \sin(\phi)$$

where V is the voltage, I is the current, and ϕ is the phase angle. By maintaining a power factor close to unity, the system minimizes losses and enhances grid stability.

Performance of the wind and solar generators

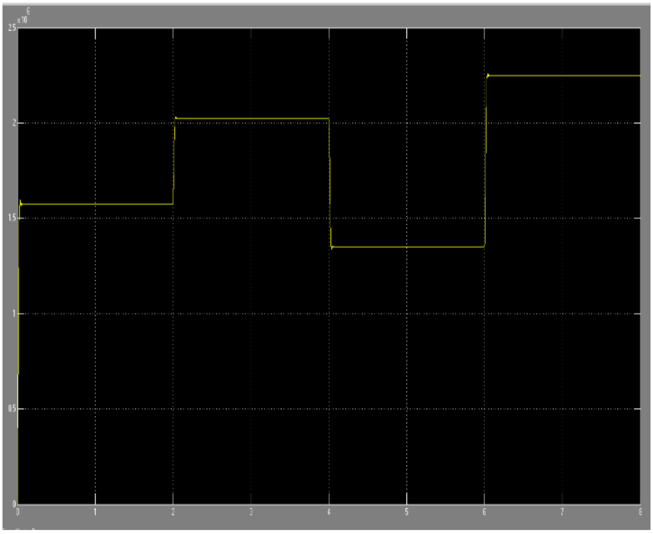


Fig.22. Wind power generation.

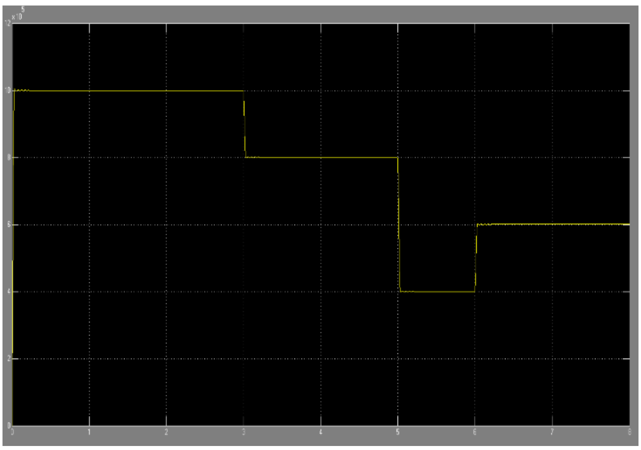


Fig.23. Solar panel generation.

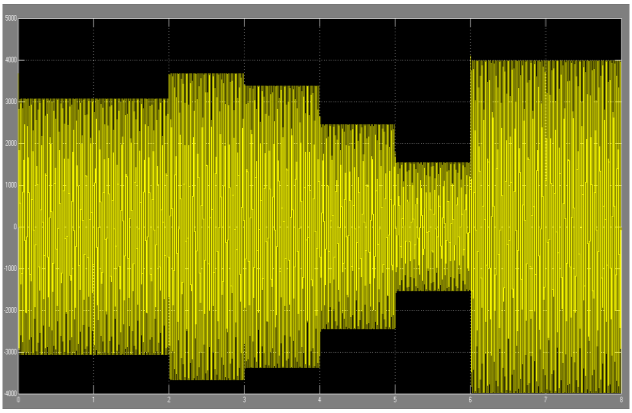


Fig.24. Grid current.

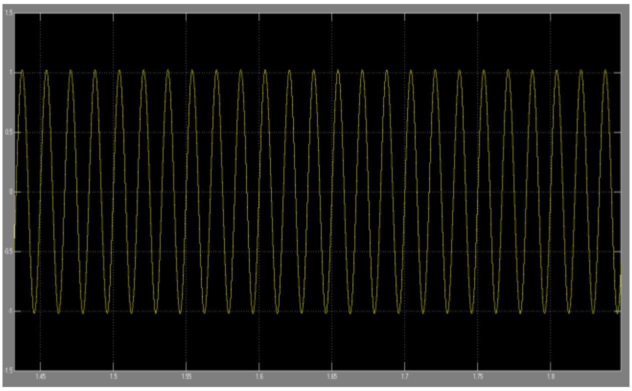


Fig.25. Voltage across the PCC.

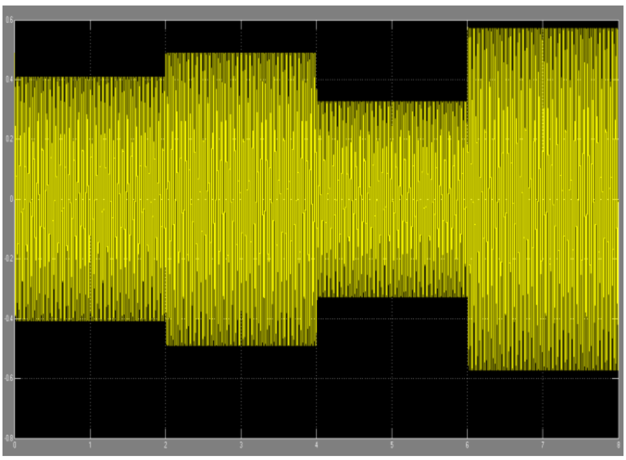


Fig.26. Output across the VSR.

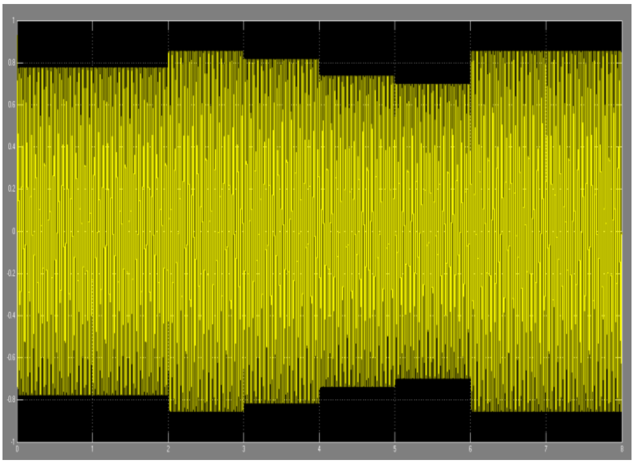


Fig.27. Output across the VSI.

Performance and Benefits

The integration of the ANFIS controller with the bidirectional VSC ensures smooth operation of the hybrid power system under varying environmental conditions. During periods of high renewable energy generation, excess power is directed to the grid, while during deficits, the grid supplements the load demand. The controller also manages battery energy storage for peak load shaving and energy backup, further enhancing reliability. Simulation studies demonstrate the system's ability to achieve low total harmonic distortion (THD) in the output voltage and current, quick response to dynamic changes, and robust performance in power factor correction. This hybrid system, governed by an intelligent ANFIS controller, exemplifies an efficient, adaptive, and scalable solution for modern sustainable energy systems.

6. Conclusion

Using vector-controlled grid-connected BtB VSCs, this research has shown planetary and wind hybrid systems. The wind generator's VSR is responsible for extracting the greatest wind power in accordance with the variations in wind speed. From the utility-grid perspective, the VSI is responsible for optimizing the power output of the PV generator, achieving power balance across the dc-link capacitor, and maintaining a constant PCC voltage in all operating modes. In order to test the safety of the system, a small-signal internalization analysis was run on the whole state-space model. A well-designed topology, improved rapid feedback control centers, and well-optimized hybrid systems may overcome this problem to a great extent. This study provided a synopsis of many research tasks concerning the control, topology of power electronics, and optimum size of hybrid solar PV and wind systems that are either linked to the grid or operate independently. No matter whether they're connected to the grid or not, hybrid systems that combine wind power with solar PV may be connected using a standard DC or air conditioning bus.

References

1. Vaibhav J. Babrekar, Shraddha D. Bandawar, Ashwini R. Behade, “Review Paper on Hybrid Solar-Wind Power Generator”, International Journal of Computer Applications (0975 – 8887) Volume 165 – No.5, May 2017.
2. R. Chedid, “A DECISION SUPPORT TECHNIQUE FOR THE DESIGN OF HYBRID SOLAR-WIND POWER SYSTEM”, IEEE Transactions on Energy Conversion, Vol. 13, No. 1, March 2017.
3. . V. K. Gajbhiye1, Prof. A. A. Kanaskar2, Prof. S. S. Jawre, “Solar Wind Hybrid System- A Review”, International Journal of Research in Advent Technology, Vol.5, No.5, May 2017.
4. M. SASHILAL Associate Professor, Dept. of Electrical Engineering Jaipur National University, Jaipur, national university jaipur, “A Review on Renewable Energy Sources for Hybrid Power generation 1 jan 2018.
5. Mohanlal Kolhe, Sunita Kolhe and Joshi J.C. (2002) ‘Economic viability of stand-alone solar photovoltaic system in comparison with dieselpowered system for India’, Energy Economics, Vol.24, pp.155-165.
6. Usha Bajpai and Suresh C Bajpai (2003) ‘Some aspects of array and storage battery sizing in stand alone photovoltaic power systems’, Proceedings of the 26th National Renewable Energy Convention of the SESI, pp. 222-227.
7. G.Venu, S.Tara Kalyani “ Robust Fractional Order Sliding Mode Controller for BLDC Motor” Journal of Advance Research in Dynamical and Control Systems,(JARDCS), Volume-12 Issue-6 March, 2020,PP.108-118 .
8. G.Venu, S.Tara Kalyani “A New Topology for Speed control of Sensor less BLDC Motor with Reduced Commutator Switches and Improved Input Power Factor” International Journal Of Engineering And Computer Science ISSN:2319-7242,Volume 3 Issue 11 November, 2014 Page No. 9243-9247.
9. G.Venu, S.Tara Kalyani “Permanent Magnet Brushless DC Motor Control Using Hybrid PI and Fuzzy Logic Controller” International Journal of Engineering Technology Science and Research”(IJETSR), ISSN 2394 – 3386,Volume 5, Issue 4,April 2018.
10. Aydogan Ozdamar, HasanYildiz and OzgurSar (2001) ‘Wind energy utilization in a house in Izmir, Turkey’, International Journal of Energy Research, Vol. 25, pp. 253-261.
11. Kanat A. Baigarin and Andre de Boer ‘Potential of renewable energy resources in Central Asia’, A text book on Renewable Energy, pp.73- 80.
12. Suresh H., Jangam shetti, and Guruprasada Rau V. (2001) ‘Optimum siting of wind turbine generators’, IEEE Transactions on Energy Conservation, Vol. 16, pp. 8-13.
13. L. Xu, X. Ruan, C. Mao, B. Zhang, and Y. Luo, “An improved optimal sizing method for wind-solar-battery hybrid power system,” IEEE Trans. Sustain. Energy, vol. 4, no. 3, pp. 774–785, Jul. 2013.
14. S. Sarkar and V. Ajjarapu, “MW resource assessment model for a hybrid energy conversion system with wind and solar resources,” IEEE Trans. Sustain. Energy, vol. 2, no. 4, pp. 383–391, Oct. 2011.
15. G.Venu, S.Tara Kalyani “Design Of FOPI Controller For Speed Control Of BLDC Motor” International Journal of Pure and Applied Mathematics, Volume 120 No. 6, 2018,PP.645-662, ISSN: 1314-3395 .
16. G.Venu, S.Tara Kalyani “ Design of Fractional Order Fuzzy Logic Controller for BLDC
17. Motor” International Journal of Innovative Technology and Exploring Engineering(IJITEE) ISSN: 2278-3075, Volume-8 Issue-5 March, 2019,PP.1072-1076 .
18. Y.-M. Chen, Y.-C. Liu, S.-C. Hung, and C.-S. Cheng, “Multi-input inverter for grid-connected hybrid PV/wind power system,” IEEE Trans. Power Electron., vol. 22, no. 3, pp. 1070–1077, May 2007.
19. S. Bae and A. Kwasinski, “Dynamic modeling and operation strategy for microgrid with wind

and photovoltaic resources," IEEE Trans. Smart Grid, vol. 3, no. 4, pp. 1867–1876, Dec. 2012.

20. B. Mangu, S. Akshatha, D. Suryanarayana, and B. G. Fernandes, "Grid-connected PV-wind-battery-based multi-input transformer-coupled bidirectional dc-dc converter for household applications," IEEE Trans. Emerg. Sel. Topics Power Electron., vol. 4, no. 3, pp. 1086–1095, Sep. 2016.
21. P. Shanthi, G. Uma, and M. S. Keerthana, "Effective power transfer scheme for a grid connected hybrid wind/photovoltaic system," IET Renew. Power Gener., vol. 11, no. 7, pp. 1005–1017, 2017.
22. T. Hirose and H. Matsuo, "Standalone hybrid wind-solar power generation system applying dump power control without dump load," IEEE Trans. Ind. Electron., vol. 59, no. 2, pp. 988–997, Feb. 2012.
23. K. Kant, C. Jain, and B. Singh, "A hybrid diesel-wind-PV based en ergy generation system with brushless generators," IEEE Trans. Ind. Inf., vol. 13, no. 4, pp. 1714–1722, Aug. 2017.
24. U. Kalla, B. Singh, S. Murthy, C. Jain, and K. Kant, "Adaptive sliding mode control of standalone single-phase microgrid using hydro, wind and solar PV array based generation," IEEE Trans. Smart Grid., vol. 9, no. 6, pp. 6806–6814, Nov. 2018.
25. A. Merabet, K. Ahmed, H. Ibrahim, R. Beguenane, and A. Ghias, "Energy management and control system for laboratory scale microgrid based wind-PV-battery," IEEE Trans. Sustain. Energy, vol. 8, no. 1, pp. 145– 154, Jan. 2017.
26. M. Meiqin, S. Jianhui, L. Chang, Z. Guorong, and Z. Yuzhu, "Con troller for 1 kW–5 kW wind-solar hybrid generation systems," in Proc. Can. Conf. Elect. Comput. Eng., Niagara Falls, ON, Canada, 2008, pp. 1175–1178.