Grid Integration of Clean Energy Sources using Fuzzy Logic Controller

Puram Joshna
Department of electrical and electronics engineering
Gokaraju Rangaraju Institute of Engineering and Technology
Hyderabad, India
puram.joshna9@gmail.com

V.Vijaya Rama Raju
Department of electrical and electronics engneering
Gokaraju Rangaraju Institute of Engineering and Technology
Hyderabad, India
Vijayram_v@yahoo.com

***Abstract*—This Wind energy and Solar energy, are considered to be the main attributes of renewable energy for electricity generation, are growing at faster rate for the last two-three decades. This paper pertains to the study integration of wind energy from grid connected Permanent Magnet Synchronous Generator (PMSG) and solar energy systems. In order to extract maximum power from Wind energy and solar energy systems a technique has been adopted, in this paper. Additionally, to maintain and sustain the continuity of supply to the load on demand at all times, the outputs of wind energy and solar energy are integrated suitably. For wind generator, the overall operation is based on the estimation of the speed, that is basically a sensor-less rotor speed estimator, which in fact avoids all mechanical sensors. The rotor speed so estimated, is used to control the turbine speed by maintaining the input dc quantities (Voltage and Current) for boost converter. Simulation studies of the proposed system are carried out using MATLAB / Simulink platform, and results are presented.**

Keywords—Grid Integration, Renewable energy, Fuzzy logic Controller

I. Introduction

With the gradual increase and continuing threat of global warming to mankind and the depletion of existing fossil fuel reserves, many countries are looking forward to sustainable green energy solutions to preserve the resources for the future generations. Other than hydro power and thermal power, wind energy and pv energy are being considered to be the preferred renewable energy, and it has the potential to meet the energy demands. Wind energy, by itself is capable to supply large amounts of power, but its existence is highly unpredictable, and depends on geographical locations and presence of tall structures. Similarly, solar energy is available throughout the day, but the solar irradiation levels vary, due to sun's intensity and unpredictable shadows cast by clouds, birds, tall buildings, trees, etc. The common drawback of wind and solar systems, are their periodic nature that make them inconsistent. Hybrid renewable energy system utilizes two or more no of energy sources, usually wind power and pv array power. The main advantage of such hybrid system is that, when these two power sources are used together, the reliability is enhanced at load side. Often, there is presence of sun rays, while there is intense wind. However, by combining both wind and solar systems power transfer, efficiency and reliability can be improved significantly. When any of the sources is unavailable or insufficient in meeting the load demands, the other energy source can compliment the deficit.

II. Literature Review

A proposal was made by sebaii and hamad [1] in 2013 in which the control technique for a variable speed, grid connected direct driven permanent magnet synchronous generator (PMSG) and also compare between two MPPT techniques, HCS and fuzzy logic The many different techniques for maximum power point tracking of photovoltaic (PV) arrays are discussed by T. Esram and P. L. Chapma [2] in 2007. The study outlines a hybrid solar-wind system that uses three-phase power grid architecture to ensure sustainable and effective power generation. The hybrid solar-wind device uses the one of the technique of Maximum Power Point Tracking (MPPT) to optimize total effectiveness at the Common Coupling Point (PCC) by combining a photovoltaic station with a wind farm which was executed by Srikanth D, G Durga Sukumar [3] in 2024. R.Esmili, L.Xu, D.K.Nichols [4] gives a new and simple control method for maximum power tracking in a variable speed wind turbine by using a step-up dc-dc converter. The output voltage of permanent magnet generator is connected to a fixed dc-link through a three-phase rectifier and the dc-dc converter. A maximum power-tracking algorithm calculates the speed command that corresponds to maximum power output of the turbine. The generating system has potentials of high efficiency, good flexibility, and low cost. Y.Xia, K.H.Ahmed, B.W.Williams[5] has presented A new maximum power point tracking technique for permanent magnet synchronous generator based wind energy conversion systems is proposed. The technique searches for the system optimum relationship for maximum power point tracking and then controls the system based on this relationship. The validity of the technique is theoretically analyzed, and the design procedure is presented. A. J. Balbino, B. d. S. Nora and T. B. Lazzarin[6] gives a constant affair current in the therapy ensures rooting the maximum electrical power available in the SWT system, independent of the rotational speed. also, this constant current value depends solely on the PMSG characteristics. thus, the proposed MPPT control strategy is a simple current mesh with a constant reference that's enforced in a dc – dc motor connected in series to the therapy, which is responsible to guarantee a constant current in the therapy affair.

III. Methodology

A. Modelling of Wind Turbine

Wind turbine simulators are artificial, controllable, and adaptable test systems that simulate genuine wind energy conversion systems. There are two methods for constructing a simulation system: first, a reference speed is established based on mathematical formulae, and then the motor is pushed to track this reference speed using a controller. Another way is to generate reference torque, which the motor should track using an appropriate control system. The wind turbine emulation system replaces the wind turbine rotor and gearbox with a motor powered by a controlled power source to generate torque or reference speed [7].

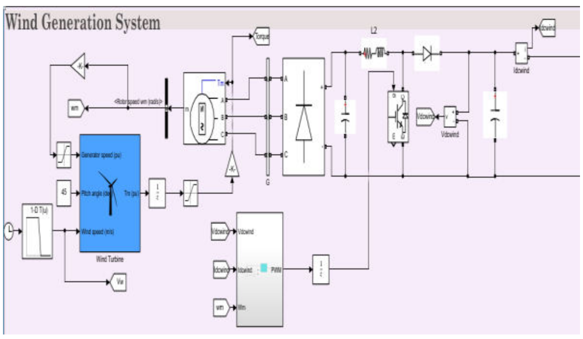

Fig.1: Simulink model of wind generating system

The Fig. shows the wind turbine simulator. Wind turbine simulators typically include an AC or DC motor, a PC-based wind turbine model, an intelligent power module, a controller, a feedback mechanism, a generator, and a load.

B. Solar PV Module

Solar energy is widely employed due to its abundance and the availability of technologies, such as solar photovoltaic (PV) cells that convert sunlight into electricity. The high installation cost of PV modules is a key disadvantage of using solar energy. However, technical advancements have helped to reduce costs. A PV module consists of solar cells connected in series or parallel. Solar cells are often linked in series to provide the desired output voltage. Variations in sun irradiation and cell temperature affect the output power of solar cells and modules over time. Although there are other elements that contribute to output variations, these two are the primary causes [8].

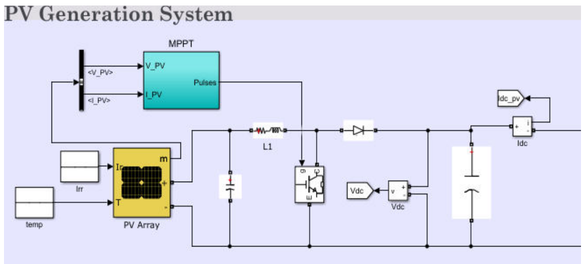

Fig.2: Simulink model of PV generating system

C. MPPT Technique

MPPT algorithms are critical in the management of any renewable resource. The wind energy system requires an algorithm to extract as much energy as possible. According to Betz theory, only 59.3% of the available 100% wind is turned into mechanical energy, resulting in wind mills operating at maximum power. Solar energy conversion is affected by various elements such as shifting solar radiation, shade, small installation surface area, and environmental conditions. The MPPT algorithms are classified into four types: Based on Tip-Speed Ratio Control (TSR), Power Signal Feedback (PSF), and Hill Climb Search (HCS) and Perturb & Observe [9].

- Hill Climbing Search

HCS is one of the simplest MPPT techniques where it requires power measurement only. This is based on perturbing the turbine shaft speed in small steps (åÀ) and observing the resulting changes in turbine mechanical power increase or decrease. The various types of HCS techniques are: viz. fixed, variable, and dual step size.

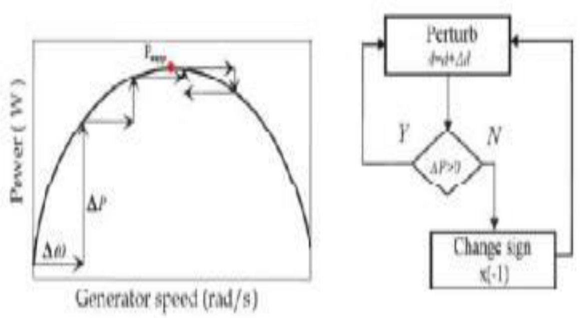

Fig.3: Hill climbing Search and Perturb & Observe

- Fuzzy Logic Controller (FL)

A logical extension of HCS technique is Fuzzy logic technique which uses continuous varying step-size. The control decision is based only on If-else statement. Like HCS, Fuzzy logic do not require any system parameters or mathematical model. But it requires only rotational speed sensors.

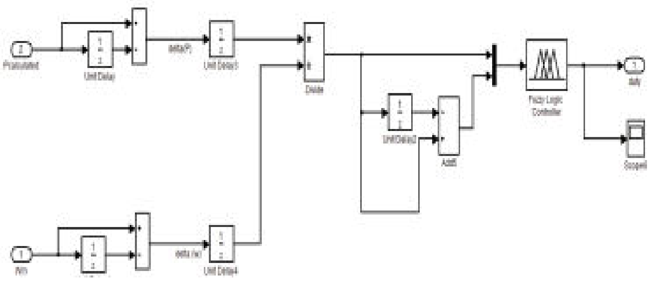

Fig.4: Simulink of Fuzzy Logic Controller

- Perturb & Observe

In P&O method, the control adjusts the voltage by small amount from array and power will be measured. If power increases, adjustments will be done to maintain the power; this is P&O method. The only thing, this differs from HCS is in perturbation, in HCS it is on duty cycle and in P&O it is based on operating voltage of DC link between PV array and power converter.

IV. Simulation Results

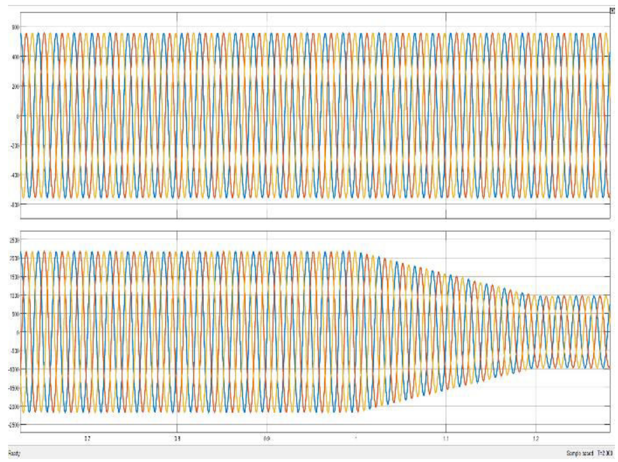

Figure 1: Voltage & Current Response for Renewable Energy Grid Integration with Fuzzy Logic Controller

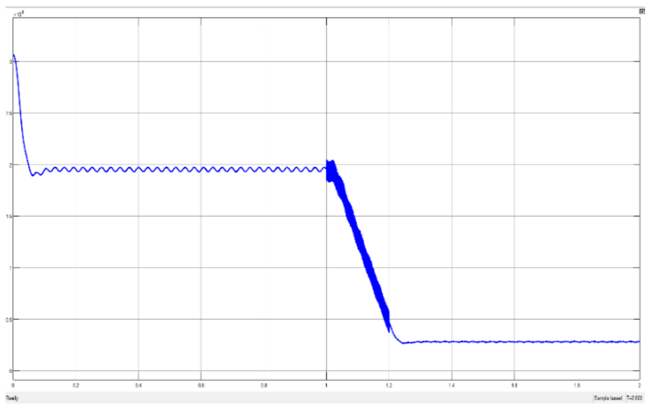

Figure 2: System Response to a Step Change in Grid Integration with Fuzzy Logic Controller

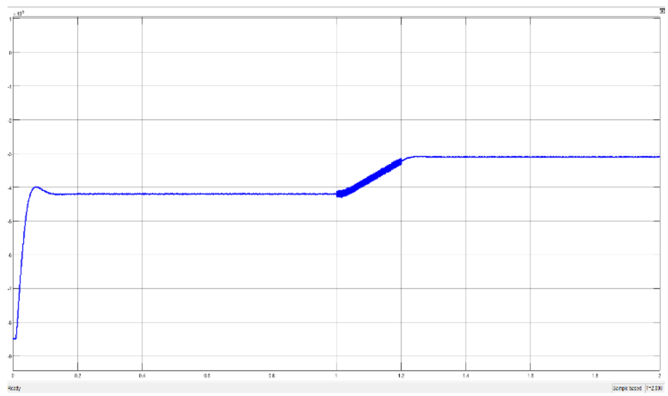

Figure 3: System Response to a Step Change in Power Input under Fuzzy Logic Control

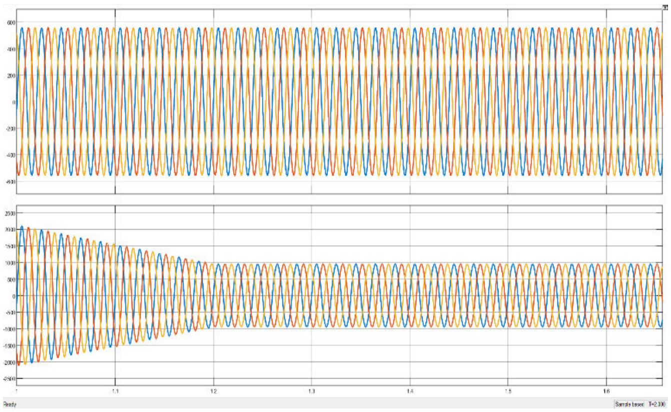

Figure 4: System Response with Fuzzy Logic Controller under Different Grid Voltage Variations

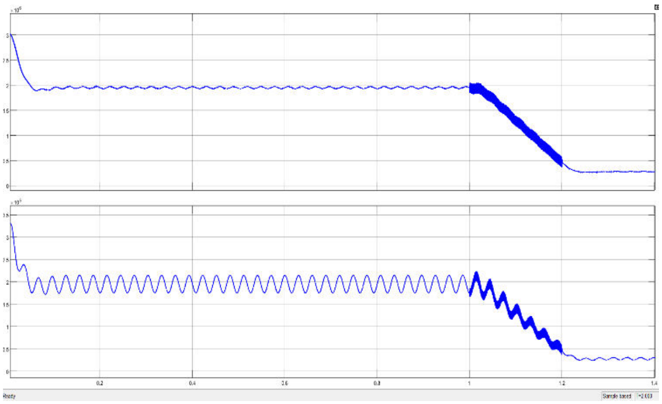

Figure 5: Comparison of System Response with Fuzzy Logic Controller and Conventional Controller

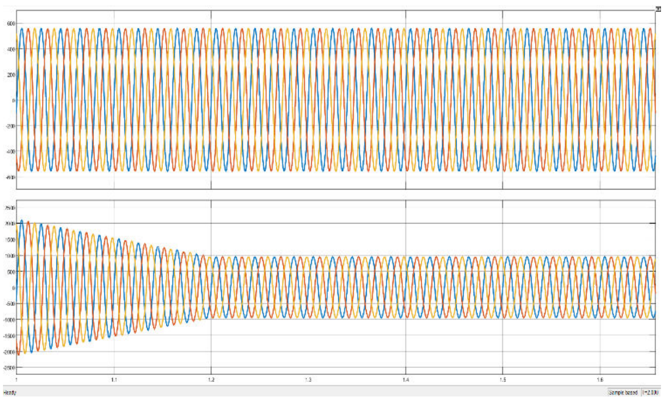

Figure 6: Three-Phase Voltage and Current Waveforms

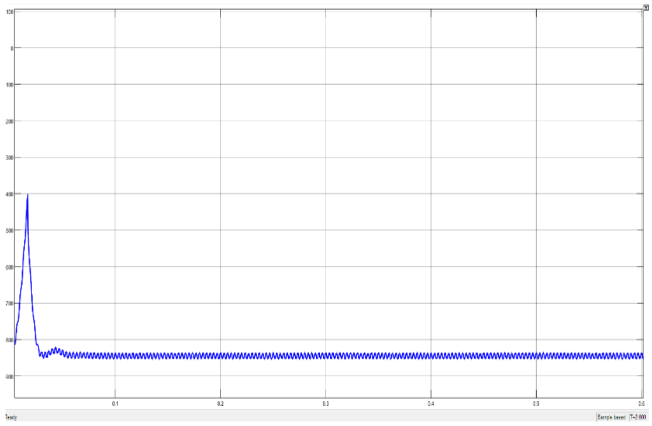

Figure 7: Transient Response of Grid-Connected Inverter

V. Conclusion

This paper presents integration of grid connected PM wind energy system and Solar PV system using different MPPT techniques. Two different MPPT techniques are employed for wind energy system and another for solar. Hill climbing search (HCS) and Fuzzy Logic (FL) are employed for WECS. For solar energy system Perturb & Observe (P&O) is introduced. The results are verified using Matlab/ Simulink platform.

VI. References

[1] M. S. H. a. A. A. H. A. M. El-Sebaii, "A sensorless MPPT technique for a grid-connected PMSG wind turbine system,," in *2nd IET Renewable Power Generation Conference* , 2013.

[2] T. E. a. P. L. Chapman, "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques,," *IEEE Transactions on Energy Conversion,* vol. 22, no. 2, pp. 439-449, 2007.

[3] G. D. S. a. P. V. S. S. S. D, "Effective Power Management of Grid-Connected PV System," in *World Conference on Communication & Computing (WCONF)*, RAIPUR, 2023.

[4] L. X. a. D. K. N. R. Esmaili, "A New Control Method of Permanent Magnet Generator for Maximum Power Tracking in Wind Turbine Application," in *IEEE Power Engineering Society General Meeting,*, 2002.

[5] K. H. A. a. B. W. W. Y. Xia, "Wind Turbine Power Coefficient Analysis of a New Maximum Power Point Tracking Technique," *IEEE Transactions on Industrial Electronics,* vol. 60, no. 3, pp. 1122-1132, 2013.

[6] B. d. S. N. a. T. B. L. A. J. Balbino, "An Improved Mechanical Sensorless Maximum Power Point Tracking Method for Permanent-Magnet Synchronous Generator-Based Small Wind Turbines Systems," *IEEE Transactions on Industrial Electronics,* vol. 69, no. 5, pp. 4765-4775, 2022.

[7] A. H. M. Y. S. K. M. J. A. A. a. N. R. N. I. M. A. Bhayo, "Modeling of Wind Turbine Simulator for analysis of the wind energy conversion system using MATLAB/Simulink," in *IEEE Conference on Energy Conversion (CENCON*, Johor Bahru, Malaysia, 2015.

[8] B. A. A. D. a. C. K. D. A. Rai, "Modeling of solar photovoltaic module and study parameter variation effect using MATLAB/Simulink," in *International Conference on Control, Computing, Communication and Materials (ICCCCM)*, Allahbad, India, 2016.

[9] V. P. a. B. B. S. Joshi, "Maximum Power Point Tracking and MPPT efficiency for wind and solar energy conversion standalone system," in *Annual IEEE India Conference (INDICON)*, Pune, India, 2014.