Fuzzy Logic Controller based Grid-Connected Wind-Photovoltaic Cogeneration Using Back-to-Back Voltage Source Converters

Tarun kumar rao[1] , Dr. Sameena Elyas Mubeen[2]

M.Tech Scholar, Department of Electrical &Electronics Engg. REC Bhopal (India)

Professor, Department of Electrical &Electronics Engg. REC Bhopal (India

Abstract: A shared DC connection connects the wind farms of PVA and PMSG to the grid, allowing them to exchange electricity. To use the electricity generated by various renewable resources, a single inverter has been incorporated. "Back-to-back (BtB) voltage-source converters" connect a permanent magnet synchronous generator-based full-scale wind turbine to the utility grid. The BtB VSCs' dc-link capacitor is linked directly to a PV solar generator. Therefore, the system efficiency is increased since no dc/dc conversion steps are needed. To get the most out of renewable energy, the suggested topology tracks the maximum power points of the wind and PV producers separately. The vector control strategy in the rotating reference frame is used to regulate the VSCs. The speed controller of the PSMG is updated with fuzzy logic controller which makes the machine side converter to operate at higher efficiency. The powers of PMSG delivered are compared with PI and FIS at different operating conditions and are presented in this project using MATLAB software.

Keywords: Wind turbine, solar photovoltaic array, voltage-source converter, fuzzy logic controller, power quality.

I.INTRODUCTION

As the use of renewable energy sources and sustainable technologies becomes increasingly popular as a means of reducing society's reliance on fossil fuels, finding ways to capture these clean energies and convert them into electricity at their peak performance is critical today more than ever before. However, the method used to connect the renewable energy sources to the main grid is as important.[1]

Because of the depletion of fossil fuel supplies, the release of damaging Green House Gases, and other factors, energy use is considered a substantial contributor to environmental damage. If population growth continues at its current pace, annual energy demand will quadruple by 2050. An increasing number of power producing methods are turning to clean, renewable energy sources including solar, wind, and tidal. [2][3]

A.Photovoltaic Array and Power Generation

Photovoltaic systems can be sorted according to their power levels or based on system configuration or the connection to utility grid. A typical PV system comprises four parts: the PV array, power conditioner, storage system, and PV inverter. Then the system is connected to the utility grid with or without local load. Fig. shown below illustrates a basic PV system integrated with utility grid and local load [4][5].

Solar cells are combined in series to construct PV modules, converting solar energy to electric power. PV modules can be combined in series and/or in parallel to assemble a PV array matching the electric power demand.[6]

A. Wind energy

Today, the windmill's modern equivalent - a wind turbine - can use the wind's energy to generate electricity. Human resort to rely on wind turbines to extract energy from wind, electric power generation ones, as wind power is used to produce mechanical energy in so-called windmills. In fact, wind is considered to be a sort of solar energy, and around 2% of the sunlight that hits the Earth's surface is converted into kinetic energy by the wind. Electrical energy may be generated from this enormous quantity of stored potential kinetic energy. In order to harvest as much energy as possible, wind turbines, which resemble windmills, are erected atop a tower. Above earth, at a height of 100 feet (30 metres), they may take use of the more rapid and less turbulent wind to their benefit. [7]

Although wind turbine technology seems straightforward, it is everything but Turbine blades rotate around a central hub powered by the wind, and the hub drives a generator to produce energy. [8]

B. PI Controller

The proportional and integral terms make up the majority of the P-I controller. It works on the comparison concept, with the primary considerations being the difference (error) between the process variable (PV) and the set-point (SP), as well as the difference between harmonics current reference signal ih and the filter. The P-I controller is used in the thesis because it provides more stable control than traditional controllers. PV and SP are two key keywords in P-I controllers. One can easily achieve desired results by altering these two parameters. The proportionate Integral is written as follows:[9]

$$u_t = k_p e + \int_{t0}^{t} eT\,dT$$

With the controller transfer function,

$$D_c S = k_p + ki$$

Where, ki are the proportional and the integral gains.

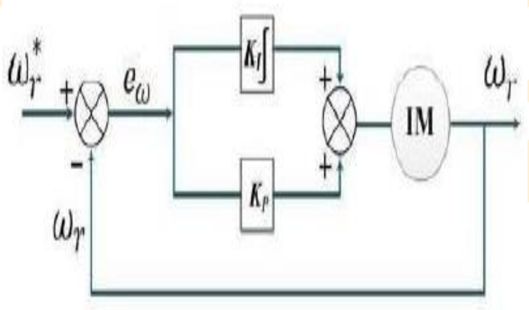

Fig. 1: PI Controller

When users give the P-I controller some data, it analyses the error between real and set points, but sometimes the integrator term of the controller integrates that error, resulting in a tiny unbalance in the input and a huge error in the system's output. As a result, it is critical to eradicate such phenomena in order to improve the controller's performance.[10]

II.OBJECTIVES

In this project PVA and PMSG wind farm renewable sources share power to the grid through a common DC link. A single inverter is integrated to inject the power from these renewable sources. Following are the objectives of the present work:

• To increase the reliability and efficiency with the combination of wind and PV generators

• To regulate the dc-link voltage under all operating conditions which is maintained by the VSI and can get a better damped performance

The integration of fuzzy logic controller is recovered by the wind farm power from lower power generation conditions to optimal when the wind speed is optimal.

III.RESEARCH METHODOLOGY

A. Proposed system

The suggested system includes a VSR for connecting the wind generator and a VSI for connecting the cogeneration system to the utility grid. A dc wire connects the PV generator to the BtB VSCs' dc-link capacitor. There are two types of two-level converters, the VSR and the VSI, both of which use insulated-gate bipolar transistors (IGBTs) in parallel with a diode. The comprehensive modelling and control of the proposed system is presented in the following subsections.

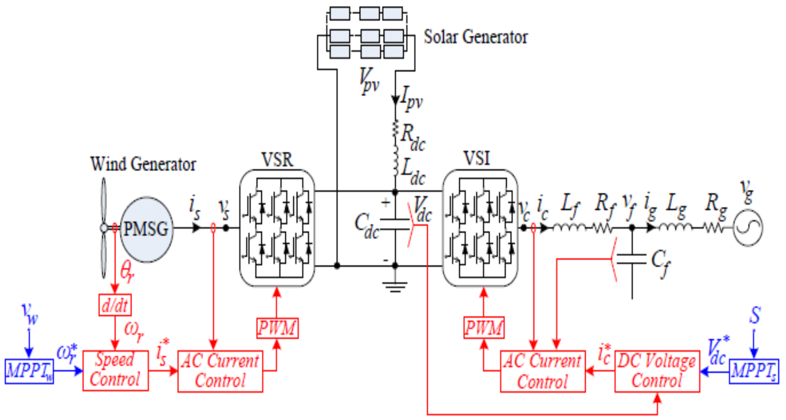

Fig. 2: The proposed wind-PV cogeneration system

B. Fuzzy Logic Controller

The DC side capacitor voltage must be measured and compared to a reference value in order to implement the control algorithm of a shunt active filter. Fuzzy processing has two inputs: error and error change. The control action of a fuzzy controller is determined by a set of linguistic rules. It has the advantage of not requiring a mathematical model and working with erroneous inputs.[11]

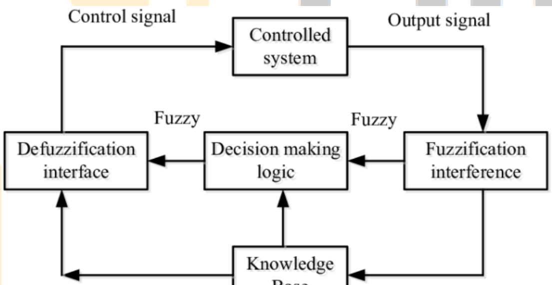

Fig. 3: Block diagram of fuzzy logic control

The Mamdani fuzzy controller outperforms the PI controller; however it comes with the drawback of a higher number of fuzzy sets and rules. Additionally, in order to surpass the typical PI controller, all of the coefficients must be increased. The fuzzy control system requires less time to settle than the PI control system and FIS system.

IV SIMULATION RESULTS AND DISCUSSION

A time-domain simulation model is developed under the Matlab/Simulink® environment as shown in figure given below to evaluate the validity and the performance of the system. The wind and PV generators are rated at 2.0 and 0.9 MVA, respectively. The complete model entities are built using the SimPower System® toolbox. The VSCs are simulated using average-model-based blocks.

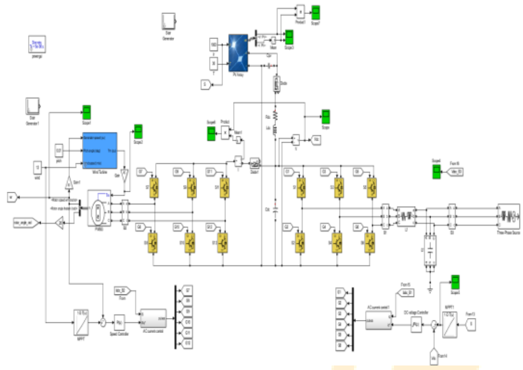

Fig. 4: Proposed test system with PSMG wind farm and PVA with PI Controller

The above shows in fig no. 4 is the proposed test system with PMSG connected to controlled rectifier. And shows in fig no. 5 is the proposed test system with PMSG connected to controlled rectifier. The rectifier is controlled by sinusoidal PWM generator with feedback from the PMSG rotor speed. The grid side converter has feedback from the solar irradiation which estimates the DC link voltage through MPPT generating the reference for the controller.

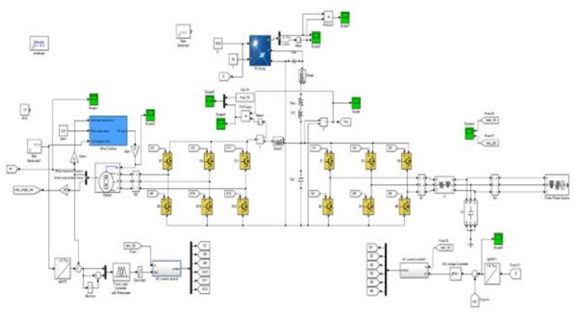

Fig. 5: Proposed system with PSMG wind farm and PVA module with fuzzy logic controller

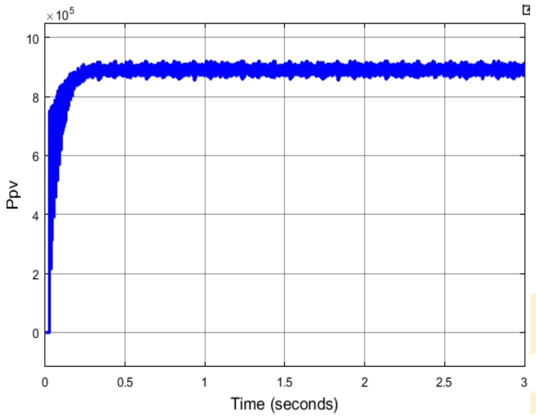

Fig. 6: PVA generated power at constant irradiation

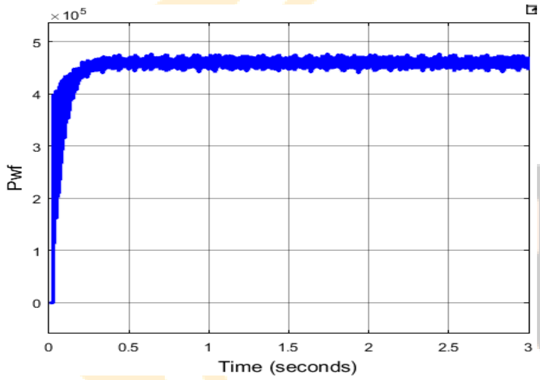

Fig. 7: Wind farm power at constant wind speed

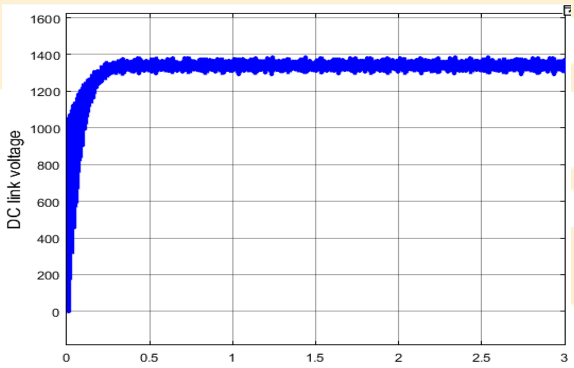

Fig. 8: DC link voltage with PI controller

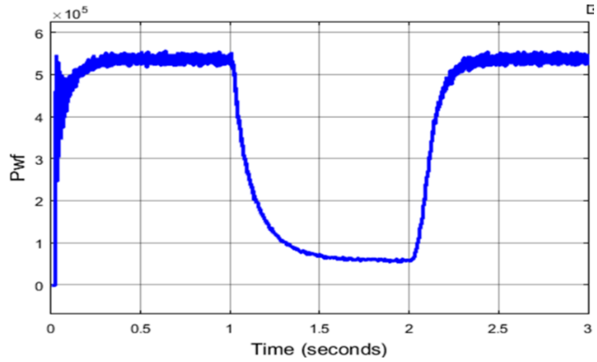

Fig. 9: Wind farm power with variable wind speed

The above fig 9 is the PMSG wind farm power with variable wind speed. From 0 to 1sec the wind speed is 12mt/sec, from 1 to 2 sec the wind speed is 5mt/sec and from 2 to 3 sec the speed is back to 12mt/sec. Similarly the below is the power of the PVA with variable solar irradiation changing from 1000W/mt2 to 200W/mt at same time intervals as mentioned above.

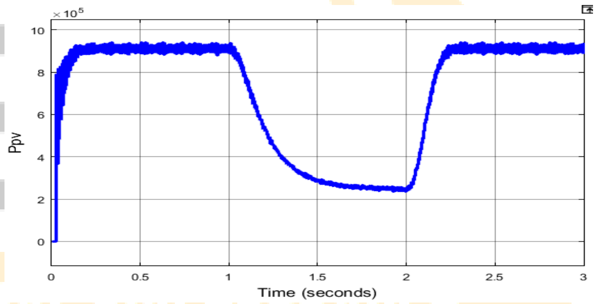

Fig. 10: PVA power variation during variable solar irradiation

The below fig 11 are the three phase voltages and current of the grid during renewable power sharing with variable environmental conditions.

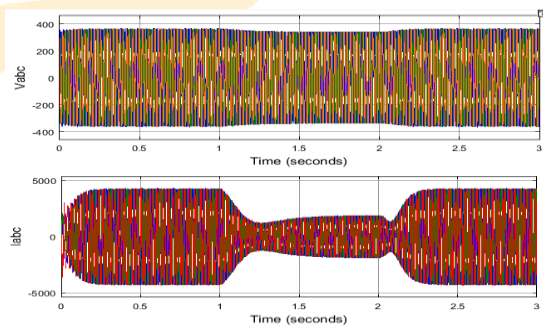

Fig. 11: Grid three phase voltages (At Variable wind speed)

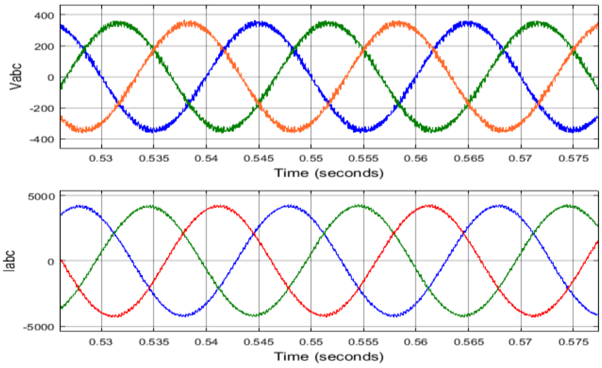

Fig. 12: Grid three phase voltages (At Constant wind speed)

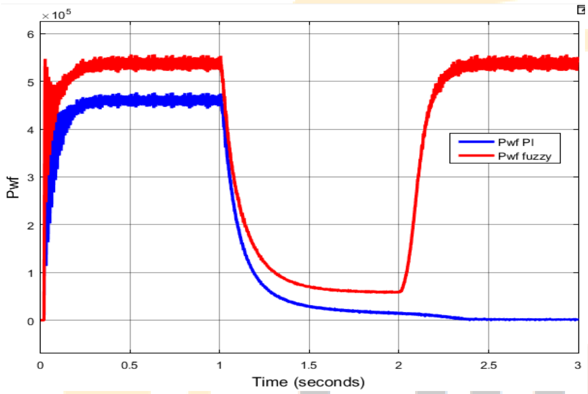

Fig. 13: Wind farm power comparison with PI and FIS controllers

For the variation of wind speeds the above is the wind farm power comparison of PI and fuzzy logic controller. As observed the power of the wind farm is more for fuzzy logic controller as compared to PI controller. The power is also not recovered after the wind speed in back to normal after some time in PI controller. The power of the wind farm is recovered to optimal value when the wind speed is back.

V.CONCLUSION

As seen in the above results the powers form the PMSG wind farm and PVA are shared to the grid through common DC link connected to single VSI. The VSR at the wind generator-side is responsible for extracting the maximum wind power following the wind speed variations. On the utility-grid side, the roles of the VSI are to extract the maximum PV power from the PV generator, achieve the balance between the input-output powers across the dc-link capacitor, and to maintain a unity PCC voltage under different modes of operation. The proposed system has the following advantages

1) The increased reliability and efficiency due to the combined wind and PV generators.

2) The independent MPPT extraction as the VSR and VSI are solely responsible for extracting the wind and PV powers, respectively.

3) The regulation of the dc-link voltage under all operating conditions is maintained by the VSI and hence a better damped performance is yielded.

4) Simple system structure and controllers design.

5) Fault-ride through can be achieved using existing protection schemes. A well-damped performance has been presented using time-domain simulations results under the Matlab/Simulink® environment.

The integration of fuzzy logic controller is recovering the wind farm power from lower power generation conditions to optimal when the wind speed is optimal. The power from the wind farm is also high with fuzzy logic controller as compared to PI controller.

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