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Design of Distributed Generation (DG) for Isolated Loads Using Fuzzy Logic Controller

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Abstract:
The proposed system presents power-control strategies of a grid-connected hybrid generation system with versatile power transfer. This hybrid system allows maximum utilization of freely available renewable energy sources like wind and photovoltaic energies . For this, an adaptive MPPT algorithm along with standard perturb and observe method will be used for the system. Also, this configuration allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The turbine rotor speed is the main determinant of mechanical output from wind energy and Solar cell operating voltage in the case of output power from solar energy.

Permanent Magnet Synchronous Generator is coupled with wind turbine for attaining wind energy conversion system . The inverter converts the DC output from non-conventional energy into useful AC power for the connected load . This hybrid system operates under normal conditions which include normal room temperature in the case of solar energy and normal wind speed at plain area in the case of wind energy. A fuzzy based PWM system will be designed to reduce the harmonic ripples. The simulation results are presented to illustrate the operating principle, feasibility and reliability of this proposed system.

Keywords:
Wind, Solar, Fuel Cell, PWM, Hysteresis control

I .INTRODUCTION:
With increasing concern of global warming and the depletion of fossil fuel reserves, many are looking at sustainable energy solutions to preserve the earth for the future generations. Other than hydro power, wind and photovoltaic energy holds the most potential to meet our energy demands. Alone, wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another. Similarly, solar energy is present throughout the day but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees, etc. The common inherent drawback of wind and photovoltaic systems are their intermittent natures that make them unreliable.

However, by combining these two intermittent sources and by incorporating maximum power point tracking (MPPT) algorithms, the system's power transfer efficiency and reliability can be improved significantly. The integration of renewable energy sources and energy-storage systems has been one of the new trends in power-electronic technology. The increasing number of renewable energy sources and distributed generators requires new strategies for their operations in order to maintain or improve the power-supply stability and quality. Combining multiple renewable resources via a common dc bus of a power converter has been prevalent because of convenience in integrated monitoring and control and consistency in the structure of controllers as compared with a common ac type. Dynamic performance of a wind and solar system is analyzed.

A wind turbine system model was developed and compared with a real system. Several methodologies for optimal design or unit sizing. Most applications are for stand-alone operation, where the main control target is to balance local loads. A few grid-connected systems consider the grid as just a back-up means to use when there is insufficient supply from renewable sources. They are originally designed to meet local load demands with a loss of power-supply probability of a specific period. Such hybrid systems, focusing on providing sustainable power to their loads, do not care much about the quality or flexibility of power delivered to the grid. From the perspective of utility, however, a hybrid system with less fluctuating power injection or with the capability of flexibly regulating its power is more desirable. In addition, users will prefer a system that can provide multiple options for power transfer since it will be favorable in system operation and management. Control strategies of such a hybrid system should be quite different from those of conventional systems.

This project addresses dynamic modeling and control of a grid-connected wind–PV–battery hybrid system with versatile power transfer. The hybrid system, unlike conventional systems, considers the stability and dispatch-ability of its power injection into the grid. The hybrid system can operate in three different modes, which include normal operation without use of battery, dispatch operation, and averaging operation. In order to effectively achieve such modes of operation, two modified techniques are applied; a modified hysteresis control strategy for a battery charger/discharger and a power averaging technique using a low-pass filter. The concept and principle of the hybrid system and its supervisory control are described. Classical techniques of maximum power tracking are applied in PV array and wind-turbine control. Dynamic modeling and simulations were based on Power System Computer Aided Design/Electromagnetic Transients Program for DC (PSCAD/EMTDC), power-system transient-analysis software.

The program was based on Dommel's algorithm, specifically developed for the simulation of high-voltage direct current systems and efficient for the transient simulation of power system under power-electronic control.

When to Consider An Hybrid Solar-Wind System:

Even during the same day, in many regions worldwide or in some periods of the year, there are different and opposite wind and solar resource patterns. And those different patterns can make the hybrid systems the best option for electricity production.

The Combination:

The combination involved on hybrid systems is rather obvious: to get a target goal of, say, 120 kWh of electricity per month we can use a single 3kW wind turbine (instead of a 6kW one.) and a solar system with a smaller array of modules.

Hybrid wind-solar electricity production system Size and Price

An hybrid wind-solar electric system demands an higher initial investment than single larger systems: large wind and solar PV systems are proportionally cheaper than two smaller systems. But the hybrid solution is the best option whenever there is a significant improvement in terms of output and efficiency - which happens when the sun and the wind resources have opposite cycles and intensities during the same day or in some seasons.

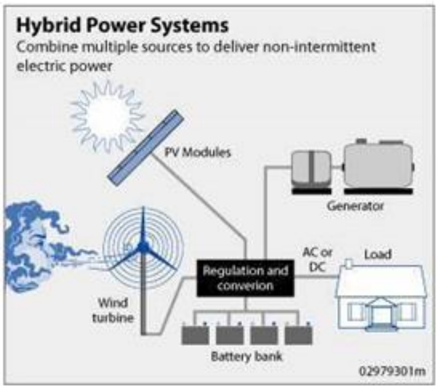

Fig 1.1:General Hybrid System

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When Hybrid Solar-Wind Systems

Aren't Suitable Obviously, hybrid solutions aren't feasible in urban and suburban environments (unless we consider new and rather untested urban wind systems) or in non-windy locations. Besides, hybrid solar-wind solutions are mainly applied to electricity production. In applications as water heating (where solar is widely used) hybrid solutions don't make direct sense.

II. SOLAR AND WIND

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels comprising a number of cells containing a photovoltaic material. Materials presently used for photovoltaic include mono crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium selenide/sulfide.[1] Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. As of 2010, solar photovoltaic generates electricity in more than 100 countries and, while yet comprising a tiny fraction of the 4800 GW total global power-generating capacity from all sources, is the fastest growing power-generation technology in the world.

Between 2004 and 2009, Grid-connected PV capacity increased at an annual average rate of 60 percent, to some 21 GW. Such installations may be ground-mounted (and sometimes integrated with farming and grazing) or built into the roof or walls of a building, known as Building Integrated Photovoltaics or BIPV for short. Off-grid PV accounts for an additional 3–4 GW. Driven by advances in technology and increases in manufacturing scale and sophistication, the cost of photovoltaic has declined steadily since the first solar cells were manufactured. Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity; have supported solar PV installations in many countries.

The photovoltaic effect is the generation of a voltage (or a corresponding electric current) in a material upon exposure to light. Though the photovoltaic effect is directly related to the photoelectric effect, the two processes are different and should be distinguished. In the photoelectric effect, electrons are ejected from a material's surface upon exposure to radiation of sufficient energy. The photovoltaic effect is different in that the generated electrons are transferred between different bands (i.e. from the valence to conduction bands) within the material, resulting in the buildup of a voltage between two electrodes. In most photovoltaic applications the radiation is sunlight and for this reason the devices are known as solar cells. In the case of a p-n junction solar cell, illumination of the material results in the generation of an electric current as excited electrons and the remaining holes are swept in different directions by the built-in electric field of the depletion region. The photovoltaic effect was first observed by Alexandre-Edmond Becquerel in 1839.

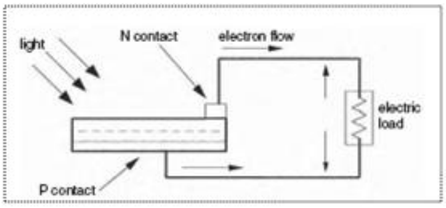

Fig 2.1: PV effect converts the photon energy into voltage across the pn junction

As of October 2010, the largest photovoltaic (PV) power plants in the world are the Sarnia Photovoltaic Power Plant (Canada, 80 MW), the Olmedilla Photovoltaic Park (Spain, 60 MW), the Strasskirchen Solar Park (Germany, 54 MW), the Lieberose Photovoltaic Park (Germany, 53 MW), the Puertollano Photovoltaic Park (Spain, 50 MW), the Moura photovoltaic power station (Portugal, 46 MW), and the Waldpolenz Solar Park (Germany, 40 MW).

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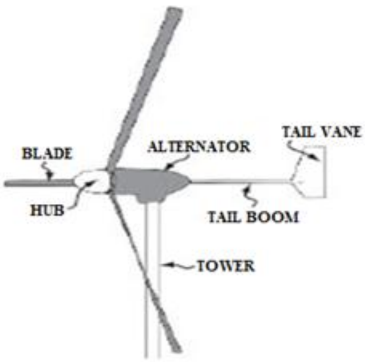

Fig 2.2:Wind turbine

III. BATTERY STORAGE

Electricity is more versatile in use than other types of power, because it is a highly ordered form of energy that can be converted efficiently into other forms. For example, it can be converted into mechanical form with efficiency near 100% or into heat with 100% efficiency. Heat energy, on the other hand, cannot be converted into electricity with such high efficiency, because it is a disordered form of energy in atoms. For this reason, the overall thermal-to-electrical conversion efficiency of a typical fossil thermal power plant is less than 50%. Disadvantage of electricity is that it cannot be easily stored on a large scale. Almost all electric energy used today is consumed as it is generated. This poses no hardship in conventional power plants, in which fuel consumption is continuously varied with the load requirement. Wind and photovoltaic's (PVs), both being intermittent sources of power, cannot meet the load demand at all times, 24 h a day, 365 d a year.

3.1 Battery control

The primary goal of the battery converter is to regulate the common dc-bus voltage. The battery load current rapidly changes according to changes in weather conditions and power command for grid inverter in dispatching or averaging mode of operation. Common dc-bus voltage must be regulated to stay within a stable region regardless of the battery-current variation. To do this, a modified hysteresis-control strategy is applied.

The concept of this strategy is to regulate the common dc voltage within a specific band, for example, a hysteresis band. Therefore, the battery charger/discharger is controlled in such a way that the dc-bus voltage should not violate the specified upper and lower limits, Vdc_up and Vdc_lw, as shown in the figure. A decision criterion for charging/discharging becomes the level of the common dc-bus voltage, and the battery buck–booster operates according to the scheme as below:

If $V_{dc} > V_{dc\_up}$, then charging $\rightarrow V^*_{dc} = V_{dc\_up}$

If $V_{dc} < V_{dc\_up}$, then discharging $\rightarrow V^*_{dc} = V_{dc\_lw}$

If $V_{dc\_lw} \le V_{dc} \le V_{dc\_up}$ then no control (rest)

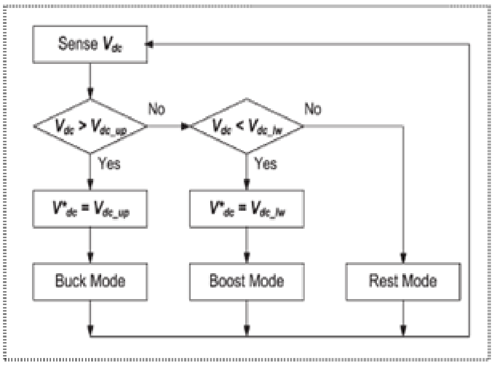

Fig. 3.1. Battery-mode control block (modified hysteresis).

When the common dc voltage V_{dc} becomes larger than the upper limit, charging mode begins with the voltage command V_{dc} equal to the upper limit and continues until the dc voltage reaches the limit. If V_{dc} goes below the lower limit, then the voltage target is bound at the lower limit and the converter starts operating in boost mode.

IV.PWM AND HYSTERESIS CURRENT CONTROL

The PWM Generator block generates pulses for carrier-based pulse width modulation (PWM) converters using two-level topology. The block can be used to fire the forced-commutated devices (FETs, GTOs, or IGBTs) of single-phase, two-phase, three-phase, two-level bridges or a combination of two

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three-phase bridges. The pulses are generated by comparing a triangular carrier waveform to a reference modulating signal. The modulating signals can be generated by the PWM generator itself, or they can be a vector of external signals connected at the input of the block. One reference signal is needed to generate the pulses for a single- or a two-arm bridge, and three reference signals are needed to generate the pulses for a three-phase, single or double bridge.

The amplitude (modulation), phase, and frequency of the reference signals are set to control the output voltage (on the AC terminals) of the bridge connected to the PWM Generator block. The two pulses firing the two devices of a given arm bridge are complementary. For example, pulse 4 is low (0) when pulse 3 is high (1). This is illustrated in the next two figures. The following figure displays the two pulses generated by the PWM Generator block when it is programmed to control a one-arm bridge.

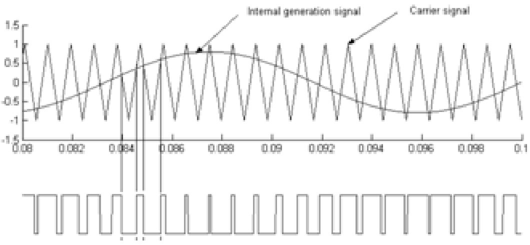

Fig:4.1 Waveform of pwm current controller

The hysteresis current control (HCC) is the easiest control method to implement; it was developed by Brod and Novotny in 1985. The shunt APF is implemented with three phase current controlled VSI and is connected to the ac mains for compensating the current harmonics. The VSI gate control signals are brought out from hysteresis band current controlle.

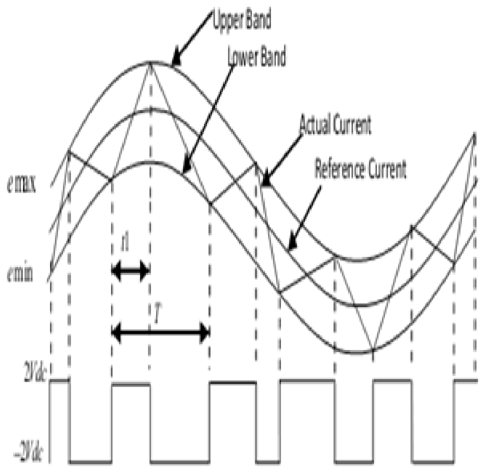

Fig:4.2 Waveform of Hysteresis current controller

A hysteresis current controller is implemented with a closed loop control system and waveforms are shown in Fig 4.4. An error signal I_{aerr} is used to control the switches in a voltage source inverter. This error is the difference between the desired current I_a^* and the current being injected by the inverter I_a. If the error exceeds the upper limit of the hysteresis band, the upper switch of the inverter arm is turned off and the lower switch is turned on. As a result, the current starts decaying. If the error crosses the lower limit of the hysteresis band, the lower switch of the inverter arm is turned off and the upper switch is turned on. As a result, the current gets back into the hysteresis band. The minimum and maximum values of the error signal are e_{min} and e_{max} respectively. The range of the error signal $e_{max} - e_{min}$ directly controls the amount of ripple in the output current from the VSI.

IV Fuzzy Logic Controllers

Introduction to Fuzzy Logic:

The logic of an approximate reasoning continues to grow in importance, as it provides an in expensive solution for controlling know complex systems. Fuzzy logic controllers are already used in appliances washing machine, refrigerator, vacuum cleaner etc.

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Computer subsystems (disk drive controller, power management) consumer electronics (video, camera, battery charger) C.D. Player etc. and so on in last decade, fuzzy controllers have convert adequate attention in motion control systems. As the later possess non-linear characteristics and a precise model is most often unknown. Remote controllers are increasingly being used to control a system from a distant place due to inaccessibility of the system or for comfort reasons. In this work a fuzzy remote controllers is developed for speed control of a converter fed dc motor. The performance of the fuzzy controller is compared with conventional P-I controller.

V. SIMULATION DESIGN

5.1. SIMULINK MODEL OF HYSTERESIS CURRENT CONTROL

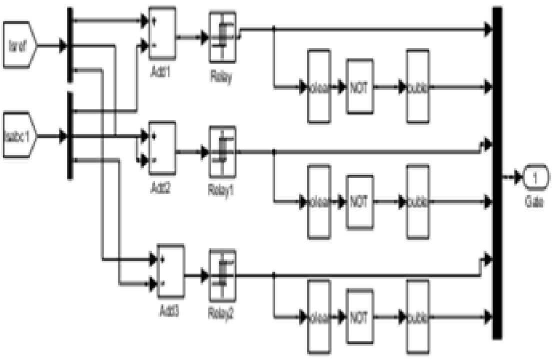

Fig. 5.1 Simulink Model of Hysteresis Current Control

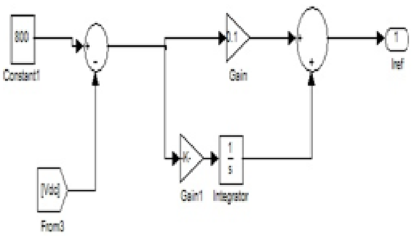

Fig.5.2 MATLAB Simulink model of PI control

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We can visualize the system by viewing signals with the displays and scopes provided in Simulink software.

Alternatively, we can build ourr own custom displays using MATLAB® visualization and GUI development tools. We can also log signals for post-processing.

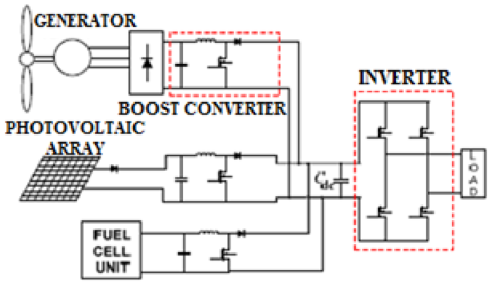

Fig 5.3Model Of Proposed Hybrid Circuit

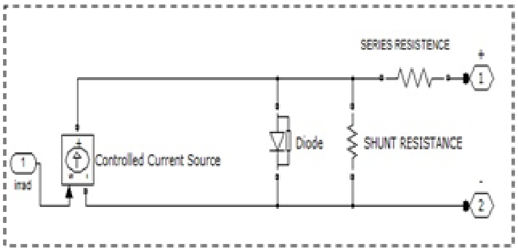

Fig 5.4 Basic Structure Of PV-Cell

The basic PV cell is built with the current supplied from the solar energy and then it is fed forward with the use of diode. There are two resistances both in shunt and series connection to enhance the working of the PV cell.

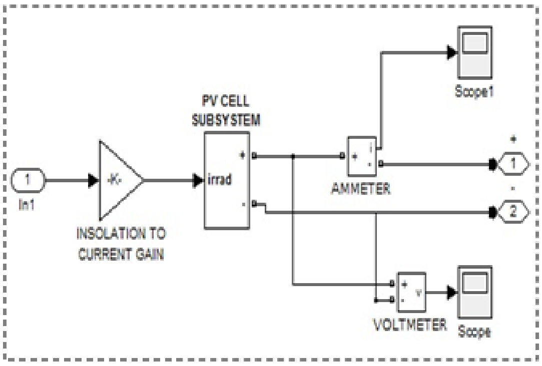

Fig 5.5 Transition Of Insolation Into Current Gain

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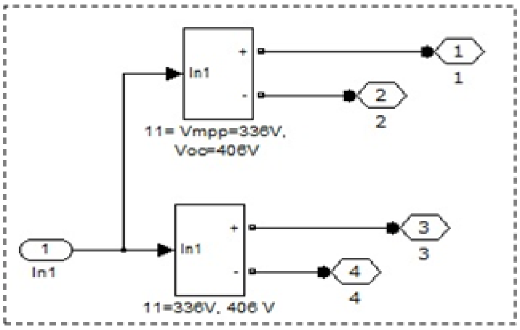

Fig 5.6 Parallel Connection Of Solar Cell

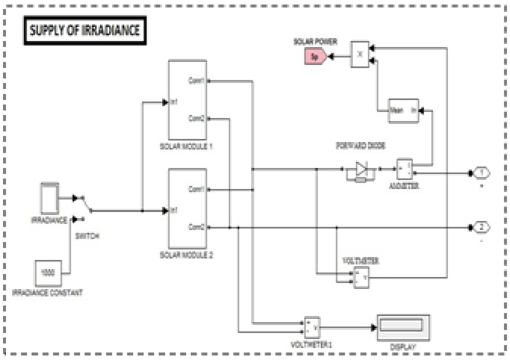

Fig 5.7 Simulation Model Showing The Utilization Of Irradiance And Solar Modules

There are two modules of PV cells in the designed PV Array. There are two rows of 11 cells in each PV module. The voltage developed at the parallel connection between the parallel connection of the PV modules is measured here with the inclusion of the Display block of simulink.

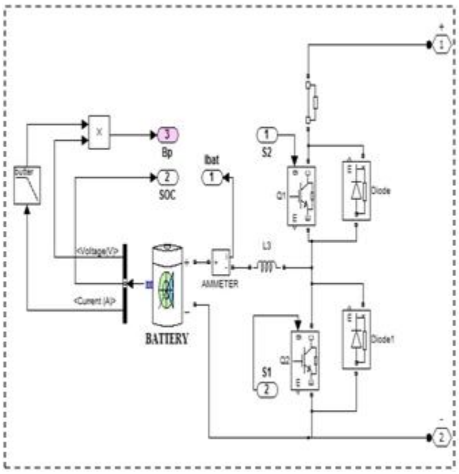

Fig 5.8 Battery Operation features sufficient supply to load

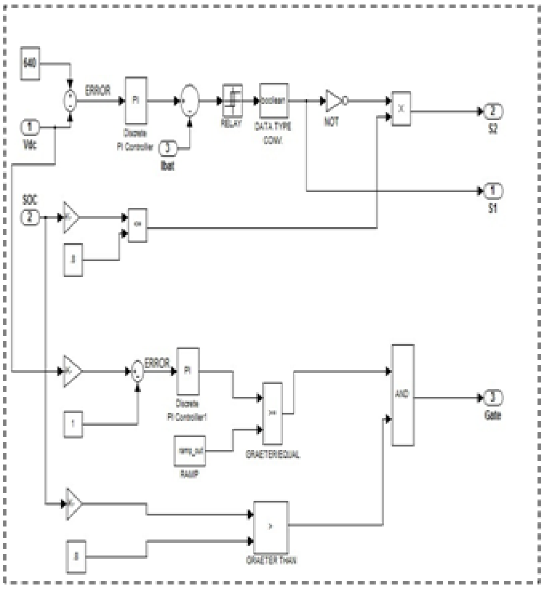

Fig 5.9 Working Logic of Battery Operation

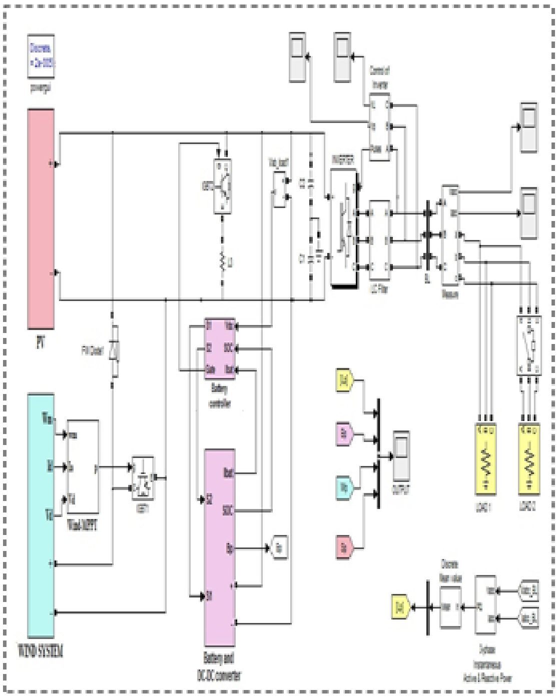

Fig 5.10 Composite Simulation Model of Proposed Hybrid System

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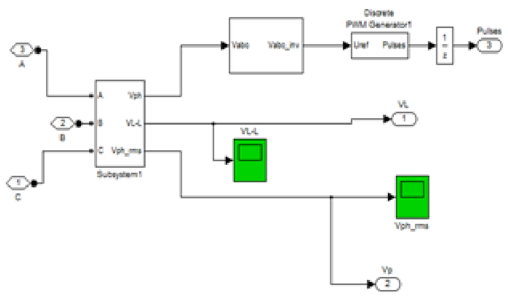

Fig 5.11 Inverter control using PWM

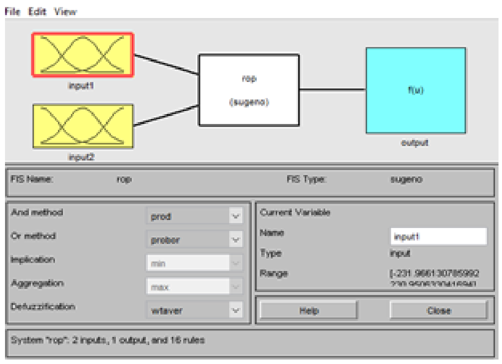

Fig 5.12 Fuzzy logic controller

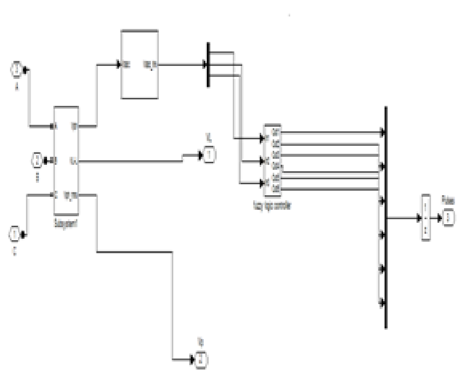

Fig. 5.13 Fuzzy logic controller based pwm controller

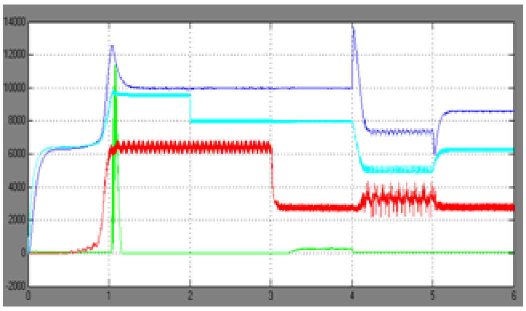

Fig 5.13 Simulation result with PI control

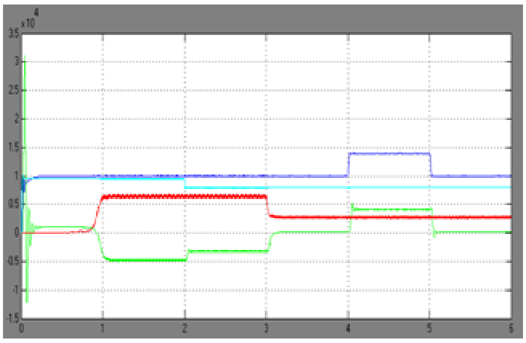

Fig 5.14 Simulation result with Fuzzy logic controller

V. CONCLUSION

The Hybrid Energy System is giving supply to load based on the changing conditions of Wind Speed and Solar Irradiation parameters. Battery is supporting the simultaneous operation of Solar and Wind Energy System. Battery is working as a Auxiliary Source of Supply to the load at the time of need. While comparing with PI controller FUZZY control gives better performance for inverter control.

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