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# Integrated Distributed Generation (PV+WIND) Using Hysteresis 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 and fuel cell. For this, an adaptive MPPT algorithm along with standard perturbs and observes 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 PWM Control is used for inverter which is replaced with hysteresis control. The simulation results are presented to illustrate the operating principle, feasibility and reliability of this proposed system.**

***Index Terms*— Wind, PV Fuel Cell, PWM, Hysteresis.**

## 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.

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.

*When to Consider a 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*

A hybrid wind-solar electric system demands a 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.

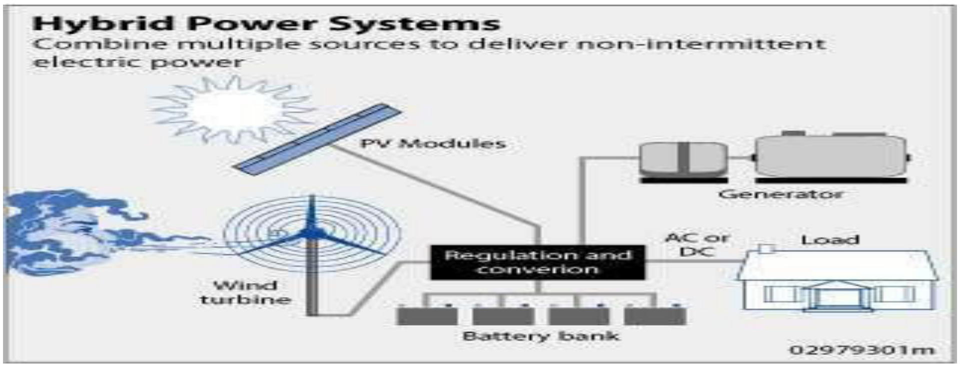


Fig 1.1: General Hybrid System

*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.

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## 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.

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.

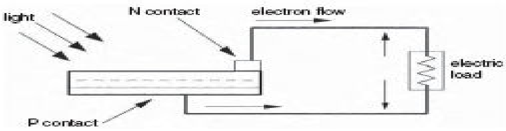


Fig 2.1: PV effect converts the photon energy into voltage across the pn junction

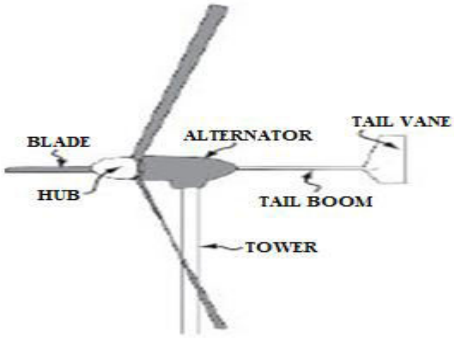


Fig 2.2:Wind turbine

## 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%.

### *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. 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 $V_{dc_{lw}} \leq V_{dc} \leq V_{dc_{up}}$ then no control (rest)

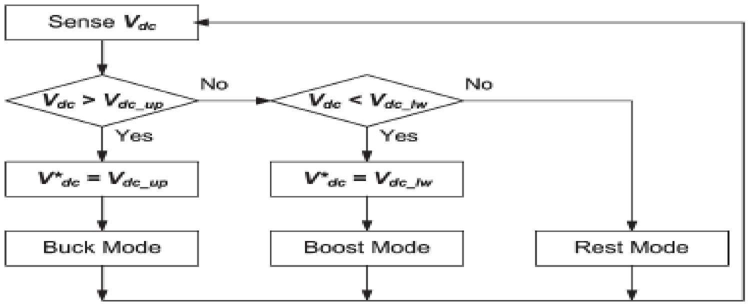


Fig. 3.1. Battery-mode control block (modified hysteresis).

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 three-phase bridges.

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

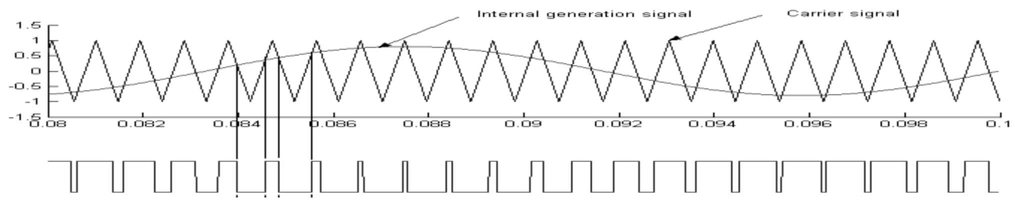


Fig: 4.1 Waveform of PWM current controller

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

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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 controller

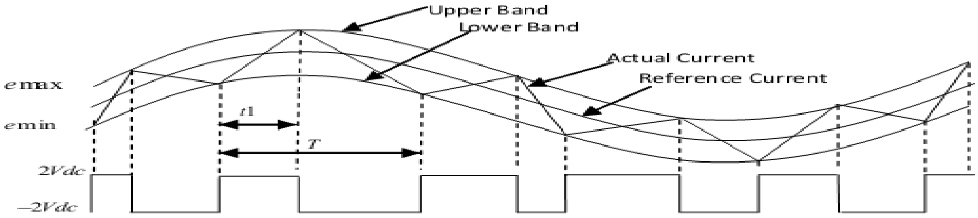


Fig: 4.2 Waveform of Hysteresis current controller

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.

## V. SIMULATION DESIGN

*5.1 Simulink Model of Hysteresis Current Control*

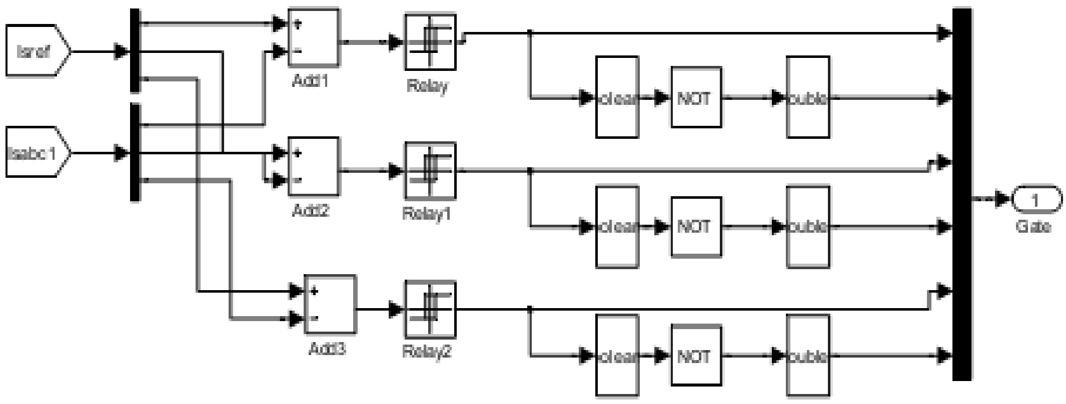


Fig. 5.1 Simulink Model of Hysteresis Current Control

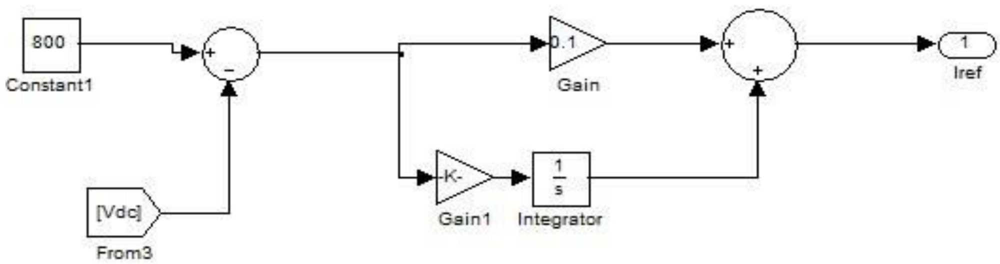


Fig.5.2 MATLAB Simulink model of PI control

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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 our own custom displays using MATLAB® visualization and GUI development tools. We can also log signals for post-processing.

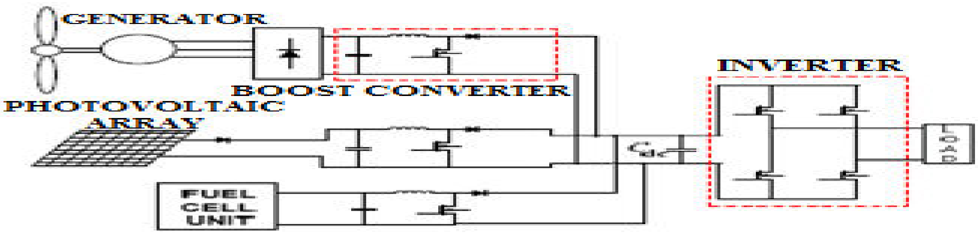


Fig 5.3 Model of Proposed Hybrid Circuit

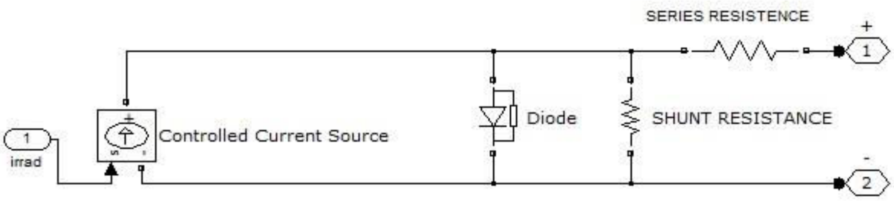


Fig 5.4 Basic Structure of PV-Cell

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.

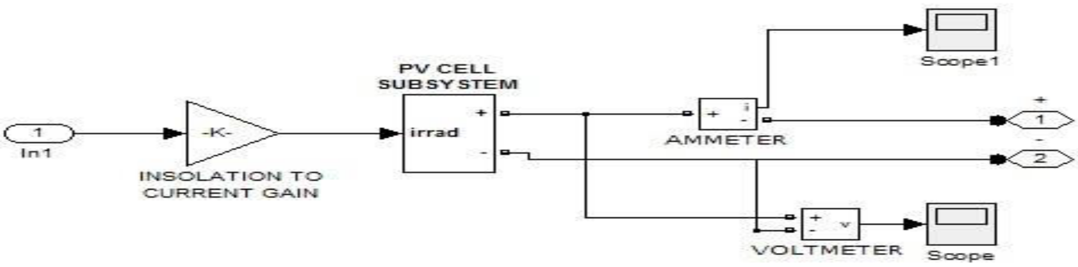


Fig 5.5 Transition of Insolation into Current Gain

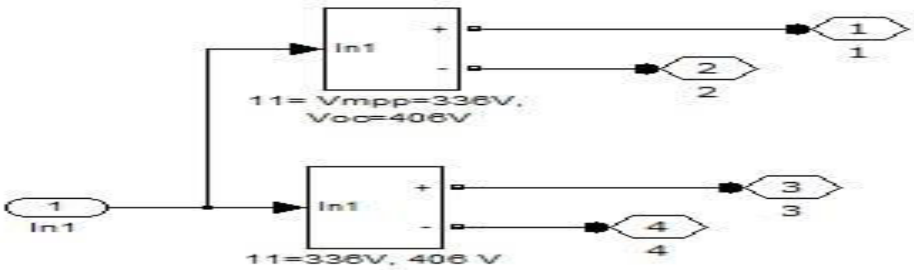


Fig 5.6 Parallel Connection of Solar Cell

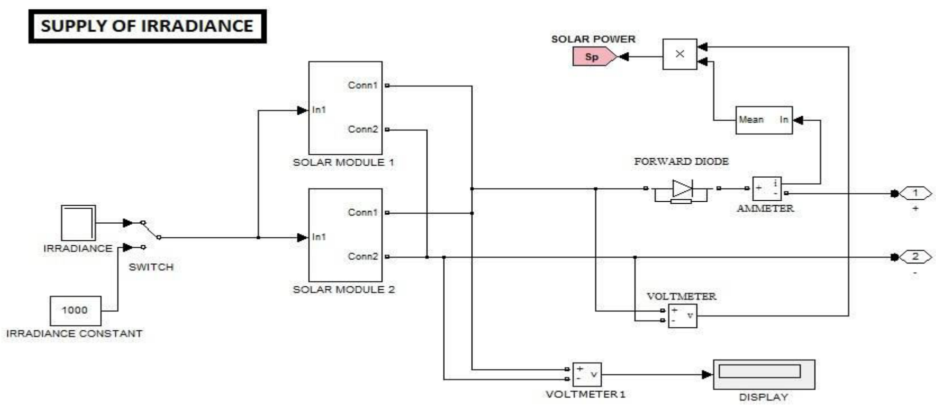


Fig 5.7 Simulation Model Showing the Utilization of Irradiance and Solar Modules

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 connections of the PV modules is measured here with the inclusion of the Display block of Simulink.

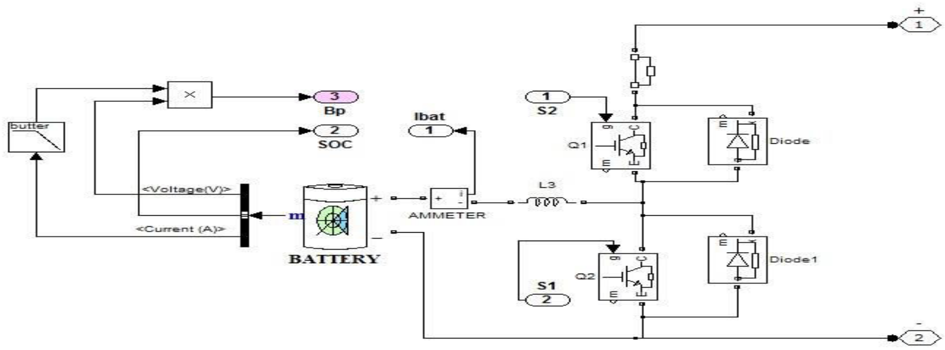


Fig 5.8 Battery Operation features sufficient supply to load

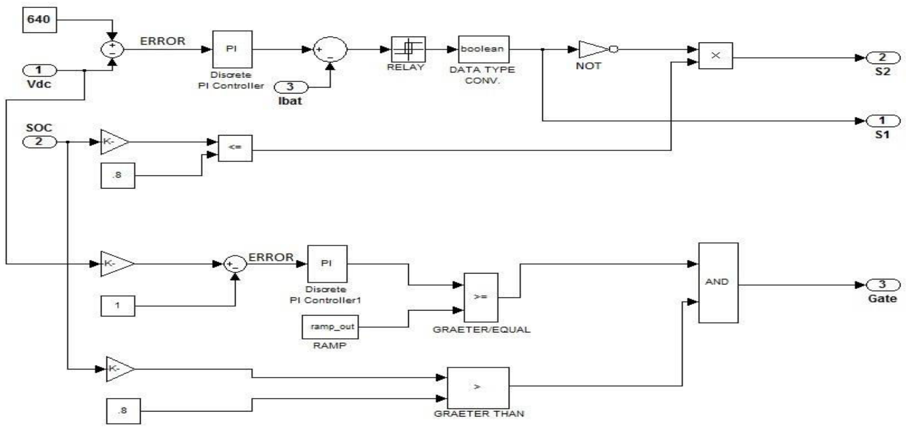


Fig 5.9 Working Logic of Battery Operation

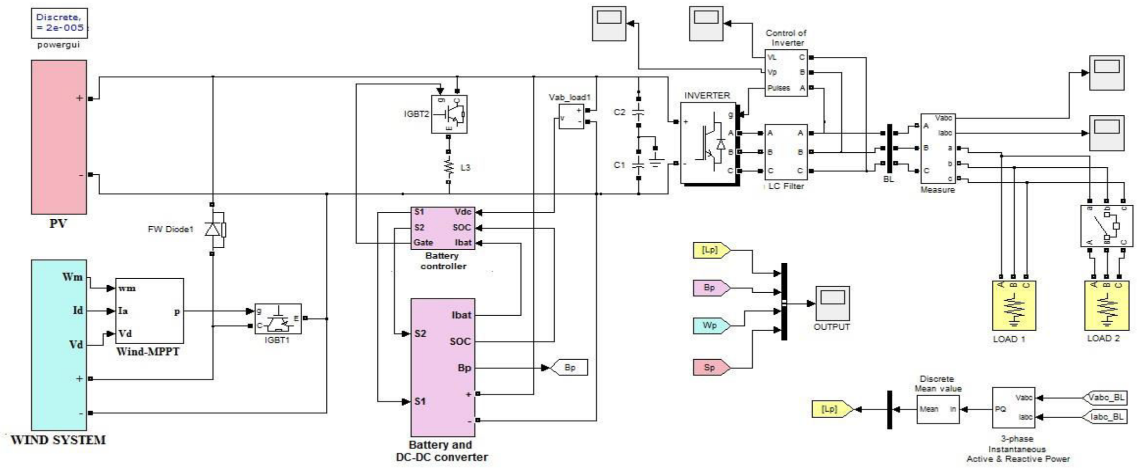


Fig 5.10 Composite Simulation Model of Proposed Hybrid System

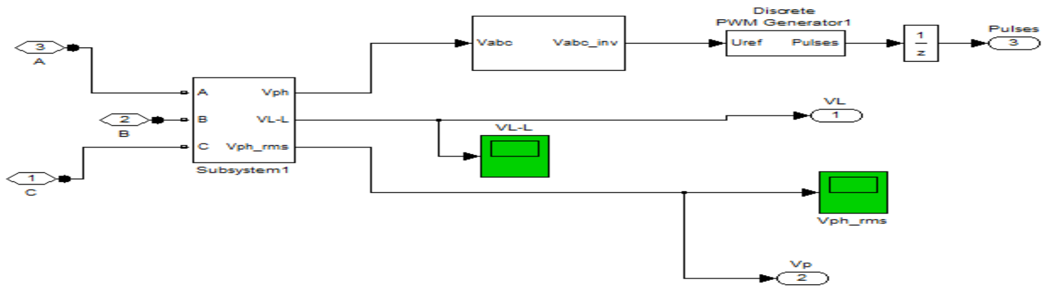


Fig 5.11 Inverter control using PWM

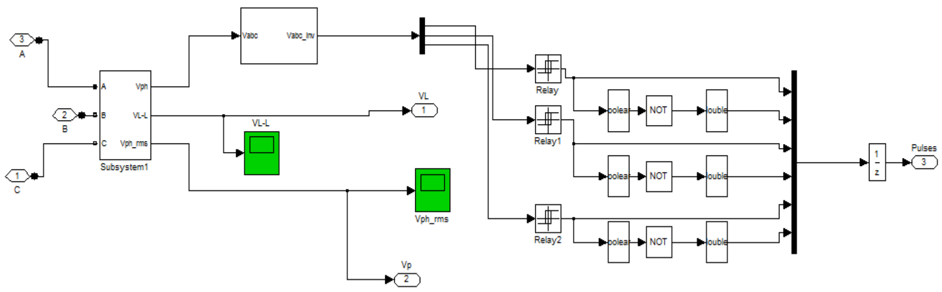


Fig 5.12 Inverter control using Hysteresis

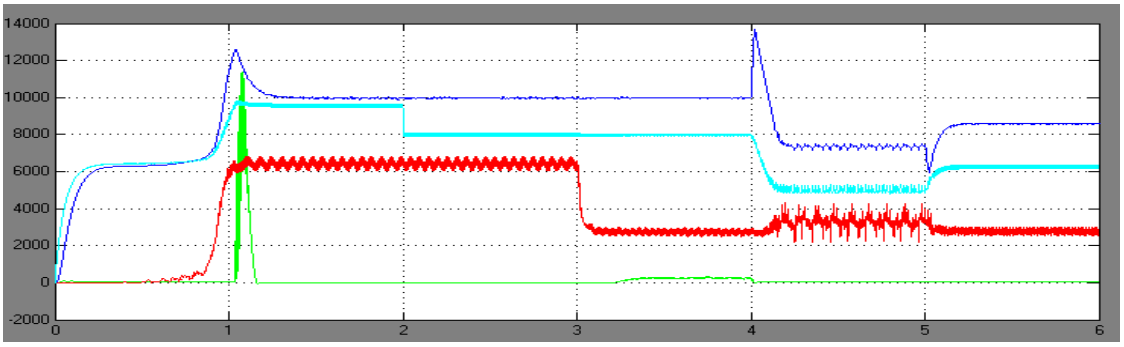

Fig 5.13 Simulation result with PWM control

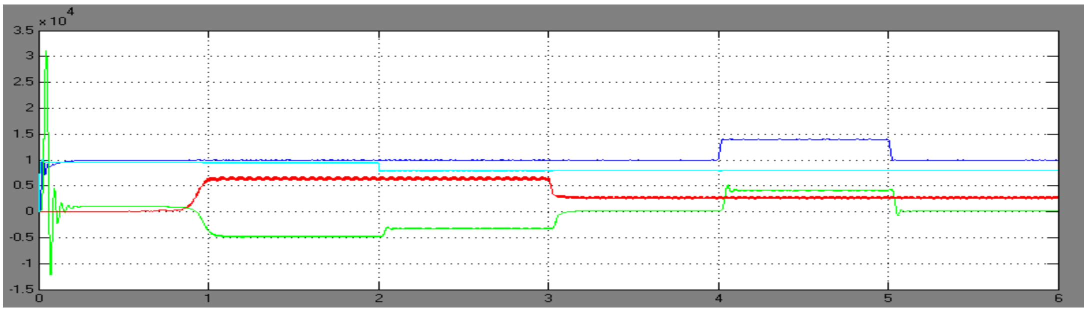

Fig 5.14 Simulation result with hysteresis control

# VI. 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 an Auxiliary Source of Supply to the load at the time of need. While comparing with PWM controller HYSTERESIS control gives better performance for inverter control.

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