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Grid Connected PV Wind Hybrid with Reactive Power Control

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Abstract: The popularity of renewable energy systems is increasing day by day due to its advantages such as unpropitious environmental effects and low cost. The convention energy sources are day by day getting replaced by renewable energy sources as intensification in energy costs is linked with conventional and established energy sources. Now a days wind energy and solar energy can be stated as the alternative to each other and combined they have potential persuade the load dilemma up to some degree. The output of wind solar hybrid (WSH) can become the future of energy generation and is capable of fulfilling the energy demand better than the conventional systems because it utilizes the advantages of both solar and wind energy. But the problem associated with this is their unstable nature and unpredictable behaviour. Hence there is a need to study this system and predict their behaviour in advance so that they can be utilized to their full potential. Hence seeing the scope of the hybrid system and the current problems associated with it this paper shows a method to study these systems effectively and understand their behaviour under different circumstances. The method to control the reactive power through a FACTS device named STATCOM is also discussed and implemented in this study.

***Index Terms* – Wind Solar Hybrid, Stability, Modelling, FACTS, STATCOM**

I. INTRODUCTION

Hybrid PV wind generation systems have become widely used now a days because of their advantages such as government subsidies, environmental benefits and less dependency on fossil fuels. Use of renewable energy sources is becoming popular day by day as renewable energy is taken from sources that are inexhaustible. Solar energy, geothermal energy, wind energy, and hydroelectric power are some examples of renewable energy sources. In this project we have used solar and wind hybrid system and simulated it in MATLAB a software which is used to analyze the performance of typically varying systems. In this project the two systems output is combined and sent to the power grid. The reactive power compensation is also done with the help of STATCOM for improving the system stability.

1.1. PV Energy Generating Systems: Solar energy is radiation from the Sun having ability of producing heat, resulting in chemical reactions and generation of electricity. The total amount of solar energy incident on Earth is huge and capable of fulfilling the world's current and anticipated energy requirements. If efficiently harnessed, this highly available source has the potential to satisfy all future energy needs. Hence, we can utilize the potential of solar energy by studying it's essential character tics and properties.

1.2. Wind Energy: Wind power is the change of wind energy into a usable form of energy, like using turbines to generate electricity, windmills to get mechanical power, wind pumps for getting pumping energy for water and to propel ships. The sum amount of power available from the wind is considerably more than present power requirement. Wind power can be a very good alternative to fossil fuels because it is abundant, it is renewable, it is widely spread, it is clean, and it produces no greenhouse gas emissions during operation. Wind power can be stated as the rapid growing source of energy in the world.

1.3. STATCOM: STATCOM is a FACTS family of device. This is a power electronic based device used for the control of reactive power and thereby increasing the Stability of the network. STATCOM can absorb or generate reactive power in any network and it is always connected in shunt with the network**.** Fig 3.1 shows STATCOM working principle. STATCOM is used as reactive power controller in this project.

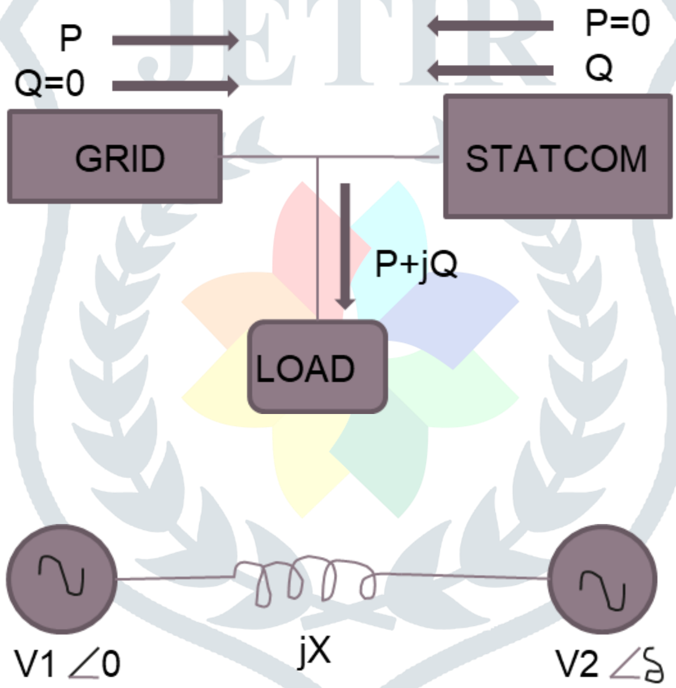

Fig 1.1: STATCOM Working

II. LITERATURE SURVEY:

For doing this project many previous studies and assignments were referred. In this project we have used flexible AC transmission (FACTS) device named static synchronous compensator abbreviated as STATCOM for controlling the reactive power. The history of FACTS devices is very long. Dr. Narain Hingori is the father of FACTS technology. The first FACTS installation was at C.J. slat substation near Arlington, Oregon (US). This was a 500kv 3 phase 60 Hz substation where FACTS devices were first implemented. After this there has been a lot of improvement in FACTS working and design. For this project STATCOM is main compensating device so if we look at its history, we can get that first STATCOM prototype was described in year 1987 by Empire State Electric Energy Research Corporation. The first STATCOM was installed in year 1995 by Westinghouse Electric at the Tennessee Valley Authority Sullivan substation which was of capacity 100 MVAR but it was quickly retired due to datedness of its components. After that there has been a lot of improvements in this technology and now, they are used for stability and power factor improvement. In this study we have developed the advance simulation model of STATCOM in MATLAB which will be very helpful for analyzing its behavior and predicting the required values of components to get the most stable system.

III. SYSTEM DEVELOPMENT:

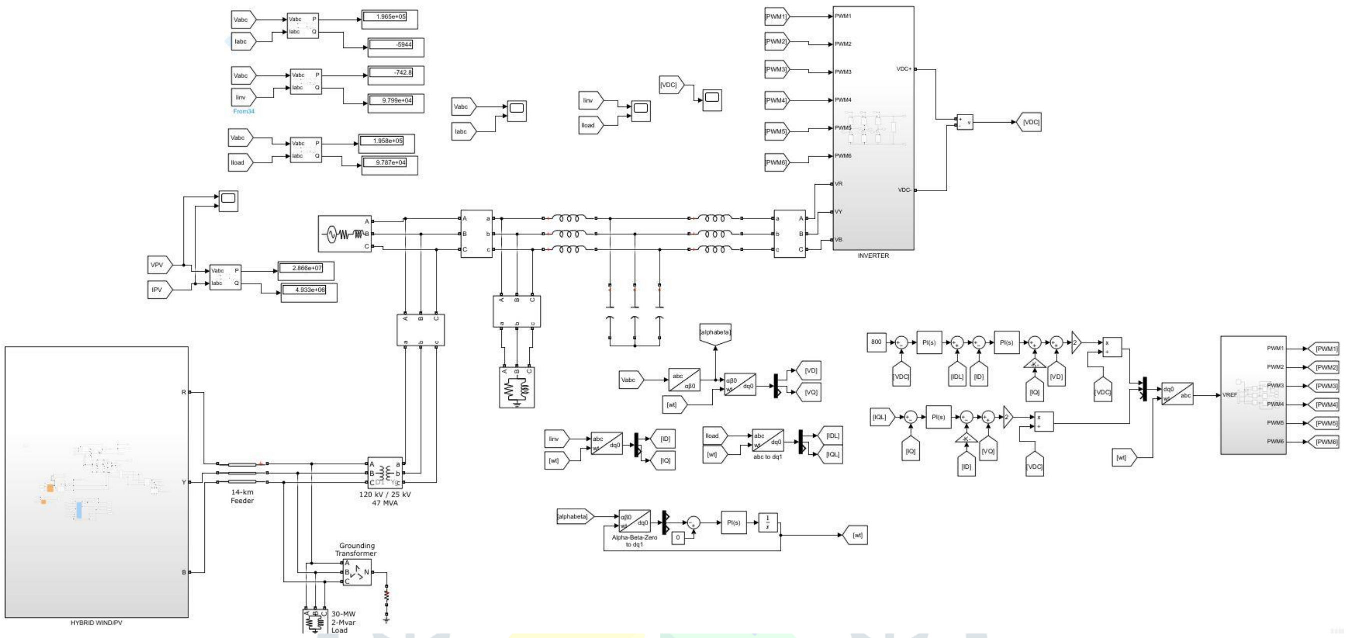

Fig 3.1: MATLAB Simulation of Whole System

The Figure 3.1 shows the complete simulation diagram of the system in MATLAB. It can be divided into following blocks:

1. PV Wind Hybrid System
2. STATCOM

1. PV Wind Hybrid System:

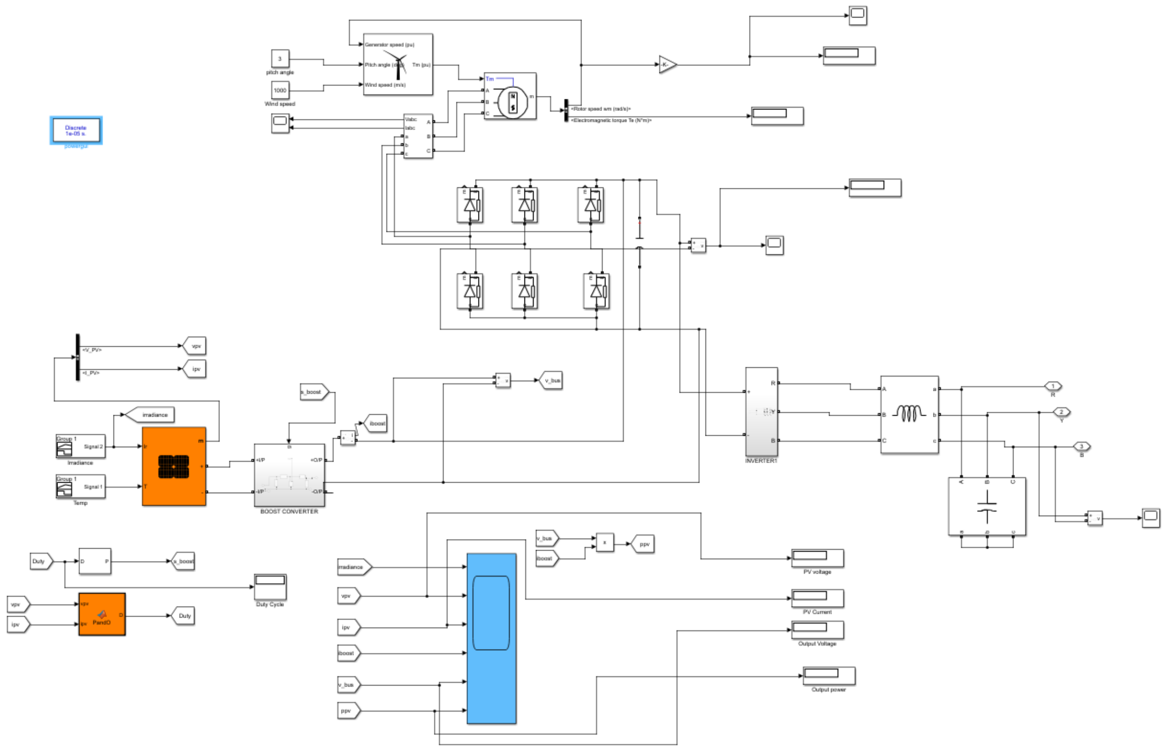

Fig 3.2: PV Wind Hybrid System in MATLAB

Whole PV wind hybrid system was developed and simulated in MATLAB as shown in Figure 3.2. Firstly, it has PV array block which simulates PV panels and we can provide values such as irradiance and temperature to simulate its behavior. Photovoltaic solar panels are of individual PV cells connected all together, then this Solar Photovoltaic Array is also known as a Solar Array is a system. In MATLAB the photo voltaic array block can be found out at Simscape / Electrical / Specialized Power Systems / Sources library. The photo voltaic array implements an array of PV modules. This is made up of strings of modules connected in parallel, each string consists of modules in series. This block will allow you to model PV modules from the National Renewable Energy Laboratory (NREL) System Advisor Model (2018) as well as modules that you define. The PV Array block is having five-parameter model current source (I_L), diode, series resistance (Rs), and shunt resistance (Rsh) to represent the irradiance- and temperature-dependent I-V characteristics of the modules.

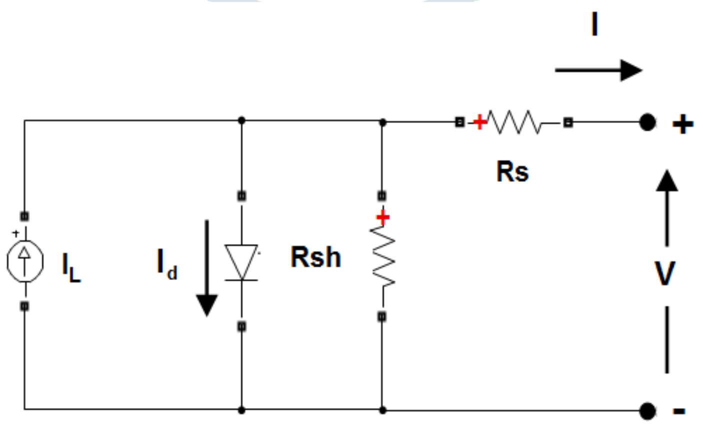

Figure 3.3: PV Array Circuit

Wind block also has properties such as pitch angle and wind speed which determines the speed of the turbine and on that speed the electric output is dependent.

The output from the PV array is given to boost converter. Boost converter not only helps in increasing the output voltage but also it stabilizes the output.

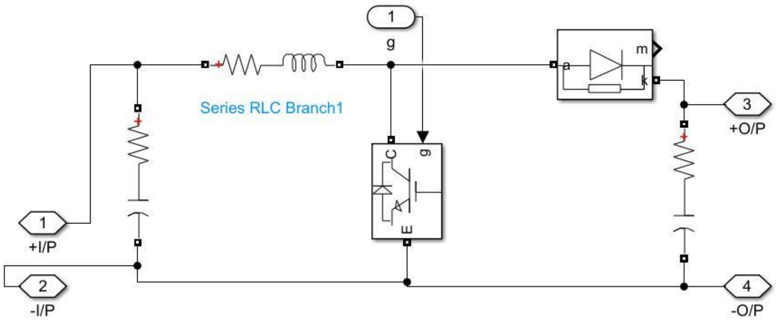

Figure 3.4: Boost converter

As seen in Figure 3.4, the boost converter is having IGBT in parallel to which gate signal is given through MPPT. MPPT is used to track the maximum point thus maximizing the power output of the system. Perturb and Observe Method is implemented in MPPT through code given in Figure 3.5.

```
function D = PandO(vpv,ipv)

persistent Dprev Pprev Vprev
if isempty(Dprev)
    Dprev=0.7;
    Vprev=190;
    Pprev=2000;

end
deltaD = 125e-6;

ppv = vpv*ipv;

if (ppv-Pprev)~= 0
    if (ppv-Pprev)>0
        if (vpv-Vprev) > 0
            D = Dprev - deltaD;
        else
            D = Dprev + deltaD;
        end
    else
        if (vpv - Vprev) > 0
            D = Dprev + deltaD;
        else
            D = Dprev - deltaD;
        end
    end
else
    D= Dprev;
end
Dprev = D;
Vprev = vpv;
Pprev = ppv;
```

Figure 3.5: MPPT Code in MATLAB

The output of wind turbine is converted to DC through a three phase fully controlled bridge rectifier and combined with the PV array output coming from boost converter. This combined DC output is given to an inverter which converts it into AC and then fed to the grid or load. The inverter which is used here is three phase inverter with MOSFET as switching device. All the values of MOSFET, IGBT and gate pulses are taken by the standards to avoid any deviation from real scenarios. The MOSFETS are given the gate pulses as required and switched on at perfect time and give required pulse width to obtain proper pulse with modulated sinusoidal wave at the output side.

2. STATCOM:

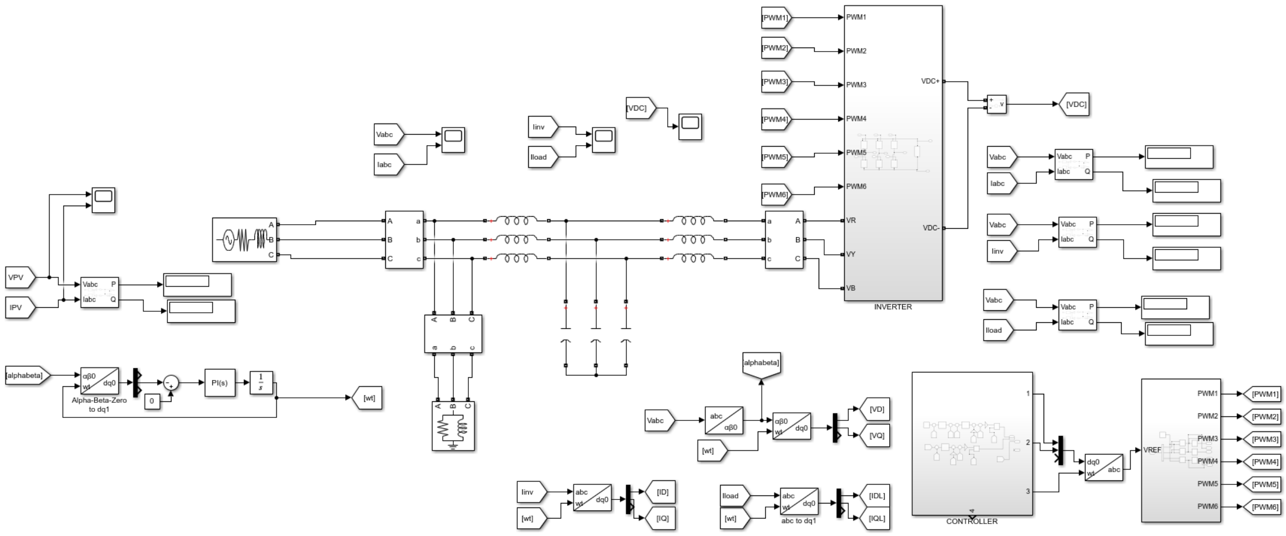

Figure 3.6: MATLAB Simulation of STATCOM

Static synchronous compensator is used to compensate for the reactive power at load side and source side. In this project STATCOM is used as reactive power controller whose simulation model can be seen in Figure 3.6. This model uses an inverter, PWM generation circuit, controller circuit and phase locked loop control system.

IV. MATLAB RESULTS AND DISCUSSION:

The main components of the project are PV wind hybrid system and STATCOM for controlling the obtained reactive power. In the previous section we have seen the whole simulation of PV System and its details and in this section, we will look at complete project simulation diagram and obtained results with STATCOM. MATLAB/SIMULINK results are presented in this section for validating steady-state and dynamic of this proposed system. In this section, the working of this proposed PV wind hybrid generation system is presented with reactive power control through STATCOM.

The reactive power in the grid which is combination of solar photovoltaic energy and wind energy can be minimized using STATCOM circuit in the proposed system. The basic function of STATCOM is to provide the reactive power required to run the load which minimizes or sometimes nullifies the reactive power of source system which intern increases system stability and its performance. The Figure 4.5 shows the STATCOM circuit used in the project.

Figure 3.6 shows the simulation of STATCOM in MATLAB. It has got inverter circuit, PWM subsystem, controller circuit and phase locked loop control system. Now we will look at the obtained values in PV wind hybrid system, the three-phase voltage obtained from PV wind hybrid system will be input to the STATCOM circuit and a RLC load. The STATCOM will absorb the reactive power and nullify it in source system

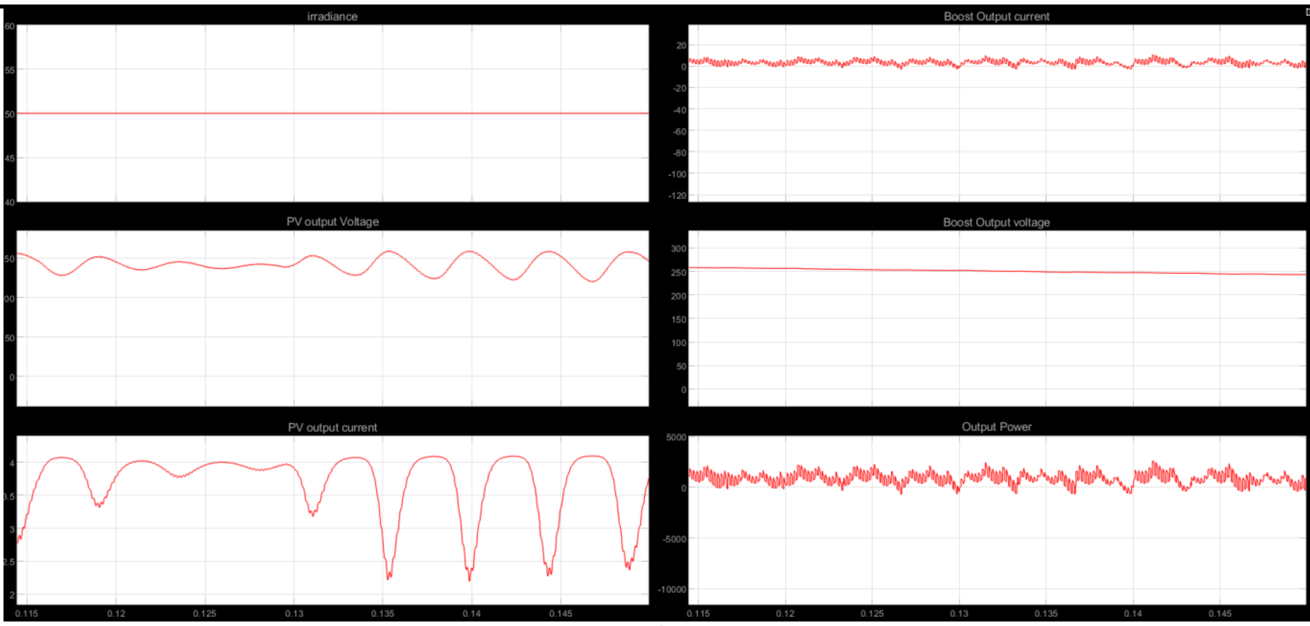

Figure 4.1: Output of PV System

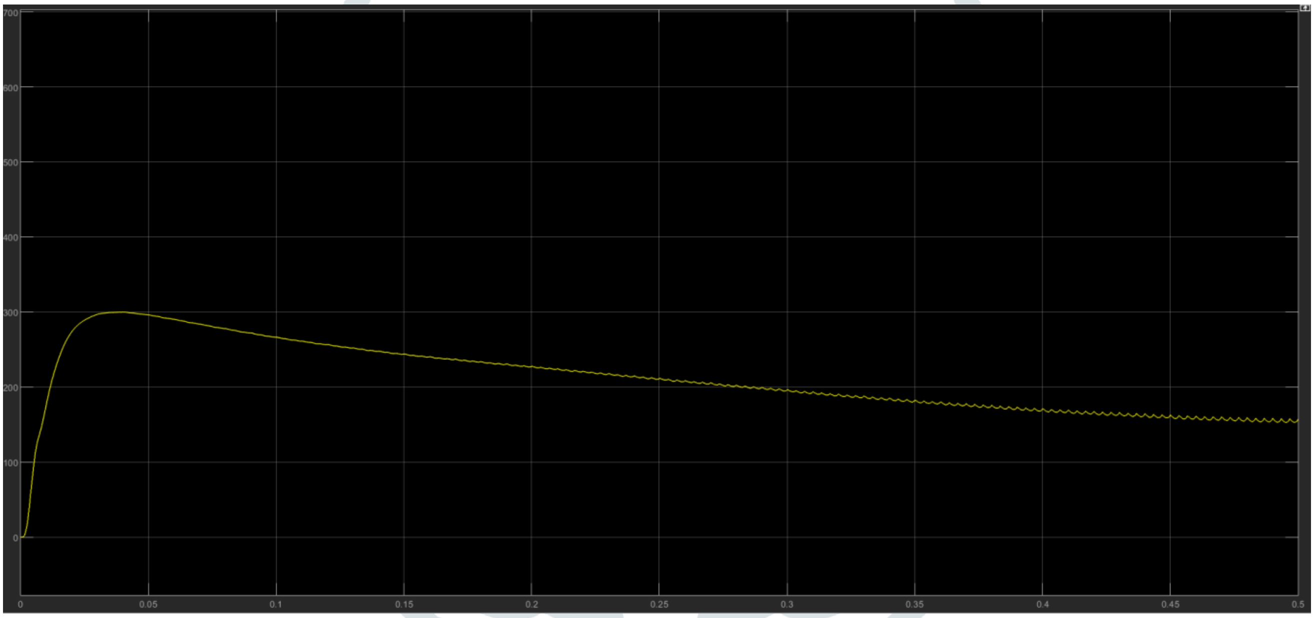

Figure 4.2: Output of Wind System

The Figure 4.1 shows the output waveforms obtained from PV system this output is filtered then optimized with the help of a buck boost converter. The Buck- Boost converter circuit was explained in the previous section of this paper. Similarly Figure 4.2 shows the output of wind energy system. This is also filtered and converted to DC supply with the help of a rectifier circuit. The rectifier circuit was also explained in the system development chapter of this paper. The radiance and temperature for PV array was kept at standard value of 1000 and 50 respectively. For the project purpose 10 parallel string and 5 series strings was taken for obtaining these values but this can be changed according to the system that we are testing or evaluating. For wind turbine the pitch angle was kept at 3 and the wind speed value was 1000 but this can also be changed according to the system that we are testing or evaluating. The output of both the system is combined and fed to an inverter to convert it into useful AC power the waveform of which can be seen in Figure 4.3. All the other values in the simulation were taken according to the standards and hence correct wave forms are obtained for all the outputs. A three-phase inverter is used to convert a DC electricity input into a three-phase AC electricity output.

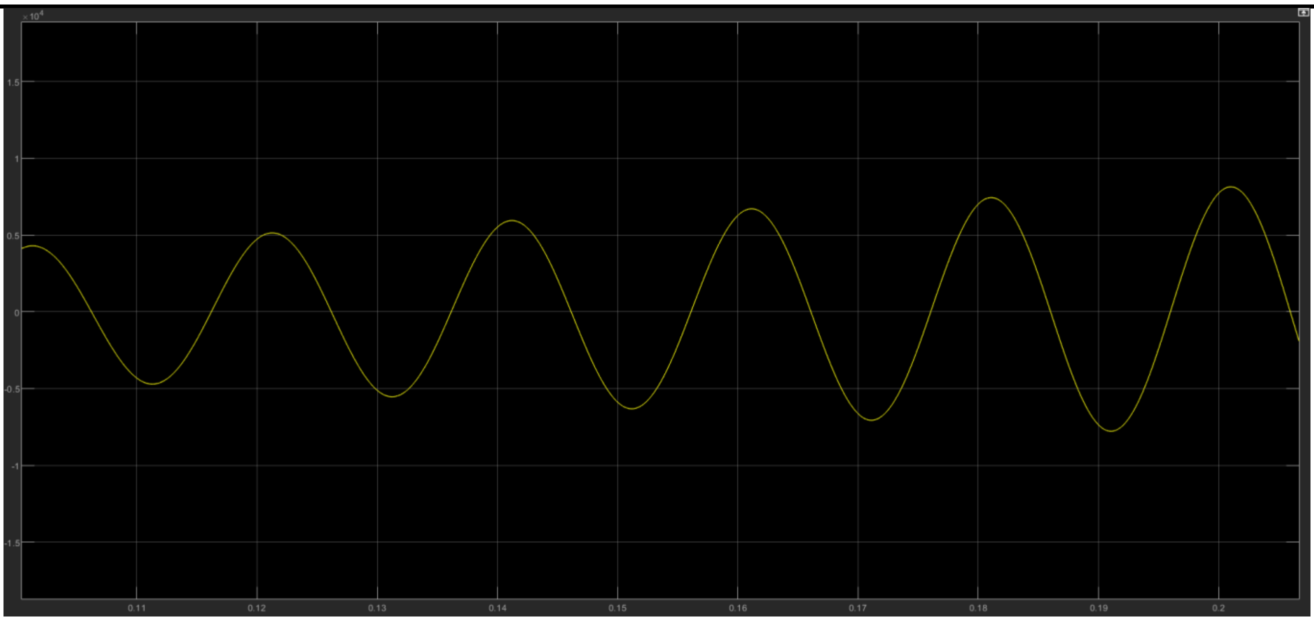

Figure 4.3: Output of PV and Wind Combined

Inverter's arms are delayed by an angle of 120° to generate a three-phase AC supply. The inverter switches each switch at a ratio of 50% and switching is done after every T/6 of the time T 60°angle interval. In simple source voltage converter(inverter), the switches have the flexibility of getting turned ON and OFF as needed. During every cycle, the switch is turned either ON or OFF at least once. This is resulted in a square wave. But if the switch is turned on for more than once than an improved waveform is obtained. The sinusoidal PWM waveform is resulted when we compare the desired modulated waveform with a triangular waveform of high frequency given externally. Irrespective of whether the voltage of the signal is smaller or larger than that of the carrier waveform, the resulting output voltage of the DC bus will be either negative or positive.

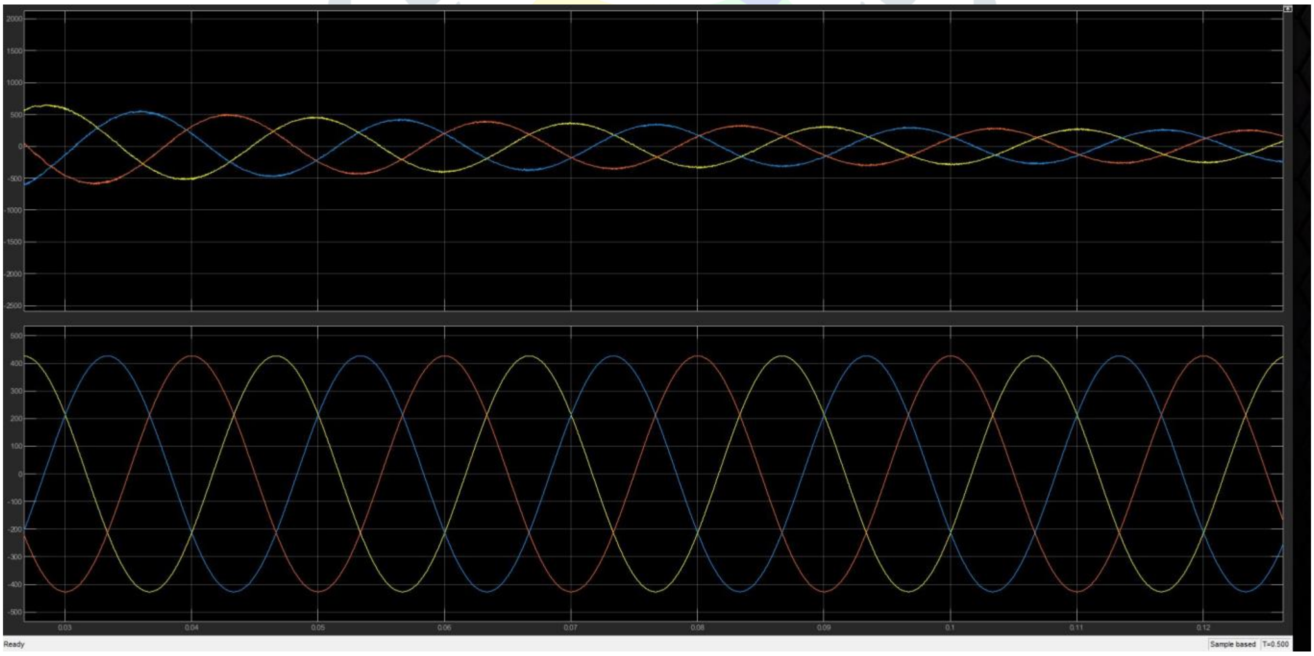

Figure 4.4: Input to Three Inverter

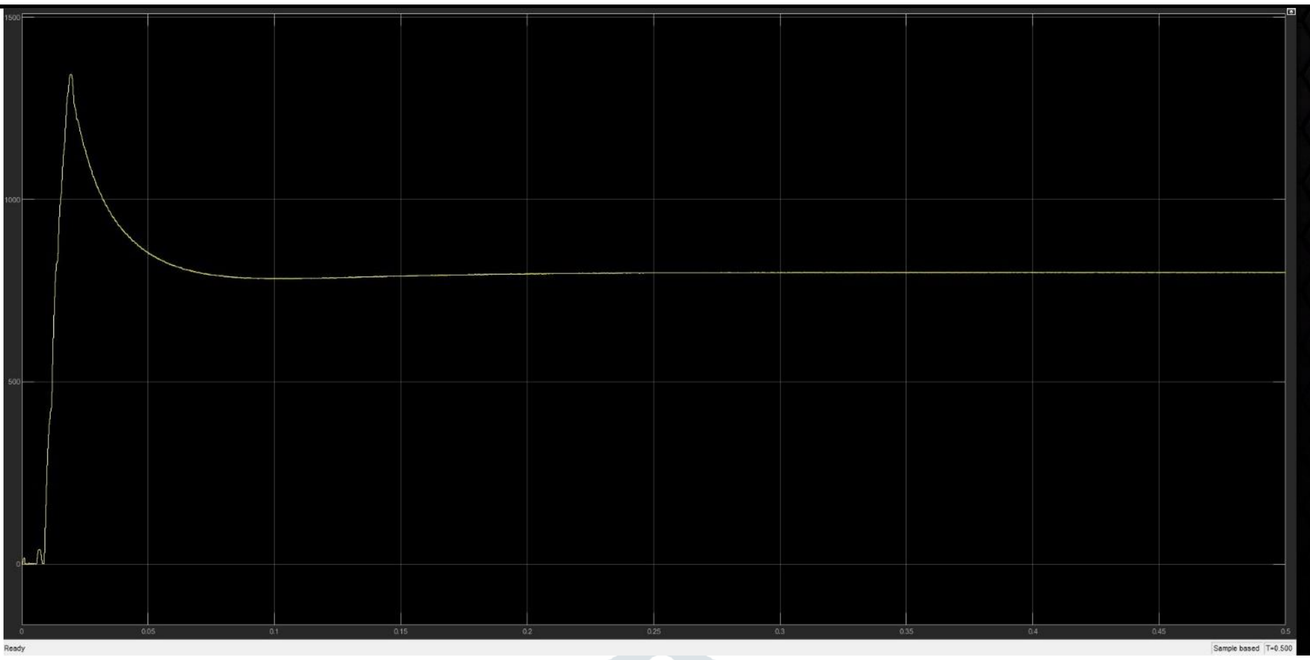

Figure 4.5: Output of Inverter

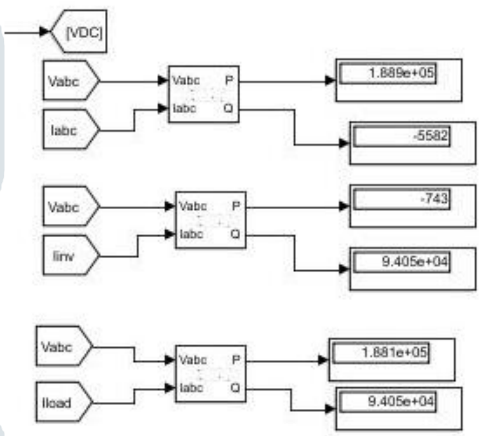

Figure 4.6: Active and Reactive Power Values of Inverter and Load

The Figure 4.9 shows the input to the three phase fully controlled bridge rectifier which is AC input the circuit converts that into DC as seen in the Figure 4.10. The value of load taken for this simulation was active power 200000 and reactive power 100000. As seen in the readings shown in Figure 4.11, the reactive power is perfectly compensated by STATCOM. The value of active power in source side is 1.889e+0.5 which is almost similar to the value of active power at load side i.e., 1.881e+0.5. Similarly, the value of reactive power supplied by inverter circuit is equal to the value of reactive power at the load side which is 9.405e+0.4. This means that there is no reactive power in source circuit and the reactive power which is required to run the load is fully compensated and supplied by the inverter circuit. The designed STATCOM circuit completely provides the reactive power necessary for the load without having any reactive power at the source side which indeed improves the system stability and increase the life of the source system. We can try this compensation for as many load values as we can and obtain the results by trying different values of the attributes in various combinations.

The final obtained results are as follows:
Source Side Active Power: 1.889e+0.5
Source Side Reactive Power: -5582
Inverter Side Reactive Power: -743
Inverter Side Reactive Power: 9.405e+04
Load Side Reactive Power: 1.881e+05

Load Side Reactive Power: 9.405e+04

V. CONCLUSION

A way to control the reactive power in grid connected PV-Wind hybrid system was described in the report with MATLAB simulation. The output of PV system was successfully regulated through a MPPT and after that it was combined with output of wind turbine and then fed to the grid. The obtained output waveforms of PV and wind generation systems were very useful in predicting the varying system performance according to uncontrollable environment factors. In the simulation reactive power was successfully controlled for different values of load by using the FACTS (Flexible AC Transmission System) family device named static synchronous compensator abbreviated as STATCOM. The reactive power value obtained from the inverter circuit was exactly similar to the value of reactive power at load side which implies that whole of the reactive power was supplied by the developed controller arrangement as a result of which the grid side will become more stable and efficient. A proper control of the reactive energy will result in maintaining healthy power factor, reducing losses and improving voltage regulation in the network thereby improving the system efficiency. Hybrid PV wind generation system was successfully configured, modelled and simulated as a renewable energy source with control strategies applied for regulating load and source side parameters which proved to be very helpful in developing a stable system. The results obtained are very useful for analyzing the performance of the system with respect to change in load values and other dynamic factors.

VI. ACKNOWLEDGMENT

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