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ANALYSIS OF THE BEHAVIOR OF REACTIVE POWER COMPENSATION FOR STATCOM CONTROLLED HYBRID SOLAR/WIND POWER GENERATING SYSTEMS

Touseef Ahmad Dar[1], Mohd Ilyas[2], J.S. Khan[3]

[1]*Student, M.Tech,* [2]*Associate Prof.,* [3]*Professor, Department of Electrical & Electronics Engineering, Alfalah University, (India)*

ABSTRACT

Now-a-days the trend goes on hybrid power generation systems but here the controlling and compensation is necessary. This thesis investigates the use of a Static Synchronous Compensator (STATCOM) along with wind farms and solar for the purpose of stabilizing the grid voltage after grid-side disturbances such as a temporary trip of a wind solar generation and sudden load changes. It has capacity to absorb or inject volt-ampere reactive (VAR) or Reactive power at faster rate. STATCOM has rehabilitation to control or stabilize the voltage sag after drastic disruption through voltage source converter. It absorbs or injects reactive power at greater rate. Due to faster dynamic response, it will go from capacitive mode to inductive mode. The strategy focuses on a fundamental grid operational requirement to maintain proper voltages at the point of common coupling by regulating voltage and reactive power. The proposed paper is shown that the use of advanced control methods, such as the standard robust control method, in the control system of FACTS could improve their performance with the help of Simulink MATLAB.

Keywords: STATCOM, Reactive Power, Wind Turbines, PV Array, MATLAB.

I. INTRODUCTION

Renewable resources are the essential resources in the power generation sector and have played a vital role till date. These resources viz. wind, solar, tidal, hydroetc. have granted power generation in different ways. Energy is needful to our society to make certain our quality of life and to predicate all other elements of our economy. The escalation in cost and environmental matters involving conventional electrical energy. Sources have increased interest in renewable energy sources. Many societies across the world in which we live have developed a large appetite for electrical energy. This inclination has been prompted by the relative ease with which electricity can be generated, distributed, and utilized, and with much diversity of applications. It is conceivable whether the utilization of electricity should be allowed to grow unbounded, but the fact is that there is an always increasing insistence for this energy form. Clearly, if this insistence is to be clash, then the generating capacity of electricity in the world will have to continue to flourish. Today the primary fuel sources like coal, oil, gas, water or fissile nuclear material are being utilized in the central power station for generation

of electricity. There are problem facing the further development of generating methods based on any of these conventional fuels. Wind-solar power generations are visible options for future power generation. Besides being free, they are free of recurring costs. They also offer power supply solutions for remote areas, not accessible by grid power supply today around 30,000 wind turbines and more than 1,00,000 off-grid solar PV systems are installed all over the world[1-5]. Wind and solar hybrid model with proper storage system have been keen interest for the last few years. In this paper a hybrid model of solar / wind is developed using STATCOM. In this paper, it is an effective way to get the electric power by integrating the Hybrid solar/wind generating system and then regulated and stabilized with the help of static compensator which includes wind power/voltage stabilization and harmonic filtering. The simulation circuit will include all realistic components of the system.

II. SOLAR PANEL MODELING

When light energy is converted into electrical energy, it is called solar power generation. Many modules and panels are connected electrically in parallel-series combination to generate the needed power. By using the effects of photoelectric effects, the light is directly converted into electric current. Depending upon the light intensity, the Photovoltaic Array produces direct current. With the help of inverter or universal bridge, the dc power is being converted into ac power having phase and frequency. In my thesis, eight photoelectric modules are being used which is shown in figure 1. The characteristics and electrical behavior depends on illumination and temperature. The maximum limit of solar irradiance is 1000 W/m^2. The circuit diagram is shown in figure 2.

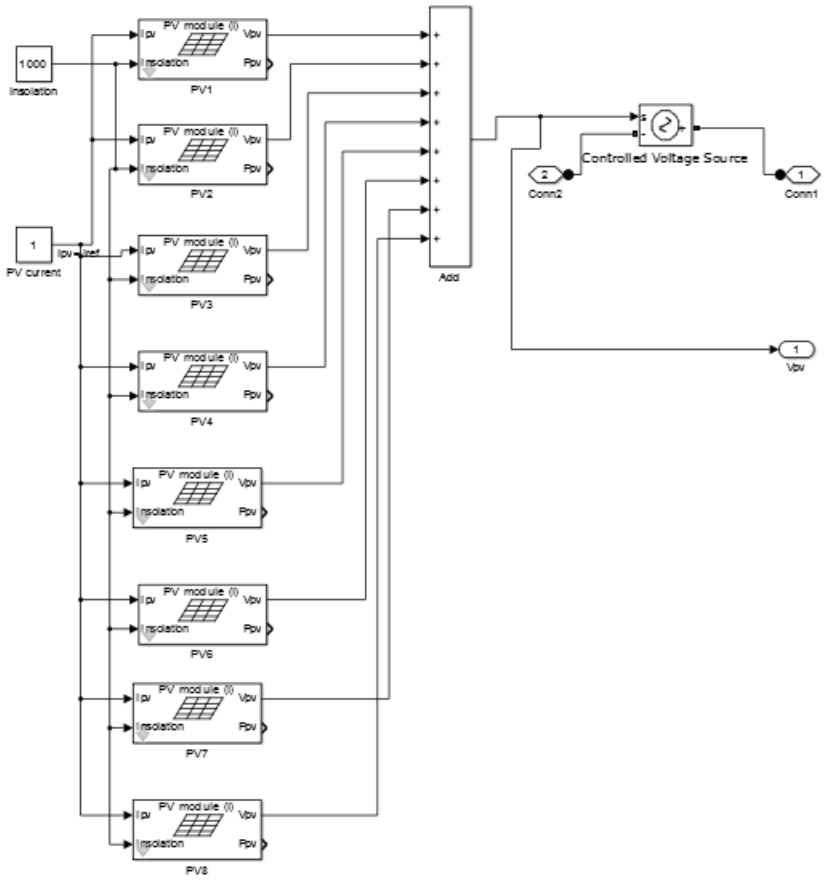

Figure 1: Simulink of Photovoltaic Module

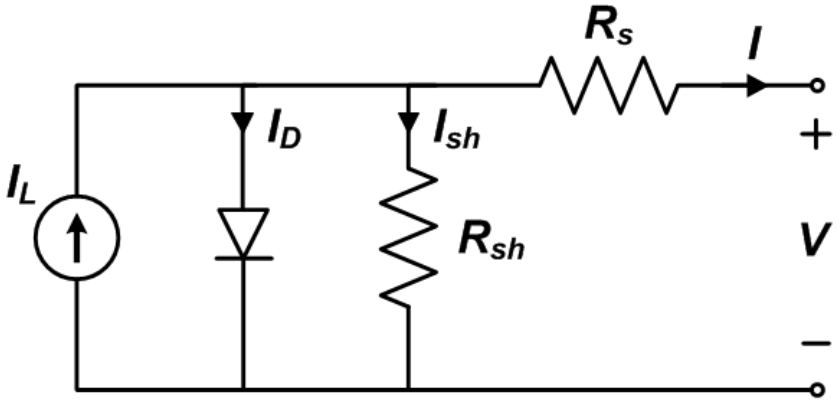

Figure 2: Equivalent Circuit Diagram of PV System with Series and Parallel Resistance

The electrical characteristics of the PV module are generally represented by the current vs. voltage (I-V) and the current vs. power (P-V) curves. The V-Icharacteristic equation of the PV module is:

$$I = I_L - I_0 (e^{q(V+IRs)/nkT} - 1)$$

Where

I_L = photo current,

I_0 = diode saturation current,

R_S = series resistance,

q = charge of electron,

T = temperature,

N = number of PV module.

Power output from the PV array can be obtained by using the equation:

$$Ppv\ (t) = Ins\ (t) * A*Eff\ (pv)$$

Where

Ins (t) = insolation data at time t (kW/ m^2),

A = area of single PV panel (m^2),

Eff (pv) = overall efficiency of the PV panels and DC/DC converters.

The open circuit voltage of a single Photovoltaic cell is approx. 0.5V.ν It needs high voltage for practical applications. Photovoltaic cells are connected in series to enhance the open circuit voltage. [4].

III. WIND TURBINE MODELING

It is one of the less expensive sources of renewable energy and this technology is publicized in many countries. A wind turbine captures the kinetic energy from rotor having many blades and converting into electrical energy. If the mechanical energy is used directly by machinery, such as a pump or grinding stones, the machine is called a windmill. If the mechanical energy is then converted to electricity, the machine is called a wind generator. Its components are designed in a proper way to get maximum energy. The output power equation of wind turbine is given by

$$P_m = C_p (\beta, \lambda)\ \rho A/\ 2(V_w)^3$$

Where Pm = Turbine mechanical output power

C_p= Performance coefficient of turbine

ρ= Air density (Kg/m^3),

λ= speed ratio

A= swept area of turbine

β= blade pitch angle

V_w= wind speed (m/s)

In this paper, Permanent Magnet Synchronous Generator is being used because of having better performance due to higher efficiency. It has less maintenance cost due to which it can be used without gearbox as it does not contain rotor current, thus the reduction of weight of nacelle and reduces cost. The mechanical energy is being obtained from Wind and converted into electricity. The Simulink model of wind Turbine is shown in figure 3.

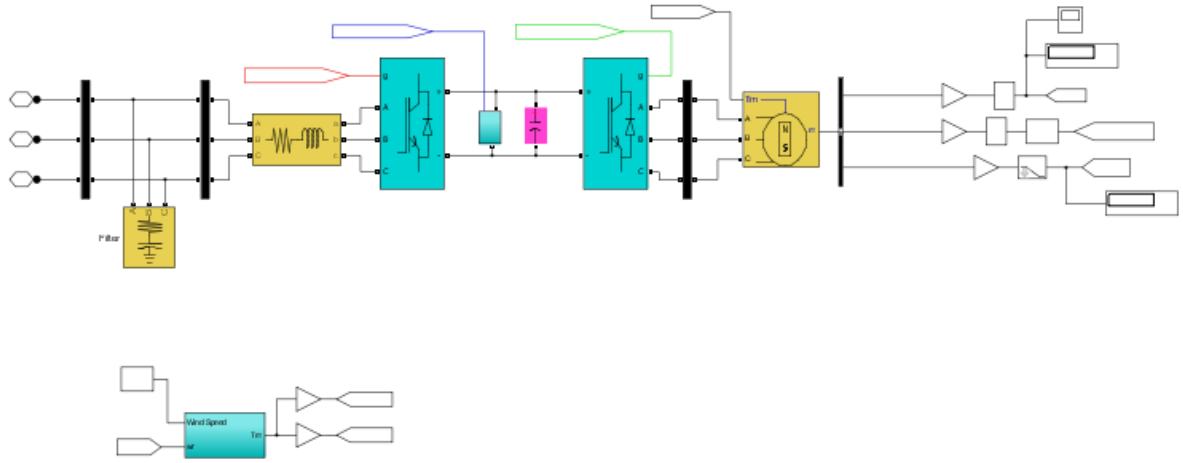

Figure 3: Simulink of wind Turbine

IV. STATCOM DESCRIPTION AND MODELLING

STATCOM is a shunt connected compensation device having the ability of injecting or absorbing the reactive power. It also improves the steady state and transient stability systems.The main components include Voltage source Inverter (VSI), DC Capacitor, Signal Generation, Coupling Transformer and Control Circuit. Its output can be varied to control the various parameters of power system. It is considered as solid state switching converter because having the capability of injecting or absorbing real and reactive powerat its output terminals when it is being supplied from solar/wind hybrid input terminal system. The three phase output ac voltage produced after using STATCOM is in phase with the corresponding ac voltage through leakage reactance.The DC side of the voltage source converter is connected to a DC capacitor carrying the input current. No power will be delivered to the system if the AC terminal voltage will become equal to the output voltage of the VSI. The operation of Statcom will be in capacitive mode if the output voltage will be greater than ac output voltage. Similarly Statcom will operate in Inductive mode if ac output voltage is greater than output voltage of VSI.The circuit diagram of Statcom is shown in figure 4.

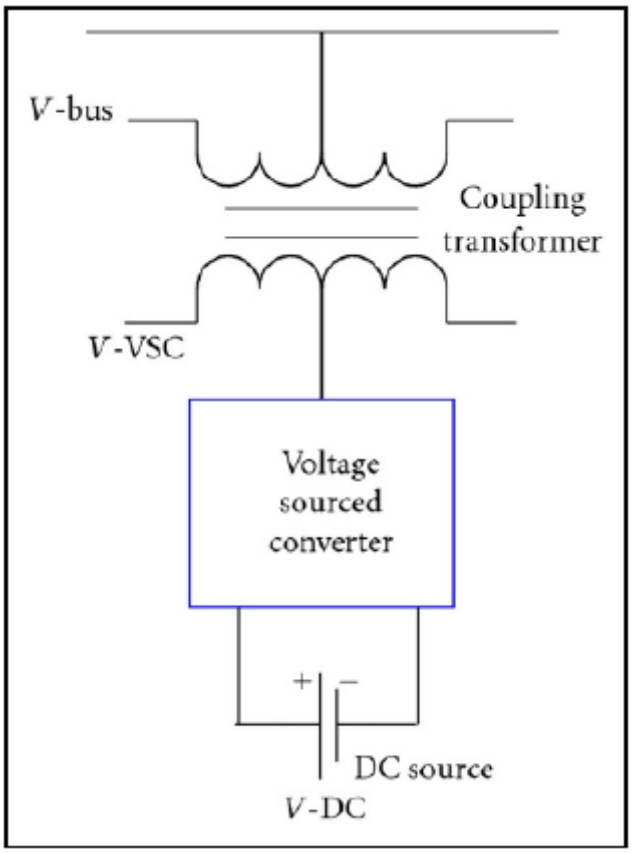

Figure 4: Circuit Diagram of STATCOM

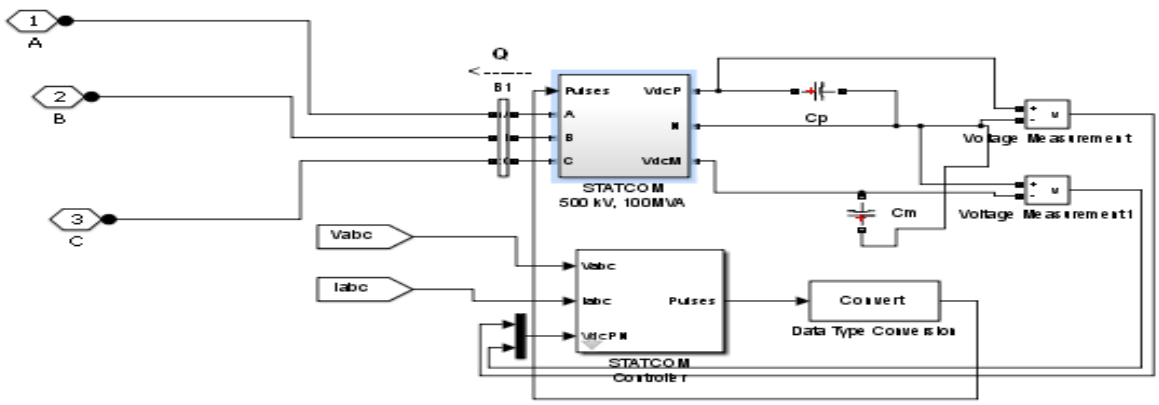

Figure 5Simulink Model of STATCOM

V. SIMULATION AND RESULTS

With above based models and methods, The PV/Wind hybrid system with power grid connected has been implemented with STATCOM in the Simulink/MATLAB as shown in figure. The proposed system consists of PV Panel which is connected to the universal bridge to convert dc into ac supply. The second part consists of Wind Turbine which is connected to the PMSG to obtain the ac supply. The ac supply from hybrid PV/WIND generating system is being supplied to grid which is unbalanced and contains harmonics. To make it stabilized

and balanced, we use STATCOM 100MVAR to this distribution network and the bus feeder is about 100km. The output of STATCOM is coupled in parallel with 1.25/25 KVA step up delta-star transformer. A filter bank is provided at the end of STSTCOM output to absorb the harmonics. The primary side of this transformer is fed with Voltage source Inverter and 3000 μF Capacitor is used as a dc voltage source for inverter.STATCOM plays a vital role for regulating the bus voltage by generating or absorbing it. STATCOM will behave as Inductive mode, if the secondary voltage is lower than the bus voltage and it will behave as capacitive mode if bus voltage is lower than secondary voltage.

The output voltage waveform of PV system is shown in figure 6. The output range of PV system is 401.2V DC.

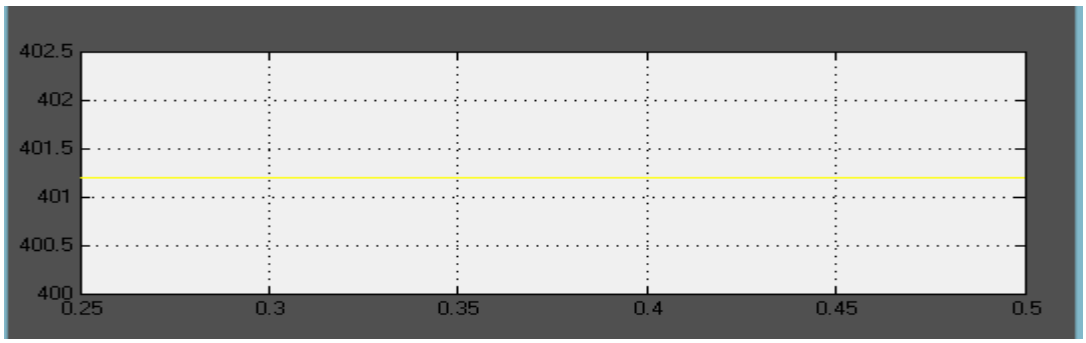

Figure 6: Output of PV as Source of STATCOM

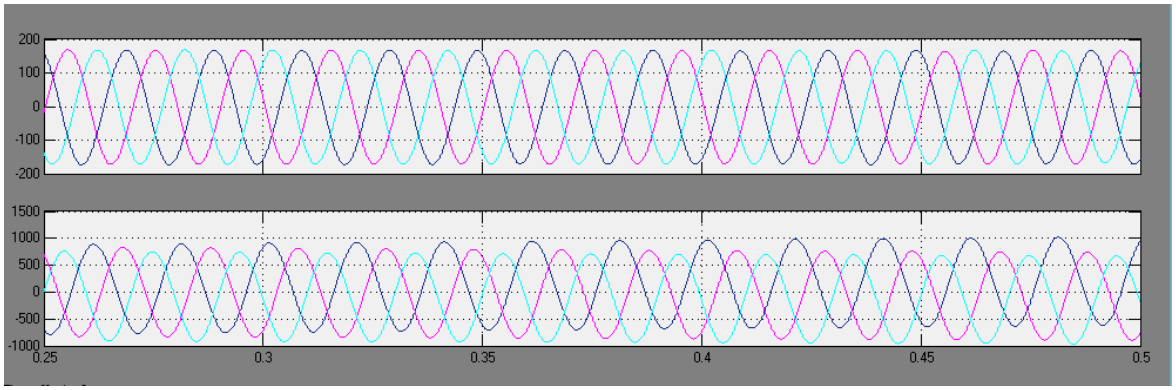

Figure 7: Voltage and Current Waveform without Using STATCOM

From above Waveforms, we see the Current is unbalanced and contains harmonics from the hybrid PV/Wind generating power system.

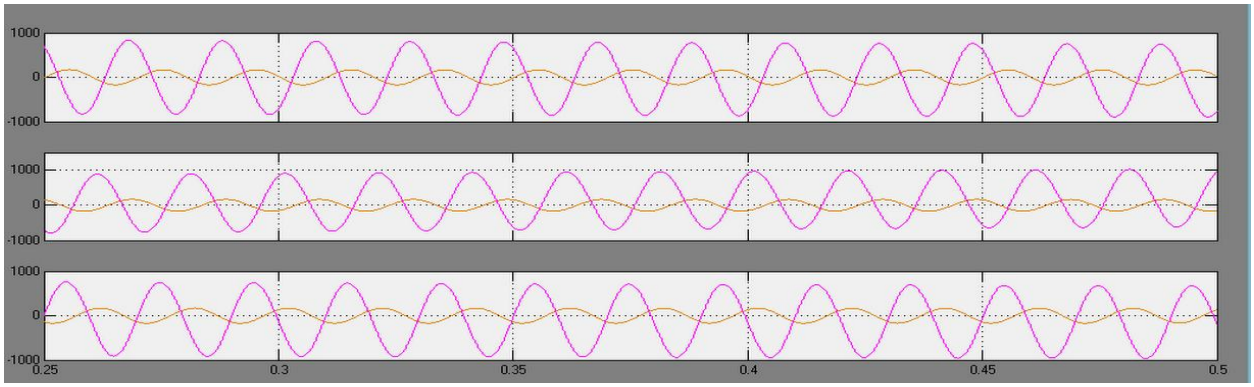

Figure 8: Voltage and Current Having Much Phase Difference Due to Low Power Factor.

Due to low power factor from the generating side, which results high amount of current is drawn at load side as shown in figure 8.

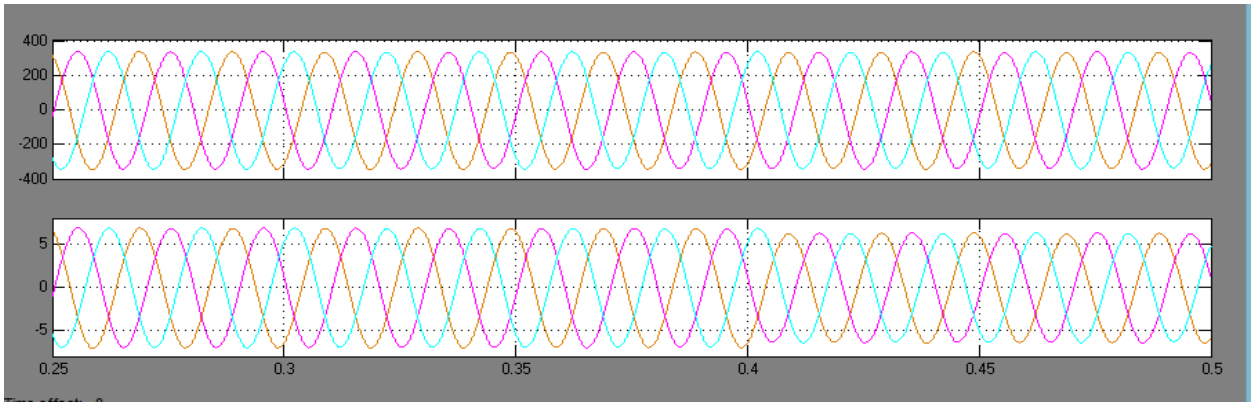

Figure 9: Voltage and Current Waveforms with STATCOM

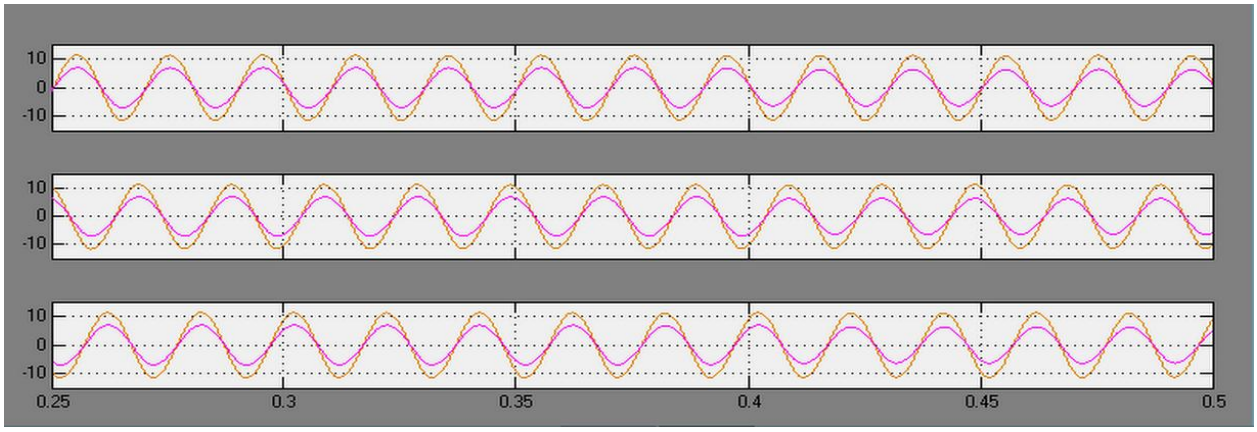

Figure 10: Voltage and Current Waveforms with Improved Phase Difference Due to High Power Factor Using STATCOM.

VI. CONCLUSIONS

In this paper, the power quality improvement with the help of STATCOM has been analyzed. STATCOM synchronize the bus voltage and maintain the reactive power. The hybrid PV/Wind generating system with STATCOM is being analyzed with the help of MATLAB/Simulink. STATCOM improves the performance of power system and make it balanced as shown in various waveforms. The voltage stability of the STATCOM is shown by altering the inductive load which regulates the load side voltage and current almost constant.

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ABOUT AUTHOR

MOHD. ILYAS was born on 2nd April 1976. He is an associate professor in department of electrical & electronics with Al-Falah University Faridabad, Haryana. He received his B.Tech in electrical engineering & M.Tech in electrical power system & management from Jamia Millia Islamia, New Delhi. Now he is pursuing PhD. from MD University, Rohtak. He has more than 14 years experience in teaching. He taught various subjects such as Power Electronics, Electrical measurement & Measuring Instrument, Electric Power Generation etc. He has published more than 15 papers in National & International Generals. He attended many national and international Seminars and conferences. He has guided number of B.Tech and M.Tech projects in his teaching career.

Touseef Ahmad Dar born 30th March 1990 is pursuing his Master of Technology in Power System from Al-Falah school of Engineering & Technology, Faridabad, Haryana. He completed his Bachelor Degree in Electrical & Electronics Engineering from Al-Falah school of Engineering & Technology, Faridabad, Haryana.

Dr. Jafar Salamat Khan (born 19th February 1950) obtained his B.Sc. Engg. (Elect.) ,M.Sc. Engg. (Elect.) and Ph.D from Aligarh Muslim University, Aligarh in 1971, 1974 and 1979 respectively. He worked with M/s. Engineering Projects (India) Ltd, New Delhi, a Govt. of India Enterprise, from 1977 to 1982. He joined Council of Scientific & Industrial Research (CSIR) in 1982 as a Scientist and superannuated from CSIR as Advisor in February 2010. He has rich and wide experience in Project Engineering, Project Marketing, R&D Planning, Technology Marketing, and Commercialization of indigenous technology developed through R&D. He has published more than 30 papers in National & International journal. He joined Al-Falah University in March - 2010 as Professor in Electrical & Electronics Engineering Department.