# A Novel Power Quality Improvement of DVSI with Hybrid Energy Grid Connected System

*Saurabh Raj[1], Padmini Katare[2]*
*[1]Research Scholar, [2]Assistant Professor*
*[1, 2]Department of EEE, MITS, Bhopal, India*

*Abstract- Technological progress and environmental concerns drive the power system to a paradigm shift with more renewable energy sources integrated to the network by means of distributed generation (DG). These DG units with coordinated control of local generation and storage facilities form a microgrid. A voltage regulation and power flow control scheme for a wind energy system (WES) WITH a solar system is proposed. The simulation result shows that the system with the proposed voltage optimizer active power control strategy proposed is better as compared to the basic phase locked loop control. Also, the system was made efficient by integrating it with the wind system and making it a hybrid power source. On comparing the active power outputs from the system with phase locked loop control with the proposed voltage optimizer active power control, it was found to be that the proposed system gives 4 MW output which is considerably more than the 0.5 MW output of the system with basic PLL control. Thus it can be drawn from this work that while designing an inverter control strategy the proposed voltage optimizer active power controller can serve the purpose with better results*
*Keywords: Dual voltage source inverter (DVSI), Hybrid renewable energy system, PLL, nonlinear load.*

## I. INTRODUCTION

Technological progress and environmental concerns drive the power system to a paradigm shift with more renewable energy sources integrated to the network by means of distributed generation (DG). These DG units with coordinated control of local generation and storage facilities form a micro grid. In a micro grid, power from different renewable energy sources such as fuel cells, photovoltaic (PV) systems, and wind energy systems are interfaced to grid and loads using power electronic converters. A grid interactive inverter plays an important role in exchanging power from the micro grid to the grid and the connected load. This micro grid inverter can either work in a grid sharing mode while supplying a part of local load or in grid injecting mode, by injecting power to the main grid. Maintaining power quality is another important aspect which has to be addressed while the micro grid system is connected to the main grid. Maintaining power quality is another important aspect which has to be addressed while the micro grid system is connected to the main grid. The proliferation of power electronics devices and electrical loads with unbalanced nonlinear currents has degraded the power quality in the power distribution network. Moreover, if there is a considerable amount of feeder impedance in the distribution systems, the propagation of these harmonic currents distorts the voltage at the point of common coupling (PCC). At the same instant, industry automation has reached to a very high level of sophistication, where plants like automobile manufacturing units, chemical factories, and semiconductor industries require clean power. For these applications, it is essential to compensate nonlinear and unbalanced load currents. Load compensation and power injection using grid interactive inverters in micro grid have been presented in the literature. A single inverter system with power quality enhancement and the main focus of this work is to realize dual functionalities in an inverter that would provide the active power injection from a solar PV system and also works as an active power filter, compensating unbalances and the reactive power required by other loads connected to the system.

## II. LITERATURE SURVEY

N. Sakthi et al. [1] in this paper the Dual Voltage Source Inverter (DVSI) is used for improving the reliability and the microgrid system quality. Here, proposed system includes two inverter, which allows the microgrid to replace the energy generated by the source of energy distribution i.e. the PV system, and more than to compensate local and non-linear load conditions. The DVSI is enabled in the network sharing modes and the injection mode conditions for the algorithms of control which are constructed by using the instantaneous symmetric component theory (ISCT).

M. V. Manoj Kumar et al. [2] this paper presents a dual voltage source inverter (DVSI) scheme to enhance the power quality and reliability of the microgrid system. The proposed scheme is comprised of two inverters, which enables the microgrid to exchange power generated by the distributed energy resources (DERs) and also to compensate the local unbalanced and nonlinear load. The control algorithms are developed based on instantaneous symmetrical component theory (ISCT) to operate DVSI in grid sharing and grid injecting modes.

Ram Bajpai et al.[3] In this paper, a simple control strategy for grid voltage control using distribution static compensator (DSTATCOM) in the voltage control mode has been proposed. The grid voltage of a distribution system is controlled in respect of the wind variation, load variation and short time interruption of the source feeder. In addition it suppresses the harmonics at the grid terminals due to the nonlinear load. At the same time the power flow has also been regulated.

Roberto F. Coelho et al.[4] This paper presents a three phase grid-connected photovoltaic generation system with unity power factor for any situation of solar radiation. The modelling of the PWM inverter and a control strategy using dq0 transformation are proposed. The system operates as an active filter capable of compensate harmonic components and reactive power, generated by the loads connected to the system. An input voltage clamping technique is proposed to control the power between the grid and photovoltaic system, where it is intended to achieve the maximum power point operation.

## III. RESEARCH OBJECTIVES

The work on the dual voltage source inverter deals with the following main objectives:

• To create a MATLAB SIMULINK model of dual voltage source inverter having split capacitor system for power flow control. The first model will consist of inverter having basic PLL controller for power conversion of the DC voltage to AC voltage of the solar PV system.

• To design a controller for enhancing the power output from the solar system. This will be made to feed nonlinear load.

• To design an inverter with hybrid energy sources and with new active power optimizer control.

• Integrate the system with wind energy system and then to the grid so as to make it more reliable and efficient.

## IV. METHODOLOGY

The model has been developed in MALAB/SIMULINK environment. This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It has following key features:

• High-level language for scientific and engineering computing ¬ Desktop environment tuned for iterative exploration, design, and problem-solving.

• Graphics for visualizing data and tools for creating custom plots.

• Apps for curve fitting, data classification, signal analysis, control system tuning, and many other tasks.

• Add-on toolboxes for a wide range of engineering and scientific applications.

• Tools for building applications with custom user interfaces.

• Royalty-free deployment options for sharing MATLAB programs with end users.

The modeling of Dual Voltage Source Inverter system is done which is capable of feeding the load with either solar or wind resources depending on the availability thus making the system more reliable.

Modeling of various parts of the system has been discussed further. The modeled PV system with MPPT technique for its optimum operation, PMSG (permanent magnet synchronous generator) connected with the wind turbine has been discussed.

The Dual voltage source inverter (DVSI) is being fed by solar system which is then integrated with the wind energy system making it a hybrid system. The dc storage capacitors system has also being modeled in accordance with the DVSI. These are connected to grid at the PCC and supplying a nonlinear and unbalanced load. The VSI delivers the available power at distributed energy resource (DER) to grid. The DER can be a dc source or an ac source with rectifier coupled to dc link.

1) PV Module Modeling

PV cells have single operating point where the values of the current (I) and voltage (V) of the cell result in a maximum power output. These values correspond to a particular resistance, which is equal to V/I. A simple equivalent circuit of PV cell is shown in Fig. 1.

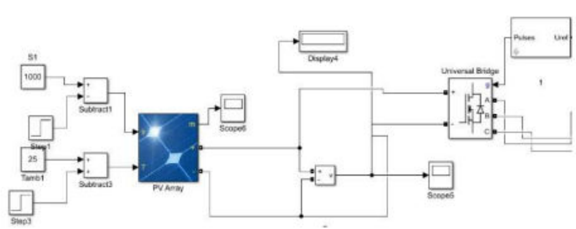

Figure 1: Modeled Solar System

A cell series resistance ($R_s$) is connected in series with parallel combination of cell photocurrent ($I_{ph}$), exponential diode (D), and shunt resistance ($R_{sh}$), $I_{pv}$ and $V_{pv}$ are the cells current and voltage respectively. It can be expressed as

$$I_{pv} = I_{ph} - I_s\left(e^{q\left(V_{pv}+I_{pv}*R_s\right)/nKT} - 1\right) - \left(V_{pv} + I_{pv} * R_s\right)/R_{sh}$$

Where:

$I_{ph}$- Solar-induced current

$I_s$ - Diode saturation current

q - Electron charge (l.6e-l9C)

K - Boltzmann constant (l.38e-23J/K)

n - Ideality factor (l~2)

T - Temperature 0K

Tc, Tr Cell working and reference temperature at STC

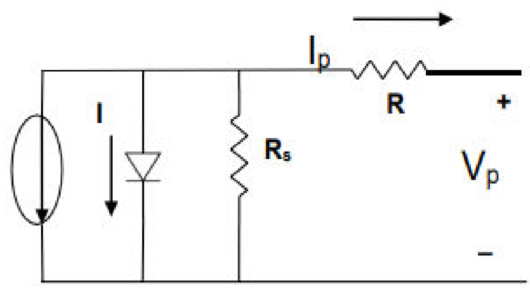


Figure 2: Equivalent Circuit of Solar PV Cell

The solar induced current of the solar PV cell depends on the solar irradiation level and the working temperature can be expressed as:

$$I_{ph} = I_{sc} - k_i\left(T_c - T_r\right) * \frac{I_r}{1000}$$

Where,

$I_{sc}$ Short-circuit current of cell at STC

$K_i$ Cell short-circuit current

$I_r$ Irradiance in w/m

A PV cell has an exponential relationship between current and voltage and the maximum power point (MPP) occur at the knee of the curve.

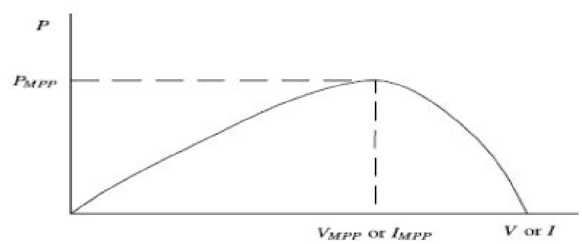


Figure 3: Characteristic PV Array Power Curve

The P&O algorithm will track the maximum power to supply the DCMGs system. The assumptions for model derivation are that the ideal current source can be presented as the PVs behavior. In addition, all power converters are operated under the continuous conduction mode (CCM) and the harmonics are also ignored.

2) Wind Energy System Modeling

Model of wind turbine with PMSG Wind turbines cannot fully capture wind energy. Output aerodynamic power of the wind-turbine is expressed as:

$$P_{Turbine} = \frac{1}{2}\rho A C_p(\lambda, \beta) v^3$$

Where, $\rho$ is the air density (typically 1.225 kg/m$^3$), A is the area swept by the rotor blades (in m$^2$), CP is the coefficient of power conversion and v is the wind speed (in m/s).

The tip-speed ratio is defined as:

$$\lambda = \frac{\omega_m R}{v}$$

Where $W_m$ and R are the rotor angular velocity (in rad/sec) and rotor radium (in m), respectively.

The wind turbine mechanical torque output m T given as:

The power coefficient is a nonlinear function of the tip speed ratio and the blade pitch angle.

Then Power output is given by

$$T_m = \frac{1}{2}\rho A C_p(\lambda, \beta) v^3 \frac{1}{\omega_m}$$

A generic equation is used to model the power coefficient $C_P$ based on the modeling turbine characteristics describe.

For each wind speed, there exists a specific point in the wind generator power characteristic, MPPT, where the output power is maximized. Thus, the control of the WECS load results in a variable-speed operation of the turbine rotor, so the maximum power is extracted continuously from the wind.

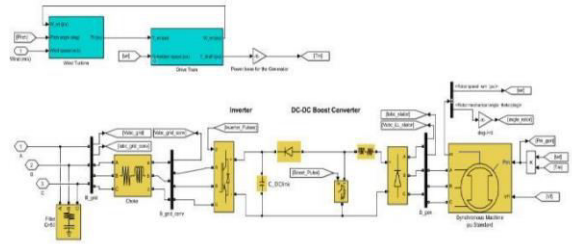

Figure 4: Modeled Wind System

3) Modeling of Inverter Control

a) Modeled PLL Control

A Phase Locked Loop (PLL) is an electronic circuit with a voltage or current driven oscillator that is constantly adjusted to match in phase with the (and thus lock on) the frequency of an input signal. The PLL is used in various applications of electrical technology as a fundamental concept. The block diagram of conventional PLL is shown in figure 5.

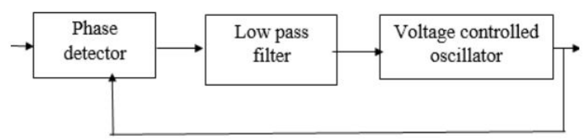


Figure 5: Phase Locked Loop Structure

The basic idea of phase locking is to evaluate the difference between phase angle of the input signal and generated output signal. The phase difference is usually estimated by a phase detector (which is usually a multiplier or comparator), Voltage-Controlled Oscillator (VCO) and loop controller or a Loop Pass Filter (LPF). The phase angle difference between of the input signal and output signal is measured by the Phase Detector and also provides a proper error signal. To generate the output signal, the LPF output signal drives the Voltage Controlled Oscillator (VCO). The VCO provides a measure of variations of the phase and generates a signal whose frequency is equal to its input signal. The deviation of the error signal from zero is because of any change in the phase angle (or frequency) of the input signal. In order to utilize renewable energy such as wind and solar energy, three-phase grid-tied inverters are widely installed in micro-grids.

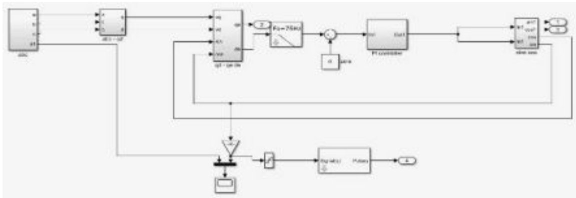

Figure 6: Modeled PLL Controller

b) Voltage optimizer active power controller

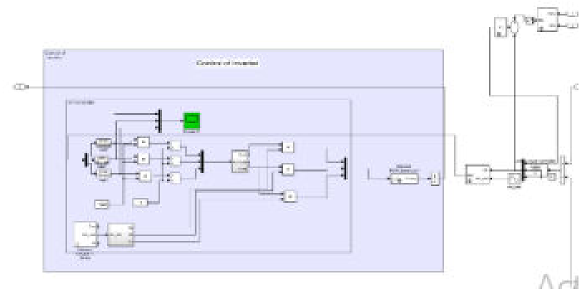

Figure 7: MATLAB Model of Voltage Optimizer Active Power Controller

The voltage and current outputs at the inverter bus is taken as input for designing the control system. This is used to drive the active power control of the inverter. The voltage and current outputs are used for calculating the active power which is when compared to a reference power and the difference calculated is fed into the PID controller.

Then the Rms value of the resultant is calculated and compared with a standard sinusoidal 50 hz waveform. It is then fed into the pulse width modulation generator for generating pulses which will then be used for driving the inverter.

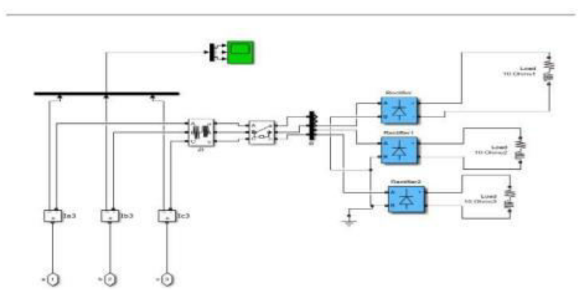

Figure 8: Modeled Nonlinear Load

## III. RESULTS AND DISCUSSION

1) Implementation Details

An analytical and numerical description of proposed algorithm for sentiment analysis of a power buffer which is simulated to obtain the performance of the proposed algorithm.

In order to evaluate the performance of proposed algorithm scheme, the proposed algorithm is simulated in following configuration:

Pentium Core I5-2430M CPU @ 2.40 GHz

4GB RAM

64-bit Operating System Matlab Platform

2) Simulation Environment

MATLAB stands for MATrix LABoratory, which is a programming package exclusively designed for speedy and effortless logical calculations and Input/output. It has factually hundreds of inbuilt functions for a large form of computations and plenty of toolboxes designed for specific analysis disciplines, as well as statistics, optimization, solution of partial differential equations, information analysis.

In this research work MATLAB platform is used to show the implementation or simulation of implemented algorithm performance. Measurement toolboxes are used and some inbuilt functions for generating graphs are used. Simulation results and comparison of the performance of implemented model with some existing ones are calculated by MATLAB functions.

3) Model Description

The first model was created using modeling of solar energy system integrated with the grid and feeding a nonlinear load. In the first model the inverter was modeled based on the phase locked loop control and the voltage profile was analyzed in MAATLAB. Further in this work the voltage profile has been improved using a modified active voltage followed power controller for the inverter. Also the second model has been integrated with the wind energy system also in order to enhance the efficiency and reliability of the system. This will ensure continuity in case the solar system is not working properly or is under maintenance. The voltage profile of the output from the system was again analyzed to observe the difference in the two models.

4) Output of Capacitor system having basic PLL control.

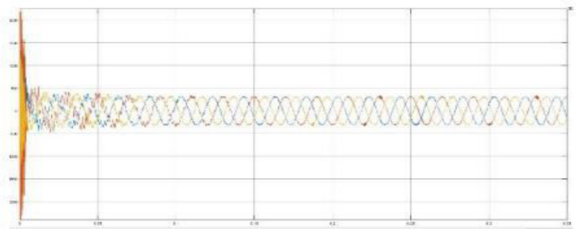

Figure 9: Voltage Output from the Split Capacitor System

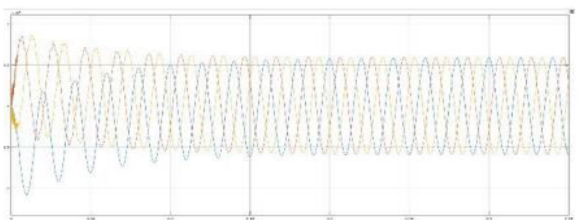

Figure 10: Current Output from the Split Capacitor System

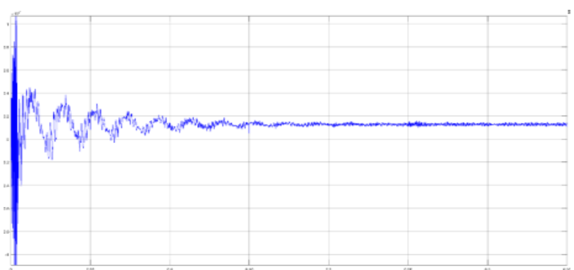

Figure 11: Active Power output from the split capacitor system

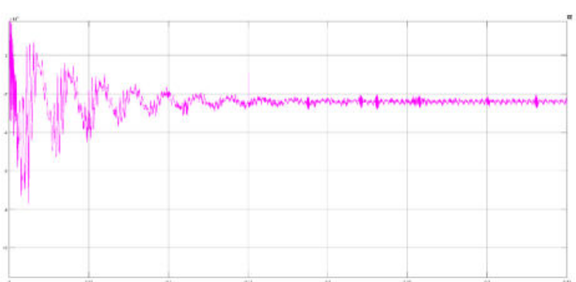

Figure 12: Reactive Power Output from the Split Capacitor System

The voltage output from the plate capacitor system is calculated 400 volt which is in accordance with the grid voltage. The active power output is approximately 2 megawatts.

5) Output of from grid system

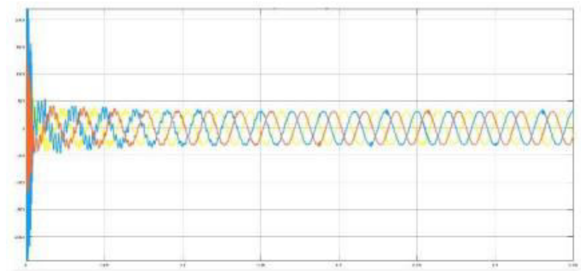

Figure 13: Voltage Output from the Grid

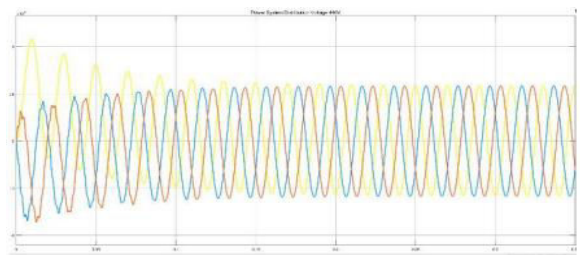

Figure 14: Current Output from the Grid

The voltage output from the grid system is calculated 400 volts with the current being drawn according to the load connected to the grid.

6) Output of at the load terminal

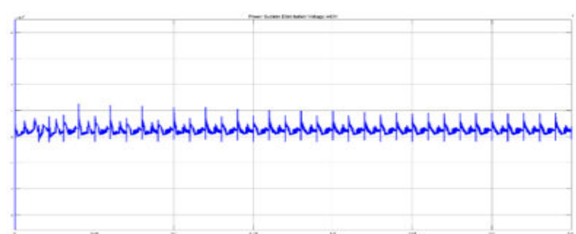

Figure 15: Active Power Output at Load Terminal

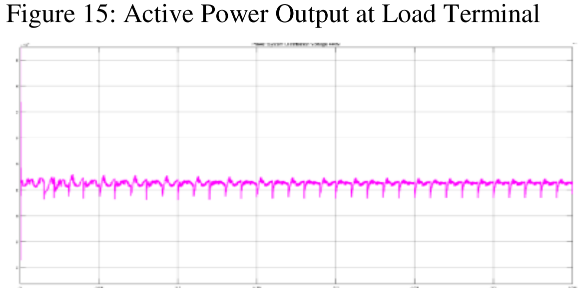

Figure 16: Reactive Power Output at Load Terminal

The voltage output at the load terminal is also 400 volt which is in accordance with the system voltage. The active power drawn is approximately 10 to 15 kilowatts. The reactive power drawn is 5 KVar

CASE 1: System with modified voltage optimizer active power controller disconnected from the load.

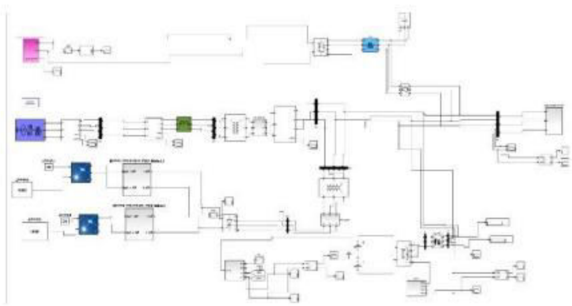

Figure 17: MATLAB/SIMULINK model of VSI Integrated with Hybrid System with Voltage Optimizer Active Power Controller

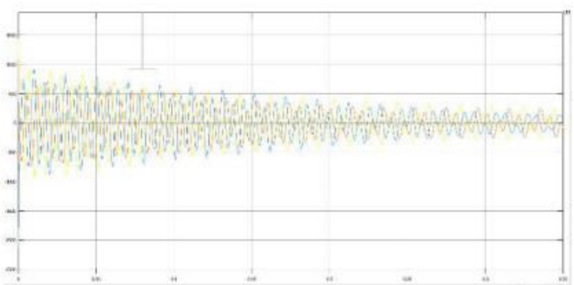

Figure 18: Voltage output from the solar system through inverter

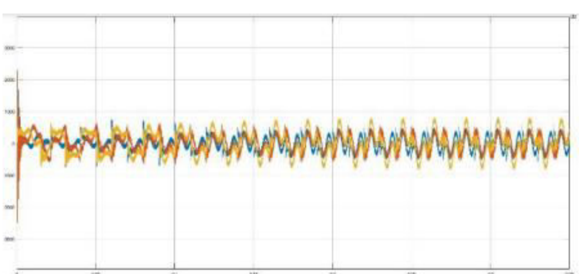

Figure 19: Current output from the solar system through inverter

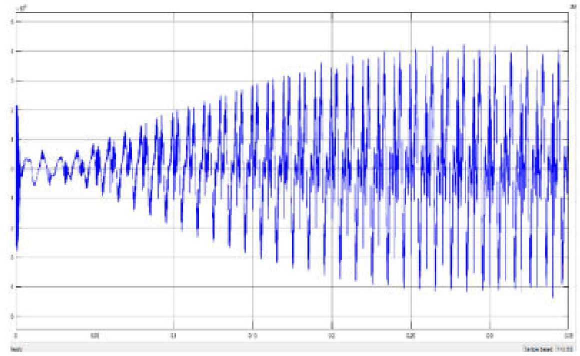

Figure 20: Active power output from the solar system through inverter

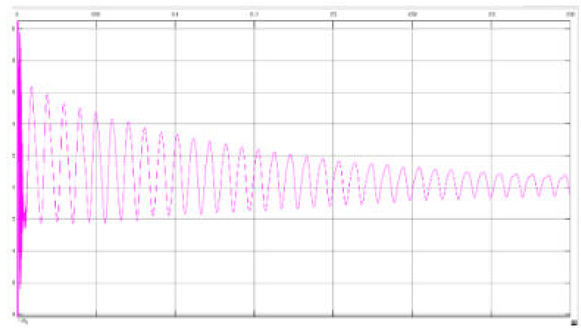

Figure 21: Reactive power output from the solar system through inverter

The voltage output from the solar system via inverter having voltage optimizer active power controller is 400 volts and active power output is approximately 4 MW.

CASE 2: System with basic PLL control disconnected from the load

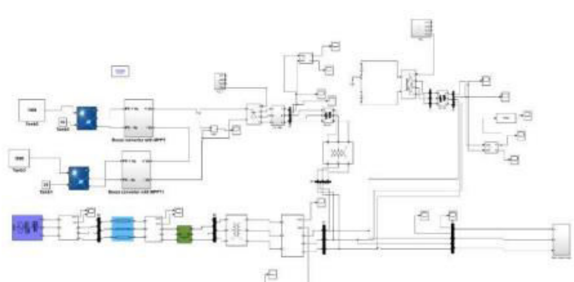

Figure 22: MATLAB/SIMULINK model of VSI integrated with solar system with basic PLL control

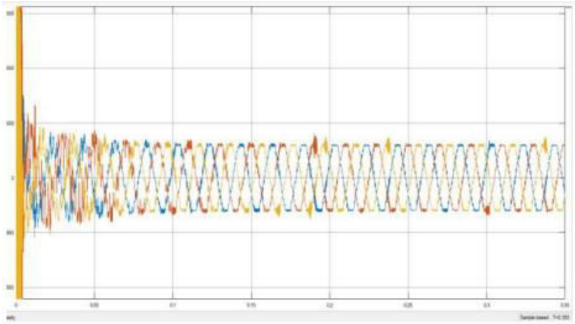

Figure 23: Voltage output from the solar system through inverter

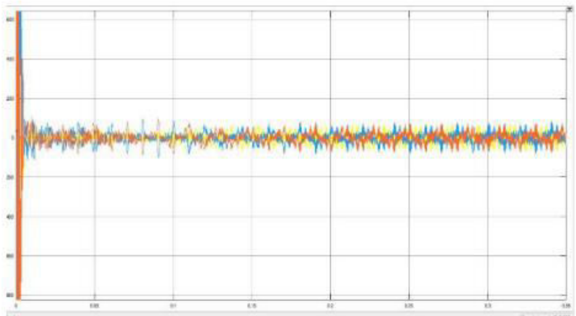

Figure 24: Current Output from the Solar System through Inverter

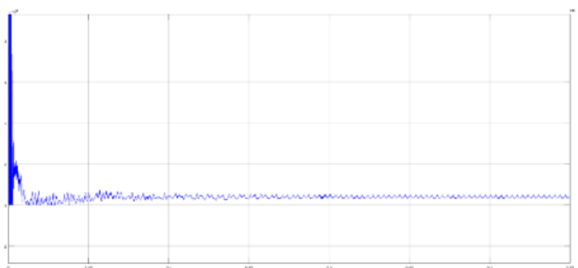

Figure 25: Active Power output from the Solar System through Inverter

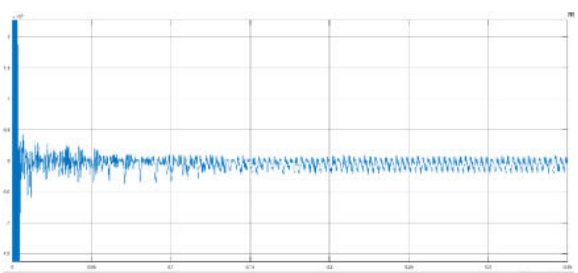

Figure 26: Reactive Power Output from the Solar System through Inverter

The voltage output from the solar system via inverter having PLL controller is 400 volts and active power output is approximately 0.1 MW.

## IV. VALIDATION

Comparative analysis of the two controls driving the inverter has been done. Voltage output waveform fft analysis has been done to observe the better waveform. Also the active power output from the two system has been measured to check the improvement for the propose controller

Figure 27: Voltage Output from the inverter with modified voltage optimizer active power controller

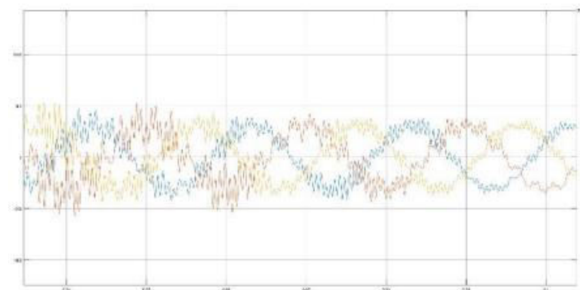

Figure 28: Voltage Output from the inverter with PLL control

On analyzing the voltage output waveforms of the two control system closely it is concluded that the voltage distortion level of the PLL controlled output is more as compared to that of new control being proposed. Hence we infer that the inverter being modelled with the proposed voltage optimizer active power controller has better output results.

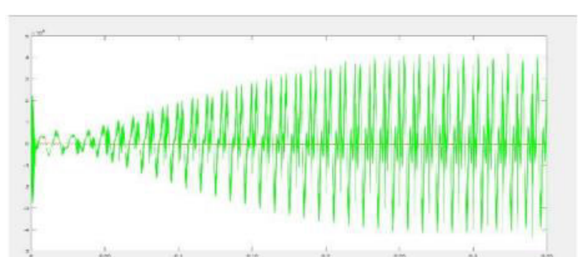

Figure 29: Power outputs from two controls

The value of active power output from the PLL controlled inverter being fed to the load is calculated to be approximately 0.1MW and the proposed controller gives approximately 4MW output along with smoothing of voltage output waveform.

## V. CONCLUSION

Renewable energy sources also called non-conventional type of energy are continuously replenished by natural processes. Hybrid systems are the right solution for a clean energy production. Hybridizing solar and wind power sources provide a realistic form of power generation. Here, a dual voltage source converter having split capacitor system and solar system with a converter topology is proposed which makes use of controller for inverter operation.

The simulation result shows that the system with the proposed voltage optimizer active power control strategy proposed is better as compared to the basic phase locked loop control. Also the system was made efficient by integrating it with the wind system and making it a hybrid power source. Following main conclusions were drawn:

- On comparing the active power outputs from the system with phase locked loop control with proposed voltage optimizer active power control, it was found to be that the proposed system gives 4 MW output which is considerably more than the 0.5 MW output of the system with basic PLL control.
- The voltage outputs from both the systems is 400 volts. The proposed controller smoothens this voltage resulting in better results.
- The system has been integrated with the grid for making it more reliable. Also power can be fed to the grid via transformer through hybrid system (wind energy system) in case of high loads.

Thus it can be drawn from this work that while designing an inverter control strategy the proposed voltage optimizer active power controller can serve the purpose with better results in terms of voltage as well as power. This control can also be used in hybrid systems thus making it more reliable controlling method. The system designed is also fitted to feed the nonlinear load.

## VI. FUTURE SCOPE

Installing this solar-grid hybrid system will be actually very fruitful because it will reduce the grid dependency. On the other hand, this system promotes green energy which is very important because all the energy sources are depleting day by day. So, people must look for new renewable sources and solar power is definitely one of the best choices in this purpose. In future work an adaptive neural network based control for improved power quality 3 phase grid integrated with nonlinear and linear loads will be designed. The expected control scheme regulates the system voltage and improves the power quality in a very effective manner.

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