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Enhancement of DC Link Voltage using Fuzzy MPPT Technique with Variable Irradiance

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ABSTRACT: This research work presents the design and implementation of a hybrid renewable energy system that allows a cost-efficient and sustainable energy supply of the loads. The integration of the solar system with the network is rather complex and expensive. With this construction proposal, however, it is not only possible to create an economical and simple hybrid system, but also a reliable, efficient and economical system. A charge controller is designed with a maximum power point tracking technique using a scrambling and observation method. The charge controller output is connected to an accumulator that provides continuous power to the grid system. An appropriate control strategy should be used to provide energy quality improvement performance to the network interface inverter. Traditional PI controllers can be replaced by a fuzzy controller for better control, improving system performance. In this research, a hybrid wind-solar hybrid system with performance-enhancing features is simulated with a PI controller, so the results are compared by replacing PI with the fuzzy controllers. This integration of hybrid renewable energy systems and energy systems is analyzed and observed to see how much the function of AC grid systems is reduced in order to save energy and promote the use of green energy in implementing this simple hybrid system. The proposed system simulation studies are performed using the Matlab / Simulink platform and the results are evaluated based on the improvement of the DC voltage and power supply of the electricity grid.

KEYWORDS: Renewable Energy system, PV Array, Wind System, Fuel Cell, MPPT Charge Controller, DC/DC Converter, Controlled Inverter, Grid System

I. INTRODUCTION

Energy incorporates a very important role for the development of a nation and it's to be preserved in a very most effective manner. Energy is that the ultimate issue accountable for each industrial and agricultural development. The new technologies that are developed to provide energy within the most environmental friendly manner and conservation of energy resources in most economical means has equal importance. The utilization of renewable energy technology to satisfy the energy demands has been steady increasing for the past few years. Import of petroleum products constitutes a serious drain on our foreign exchange reserve. Renewable energy sources are considered to be the higher choice to meet these challenges. The necessary drawbacks related to renewable energy systems are their inability to ensure reliability and their intermittent nature. A serious challenge of grid integration an increasing number of renewable-energy-based distributed generators is featured whereas making certain stability, voltage regulation, and power quality [1].

A. *Distributed Generation*

The first power systems were DG systems designed to meet the needs of local areas. The development of technology and the increase in energy demand have led to the development of large centralized networks linking regions and entire countries. Full load DG applications showed greater benefits in terms of power and performance as well as reducing transmission losses.

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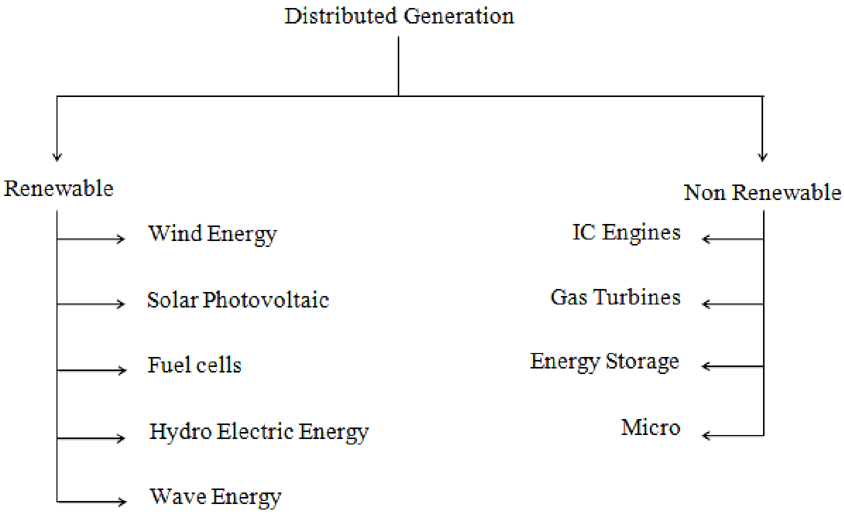

Figure 1: Distributed generation

B. *Modelling of PV Array*

The photovoltaic system connected to the grid is a more reliable solution to increase the demand for energy. The network connection of a photovoltaic power generation system has the advantage of more efficient use of the generated energy [2]. The PV systems are connected to the grid via the inverter, which converts the DC energy generated by the PV modules into alternating current. The inverter technology is very important to ensure a reliable connection and safe operation of the photovoltaic network.

Again, the power generated by a single module is not sufficient to meet performance requirements for most practical purposes. PV Molds These inverters can be used to convert the DC output into AC and use it for motors, lighting and other loads [3]. The modules are connected in series for more voltage and then in parallel to meet the current specifications. A PV module consists of variety of series cells NS whereas the cells are connected in series and parallel in PV arrays wherever the arrangement defines the maximum output voltage VM and maximum output current IM [4].

The cells are made in mono crystalline or polycrystalline structure relying to the purity of semiconductor [5–7]. The polycrystalline cells that give limited potency around 13–14% are less economical comparing to the mono crystalline that the efficiency will increase up to 20. This circuit shown in Fig 5 includes a photocurrent source, a diode, and serial and shunt resistors that are referred to as one-diode or five-parameter model [8]. The calculations of the one-diode model are depended to the output current:

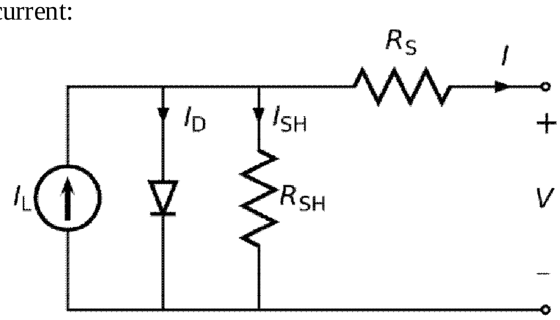

Figure 2: Electrical Equivalent of PV Cell

$$I_o = I_{PV} - I_D(V) - I_{SH}(V)$$

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Where (V) shows the dependency of diode current and resistor current to the terminal voltage whereas they're independent from irradiation value.

C. Solar Power Conversion and MPPT

The solar panel may be a combination of PV modules serial and parallel to get the desired power in various voltage and current ratings. The power conversion stage consists of dc power interface and its ac conversion pairs. The dc-dc converters are wont to stabilize the intermittent characteristic of solar array that's significantly depended to solar irradiation and ambient temperature [6-9]. the ability conversion structure are often in single-stage or double-stage interface wherever the single-stage includes simply a dc-ac inverter whereas the double-stage consists of dc-dc converter and dc-ac electrical converter as seen in Figure 3.

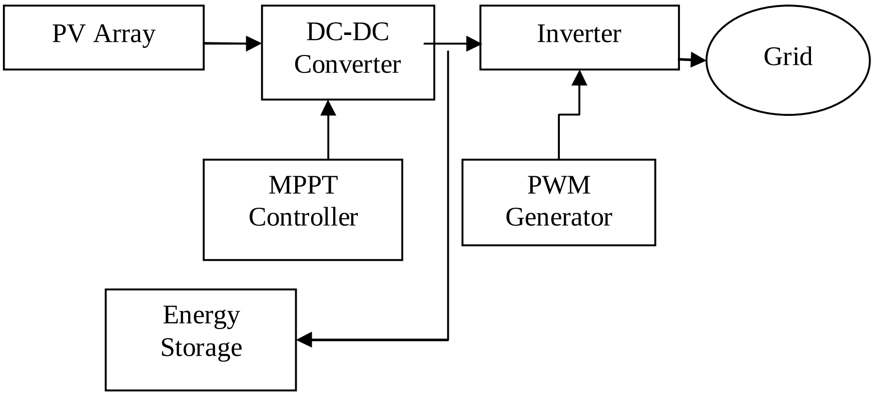

Figure 3: Block Diagram of a Solar Power Generation System

The single-stage interface lacks in the stabilizing the dc bus voltage against speedily variable dc output of solar panel. However, the electrical converter needs operative an algorithm to trace the utmost power point so as to match dc bus voltage of solar panel. However, it's impractical to sustain optimum matching at all radiation levels since the utmost power point rapidly fluctuates relying to the radiation and temperature. This operation will be performed in large-scale solar plants wherever the generated dc bus voltage excesses the specified offer voltage of inverter [7]. A dc-dc convertor is connected between solar panel and electrical converter to match the specified dc bus voltage within the double-stage power conversion system. The dc-dc convertor handles the MPPT operation and therefore the dc bus voltage is matched at this first stage. The MPPT algorithm of converter will increase or decreases the dc bus voltage in keeping with varied atmospheric condition and maintains the match between dc supply limits of inverter. The MPPT algorithm controls the duty cycle of dc-dc converter wherever it changes the regenerate dc voltage level by adjusting the operation amount of semiconductor switch within the topology. Thus, the maximum power is extracted from solar panel by suitably matching I-V balance of solar modules. The widely used dc-dc converter topologies are Buck-Boost and Cuk besides classical buck or boost topologies in solar energy generation systems. The second interface employed in double-stage is electrical converter that converts the dc bus voltage to ac power wherever the converted ac power is either provided to the standalone loads or is injected to the utility grid [9-15]. The electrical converter topology to be employed in this interface depends to the power level wherever two-level or multilevel topologies are often chosen.

D. *Wind Energy*

The kinetic energy of the wind causes the wind turbine blades to rotate. This leads to a rotation of the generator shaft, which is connected to the rotor blades. The generator converts the mechanical energy of the rotating shaft into electrical energy [16-18]. It is optional to connect the slow shaft of the rotor blades with a reducer to the high speed shaft of the generator. In some cases, transmissions are not desirable because they are expensive, cumbersome and heavy. A multipolar generator is an alternative possibility of a gearless system.

The power cable transfers electricity to a transformer. The transformer increases the low voltages of the generator to the level of distribution or sub-transmission of the connected system

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The wind turbine (WT) converts wind energy to mechanical energy. The power output of a wind turbine can be expressed as shown in Figure 3.2 and the aerodynamic torque is given by:

$$P_w = 0.5 C_p \rho A V_w^3$$
$$T_w = \frac{P_w}{\omega_W}$$

Where P_W = Wind Turbine Power (in Watt)
P= Air Density (in Kg/m^3)
A= Rotor Area (in m^2)
V_W = Velocity of wind (in m/sec)
ω = Turbine rotor speed (in rad/sec)/
C_P = Power Co-efficient, It is the function of tip speed and blade pitch angle.

II. Literature Review

Hadi Sefidgar et al. [2] proposed a Fuzzy Logic Control (FLC) for monitoring the maximum power (MPPT) on the connection of the wind turbine to the permanent magnet synchronous generator (PMSG).
Y. Xia et al. [8] proposed a new method of detecting the maximum power point for a wind energy conversion system based on a synchronous permanent magnet generator.
Emad M. Natsheh. et. al. [9] presented a new adaptive scheme for energy management in autonomous hybrid systems. The proposed management system is designed to manage the flow of energy between the hybrid power system and the energy storage elements to meet the load requirements based on the artificial neural network (ANN) and fuzzy logic controls.
Ujjwal Kumar Kalla et al. [15]introduced an adaptive learning scheme for backpropagation for a three-phase, three-wire photovoltaic solar array powered by a battery-powered microarray, which simultaneously provides three-phase and single-phase non-linear loads.
Ashwini A. Patil et al.[17] proposed a system that can be reached by a maximum power point detection with a backup battery when wind power is not available.
Jayasankar V N et al. [19] A grid connected hybrid system of wind-solar with power quality improvement features is proposed with a PI controller.

III. METHODOLOGY

Scenario I (Solar-Wind Renewable Energy Grid System)

Grid connected wind-solar hybrid renewable energy system is simulated and analyzed in this research work. The overall block diagram of the system under discussion is shown in Fig. 4.

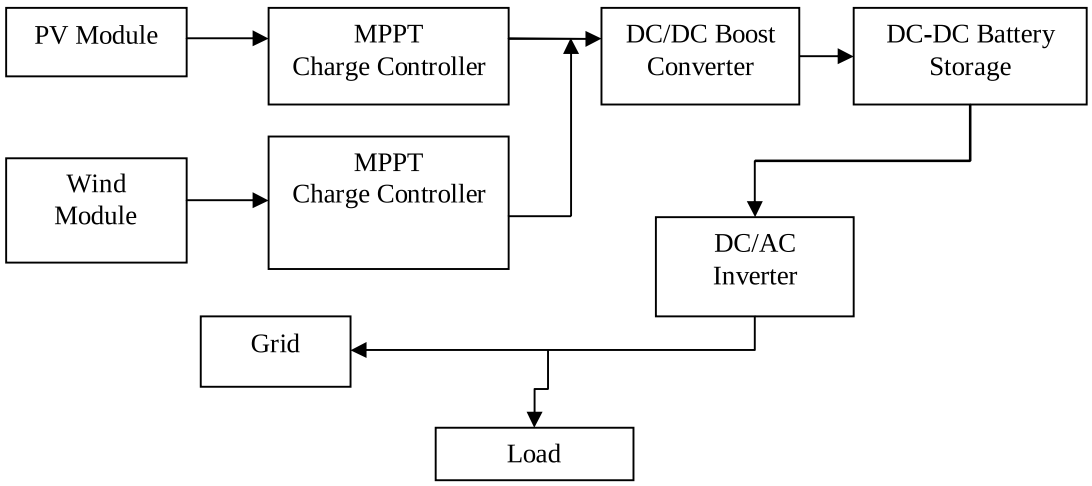

Figure 4: Block diagram of Scenario I (Solar-Wind RE System)

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A conventional inverter is used for interfacing the renewable energy system with the grid. Here, inverter not only acts as an interfacing system for real power flow to the grid, but acts as a power quality improving device also. Control methods used for the system plays an important role in the performance of the inverter.

Scenario II (Hybrid Renewable Energy Grid System with Fuzzy Inverter Controller)

Grid connected hybrid renewable energy system is simulated and analyzed in this research work. The overall block diagram of the system under discussion is shown in Fig. 5.

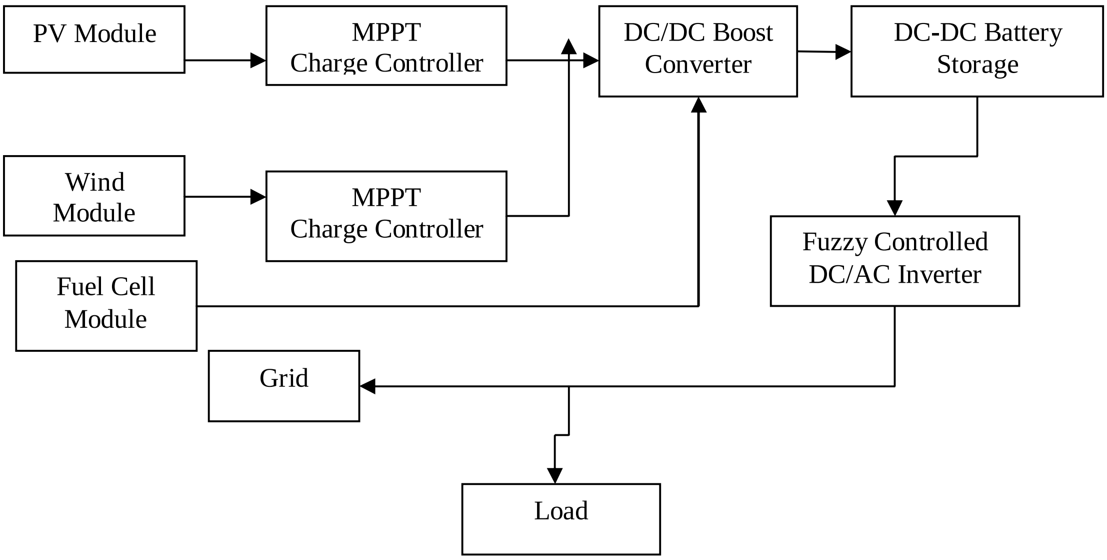

Figure 5: Block diagram of Scenario II (Hybrid RE System with Fuzzy Controlled Inverter)

Table I shows the rules formed on the basis of the fact that control output should be high and low error. Figure 3.4-3.6 shows the input variables and output variable membership functions.

Table I: Fuzzy Rule Table for Inverter

Error/COE	**NM**	**NS**	**Z**	**PS**	**PM**	**NL**	**PL**
NM	NH	NH	NM	NL	Z	NH	PL
NS	NH	NM	NL	Z	PL	NH	PM
Z	NM	NL	Z	PL	PM	NH	PH
PS	NL	Z	PL	PM	PH	NM	PH
PM	Z	PL	PM	PH	PH	NL	PH
NL	NH	NH	NH	NM	NL	NH	Z
PL	PL	PM	PH	PH	PH	Z	PH

Simulation is carried out for a fixed RES generation, which is greater than the load demand. The result of both scenarios is compared.

IV. Simulation Results

A. *Scenario I*

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 MPPT algorithm along with standard perturbs and observes method will be used

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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. The simulation results are presented to illustrate the operating principle, feasibility and reliability of this proposed system. The system parameters used in scenario are as shown in Table II.

Table II: Scenario I System Parameters

S. No.	System Parameters	Values
1	Hybrid System	Solar & Wind System
2	Solar Panels	11*2=666 V
3	Wind Speed	12 m/s
4	Storage Battery	200 volts, 6.5 Ah Ni-MH battery
5	LC Filter	L = 50 milli henry, C = 2000µfarad
6	3 Phase RLC Load	3KW
7	Proportional Gain (K_p)	0.5
8	Integral Gain (K_i)	7.5
9	Inverter	Carrier frequency= 2000 Hz, sampling time= 20 µsecs
10	Switching Device	IGBT

B. *Scenario II*

The system consists of a solar panel, wind system and fuel cell system with maximum power point tracking charge controller, battery packs, AC/DC converter (output voltage can be varied) and fuzzy controller for power improvement. In this system, the load has been supplied by DC, not AC. Such as, grid synchronization, where Information about phase angle of the grid voltage is required to transfer the power from converters. To avoid the complications, a simple yet efficient system have been proposed. The charge controller actually is a DC/DC converter that tracks the maximum power from the solar panel. As the maximum power varies with the change of the weather condition, a maximum power point tracking algorithm (perturb and observe) is implemented in the charge controller. Here, inverter not only acts as an interfacing system for real power flow to the grid, but acts as a power quality improving device also. Control methods used for the system plays an important role in the performance of the inverter. Conventional controllers are replaced by fuzzy controllers at this stage. 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.

Table III: Scenario II System Parameters

S. No.	System Parameters	Values
1	Hybrid System	Solar, Wind System & Fuel Cell
2	Solar Panels	11*2=666 V
3	Wind Speed	12 m/s
4	Storage Battery	200 volts, 6.5 Ah Ni-MH battery
5	LC Filter	L = 50 milli henry, C = 2000µfarad
6	3 Phase RLC Load	3KW
7	Proportional Gain (K_p)	Fuzzy Controlled
8	Integral Gain (K_i)	
9	Inverter	Carrier frequency= 2000 Hz, sampling time= 20 µsecs
10	Switching Device	IGBT

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The simulation results are presented to illustrate the operating principle, feasibility and reliability of this proposed system are shown below for both scenario.

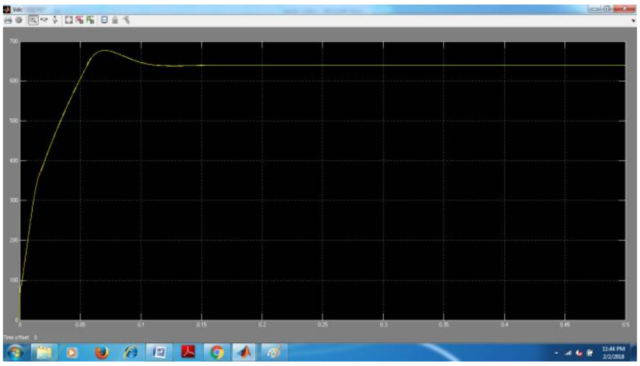

Figure 6: DC Voltage obtained in Scenario I

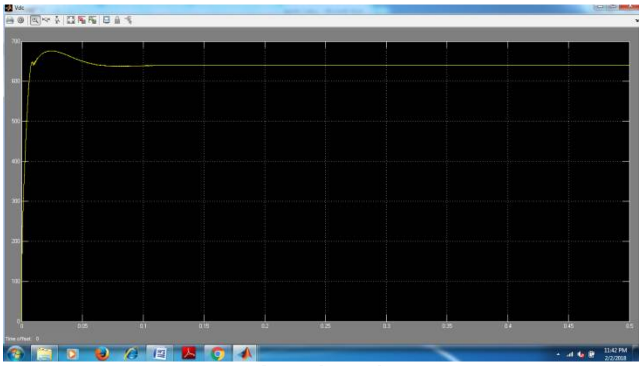

Figure 8: DC Voltage obtained in Scenario II

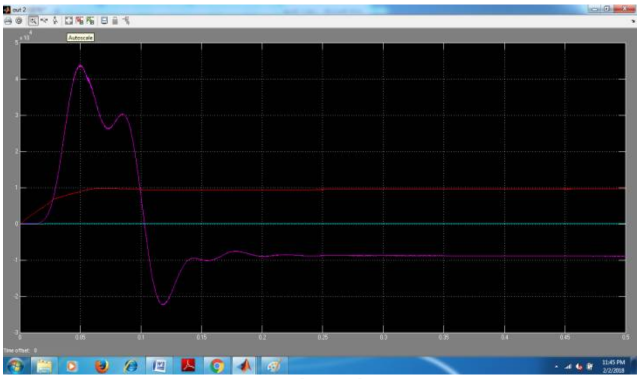

Figure 7: Power Obtained in Scenario I

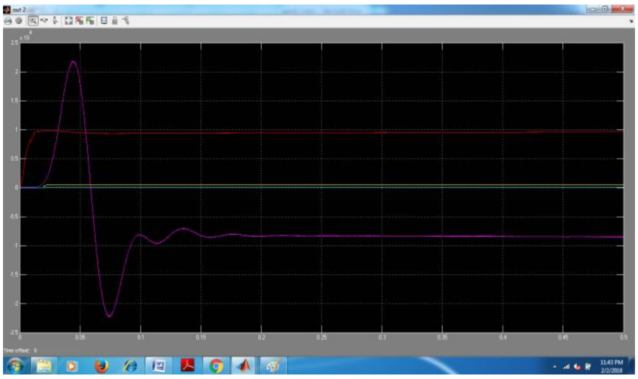

Figure 9: Power Obtained in Scenario I

C. *Comparison of Scenario I and Scenario II*

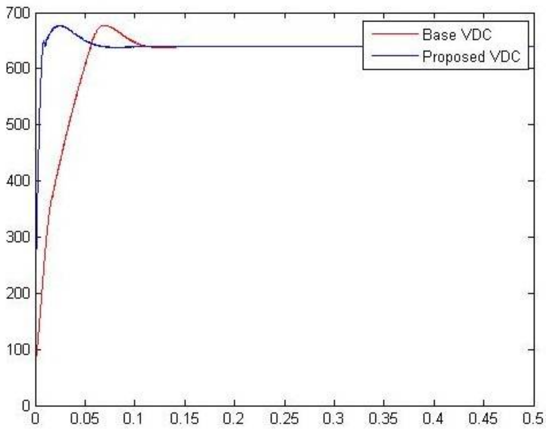

Figure 10: DC Voltage Comparison of Scenario I and Scenario II

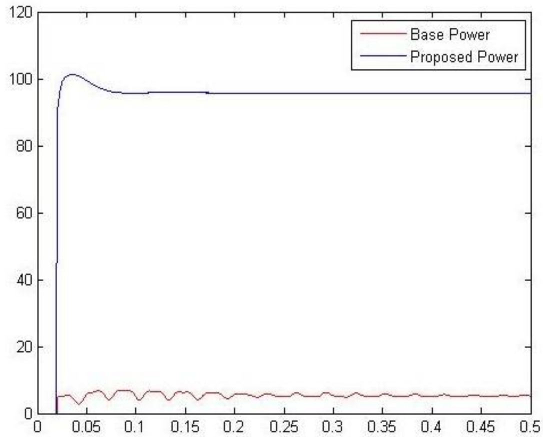

Figure 11: Power Comparison of Scenario I and Scenario II

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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 hybrid wind solar energy and fuel cell system with a converter topology is proposed which makes use of Boost Converter and fuzzy controlled inverters in the design. Furthermore, a battery module is added as an energy storage system during surplus power and/or backup device during load demand. The system is implemented using fuzzy controlled inverter design that overcomes the drawbacks of the earlier conventional inverters. This topology allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. MPPT control is done for PV and wind energy so that maximum power is tracked and system work more reliably and efficiently. This system has lower operating cost and finds applications in remote area power generation, constant speed and variable speed energy conversion systems and rural electrification. MATLAB/ SIMULINK software is used to model the PV panel, wind turbine, DC-DC converters, MPPT controller and proposed hybrid system.

The models of hybrid renewable energy systems are integrated with the grid through Voltage Source Inverter. Fuzzy based control strategy is used to add active power filter functionality to the interfacing inverter. The PI controller is replaced with a fuzzy controller and it is found that the efficiency of grid DC Voltage has been improved.

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