

Design & Simulation of Hybrid Solar – Wind Electric Power System Interface to Grid System

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Abstract— This paper describes the renewable based combined design of a solar tracking Photo- Voltaic (PV) array system and Wind Hybrid Electric Power System (HEPS) interface to Grid System. In this paper the combined generation of electricity improved the power quality of the system. Generally in low radiation PV array system inverter gives the lower voltage than the rated voltage which affects the power quality. So, in this paper we are considering the combined generation of electricity by wind and solar energy taking into account all radiation, temperature, wind speed and variation of the load demand during the day. The paper presents the design and analysis PV/Wind Hybrid Electric Power System in MATLAB. The evaluation of the method has been done based on experimental system at NRI Institute of Technology, and an economic analysis is made on this system cost effectiveness.

Index Terms— Grid, Power Quality, Photovoltaic, Wind Turbine Generator.

INTRODUCTION

Day by day energy demand increases all over the world. Presently 80% contribution to world energy supplied from the conventional energy sources which will harm the environment. So there is a need for renewable energy sources that will not harm the environment. Some surveys indicate that the demand will increase by three times in the world by 2050 [1].

PV and wind energy system are the most promising as future energy technology. D. Hansen et. al. [2] presented a number of models for modeling and simulation of stand-alone PV system with battery bank verified against a system installed at Risoe national laboratory. The implementation has been done using Matlab/simulink.

Generally all the researches haven't modeling and simulation of PV/Wind Hybrid Electric Power Systems. So, the objective of this paper is to present modeling, simulation, design and analysis DC/AC converter and its controller for PV/Wind Hybrid Electric Power System.

In this paper we are considering combined PV-array System and Wind energy system because Solar and wind energy are nondepletable, site-dependent, non-polluting, and potential sources of alternative energy options. Many countries are pursuing the option of wind energy conversion systems; in an effort to minimize their dependence on fossil-based non-renewable fuels. Also, presently thousands of photovoltaic (PV) deployments exist worldwide, providing power to small, remote, grid-independent or stand-alone applications.

The proposed PV/WES HEPS composed of four design variables: (WTG's), PV arrays, batteries and grid-linked substations. The design of a PV/WES HEPS based on political and social conditions and uses trade-off /risk method. O. Omaril, et. al. [3] the DC coupled PV/WES HEPS discussed, control and management strategies that applied to a simulation model of an example of this type presented. Yará Najem and Méndez Hernández [4] simulation models of the PV/WES HEPS verified with measured data in a real system located near the department efficient energy conversion of the Kassel University. But most of the researches haven't modeling and simulation of PV/Wind HEPS at the point of connection of operation in details. So, the objective of this paper is to present modeling, simulation, design and analysis DC/AC converter and its controller for PV/Wind HEPS.

I. DESCRIPTION OF THE SCHEME

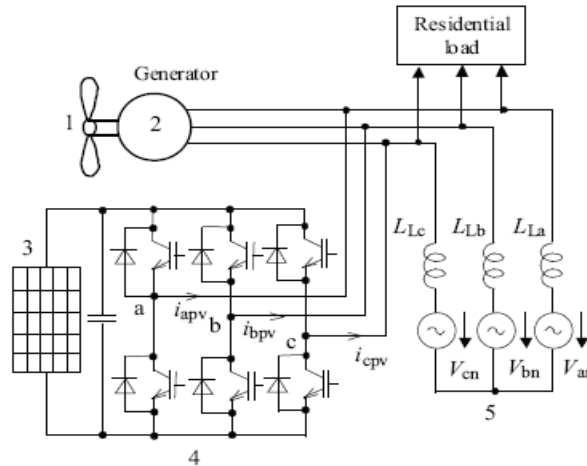


Fig. 1. Schematic diagram Grid connected Hybrid Scheme: 1- Wind Turbine, 2- Induction Generator, 3- PV Array, 4-Three Phase VSI, 5-Grid

The Proposed schematic diagram is shown in Fig.1 where the wind-driven Induction generator is integrated with the grid when the wind-speed is greater than cut-in wind speed. The three-phase currents of the inverter are detected and compared with the corresponding phase current references individually. The PV array voltage is fed to a three-phase six step Current-Controlled Voltage Source Inverter (CC-VSI). This CC-VSI is connected to the grid through an inductor. The controller for the inverter varies the inverter current to follow a reference current.

The resulting current errors are directly used to generate the desired firing pulses for the inverter through an Average Current Mode Controller (ACMC). This is a current control technique that has fast response time and is capable of supporting wide range of power circuit topologies. The wind and PV generators can individually supply power to the grid and the control of the inverter meets the reactive power requirement of the induction generator. It should be noted that in the absence of the grid, the proposed scheme can supply power to a consumer by altering the current control of the inverter to simple SPWM operation. In such operation a three- phase fixed amplitude, fixed frequency supply obtained from the simple SPWM inverter forms the local grid to which the IG is kept integrated.

A. Proposed System Model

The proposed system model is shown in Fig.2 represents the PV array and Wind Hybrid Electric Power System connected to 50 Hz, 22kV Electric Utility Grid. In this the PV array is connected to DC/DC Boost converter, DC/AC Inverter, LC filter and 400/2000V, 5000kVA transformer [5]. Wind Turbine Generator is connected to Electric Utility through a variable frequency PWM boost rectifier, DC link, constant frequency PWM Inverter, LC filter and 400/2000kV, 500kVA transformer [6]. Load is connected to 22kV bus bar through a step down transformer.

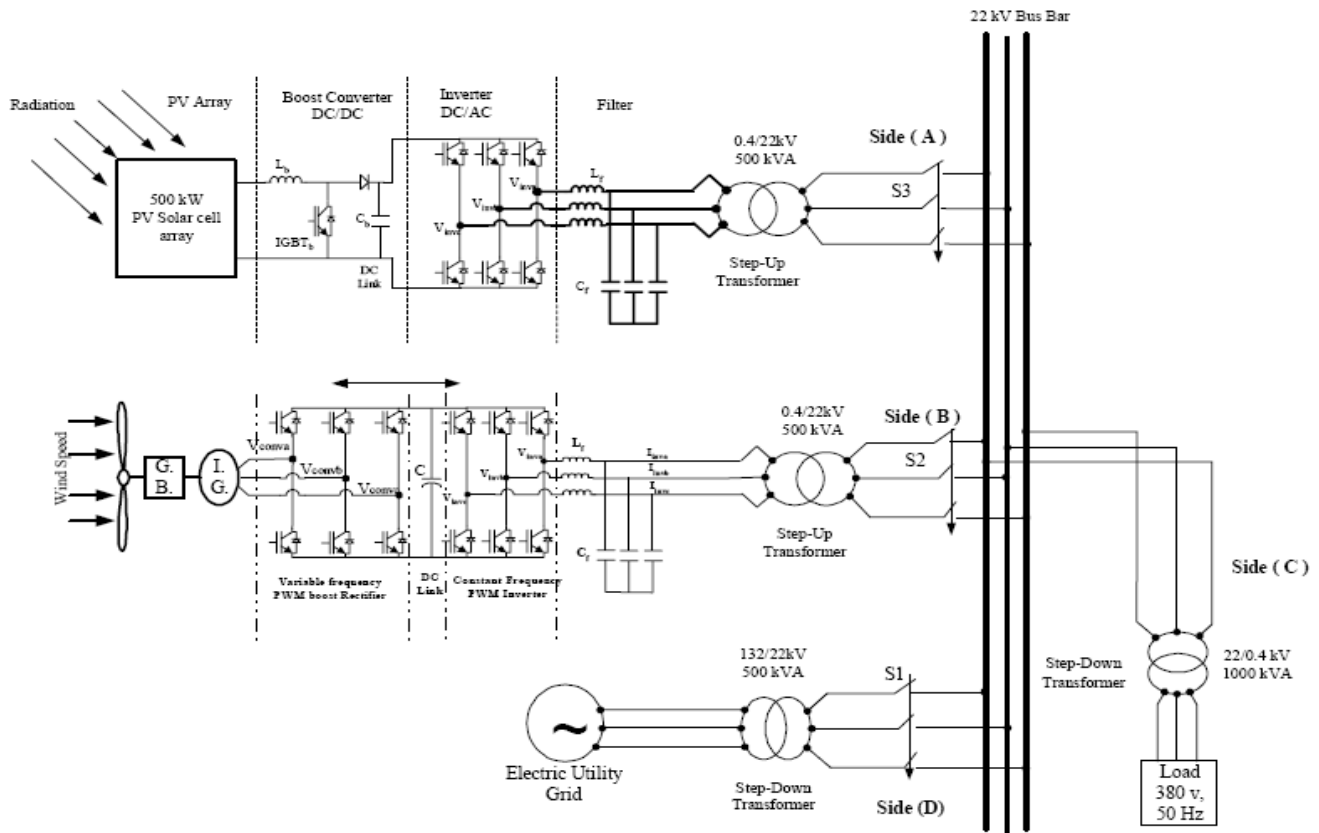


Fig. 2. Proposed System Model of PV/WTG HEPS connected to Grid

B. Model Description

The proposed model description is explained below. The power obtained by the PV system is applied to DC/DC Boost Converter. This feed the DC capacitor link with a maximum power point tracker. The variables which will be sensed for the controller of PV system are PV solar cell array current I_{PV} , DC link voltage, V_{dcpv} , inverter filter output currents I_{fpva} , I_{fpvb} , I_{fpvc} , load phase currents I_{La} , I_{Lb} , I_{Lc} and load phase voltages V_a , V_b , V_c . The variables which will be sensed for the controller of

WTG are DC link voltage, V_{dcw} , inverter filter output currents I_{inwaw} , I_{inwbw} , I_{invcw} , load currents I_{La} , I_{Lb} , I_{Lc} and load phase voltages V_a , V_b , V_c . To provide the active filtering function, the filter output currents are controlled to ensure that the utility line currents and load current are sinusoidal and in phase with the phase voltage. The filter output currents are also controlled to pass power from the PV/Wind HEPS to the load and/or EU. The DC link voltage, V_{dcpv} and V_{dcpw} must be controlled to be higher than the peak line voltage of the EU. The proposed system control scheme for the system under study usually uses the Instantaneous Reactive Power Theory, IRPT. The load currents and load voltages are sampled and transformed into the two-axis $\alpha\beta$ -coordinate system and then into the rotating dq-coordinate system. IRPT uses the park transformation, as in (1) to generate two orthogonal rotating vectors α and β from the three-phase vectors a, b and c. This transformation is applied to the voltages and currents and so the symbol x is used to represent volt or current. IRPT assumes balanced three-phase loads and does not use the x_0 term [5], [6], [7].

$$\begin{bmatrix} x_o \\ x_\alpha \\ x_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} \quad (1)$$

The instantaneous active and reactive powers p and q are calculated from the transformed voltage and current. Then the reference compensating currents have been determined as in (2).

$$\begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} = \frac{1}{V_\alpha^2 + V_\beta^2} \begin{bmatrix} V_\alpha & -V_\beta \\ V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} P_{pv} + P_w \\ q_{pv} + q_w \end{bmatrix} \quad (2)$$

In a balanced three-phase system with linear loads, the instantaneous real power p and imaginary power q are constant and equal to the three-phase conventional active power $P_{3\phi}$ and reactive power $Q_{3\phi}$ respectively. So, the inverse park transformation is applied to i_α^* and i_β^* and this gives the output currents in standard three-phase form, as in (3) [5], [6], [7].

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} \quad (3)$$

II. SIMULINK MODEL

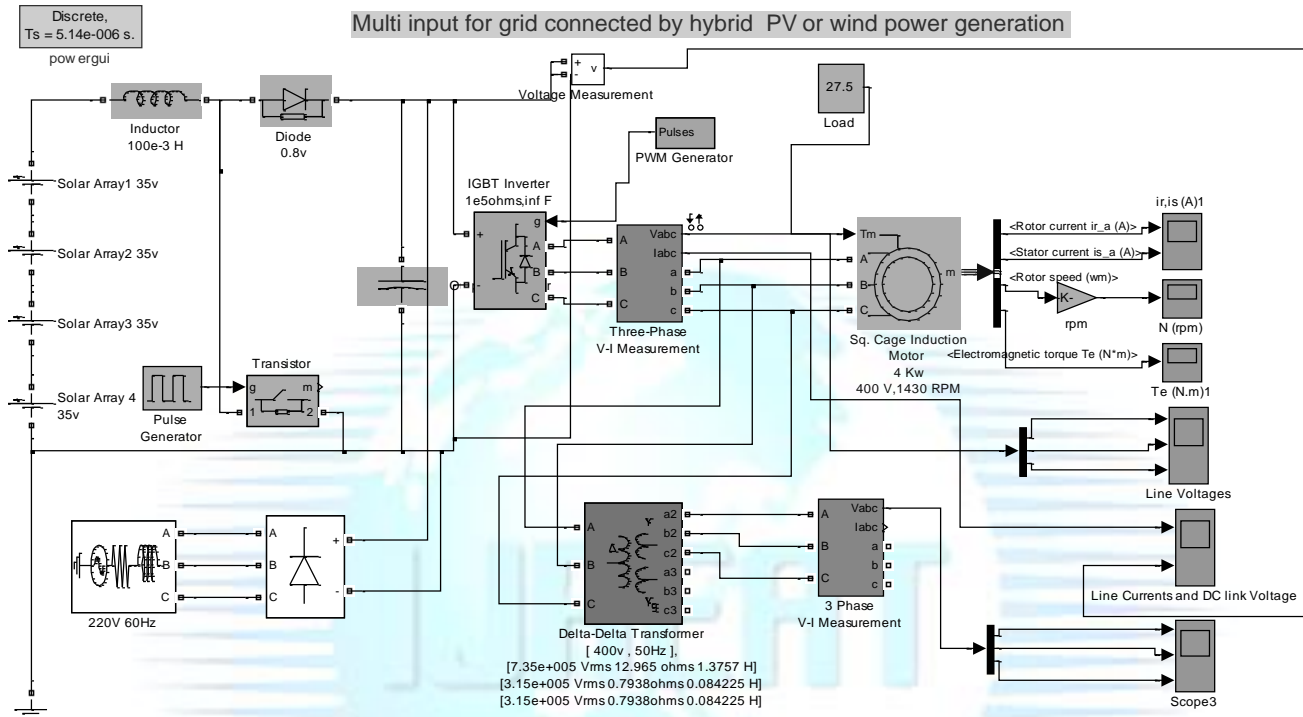


Fig. 3. Simulink diagram of PV/WTG HEPS connected to Grid

Figure 3 shows the Simulink diagram of PV/WTG Hybrid Electric Power System.

The total power load level is 4 kw. A per phase load current for a duration 0.4 sec. The variation of the generated voltage from hybrid PV/WGT according to radiation and wind speed variation is shown in figure 4. The proposed model has a purely sinusoidal controlled ideal voltage source at the inverter terminals. Figure 5 shows the line currents and DC link voltage of PV.WTG System. Figure 6 shows the rotor and stator currents of Induction motor which is acting as a load. Figure shows the electromagnetic torque of Induction Motor.

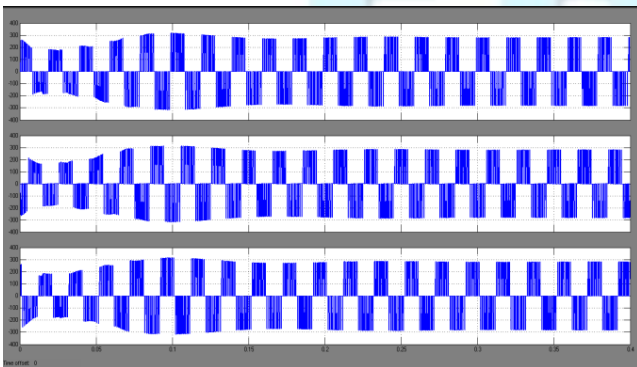


Fig. 4. Line voltages to Load of PV/WTG System

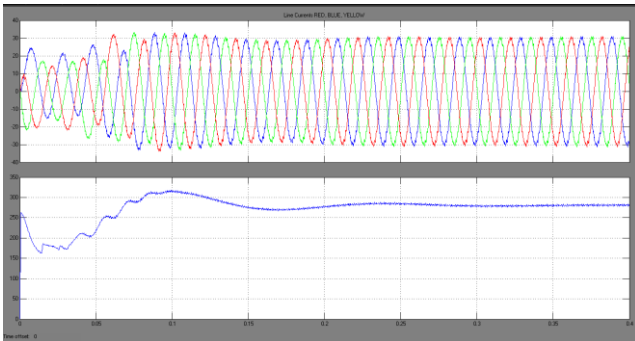


Fig. 5. The Line Currents & DC link voltage of PV/WTG System

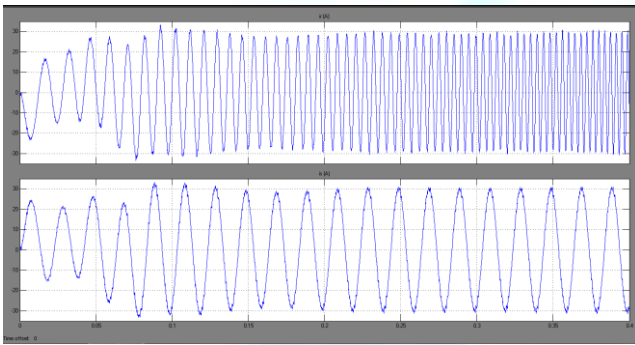


Fig. 6. The Rotor & Stator current of Load to PV/WTG System

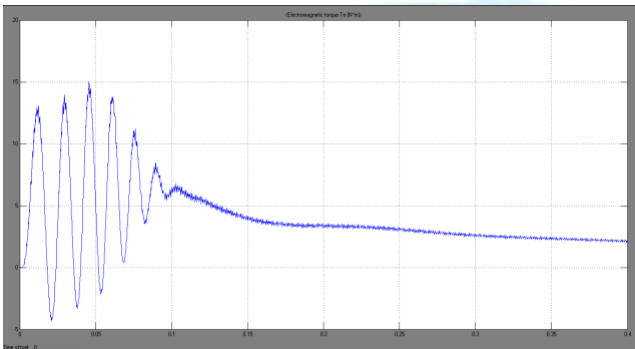


Fig. 7. Electromagnetic Torque of Motor as load to PV/WTG System

III. EXPERIMENTAL RESULTS

A. Prototype Model Circuit

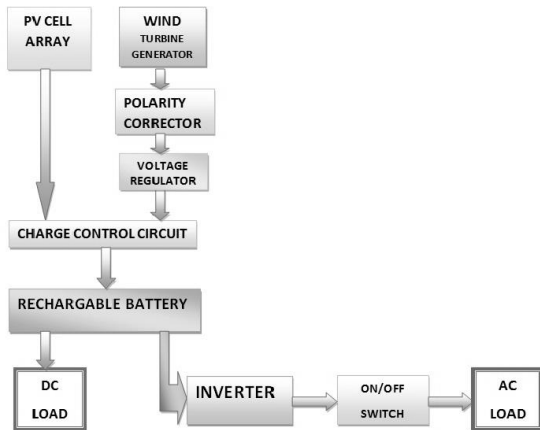


Fig. 8. Prototype Model Circuit of PV/WTG Hybrid Electric Power System

B. Circuit Description

Hardware system includes the following equipments. The function of each equipment is explained in below.

PV Array:

A number of PV panels connected in series and/or in parallel giving a DC output out of the incident irradiance. Orientation and tilt of these panels are important design parameters, as well as shading from surrounding obstructions.

Wind Turbine Generator:

This is installed on top of a tall tower, collects kinetic energy from the wind and converts it to electricity that is compatible with a home's electrical system.

Charge controller:

It controls battery bank charge and discharge reasonable and safety.

Battery bank:

It can be a single battery or multiple batteries connected together to create essentially one large battery of the required voltage and amp-hour capacity. In some ways the battery configuration and capacity are the most important electrical power decision to make, and a wise choice can help guarantee a steady supply of electrical power as well as a system that is simple to operate and maintain.

Inverter:

A power converter that inverts the DC power from the panels into AC power.

Loads:

Stands for the network connected appliances in the building that are fed from the inverter (AC loads), or from the battery bank (DC loads).

Battery Level Indicator Circuit:

A Battery Level Indicator is used for the battery for purpose. A circuit that lets you know the battery level of a device from the number of LEDs that are glowing. It uses ten LEDs in all. So if three LEDs glow, it indicates battery capacity of 30 per cent. the battery-level indicator function is integrated with other functions, here only one comparator IC (LM3914) does it all.

The LM3914 uses ten comparators, which are internally assembled in the voltage divider network based on the current-division rule. So it divides the battery level into ten parts. The circuit derives the power supply for its operation from the battery of the device itself. It uses ten LEDs wired in a 10-dot mode. The use of different colored LEDs makes it easier to recognize the voltage level on the basis of the calibration made. Red LEDs (LED1 through LED3) indicate battery capacity of less than 40 per cent. Orange LEDs (LED4 through

LED6) indicate battery capacity of 40 to less than 70 per cent and green LEDs (LED7 through LED10) indicate battery capacity of 70 to under 100 per cent.

The brightness of the LEDs can be adjusted by varying the value of preset VR2 between pins 6 and 7. Diode D1 prevents the circuit from reverse-polarity battery connection. The tenth LED glows only when the battery capacity is full, i.e., the battery is fully charged. When the battery is fully charged, relay-driver transistor T1 conducts to energise relay RL1. This stops the charging through normally-open (N/O) contacts of relay RL1. For calibration, connect 15V variable, regulated power supply and initially set it at 3V. Slowly adjust VR1 until LED1 glows. Now, increase the input voltage to 15V in steps of 1.2V until the corresponding LED (LED2 through LED10) lights up.

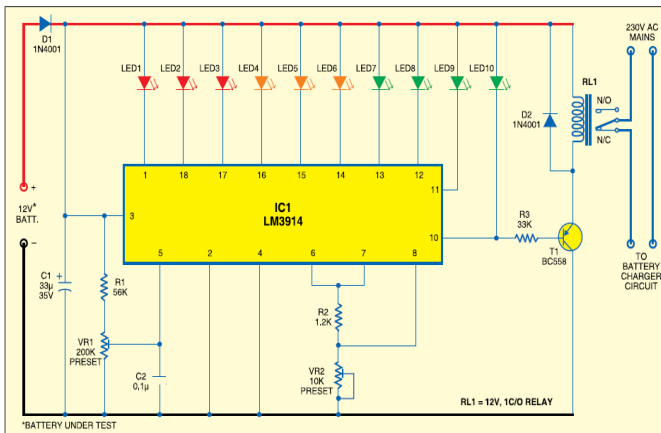


Fig. 9. Battery Level Indicator Circuit

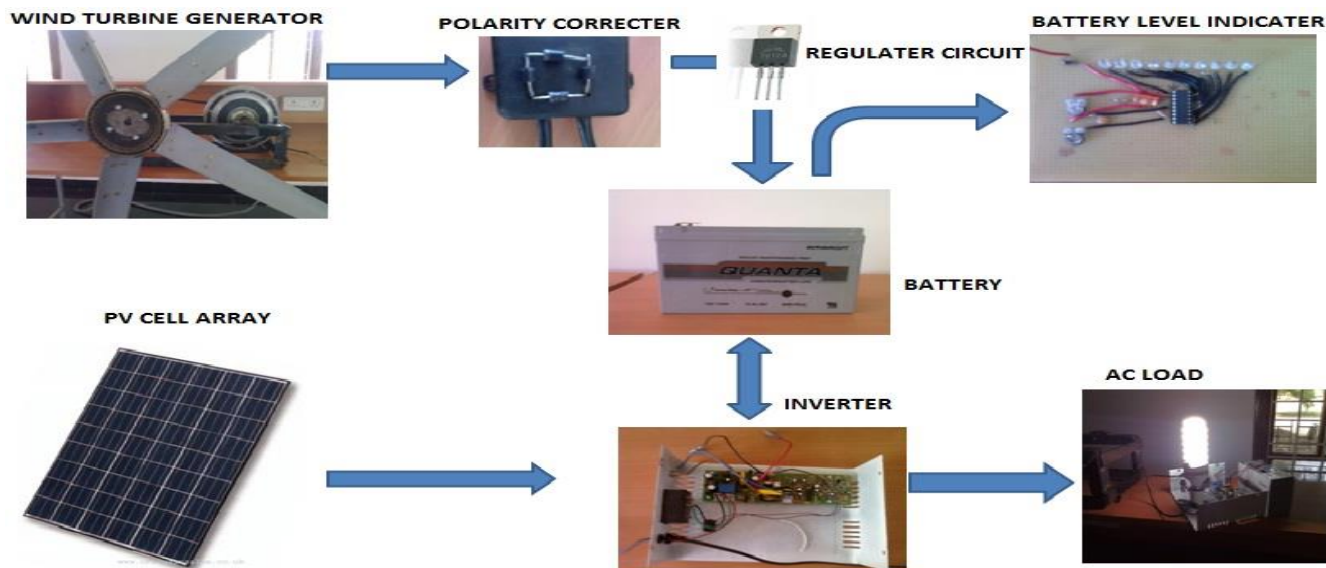


Fig. 10. Experimental setup of PV/WGT Hybrid Electric Power System at NRI Institute Of Technology, Agiripalli, Andhrapradesh.

Figure 10 shows the experimental setup of combined PV array and Wind Turbine Generator Hybrid Electric Power System. The power obtained from the PV array is given to the inverter to convert into AC power. The power obtained from the wind turbine generator is AC. These both powers are combined to drive the AC Load.

Power from Wind Turbine Generator:

The wind fan may rotate in clockwise or anti clockwise direction. So the power generated from wind generator may be positive or negative, in order to get the positive power polarity corrector is connected to the wind turbine. This converts the AC power into DC power. Wind power may not be constant so a regulator circuit is connected and this regulated power is given to charge the battery.

PV Array:

The power from the PV array is DC. This DC power is given to charge the battery. So the power from both the sources is in DC this DC power is given to the charge the battery. Here the battery is acting as Electric grid. The power from the charged battery is given to the inverter to convert the power into AC.

CONCLUSIONS

We conclude that the combination of PV/Wind Hybrid Electric Power System interface to grid was modeled and simulated in Mat lab/Simulink. Designed the DC/AC converter, designed the control circuit for the converter for all radiation and wind speed have been studied and proposed. From the above results we conclude the total harmonic distortion at local bus was within acceptable limits.

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Author Biography



N. Sambasiva Rao received the B.Tech degree in Electrical & Electronics Engineering and M. Tech in Electrical Power Engineering from JNTU Hyderabad, India. He has 12 years' experience in teaching. He is perusing his Ph.D from JNTU, Hyderabad, India. He published a 7 research papers in various International Journals and 2 research papers in National Conferences. He is the Member of International Association of Engineers (IAENG) and Life member of ISTE.

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