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Analysis and Simulation of Hybrid Solar - Wind Renewable Energy Systems

G. Joga Rao[1], S.K Shrivastava[2], V.L Ranjith[3]
EEE Department, Sun Rise University, Alwar, India [1, 2]
EEE Department, Chirala Engineering College, Chirala, India [3]

Abstract: Due to rapid expansion in energy issue, the developments of renewable energy source are becoming more popular and attractive. The commonly used renewable sources are solar photovoltaic and wind energy systems have received a great acceptance in field of power generation for pollution free performance, free availability and for great reliability. Further development and effective use of natural resources, the hybrid systems are developed. This system has combination of two energy resources is takes place i.e. wind and solar energy. Basically this system involves the integration of two energy system that will give continuous power. Solar panels are used for converting solar energy and wind turbines are used for converting wind energy into electricity. This electrical power can utilize for various purpose. Generation of electricity will be takes place at affordable cost. In this Paper, the modeling of hybrid solar photovoltaic and wind energy system are done by using MATLAB/Simulation.

Keywords: Hybrid Energy System, Solar Photovoltaic System, Wind Energy System, MATLAB/ Simulation.

I. INTRODUCTION

Electricity is most needed for our day to day life. There are two ways of electricity generation either by conventional energy resources or by non-conventional energy resources. Now a day's electrical energy is generated by the conventional energy resources like coal, diesel, and nuclear etc. The main drawback of these sources is that it produces waste like ash in coal power plant, nuclear waste in nuclear power plant and taking care of this wastage is very costly and also damages the nature. The nuclear waste is very harmful to human being also. The conventional energy resources are depleting day by day. Soon it will be completely vanishes from the earth so we have to find another way to generate electricity. The non-conventional energy resources should be good alternative energy resources for the conventional energy resources. There are many non-conventional energy resources like solar, wind; geothermal, tidal, etc. the tidal energy has drawbacks like it can only implemented on sea shores. While geothermal energy needs very lager step to extract heat from earth. Solar and wind are easily available in all condition. The non-conventional energy resources like solar, wind can be good alternative sources and they are reliable, pollution free and economical.

In this proposed system solar and wind power is used for generating power. Solar and wind has good advantages than other than any other non-conventional energy sources. Both the energy sources have greater availability in all areas. It needs lower cost. There is no need to find special location to install this system. The importance of hybrid systems grown as they appeared to be the right solution for a clean and distributed energy production. In this paper the solar photovoltaic model and wind energy model is modeled by simulation/MATLAB and their corresponding results are also presented in this paper.

II. HYBRID ENERGY SYSTEM

Hybrid power systems consist on a combination of renewable energy sources such as photovoltaic (PV), wind generators, hydro, etc., to charge batteries and provide power to meet the energy demand, considering the local geography and other details of the place of installation. The design process of hybrid energy systems requires the selection and sizing of the most suitable combination of energy sources, power conditioning devices, and energy storage system together with the implementation of an efficient energy dispatch strategy. The selection of the suitable combination from renewable technology to form a hybrid energy system depends on the availability of the renewable resources in the site where the hybrid system is intended to be installed.

In this proposed system solar and wind power is used for generating power. Solar and wind has good advantages than other than any other non-conventional energy sources. Both the energy sources have greater availability in all areas with lower cost.

A. SOLAR ENERGY

Solar energy is that energy which is gets by the radiation of the sun. Solar energy is present on the earth continuously and in abundant manner. Solar energy is freely available. It doesn't produce any gases that mean it is pollution free. It is affordable in cost. It has low maintenance cost. Only problem with solar system it cannot produce energy in bad weather condition. But it has

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greater efficiency than other energy sources. It only need initial investment. It has long life span and has lower emission.

B. WIND ENERGY

Wind energy is the energy which is extracted from wind. For extraction we use wind mill. The wind energy needs less cost for generation of electricity. Maintenance cost is also less for wind energy system. Wind energy is present almost 24 hours of the day. It has less emission. Initial cost is also less of the system. Generation of electricity from wind is depend upon the speed of wind flowing.

The hybrid system is shown in Fig. 1. In the following sections, the model of components is discussed.

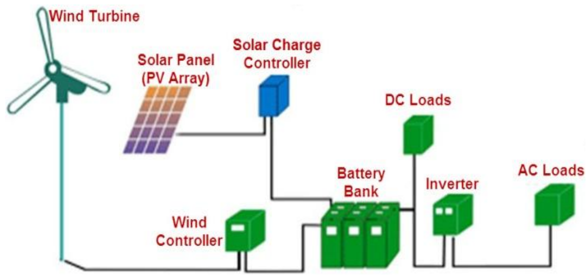

Fig. 1 The hybrid renewable energy system

III. HYBRID SOLAR-WIND ENERGY SYSTEM MODELING

A. MODELING THE SOLAR PHOTOVOLTAIC SYSTEM

A photovoltaic PV generator consists of an assembly of solar cells, connections, protective parts, supports etc. Solar cells are made up of semiconductor materials (usually silicon),which are specially treated to form an electric field, positive on one diode(backside) and negative on other (towards the sun). When solar energy (photons) solar hits the solar cell, electronics are knocked loose from the atoms in the semiconductor material, creating electron-hole pairs. If the electrical conductors are then attached to the positive and negative sides, forming an electrical circuit, the electrons are captured in the form of electric current (photo current).

The model of the solar cell can be realized by an equivalent circuit that consists of a current source in parallel with a diode as shown in Fig.2. For ideal model Rs, R_p and C components can be neglected.

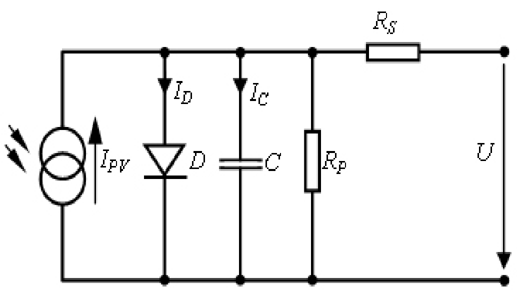

Fig. 2 Equivalent Circuit diagram of a solar pv cell

The p-n junction has a certain depletion layer capacitance, which is typically neglected for modeling solar cell. At increased inverse voltage the depletion layer becomes wider so that the capacitance is reduced similar to stretching the electrodes of a plate capacitor. Thus solar cells represent variable capacitance whose magnitude depends on the present voltage. This effect is considered by the capacitor C located in parallel to the diode.

Series resistance R_s consists of the contact resistance of the cables as well as the resistance of the semiconductor material itself. Parallel or shunt resistance R_P includes the leakage current at the photovoltaic cell edges at which the ideal shunt reaction of the p-n junction may reduced. This is usually within the KΩ region and consequently has almost no effect on the current-voltage characteristics.

The diode is the one which determines the current-voltage characteristic of the cell. The output of the current source is directly proportional to the light falling on the cell. The open circuit voltage increases logarithmically according to the Shockley equation which describes the interdependent of current and voltage in a solar cell.

$$I = I_{PV} - I_0\left(e^{\frac{qU}{kT}} - 1\right) \text{----(1)}$$

$$U = \frac{kT}{q}\ln\left(1 - \frac{I - I_{PV}}{I_0}\right) \text{-----(2)}$$

Where

k- Boltzmann constant;

T-reference temperature of the solar cell;

q-elementary charge ($1.6021\ 10^{-19}$ As);

U-solar cell voltage (V);

I_0 – saturation current of the diode (A);

I_{PV} – photovoltaic current (A);

Equations (1) and (2) lead to the development of a Matlab Simulink for the PV module presented in Fig.3.

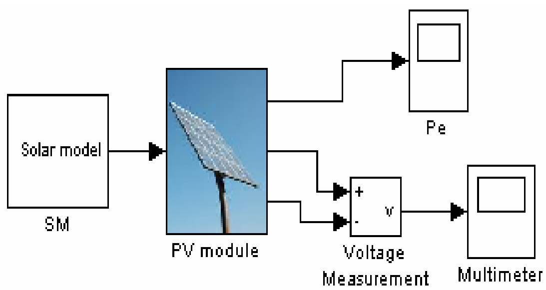

Fig. 3 Matlab Simulink Library PV module

The solar system model consists of three Simulink blocks: the solar model block, the PV model block and energy conversion modules. The solar model block implements the mathematical model of the solar radiation. This is done by using standard Simulink and Matlab modules and functions. The PV module implements the equivalent circuit of a solar cell, shown Fig.2. Standard functions and blocks of Matlab and Simulink were used to obtain this model; Its structure is represented in Fig.4.

The output of the PV module is processed by an energy conversion block implemented with a PWM IGBT inverter block from standard Simulink/SimPower Systems library.

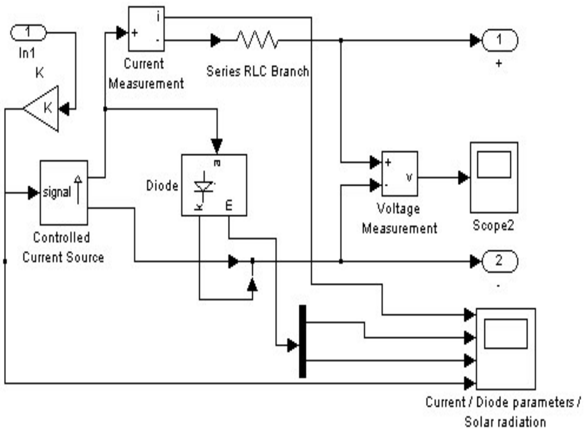

Fig. 4 Matlab Simulink implemented of the PV module.

B. MODELING THE WIND ENERGY SYSTEM

Modeling the wind energy converter is made considering the following assumptions:

Friction is neglected;

Stationary wind flow;

Constant, shear-free wind flow;

Rotation-free flow;

Incompressible flow (ρ=1.22 kg/m^3);

Free wind flow around the wind energy converter.

On the above condition the maximum physical achievable wind energy conversion can be derived using theoretical model that is independent of the technical construction of a wind energy converter. The flow air mass has certain energy. This energy is obtained from the air movement on the earth's surface determined by the difference in speed and pressure. This the main source of the energy used by the wind turbines to obtain electric power. The Kinetic energy W taken from the air mass flow m at speed v_1 in front of the wind turbines pales and at the back of the pales at speed v_2 is illustrated by equation (3):

$$W = \frac{1}{2}m(v_1{}^2 - v_2{}^2) \text{ ------------- (3)}$$

The resulted theoretical medium power p is determined as the ratio between the kinetic energy and the unit of time and is expressed by equation (4):

$$P = \frac{1}{2}\frac{m}{t}(v_1{}^2 - v_2{}^2) = \frac{1}{2}\frac{V\rho}{t}(v_1{}^2 - v_2{}^2) \text{----- (4)}$$

Where:

V- air mass volume; t- time; ρ - Air density.

Assuming the expression of the mean air speed $V_{med} = \frac{1}{2}(v_1 + v_2)$

the mean air volume transferred per unit time can be determined as follows:

$$V_{med} = \frac{V}{t} = Av_{med} \text{ --------------- (5)}$$

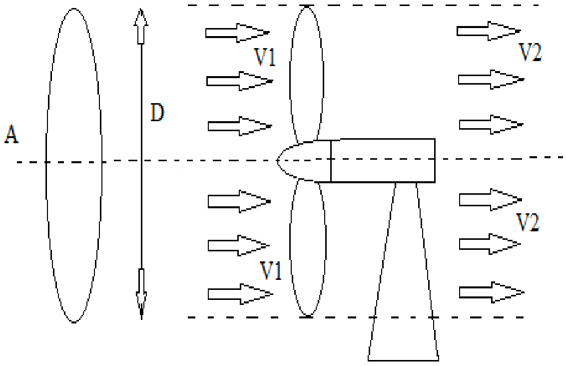

Fig. 5 Flow through a wind energy converter.

The equation for the mean theoretical power is determined using equation (5)

$$P = \frac{1}{4}A\rho(v_1{}^2 - v_2{}^2)(v_1 + v_2) = \frac{A}{4}A\rho v_1{}^3\left(1 - \frac{v_2{}^2}{v_1{}^2}\right)\left(1 - \right. \text{V2V1 ------- (6)}$$

We can conclude that an adequate choice of v_1/v_2 ratio leads to a maximum power value taken by the wind converter from the kinetic energy of the air masses, as shown by equation (7)

$$P_{max} = \frac{8}{27}A\rho v_1{}^3 \text{------------- (7)}$$

This power represents only a fraction of the incident air flow theoretical power given by

$$P_{wind} = \frac{1}{2}A\rho v_1{}^3 \text{ -------------- (8)}$$

Equations (7) and (8) leads to:

$$P_{max} = \frac{8}{27}A\rho v_1{}^3 = \frac{1}{2}A\rho v_1{}^3 = P_{wind} \cdot C_P \text{ --- (9)}$$

Where C_p represents the mechanical power coefficient which express that the wind kinetic energy cannot be totally converted in useful energy. This coefficient, meaning the maximum theoretical efficiency of wind power. The electrical power obtained under the assumptions of a wind generator's electrical and mechanical part efficiency is given by:

$$P_{ele} = \frac{1}{2}C_e A\rho v_1{}^3 \text{ --------------(10)}$$

Where C_e represents the total net efficiency coefficient at the transformer terminals

A Matlab/simulink model, based on the equations mentioned above, was developed for the wind generator module. This model is shown in fig. 6

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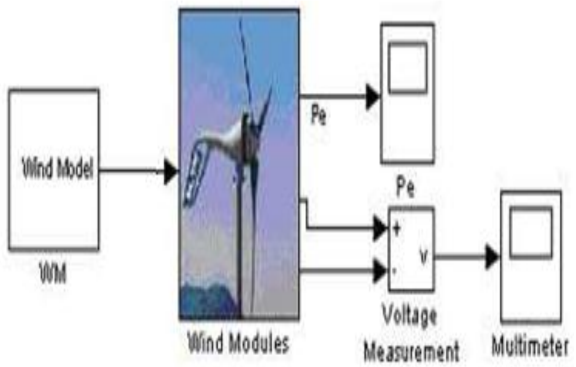

Fig 6 The Matlab simulink model of the wind generator module

The wind system model consists of three simulink blocks: the wind model block, the wind generator model block and energy conversion modules. The wind model block implements the mathematical model of the air mass flow. This is done by using standard Matlab/Simulink modules and functions. This block allows the selection of different patterns for the air mass flow and the equations mentioned above were used in the design of this model. The wind energy generator model was implemented by a module having configurable parameters based on the equation (10) and using the equivalent model of a generator. This model takes the following form and is shown in fig. 7

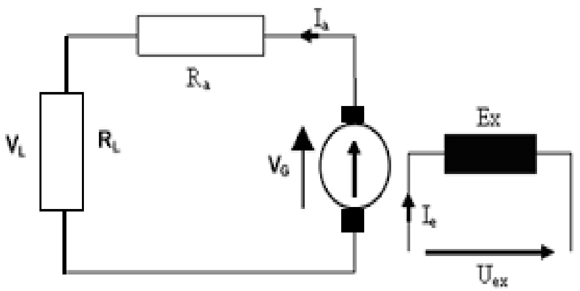

Fig. 7 Equivalent circuit diagram of a small wind generator

In the equivalent circuit diagram of a small wind generator the notations are:

R_a - rotor winding resistance
Ex - generator separate excitation winding; current I_e through this winding generates the main field
V_e - induced voltage in the rotor (armature) V- terminal voltage
$V = V_e - R_a\ I_a$

The resulted Matlab/Simulink model for the wind generator is a particular case of the more general model of an electrical generator, which is presented in figure 8.

The output of the wind energy generator module is processed by an energy conversion block implemented with a PWM IGBT inverter block from the standard Simulink/SimPower systems library.

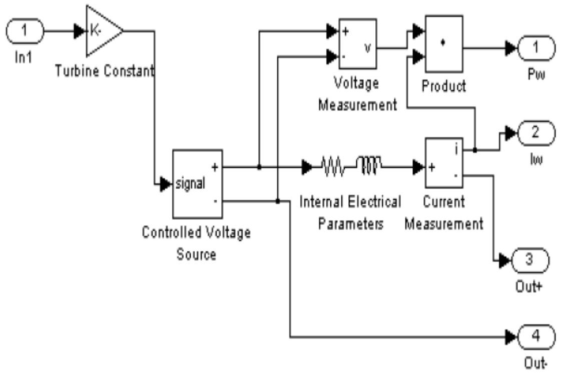

Fig. 8 Matlab-Simulink model of the wind generator

IV. MODELING AND SIMULATION OF THE HYBRID RENEWABLE ENERGY SYSTEM

Considering the above models, by using Matlab- Simulink environment, an application useful for study of hybrid renewable energy system connected to a local grid was developed. The purposes of the application reside in scientific studies and, also didactical ones, concerning renewable hybrid solar-wind-hydro systems. The structure of the application is based on solar, wind, hydro, energy conversion, transport and consumer modules shown in Fig. 9.

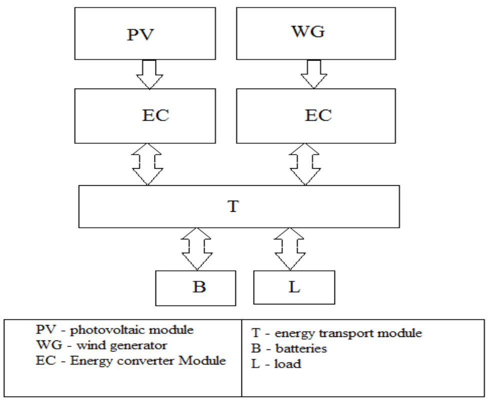

Fig. 9 Architecture of the hybrid solar-wind system

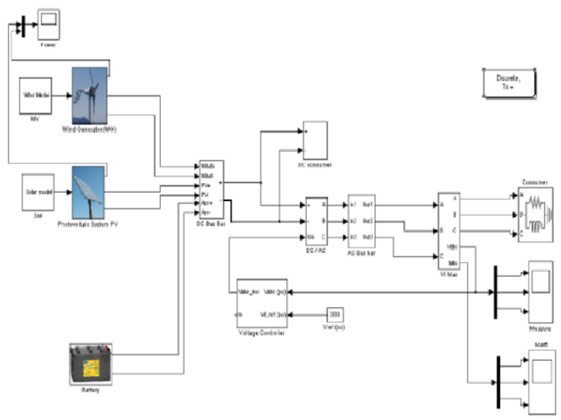

Fig. 10 Simulation model of a hybrid renewable energy system.

By using the presented simulation several functioning studies of solar-wind hybrid system can be performed. Different patterns of solar, wind models and also different type of loads can be selected.

Fig. 11 illustrates the voltage waveform measured at the bus bar. It can be seen a voltage waveform distortion caused by electronic devices inverters used for energy conversion.

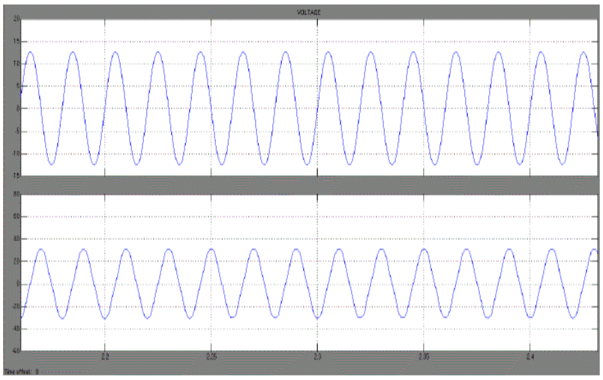

Fig. 11 Voltage waveform at the bus bar

V. CONCLUSION

This paper presented the analysis and modeling of a hybrid solar-wind energy system using Matlab/Simulink environment. This application is useful for analyse and simulate a real hybrid solar-wind energy system connected to a local grid. The blocks like wind model, solar model, energy conversion and load are implemented and the results of simulation are also presented. Hybrid power generation system is good and effective solution for power generation. People should motivate to use the non conventional energy resources. It is highly safe for the environment as it doesn't produce any emission and harmful waste product like conventional energy resources. It is cost effective solution for generation. It only need initial investment. It has also long life span. Overall it good, reliable and affordable solution for electricity generation.

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BIOGRAPHIES

G. Joga Rao Received B.Tech (Electrical &Electronics Engineering) degree from Kamala Institute of Technology & Science, Jawaharlal Nehru Technological University, Hyderabad, India, in 2004 and the M.Tech degree from Jawaharlal Nehru Technological University College of Engineering, Hyderabad, India in 2007. Later he joined in Chirala Engineering College, Chirala, and Andhra Pradesh as an assistant professor in the department of Electrical & Electronics Engineering and serves more than 8 years. Currently pursuing his Ph.D in SunRise University, Alwar, Rajasthan, India. His area of interest includes Power Systems, Energy Systems, and Renewable Energy Sources, Micro Grids and Smart Grids. He is a Life Member of the Indian Society for Technical Education.

S.K Shrivastava Received B.Tech in Electrical Engineering from Nagpur University, Nagpur in 1984, M.Tech from Indian Institute of Technology IIT(B), Bombay in 1987 and Ph.D from Allahabad Agriculture University (currently Sam Higginbottom Institute of Agriculture, Technology and Sciences, Deemed University) Allahabad, Uttar Pradesh in 2006. He has more than 27 years of teaching experience in various colleges in different positions and acted as a technical advisor and reviewer for different programmes. His area of interest includes Energy Systems and power systems. He is a life member of different professional bodies like ISTE, Fellow the Institution of Engineers (IE),The Institution of Electronics & Telecommunication Engineers.

V.L Ranjith Received B.Tech (Electrical & Electronics Engineering) degree from Chirala Engineering College, Jawaharlal Nehru Technological University, Hyderabad, India, in 2007 and the M.Tech degree from Jawaharlal Nehru Technological University College, Anantapur, India in 2013. Later he joined in Chirala Engineering College, Chirala, and Andhra Pradesh as an assistant professor in the department of Electrical & Electronics Engineering. His area of interest includes Power Systems, and Renewable Energy Sources.