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Simulation and design of wind-PV hybrid power generation systems

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Abstract: This paper proposes a hybrid energy conversion system combing photo voltaic and wind turbine as a small-scale alternative source of electrical energy. The set-up consists of a photo-voltaic solar-cell array, a mast mounted wind generator, lead-acid storage batteries, a PWM inverter unit to convert DC power to AC power, IGBT and 3-phase loads. Thus Hybridizing solar and wind power sources together with storage batteries is better option. Photo-Voltaic or solar cells, convert the energy from sunlight into DC electricity. PVs holds advantage over other renewable energy sources in that they give off no noise, and practically require no maintenance. Wind- turbines and PV cells provide DC power. A semiconductor-based device known as a power inverter is used to convert the DC power to AC power. The hybrid unit contains two complete generating plants, a PV solar cell plant and a wind-turbine system. These sources are connected in parallel to a 12V DC line. The power is next connected to a DC to AC inverter and is then supplied from the inverter's output to a 3 phase load. The output voltage across load and inverter is studied.

Keywords: PV model, Wind Model, Hybrid system, IGBT, Battery, PWM Inverter, load.

I. INTRODUCTION

As power demand increasing day by day, the renewable energy power sources, wind and solar have experienced a rapid growth around the world. Having wide geographical spread they can be generated near load centers, thus eliminating the need of high voltage transmission lines running through rural and urban landscapes. The abundant energy available in nature can be harnessed and converted to electricity in sustainable and clean way to supply the necessary power without access to electricity grid. In reference to previous paper published this paper proposes a hybrid energy conversion system combing photovoltaic and wind turbine as a small-scale alternative source of electrical energy.

II. RELATED WORK

It includes work in various fields like analysis of cost effectiveness of stand-alone hybrid system. Feasibility of solar wind system in villages. The sizing and simulation of hybrid power system and modeling of wind PV hybrid system using a new converter topology.

III. PV CELL

PV cell is basically a semiconductor *p-n* junction-based photodiode. This semiconductor photodiode generates electrical power when exposed to light. The power produced by a single PV cell is not enough Therefore, by connecting PV cells in series, higher voltage can be obtained and in parallel higher current can be obtained consequently higher power. Generally, a combined series and parallel connection of PV cells is known as a module. Mostly, commercial modules consist of 36 or 72 cells. The modules consist of transparent front side, encapsulated PV cells, and back side. The front side material is usually made up of low-iron and tempered glass. A PV array (system) is an interconnection of modules which in turn is made up of many PV cells connected in series and parallel. The power produced by a single module is seldom enough for commercial use, so modules are connected to form an array to supply the load. PV module represents the fundamental power conversion unit of a PV generator system. The output characteristics of PV module depends on the solar insolation. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect.

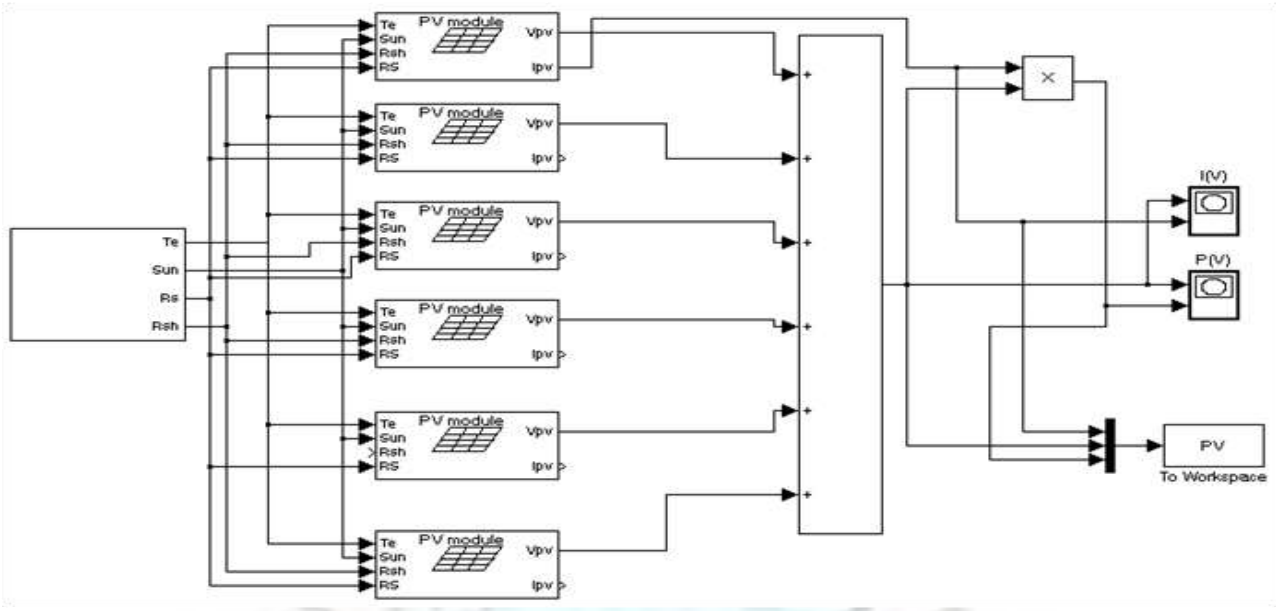


Fig. 1

The equivalent circuit of a PV cell is shown in Fig. It includes a current source, a diode, a series resistance and a shunt resistance In view of that, the current to the load can be given as

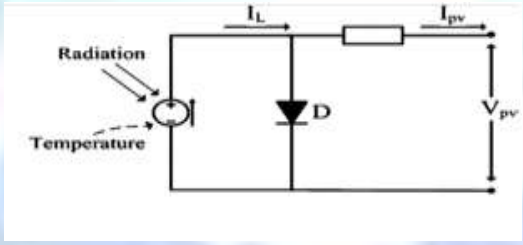


Fig. 2

$I = i_{qv} - i_o (e^{qv/Kt} - 1)$
$V = kt/q \ln(I - i_{PV} / i_O)$
Where:
k - Boltzmann constant (1.3806 10-23 J/K)
t - Reference temperature of solar cell
q - Elementary charge (1.6021 10-19 As)
V - Solar cell voltage (V)
i_0 - saturation current of the diode (A)
i_{pv} - Photovoltaic current (A)

With help of these equations simulink model of photovoltaic is designed. In view of that, the current to the load can be given as:

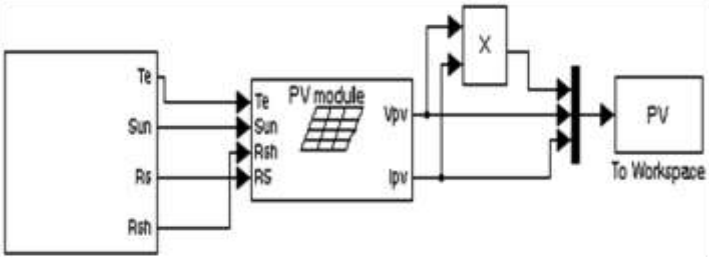


Fig. 3

IV. WIND POWER

The wind is a renewable energy source, continuously generated or replenished by the forces of nature. Wind Power is energy extracted from the wind, passing through a machine known as the windmill. Electrical energy can be generated from the wind energy. This is done by using the energy from wind to run a windmill, which in turn drives a generator to produce electricity. The windmill in this case is usually called a wind turbine. This turbine transforms the wind energy to mechanical energy, which in a generator is converted to electrical power. An integration of wind generator, wind turbine, aero generators is known as a wind energy conversion system (WECS) Component of a wind energy project Modern wind energy systems consist of the following components:

A tower on which the wind turbine is mounted, A rotor that is turned by the wind, The nacelle which houses the equipment, including the generator that converts the mechanical energy in the spinning rotor into electricity. The diameter of the area swept by the rotor is also important. The amount of power transferred to a wind turbine is directly proportional to the area swept out by the rotor, to the density of the air, and the cube of the wind speed. The power P in the wind is given by

$P = ½ Cp. \rho.A. V'3$

Where,

Cp is the turbine power coefficient. A theoretical maximum value of 0.593 has been proposed for Cp.

ρ = air density (kg/m3)

A is the rotor swept area = $\Pi d^2/4$ (m^2)

d is the rotor blade diameter (m) and

V´ = mean wind speed (ms-1)

Batteries: Many wind energy systems use batteries to supply electricity when the wind is not adequate. A system without batteries will only provide power when sufficient wind is blowing to meet the demand.

Inverters: Energy stored in batteries is available as DC power. Some appliances and equipment are designed and built to run on DC power. In this paper a pv-wind hybrid system is designed, which includes solar panel that gives dc energy. This dc energy is converted to ac with the help of inverter. The ac output can be seen on scopes. Similarly, wind energy is saved and given to load.

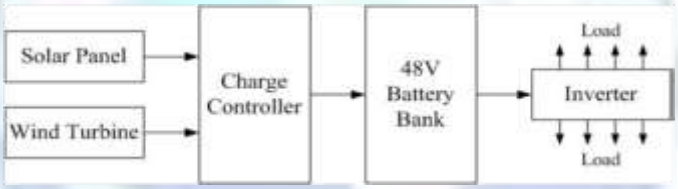


Fig. 4

Using the RegenSim. Library a renewable energy hybrid System developed consist of power generation blocks from renewable energy sources such as sun, wind, battery blocks (providing the energy storage), measurements blocks for electrical parameters (voltage, current etc), inverter blocks (for power generation in DC voltage), energy consumer block

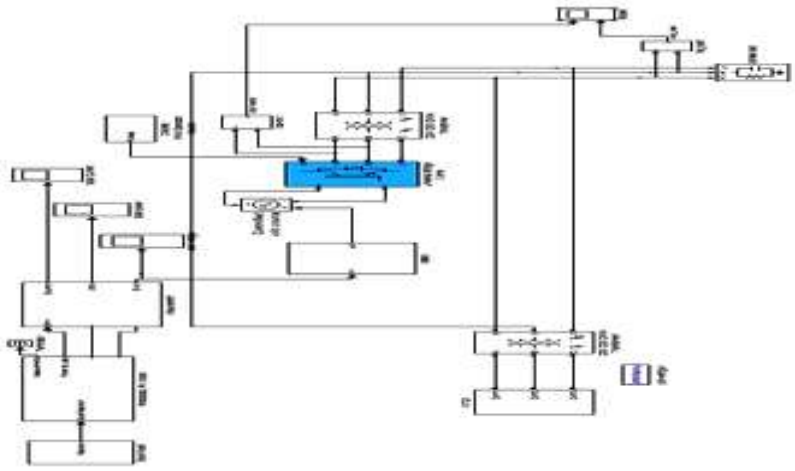
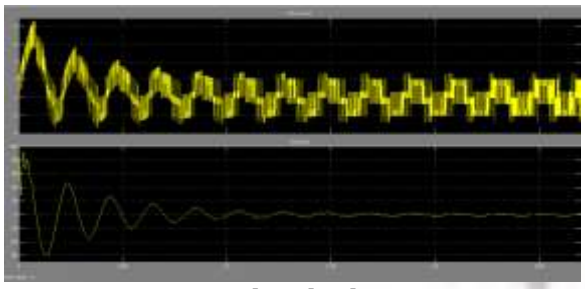


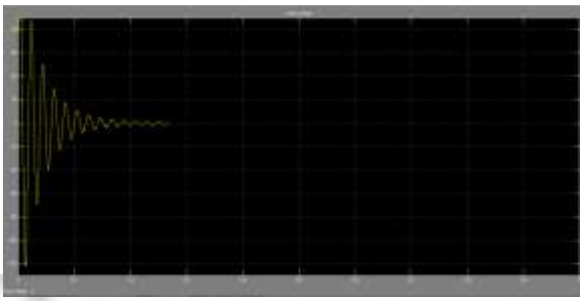
Fig. 5

V. SIMULATION RESULTS

The power is generated from the hybrid PV/Wind system. It is stored in battery. The results obtained across the load and inverter contains time as x axis and voltage as y axis. Similarly the wind and solar voltage is observed between time and output voltage. Harmonics which is observed are as shown.

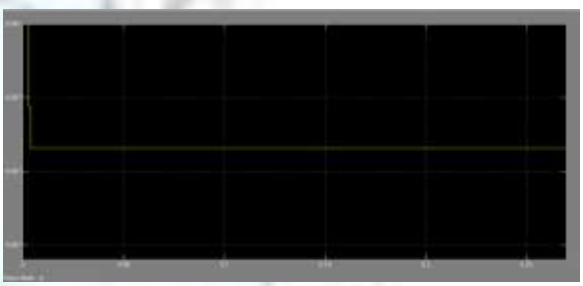


a. $V_{ab\ invereter}$ and V_{ab} load



b. Wind voltage

c. Solar voltage



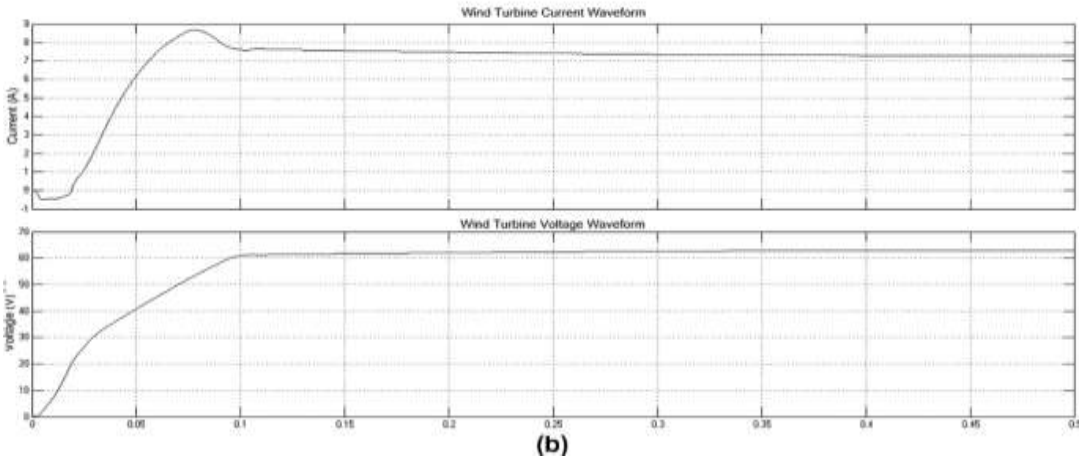
d. Solar current

Fig. 6

VI. RESULT ANALYSIS

The waveform analyses of the entire system are seen in Fig.7 The generated AC output of wind turbine is converted to DC with an uncontrolled full bridge rectifier. The DC outputs of rectifier are seen in Fig. 7a where the current and voltage are stabilized up to the desired value in 0.1s. It is seen that output current of rectifier is equal to output current of wind turbine, while the voltage values are generated at proper values in wind turbine. The output phase voltages of inverter are seen with the mean value in the curve.

(a)



(b)

Fig.7: Waveform analysis of the proposed current and regulated voltage output of wind turbine

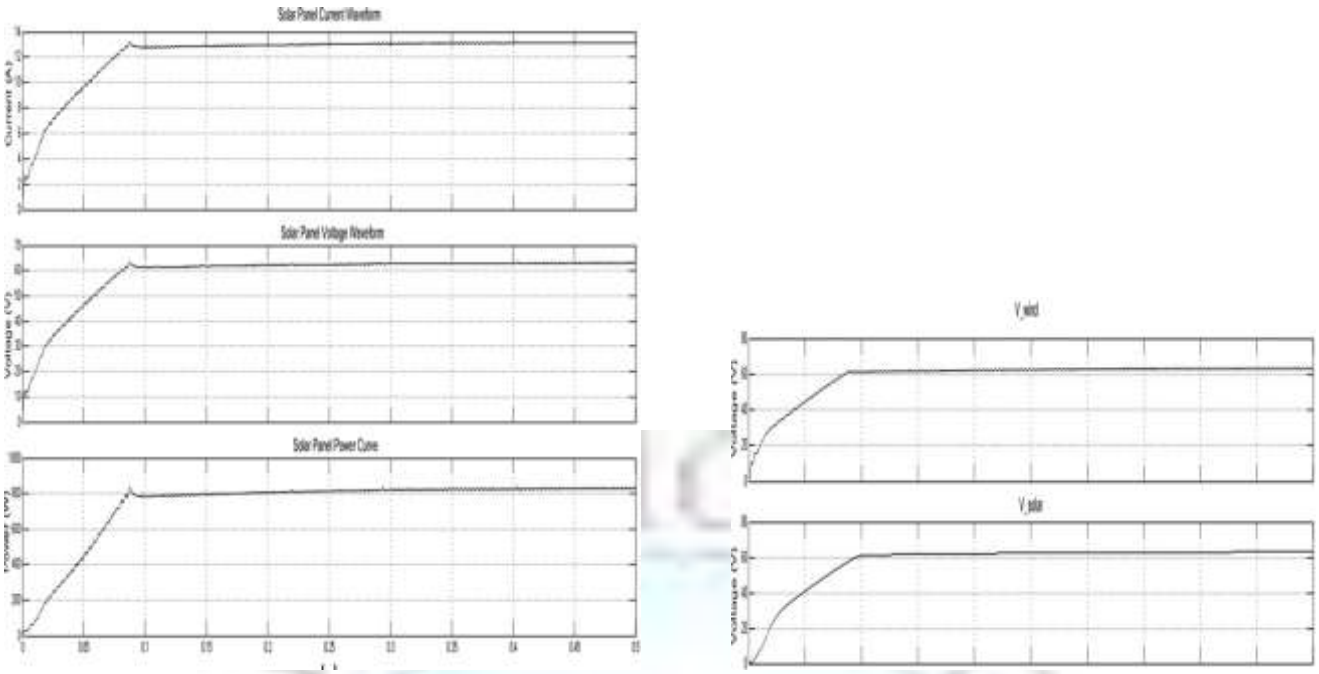


Fig. 8 Waveform analysis of the proposed output voltages of wind, solar

VII. CONCLUSION

A generalized PV model which is representative of the all PV cell, module, and array has been developed with Matlab/Simulink and been verified with a PV cell and a commercial module. The proposed model takes sunlight irradiance and cell temperature as input parameters and outputs the I-V and P-V characteristics under various conditions. This model has also been designed in the form of Simulink block libraries. Such a generalized PV model is easy to be used for the implementation on Matlab/Simulink modeling and simulation platform. Especially, in the context of the Sim Power System tool, there is now a generalized PV model which can be used for the model and analysis in the field of solar PV power conversion system. The proposed system will be extended by adding fuel cell and ultra capacitor applications in future works. In addition to this, the comparison between results of both the simulink model can be made. The results of ongoing experimental studies will also prove the efficiency of proposed system in real time.

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