Non-Conventional Power Generation Using Solar And Wind With The Aid Of Hydro Power Generation

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Abstract— **The latest trend in generating power for industrial and domestic purposes is the hybrid power generation using non-conventional energy sources. The non-conventional energy sources are the renewable sources that can be utilized again after every use and also whose supply is abundant in nature. This paper presents a new system configuration of the front-end rectifier stage for a hybrid wind/photovoltaic energy system. The configuration allows the two sources to supply load simultaneously depending on the availability of energy sources. This paper also describes about the design aspects of the renewable energy sources like Solar (PV) and Wind. PV/Wind module designs, parameters are mentioned in this particular paper. Operational analysis of the proposed system will be discussed in this paper. Simulation results are given to highlight the merits of the proposed circuit.**
Keywords— **PV cells, Irradiation, Insolation, Wind turbine, Hydro turbine, Synchronous Machine, Inverter.**

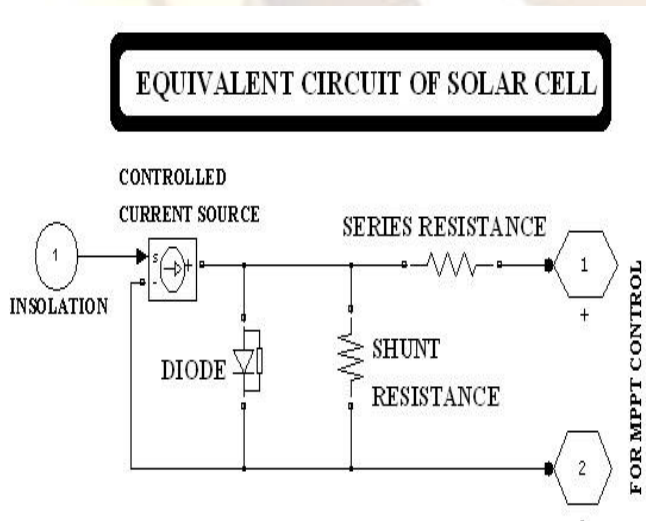## I. BASIC PV CELL MODEL

Fig.1. Equivalent Solar cell developed in
       Simulink/Simpowersystem

Operation of PV:
        A solar cell is the most fundamental component of a photovoltaic (PV) system, which converts the solar energy into electrical energy. A solar cell essentially consists of a pn junction formed by semiconductor material. When sunlight falls on a solar cell an electron-hole pair is generated by the energy from the light (photons). The electric field created at the junction causes the electron-hole pair to separate with the electrons drifting towards the n-region and the holes towards the p-region. Thus there is a bombardment of electrons and holes resulting in the generation of energy. Hence electrical voltage is generated at the output. The photocurrent (Iph) will then flow through the load connected to the output terminals of the cell [5]**.**

        The ideal equivalent circuit of a solar cell consists of a current source in parallel with a diode. The output terminals of the circuit are connected to the load. Ideally the voltage-current equation of the solar cell is given by [3]:

$$I = I_{Ph} - I_o \left(e^{(V+iR_s/n_s v_t)} - 1 \right) - (v+iR_s)/R_{sh} \qquad (1)$$

Where:
I_{ph}	=	Photo current (A)
I_o	=	Diode Reverse saturation current(A)
V_t	=	Junction terminal voltage
v	=	terminal voltage
R_s	=	Panel series Resistance
R_{sh}	=	Panel shunt Resistance
n_s	=	Number of cells in panel connected in series

The power output of a solar cell is given by:

$$P_{PV} = V_{pv} * I_{PV} \qquad (2)$$

Where:
I_{PV}	=	Output current of solar cell (A).
V_{PV}	=	Solar cell operating voltage (V).
P_{PV}	=	Output power of solar cell (W).

II.   WIND ENERGY CONVERTION SYSTEM AND ITS OPERATION
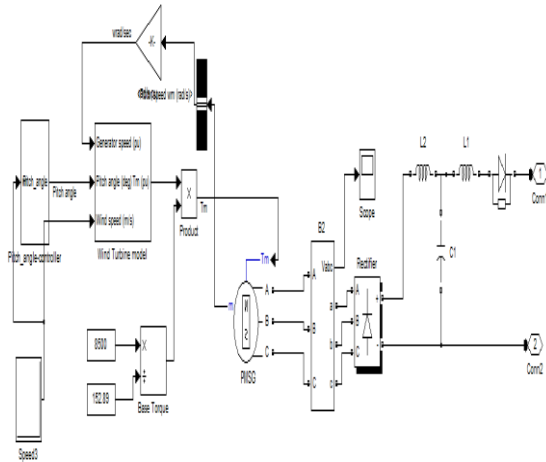

Fig.2. Wind conversion system

The wind energy system here consists of a Permanent Magnet Synchronous Generator (PMSG) that converts the rotational movement of the rotor of the wind turbine to the electrical output. The output of the wind turbine is controlled using a control block which consists of the Pitch angle, Wind speed and Generator speed [4]. This output which is an AC is converted into DC using a rectifier to combine it with the existing PV module output which is also DC [1], [2].

III. HYDRO ELECTRIC SYSTEM AND ITS OPERATION

This model comprises of a 3-phase synchronous machine associated with the Hydraulic turbine and Governor and Excitation systems.

The d-axis and the q-axis time constants are short circuited and open circuited respectively. The stator winding are connected in wye to an internal neutral point. The Hydraulic Turbine and Governor block implements a nonlinear hydraulic turbine model, a PID governor system, and a servomotor.
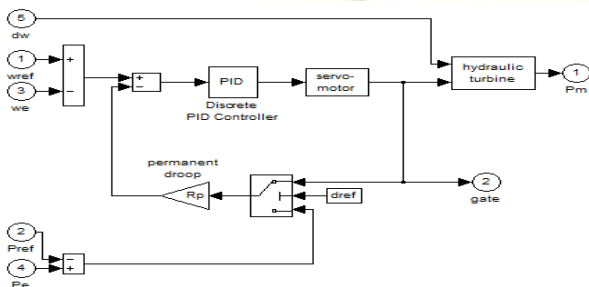

Fig. 3. Hydraulic Turbine Governor model.
W_{ref} = Reference speed, in pu
P_{ref} = Reference mechanical power in pu.

This input can be left unconnected if you want to use the gate position as input to the feedback loop instead of the power deviation.
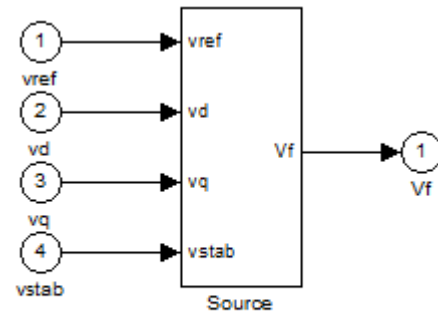
W_e = Machine actual speed, in pu.
P_{e0} = Machine actual electrical power in pu.

This input can be left unconnected if you want to use the gate position as input to the feedback loop instead of the power deviation.

D_w = Speed deviation, in pu.
P_m = Mechanical power Pm for the Synchronous Machine block, in pu.
Gate = Gate opening, in pu.

The simulink model of the Excitation system

Fig 4. Excitation system Model

V_{ref} = The desired value, in pu, of the stator terminal voltage.
V_d = v_d component, in pu, of the terminal voltage.
V_q = v_q component, in pu, of the terminal voltage.
V_{stab} = Connect this input to a power system stabilizer to provide additional stabilization of power system oscillations.
V_f = The field voltage, in pu, for the Synchronous Machine block.

IV.   INVERTER

The combined outputs of all the three sources i.e. Wind and PV and Hydro which is a DC are fed as input to an inverter or a pulse triggered thyristor [1]. This inverter then converts the DC into AC. The rectified AC is then given to loads.

V.   PROPOSED MODEL FOR BOTH PV, WIND and HYDRO

The model shows the proposed model for the combined operation of both PV and Wind modules along with the Hydro generating source. The Wind system, the PV system and the Hydro system are combined together and is fed to a DC/AC inverter. The then output which is AC is given to the load [7] [8].
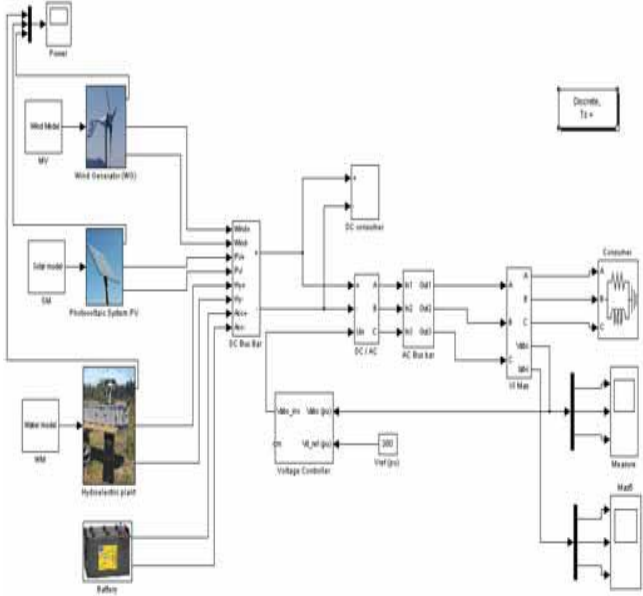
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Fig.5. Proposed model for PV, Wind and Hydro sytems

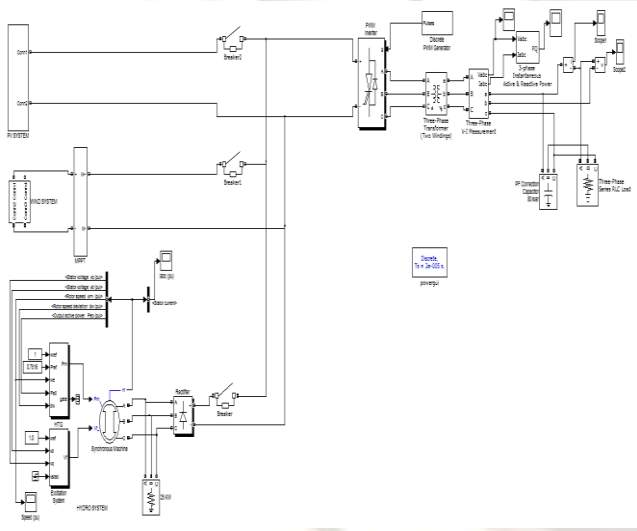## VI. SIMULINK MODEL OF THE PROPOSED SYSTEM

Fig.6. Simulink model for the proposed Hybrid system
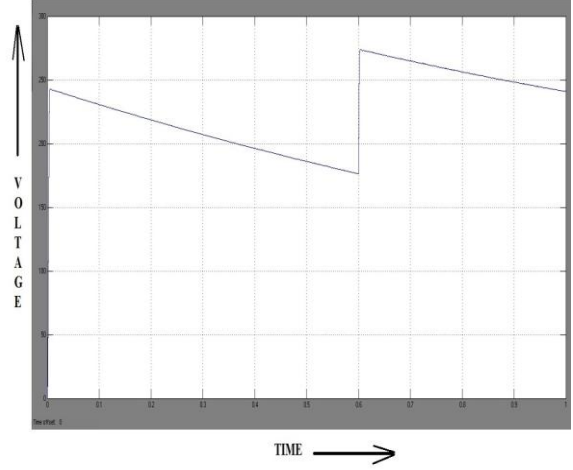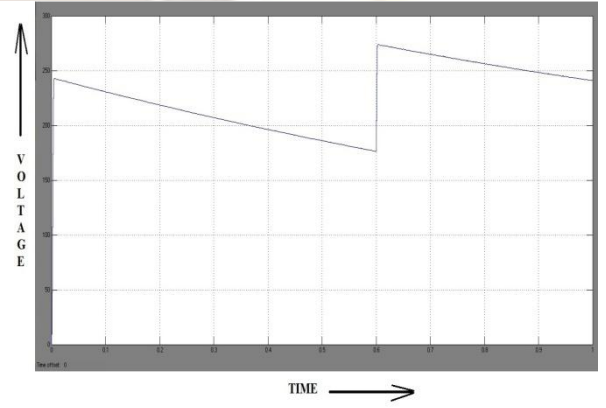### VII.   SIMULATION RESULTS

Fig.7. DC Output of PV Module.

Fig.8. DC Output of Wind Module.
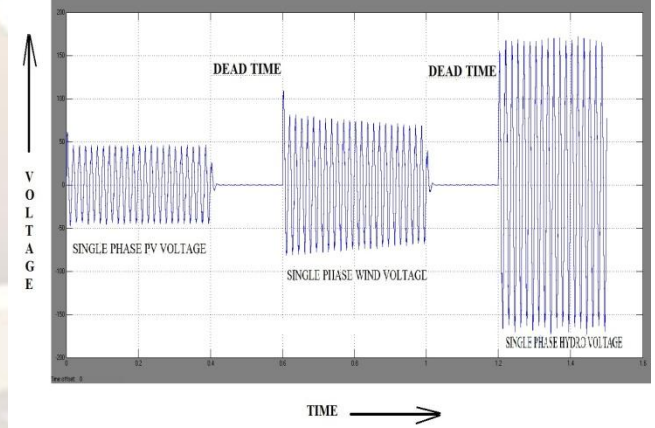

Fig.9. Single Phase Voltages of PV, Wind and Hydro Models

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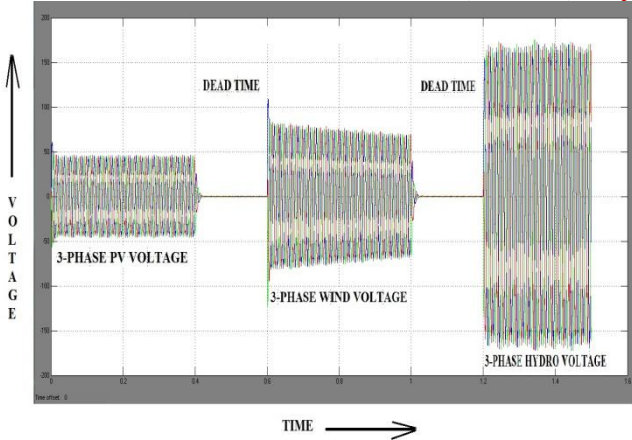Vol. 2, Issue 4, July-August 2012, pp.271-274**

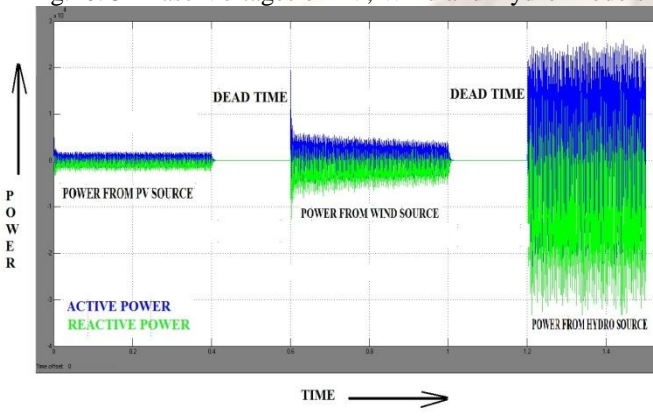Fig.10. 3-Phase Voltages of PV, Wind and Hydro Models

Fig.11. 3-Phase Output Power at Load

VIII.   ANALYSIS

The above figures are the obtained simulation outputs for PV, Wind and Hydro energy systems. The figures starting from fig to fig, there is a gap from time 0.4 to 0.6 and from which is called as the "Dead Time" or "No Operation Zone". This is created to know that PV energy source operates from 0 to 0.4 and Wind energy source operates from 0.6 to 0.8 and Hydro energy source from 1 to 1.4. The purpose of introducing Hydro generation is to compensate the loss of power at the load during power mismatch. This paper is limited to small amount of power generation for small application purposes. The generation can be increased further by increasing the number of PV cells in the case of PV module and the turbine performance of the wind module can be improved by replacing the existing model.

IX.   CONCLUSION

It has been observed that the combination of both PV and Wind modules can deliver sufficient power to the load as long as source for both exists. If there is an increase in load or failure of either of PV and Wind sources, Hydro can serve as the backup for providing continuous supply. The dead time can be compensated with the aid of Hydro Power generating source.

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