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Control of Hybrid renewable energy system connected to the grid using MATLAB/Simulink

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Abstract—As the rate of electrical energy demand is increasing due to the population growth and economic development, Hybrid renewable energy systems such as Solar and Wind sources are becoming popular in order to satisfy the demand. This paper defines control and simulation of energy systems under certain meteorological conditions such as wind speed and variable solar radiation in order to extract maximum energy from sources while maintaining power quality at a desired level. MAXIMUM POWER POINT TRACKING algorithm is used to capture maximum power. Incremental conductance method is applied for demonstrating the maximum power of Photovoltaic generator. Nickel Metal Hydrid battery is connected by bi-directional dc-dc converters which is used as back up source when these two renewable sources are not able to full fill the demand. A phase locked loop control applied between the inverter and grid side in order to ensure the synchronization. The inverter adjusts the DC link voltage at desired voltage reference with the help of this control strategy. The results show that the current and the voltage of grid side are alternative and sinusoidal forms, and the power fed to the grid is around the power obtained by the two renewable sources.

Index Terms—Solar system, wind system, storage system, MPPT, PLL control, Inverters, grid connected and DC link

1 INTRODUCTION

Many countries are looking forward to sustainable green energy solutions to preserve the resources for the future generations due to the increase and continuing threat of global warming to mankind and the depletion of existing fossil fuel reserves. Apart from hydro power and thermal power, renewable sources like wind energy and pv energy are being considered as the vital energy sources to meet the energy demands. Wind energy has the ability to supply enormous amounts of power. Similarly, solar energy is available throughout the day, but the solar irradiation levels vary, due to sun's intensity and unpredictable shadows caused by tall buildings, trees, clouds, birds, etc. The common drawback of wind and solar systems, are their seasonal which make them inconsistent. Hybrid renewable energy system utilizes two or more no of energy sources, usually wind power and PV array power. The main advantage of such hybrid system is that, when these two power sources are used together, the reliability is enhanced at load side. Often, there is presence of sun rays, while there is intense wind. However, by combining both wind and solar systems power transfer, efficiency and reliability can be improved significantly.

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When any of the sources is unavailable or insufficient in meeting the load demands, the other energy source can compliment the deficit. This paper proposes simulation study where MPPT algorithm is used to extract maximum power two renewable sources. Renewable energy systems connected DC link through boost converters. The battery storage is as back up source which is connected by bi-directional dc-dc converter. A proportional integral (*PI*) controller was utilized in [1] to control the DC bus voltage and grid current. Although such control scheme is basic, it requires tuning of several parameters to ensure an adequate response. In [2], bidirectional power flow was achieved through a pulse width modulated, multilevel converter producing a low distortion output current. The advantages of multilevel converter are: 1)It produces common mode voltage which reduces the stress of the motor and avoids the damage of the motor. 2) It can draw input current with minimum distortion.3) It can operate at both switching frequencies that are higher and lower frequency. Lower switching frequencies gives less loss at high efficiencies. 4) Reduced harmonic distortions.

Different types multilevel inverters are

a) 5-level Diode clamped multilevel inverter By xplqa30.ieee
b) 5-level flying capacitors multilevel inverters by orginars
c) 5-H bridge multilevel inverter by power.aecss.

In this work , diode clamped multilevel inverter [3] is used which gives lower distortions in current and voltage output waveforms.

2 MODELLING OF HYBRID SYSTEM

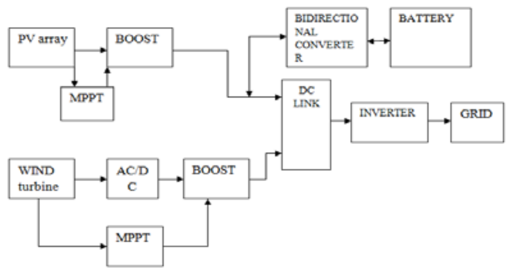

Fig 2: Block diagram of Hybrid system

A. PHOTOVOLTAIC SYSTEM:

In order to generate required voltage and current PV array is composed of various modules connected in series-parallel combination. In this work, the proposed PV model is based on the static behaviour of a conventional PN junction diode, and the equivalent circuit of a PV cell is shown in Figure 2. This model consists of a direct current generator Iph in parallel with a diode and shunt resistor Rsh and series resistor Rs [4], $V_{pv}$is the panel voltage.

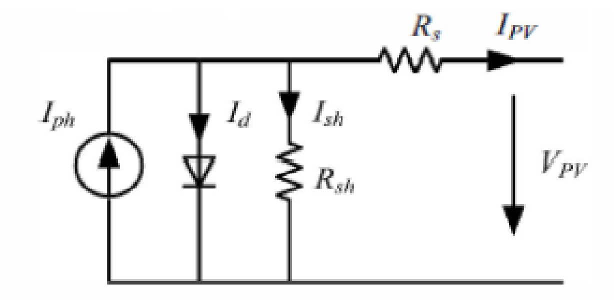

Fig 2: PV panel circuit diagram

The output voltage can be expressed as:

$V_{PV} = V_d - I_{pv} R_s$ (1)

The output current can be expressed as:

$I_{PV} = I_{ph} - I_d - I_{sh}$ (2)

Where I_{PV} is the panel current, $I_{ph}$is the photocurrent propotional to sunlight propotional to the sunlight intensity, I_d is the diode current and $I_{sh}$is the pv cells leakage current.

$I_d = I_{sat}\{\exp[q(V_{PV} + I_{PV}R_s)/AkT]-1\}$ (3)

Where $I_{sat}$is the reverse saturation current of the diode, q is the electronic charge, k is the Boltzman constant, T is the absolute temperature (K) and A is the ideality factor of PN junction.

$I_{sh} = (v_{pv} + I_{PV})/R_{sh}$ (4)

Then, (2) can be written as

$I_{PV} = I_{ph} - I_{sat}\{\exp[q(V_{PV} + I_{PV}R_s)/AkT]-1\} - (v_{pv} + I_{PV})/R_{sh}$ (5)

$I_d = I_{sat}[\exp(V_d/V_T) - 1$ (6)

VT = K xT / q xAxNcellxNser(7)

Which: Vd is the diode voltage (V), Isat is the current of saturation of diode (A), VT is thermique voltage (V), Ncell is number of cellule connected in series by module, Nser is number of module connected in series by string.

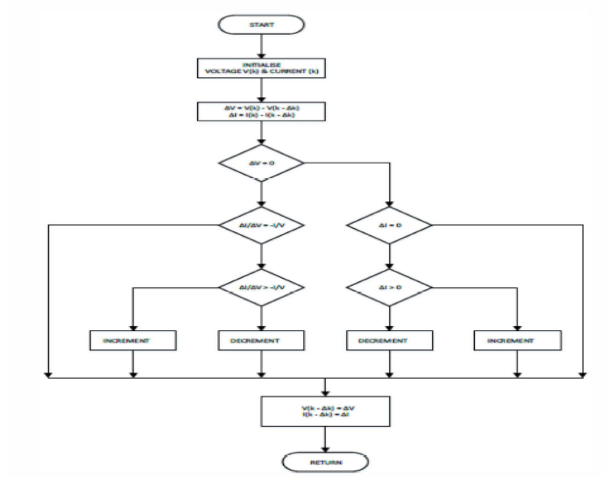

Fig 3: Flow chart for conductance method applied to PV

The power generation is equal to P = VI, at the maximum power point, dP/dV may be determined using the following equation

$$\Delta V/\Delta P = 0(\Delta I/\Delta P = 0) \quad (8)$$

$$\Delta V/\Delta P > 0(\Delta I/\Delta P < 0) \quad (9)$$

$$\Delta V/\Delta P < 0(\Delta I/\Delta P > 0) \quad (10)$$

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \cong I + V\frac{\Delta I}{\Delta V} \quad (11)$$

Equations (8), (9), (10) can be expressed:

$$\frac{\Delta I}{\Delta V} = \frac{-I}{V}, \text{ at MPP} \quad (12)$$

$$\frac{\Delta I}{\Delta V} > \frac{-I}{V}, \text{ on the left} \quad (13)$$

$$\frac{\Delta I}{\Delta V} < \frac{-I}{V}, \text{ on the right} \quad (14)$$

These are equations for MPPT

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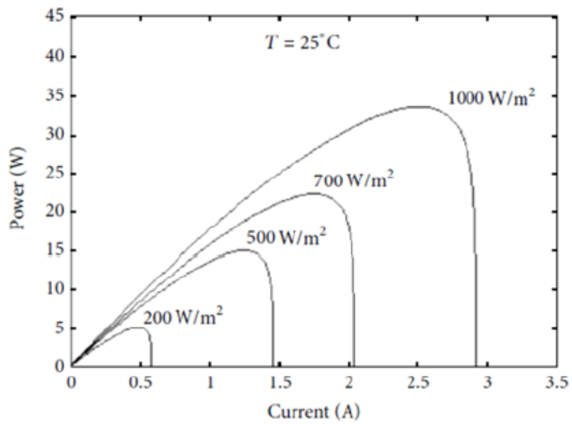


Fig 4: Output characteristics of PV panel

B. WIND GENERATION MODELLING

The wind turbine system is equipped with a variable speed generator. An appropriate fit is required between the torque and speed characteristics of the turbine and electric generator [14].The output power of the wind turbine is given by the following equation

$$P_t = 0.5\rho A C_p(\lambda,\beta)\times(v_w)^3 = 0.5\rho A C_p \times \left(\frac{\omega_m R}{\lambda}\right)^3 \qquad (15)$$

Where C P is the turbine rotor power coefficient, A is the tip-speed ratio and P is the pitch angle (degrees), p is the air density (kg/m3), A is the blades swept area (m2), Vw is the wind speed (m/s), wm is rotational speed of turbine rotor (rad/s), and R is radius of the turbine (m).

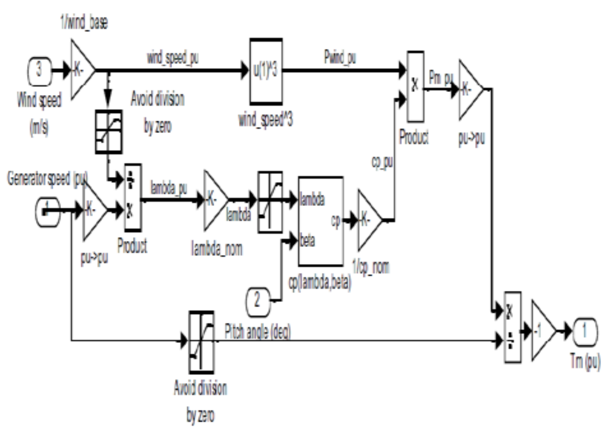
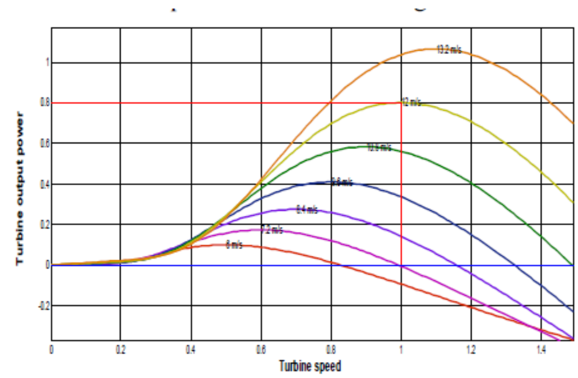


Fig 5: Simulation model of wind turbine



.Fig 6: Output characteristics of wind turbine

C. DC- DC BOOST CONVERTERS:

DC-DC boost converter is a most efficient topology which ensures good efficiency along with low cost. A DC-DC boost converter is connected in series with the PV model and in series with rectifier used for the Wind turbine. The model consists of an input voltage which is output voltage of PV source is connected in series with inductor (L), switch, diode (D), Capacitor (C), and Resistor (R_0)

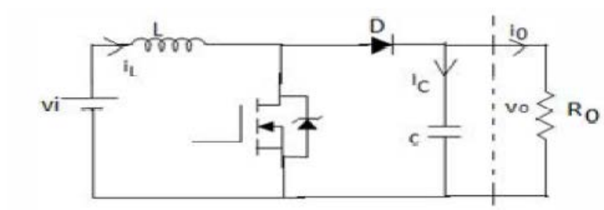


Fig 7: Circuit diagram of dc-dc boost converter

The model of the boost converter is required to simulate and analyze the behaviour. The relation between input and output voltage of the boost converter under an ideal condition can be related as

$V_i = V_0 * (1-D)$ (16)

V_i is the input voltage, Vo is the output voltage and D is duty cycle.

$L_{min} = (1-D)\, DR_0/2f$ (17)

$C_{min} = DV_0/V_rR_0f$ (18)

Where, Vr is the ripple voltage, Ro is the output resistance and f is the switching frequency.

Here capacitor is used to reduce the repulsive voltage across the load. The pulses are given to switch through MPPT analysis.

D. STORAGE SYSTEM

The simplest electric model consists of an ideal voltage source E_0 in series with an internal resistance R_b. In this proposed system, a generic battery model suitable for dynamic simulation is considered. This model assumes that the battery is combination of a controlled-voltage source and a series resistance, as shown in Fig.6. This generic battery model considers the SOC as the only state variable [6].

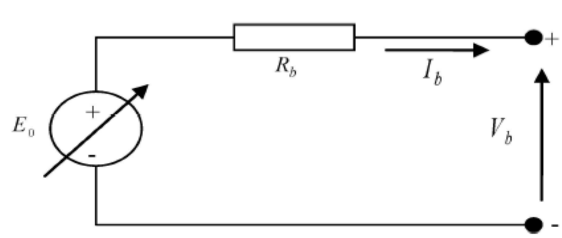


Fig 8: Circuit diagram for battery

The controlled voltage source is given by the following expression [16]:

$$E = E_0 - \frac{V_p Q_b}{Q_b - \int i_b dt} + \tilde{A} \exp\left(-B_t \int i_b dt\right)$$

E. MULTI-LEVEL INVERTER

Some medium voltage motor drives and utility applications require medium voltage. The multi level inverter has been introduced as alternative in high power and medium voltage situations. The Multi level inverter is like an inverter and it is used for industrial applications as alternative in high power and medium voltage situations.

Diode Clamped Multilevel Inverter:

The main concept of this inverter is to use diodes and provides the multiple voltage levels through the different phases to the capacitor banks which are in series. A diode transfers a limited amount of voltage, thereby reducing the stress on other electrical devices. The maximum output voltage is half of the input DC voltage. It is the main drawback of the diode clamped multilevel inverter. This problem can be solved by increasing the switches, diodes, capacitors. Due to the capacitor balancing issues, these are limited to the three levels. This type of inverters provides the high efficiency because the fundamental frequency used for all the switching devices and it is a simple method of the back to back power transfer systems.

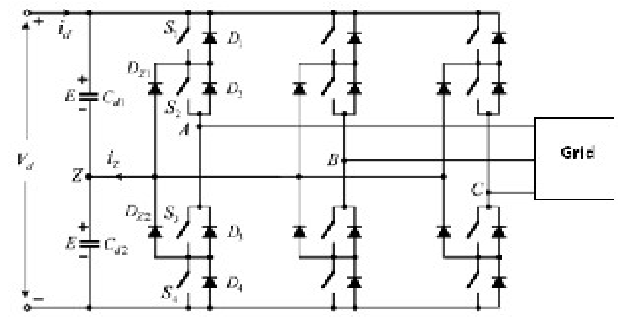
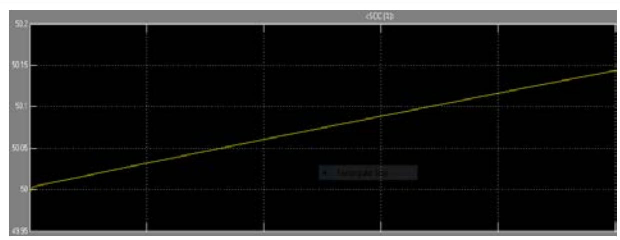


Fig 9: Circuit diagram for multilevel inverter

3. SIMULATION RESULTS

1. BATTERY CHARGING CHARACTERISTICS



. fig 10: Battery discharging characteristics

2. DC LINK VOLTAGE

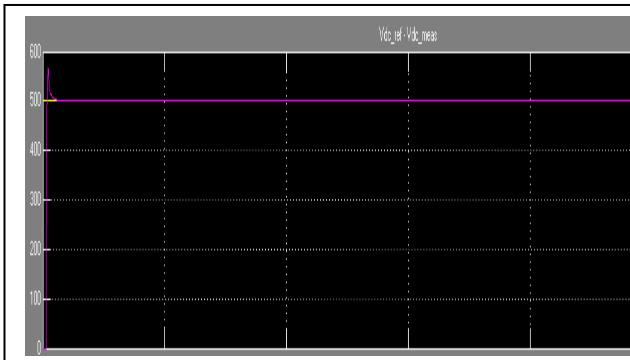


fig 11: DC link voltage which maintains constant voltage

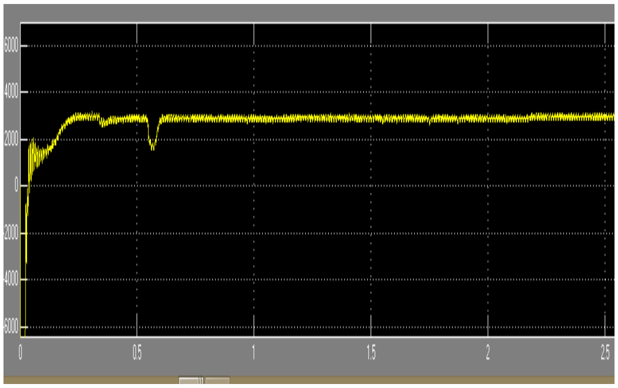


fig 12: power flow at the grid

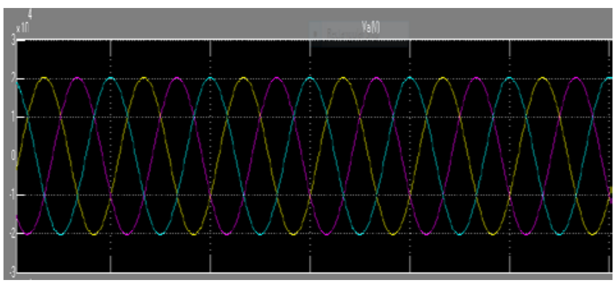


fig 13: Sinusoidal waveforms of the voltage at the grid side

4. CONCLUSION

The simulation results obtained shows that the voltage wave forms across the grid side are sinusoidal and alternative forms. From the voltage source control the synchronization is achieved between the inverter and the grid side. The power fed to the grid is around the power produced by the two renewable sources. Storage system helps to maintain balance between sources and the load. The proposed system with the control algorithms can efficiently increase the system stability.

5. REFERENCES

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