Hybrid Renewable Energy System for Agriculture Irrigation

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Abstract: *Hybrid (Solar & Wind) renewable power system can be used to preserve the non-renewable fossil fuels. The Photovoltaic-wind hybrid system profits the lowest unit cost values to sustain the same level of Deficiency of Power Supply Probability as compared to standalone solar and wind systems. For all load demands, the optimal energy cost for Photovoltaic-wind hybrid system is always lower than that of standalone solar PV or wind system. The Photovoltaic-wind hybrid system is best techno-economically practicable& achievable for agriculture irrigation system. This paper represents the hybrid energy system using solar and wind energy resources & multilevel converter for the control of agriculture irrigation system. The multilevel inverters are applied in high voltage PV power plant mainly due to the high voltage capability, low switching frequency, and low power losses. The power system is connected to a water pump to work as the agriculture irrigation system. The objective of this paper is to presents a simulation; modelling and analysing of a seven-level inverter operate on photovoltaic and wind power for agriculture irrigation system. Solar-wind hybrid renewable energy system for agriculture irrigation system control is an intelligent, small scale, and off grid lighting system. The advantage of this idea is to avoid daily running cost and make the system more independent.*
Keywords: model, solar, wind, hybrid, energy, photovoltaic.

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I.   Introduction

In recent years, there has been an increasing interest in electrical power generation from renewable energy sources not only because they are naturally available, pollution free and inexhaustible but also as day by day the power crisis increases in our country, the government also attracting the peoples to use renewable energy by giving 50% subsidy. Now we are in the exact time to elevate from conventional power generating system. Energy is a basic need for the progress of all country and it must be preserved in a most efficient way. Not only the technologies should be developed to produce electrical energy in a most nature-friendly manner from all varieties of renewable & non-renewable fuels but also ample importance should be given to preserve the energy resources in the most efficient way. Energy is the crucial factor responsible for both manufacturing and farming development. The use of renewable energy sources to meet the energy demands has been progressively increasing from the past few decades. However, the main disadvantages associated with renewable energy systems are their inability to assurance reliability and their lean nature. Import of petroleum products creates a major drain on our foreign exchange reserve. Renewable energy resources are considered to be the better option to meet these current challenges.

At present, standalone solar photovoltaic and wind systems have been promoted around the globe on a comparatively larger scale. These separate systems can't provide continuous source of energy, as they are seasonal. For example, standalone solar photovoltaic energy system cannot provide reliable power during non-sunny days. The standalone wind system cannot satisfy constant load demands due to significant fluctuations in the magnitude of wind speeds from hour to hour throughout the year. Therefore, energy storage systems will be required for each of these systems in order to satisfy the power demands. Usually storage system is expensive and the size has to be reduced to a minimum possible for the renewable energy system to be cost effective. Hybrid power systems can be used to reduce energy storage requirements cost.

Like several other developing countries, India is characterized as severe energy deficit. In most of the urban & rural locations, there are number of problems such as low load factor, poor voltage regulation, poor voltage supply and poor frequency supply, frequent power supply interruptions. The above energy deficiency problems can be substantially reduced with this small effort and hence concentrated efforts are continually provided in implementing hybrid solar-wind renewable energy systems at sites that have a large

potential of solar & wind both. The hybrid renewable energy lighting systems are self-sustaining, standalone solutions and also it reduces the transmission and distribution losses. This proposed system is supreme solutions for not only agriculture irrigation but for many applications in rural and urban areas.

The main objective of the paper is to implement a power system that is a hybrid of both Photovoltaic and wind powers. The step by step objectives are to study and model PV cell, PV array and PV panels, effect of variation of environmental-conditions like temperature and irradiation on them, To trace the maximum power point of operation the PV panel irrespective of the changes in the environmental conditions and to simulate and Implement hybrid system and track its maximum power point.

II. Literature Survey of Hybrid Renewable Energy System

Due to high demand of energy and limited availability of conventional energy, nonconventional sources become more popular among researchers. A lot of research work is going on to enhance the power efficiency of non-conventional sources and make it more reliable and beneficial. Hybrid generation system uses more than one source, so that we can extract energy from different sources at the same time which enhances the efficiency. From [2],[3] the working of PV /Wind hybrid system is understood, different topologies that can be used for the hybridization of more than one system and also about advantages and disadvantages of hybrid system. From [1], [4] and [5] basic details of PV cell, PV module, PV array and their modelling are studied. Also, the behaviour of PV modules at varying environmental conditions like solar irradiation and temperature are studied. Behaviour of PV module during partial shading condition and also how it's bad effects can be minimized is explained in [6]-[8]. Different MPPT techniques, their advantages and disadvantages and why MPPT control is required is explained in [9]-[11].The wind energy system, its working and also techniques to extracts the maximum power from the wind energy system is understood from [13]-[17]. From [18]-[20] study about different type of bi-directional converters, their working and how to use them in battery charging and discharging is carried out.

III. Theoretical study of hybrid energy system

Hybrid energy system is the grouping of two renewable energy sources for providing energy to the agriculture irrigation i.e "Energy system which is invented or designed to extract energy by using two energy sources is called as the hybrid energy system." Hybrid energy system has good consistency, efficiency, no emission, and lower cost. In this proposed system, both the energy sources have greater ease of use in all areas particularly in India. It necessities lower cost & no need to find special location to install this system.

A. *Solar Energy*

Solar energy is the energy which is obtained by the radiation of the sun. Solar energy is present on the earth endlessly and in ample manner, freely available. It doesn't produce any pollution. It is inexpensive in cost. It has low maintenance cost. Only problem with solar system it can't produce energy in bad climate condition but it has superior efficiency than other energy sources. It only need initial asset. It has long life span and has lower emission.

B. *Wind Energy*

Wind energy is the energy which is obtained from wind for that we use wind mill. The wind energy essentials require less cost for electricity generation. Initial and maintenance cost is also lesser. Wind energy is present almost 24 hours of the day. Electricity generation from wind is depending upon the speed of wind flow. The major drawback of using standalone renewable energy system is that unavailability of power for all time. For overcoming this, we practice solar and wind system together. So that any one power source fails other will take care of the system power generation. In this proposed system we can use both sources combine. Additional way is that we can use any one system either solar or wind and keep another system as a stand by unit. This will provides stability of energy system and make system more reliable. The main drawbacks of this system are that it needs high initial cost except that it is highly reliable, has less emission, less maintenance cost, more Life span and superior efficiency. A main advantage of this system is that it gives continuous power supply.

Major System Components for hybrid energy system

The functional and operational requirements will determine which components the system will include. It may include major components as; DC-AC power inverter, battery bank, system and battery controller, auxiliary energy sources and sometimes the specified electrical loads

i.   PV Modules: - Convert sunlight instantly into DC electric power.
ii. Wind turbine: - extracts energy from wind by rotation of the blades of the wind turbine. Basically wind turbine has two types one is vertical and another is horizontal. As the wind speed increases power

generation is also increases. The power generated from wind is not continuous its fluctuating. For obtain the non-fluctuating power we have to store in battery and then provide it to the load.

iii. Inverter: - Converts DC power into standard AC power for use in the home, synchronizing with utility power whenever the electrical grid is distributing electricity.

iv. Battery Bank: - Stores energy when there is an excess coming in and distribute it back out when there is a demand. A solar PV panel continues to re-charge batteries each day to maintain battery charge.

v. Charge Controller - Prevents battery overcharging and prolongs the battery life of your PV system. In addition, an assortment of balance of system hardware; wiring, overcurrent, surge protection and disconnect devices, and other power processing equipment.

vi. System Sizing: - The size of the PV system that will meet your expectations depends on your individual needs, site location and climate.

vii. PV System Maintenance: - PV systems require very little maintenance. Having no moving parts makes them practically maintenance-free. Hose down the (cool) modules occasionally.
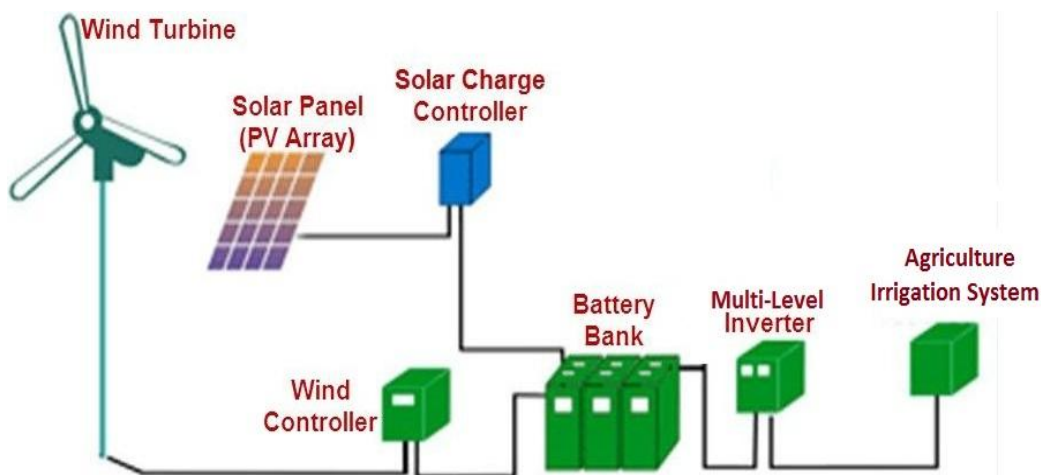

Figure 1 Hybrid Solar-wind Energy system for agriculture irrigation system
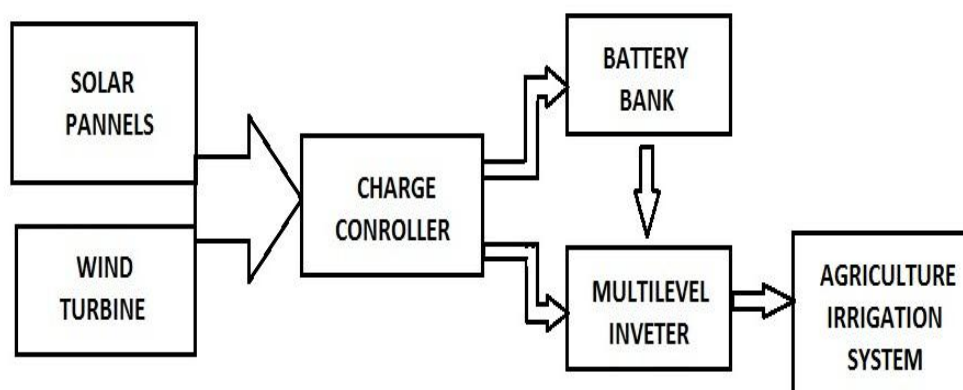
IV. Proposed Methodology

Figure 2 Proposed Block diagram for Hybrid Solar-wind Energy system for agriculture irrigation system

The total power generated by this system may be given as the addition of the power generated by the solar PV panel and power generated by the wind turbine.
Mathematically it can be represented as, **Pt =Nw*Pw+Ns*Ps**

                Where,

                        Pt is the total power generated
                        Pw is the power generated by wind turbines
                        Ps is the power generated by solar panels
                        Nw is the no of wind turbine
                        Ns is the no of solar panels used

A. Calculations for wind energy

Both induction and synchronous generator can be used for wind turbine systems. Variable speed direct driven multi pole permanent magnet synchronous generator (PMSG) is also extensively used in wind power system because of it higher efficiency, low weight, less maintenance, easier controllability and no need for reactive and magnetizing current. The presence of gearbox in variable speed wind turbine generates extra burden of cost and maintenance. Using direct driven PMSG not only increases reliability but also decreases weight in nacelle. The model of PMSG is done based on d-q synchronous reference frame. PMSG voltage equation is given by

$$V_d = -R_s i_d - L_d \frac{di_q}{dt} + \omega L_q i_q \quad \text{.. (1)}$$

$$V_q = -R_s i_q - L_q \frac{di_q}{dt} - \omega L_d i_d + \omega \lambda_m \quad \text{.................................... (2)}$$

The electronic torque is given by

$$T_e = 1.5\rho \left[\lambda i_d + \left(L_d - L_q \right) i_q i_d \right] \quad \text{... (3)}$$

Where Lq is q axis inductance, Ld is d axis inductance, iq is q axis current, id is d axis current, Vqis q axis voltage, Vdis d axis voltage, ωr is angular velocity of rotor, λ is amplitude of flux induced, and p is number of pairs of poles. In case of squirrel cage induction generator (SCIG) following equation in stationary d-q frame of reference can be used for dynamic modelling equation.

$$\begin{bmatrix} V_{qs} \\ V_{ds} \\ V_{qr} \\ V_{dr} \end{bmatrix} \begin{bmatrix} R_s + pL_s & 0 & pL_m & 0 \\ 0 & R_s + pL_s & 0 & pL_m \\ pL_m & -\omega_r L_m & R_r + pL_r & -\omega_r L_r \\ \omega_r L_m & pL_m & \omega_r L_r & R_r + pL_r \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix} \quad \text{................................ (4)}$$

From stator side the equations are

$$\lambda_{ds} = L_s i_{ds} + L_m i_{dr} \quad \text{... (5)}$$

$$\lambda_{qs} = L_s i_{qs} + L_m i_{qr} \quad \text{... (6)}$$

$$L_s = L_{is} + L_m \quad \text{...(7)}$$

$$L_r = L_{lr} + L_m \quad \text{... (8)}$$

$$V_{ds} = R_s i_{ds} + \frac{d}{dt}\lambda_{ds} \quad \text{.. (9)}$$

$$V_{qs} = R_s i_{qs} + \frac{d}{dt}\lambda_{qs} \quad \text{...(10)}$$

From rotor side the equations are

$$\lambda_{dr} = L_r i_{dr} + L_m i_{ds} \quad \text{.. (11)}$$

$$\lambda_{qr} = L_r i_{qr} + L_m i_{qs} \quad \text{... (12)}$$

$$V_{dr} = R_r i_{dr} + \frac{d}{dt}\lambda_{dr} + \omega_r \lambda_{qr} \quad \text{.......................... (13)}$$

$$V_{qr} = R_r i_{qr} + \frac{d}{dt}\lambda_{qr} - \omega_r \lambda_{dr} \quad \text{.......................... (14)}$$

For the air gap flux linkage the equations are

$$\lambda_{dm} = L_m(i_{ds} + i_{dr}) \quad \text{..(15)}$$

$$\lambda_{qr} = L_m(i_{qr} + i_{qs}) \quad \text{... (16)}$$

Where Rs, Rr, Lm, Lls, Llr, ωr, id, iq, Vd, Vq, λd and λq are the stator winding resistance, motor winding resistance, magnetizing inductance, stator leakage inductance, rotor leakage inductance, electrical rotor angular speed, current, voltage, and fluxes respectively of the d-q model respectively. The output power and torque of turbine (Tt) in terms of rotational speed can be obtained by substituting equation.

$$P_w = \frac{1}{2}\rho A C_p(\lambda, \beta) \left(\frac{R\omega_{opt}}{\lambda_{opt}} \right)^3 \quad \text{.. (17)}$$

$$T_t = \frac{1}{2}\rho A C_p(\lambda, \beta) \left(\frac{R}{\lambda_{opt}} \right)^3 \omega_{opt} \quad \text{.. (18)}$$

The power coefficient (Cp) is a nonlinear function expressed by the fitting equation in form

$$C_p(\lambda, \beta) = C_1 \left(C_2 \frac{1}{\lambda_i} - C_3\beta - C_4 \right) e^{-C_5 \frac{1}{\lambda_i}} + C_6\lambda \quad \text{............................... (19)}$$

With,

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad \text{.. (20)}$$

B. Calculations for solar energy

PV cells are grouped in larger units called PV modules, which are further interconnected in a series-parallel configuration to form PV arrays. The following are the basic equations from the theory of semiconductor sand photovoltaic that mathematically describe the I-V characteristic of the photovoltaic cell and module .So, according to the law of Kirchhoff to the nodes A and B, we have:
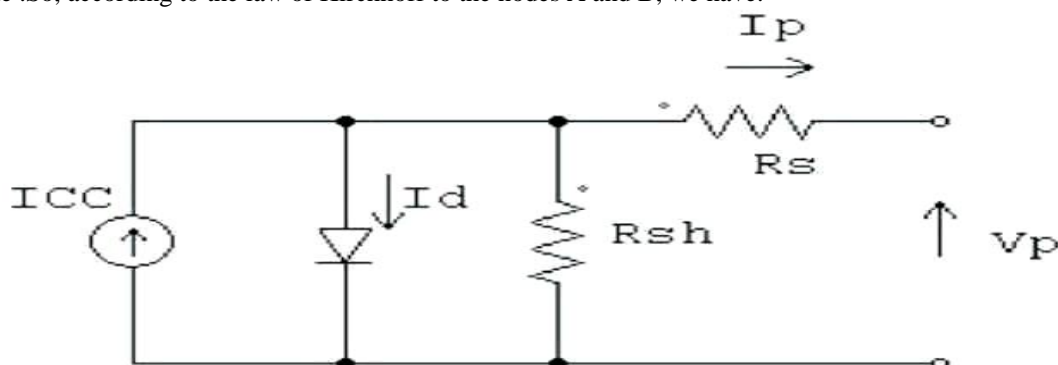

Figure 3 Circuit diagram of PV solar system

As shown figure 5.1.1 output current of solar panel

$$I = I_{PH} - I_D - I_p \quad \text{...(21)}$$

Where ,

I: is the light-generated current at the nominal condition (25°C and 1000W/m2), it is linearly dependent on the solar radiation and is also influenced by temperature according to the following equation.

$$I_{PH} = [I_{scr} + K_i(T_k - T_{ref})] \times \frac{G}{1000} \quad \text{.. (22)}$$

Where ,

Ki: is the short-circuit current/ temperature coefficient of cell.
Tk and Tref: are the working temperature of cell and reference temperature respectively in °K.
G: is the solar radiation on the cell surface (W/m2).
Ip: Current through Rp.
Id: Diode Current, it is given by:

$$I_D = I_0 \left[\exp \left(\frac{qV_D}{AKT} \right) - 1 \right] \quad \text{.. (23)}$$

Also the diode voltage is given as ,

$$V_D = V + R_s I \quad \text{.. (24)}$$

Where,

q: is the electron charge constant (1.6.10-19C),
K: Boltzmann's constant (1.38.10-23J/K),
T: Cell temperature (°K).
Io: is the saturation current of the diode and it is given by:

$$I_0 = I_{rs} \left[\frac{T_k}{T_{ref}} \right]^2 \exp \left[\frac{qE_{go}}{AK} \times \left(\frac{1}{T_k} - \frac{1}{T_{ref}} \right) \right] \quad \text{.................................. (25)}$$

Irs: is the reverse saturation current and it is given by:

$$I_{rs} = \left[\frac{I_{scr}}{\exp \left(\frac{qV_{oc}}{N_s KAT} \right) - 1} \right] \quad \text{.. (26)}$$

Where,

A is the ideality factor of the cell depends on recombination mechanisms in the space charge zone.
Ego: is the band gap energy of the semiconductor (Ego ≈ 1.1 eV for the polycrystalline Si at 25°C).
The voltage, current (V-I) characteristic equation of PV/solar cell is given by-

$$I = N_P I_{PH} - N_P I_0 \left[\exp \left(\frac{qV_D}{N_s KAT} \right) - 1 \right] - \frac{V + R_s I}{R_p} \quad \text{.. (27)}$$

Where,

Np and Ns are, respectively, the number of parallel and series connections of cells in the given photovoltaic Module (Np = 1 and Ns = 60).In the ideal case, Rs tends towards 0 and Rp to infinity. And in the real case, these resistors provide an assessment of the imperfections of the diode; considering that the resistance Rs has a low value, the slopes of the I-V characteristics are calculated at I=0 open circuit and short circuit V=0 and respectively give the inverse of series and shunt resistance values.

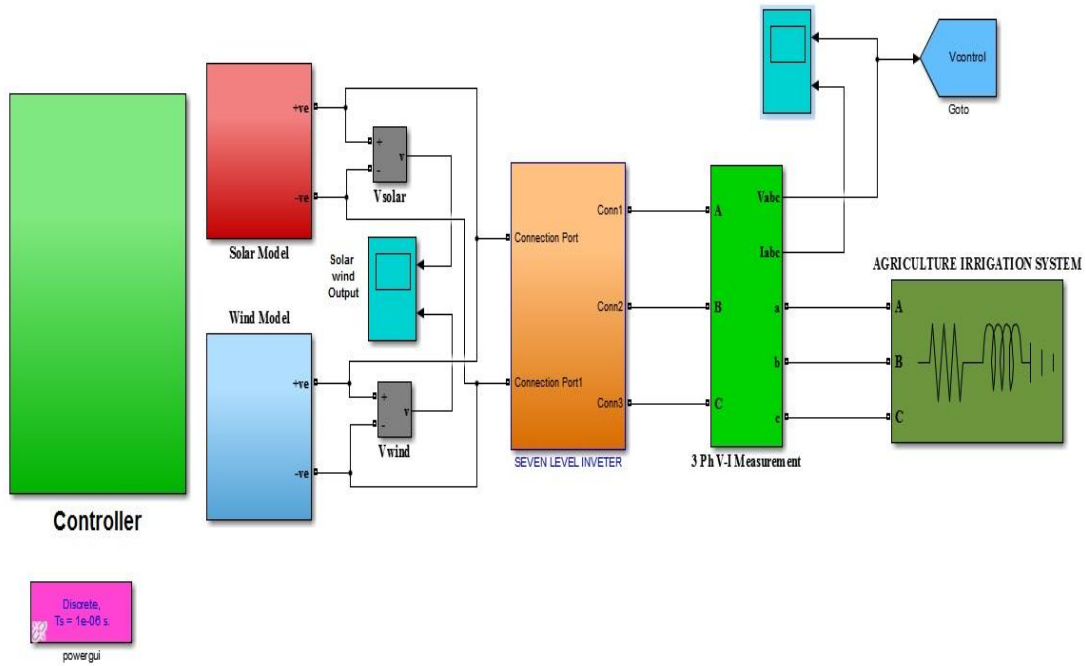## V. Simulation Performance of Proposed System

Figure 4 Circuit diagram of PV solar system

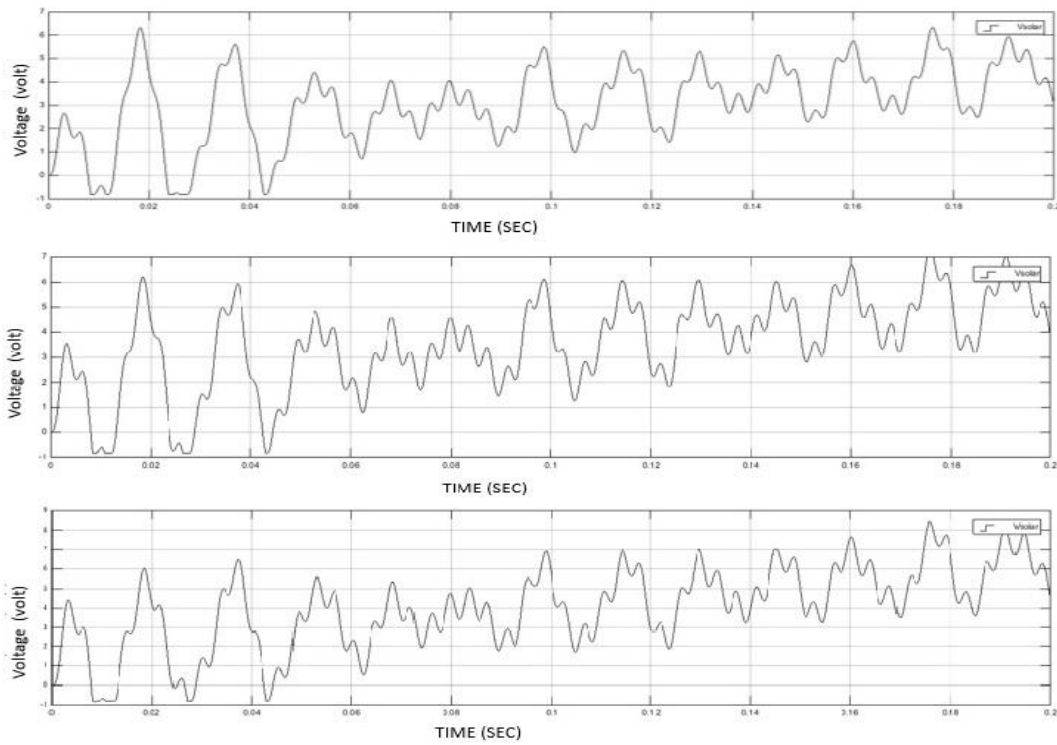### A. Simulation performance for PV System

Figure 5 PV solar system output Voltage for 600, 800, 1000 constant values respectively
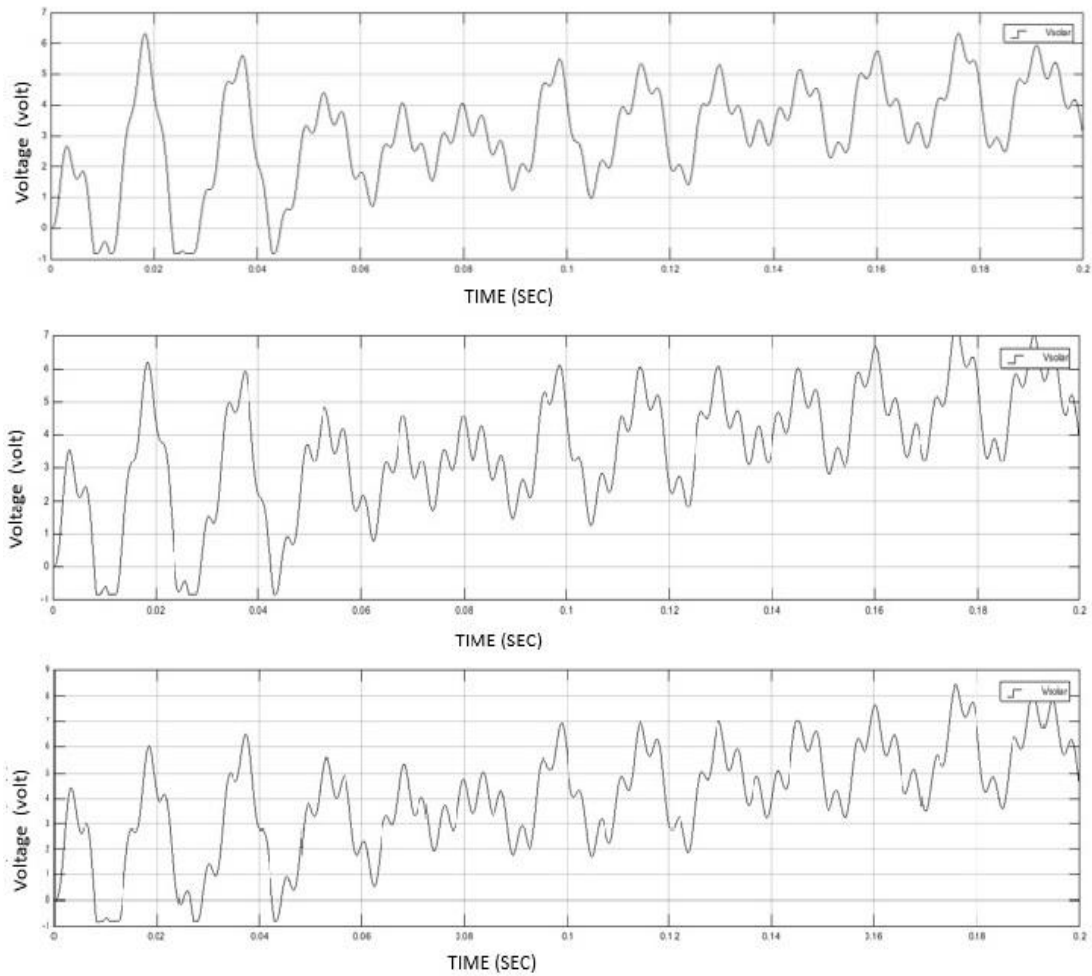
B. Simulation performance for wind system

Figure 6 Wind system output Voltage for wind speed of 12 m/s , 15 m/s, 18m/s respectively

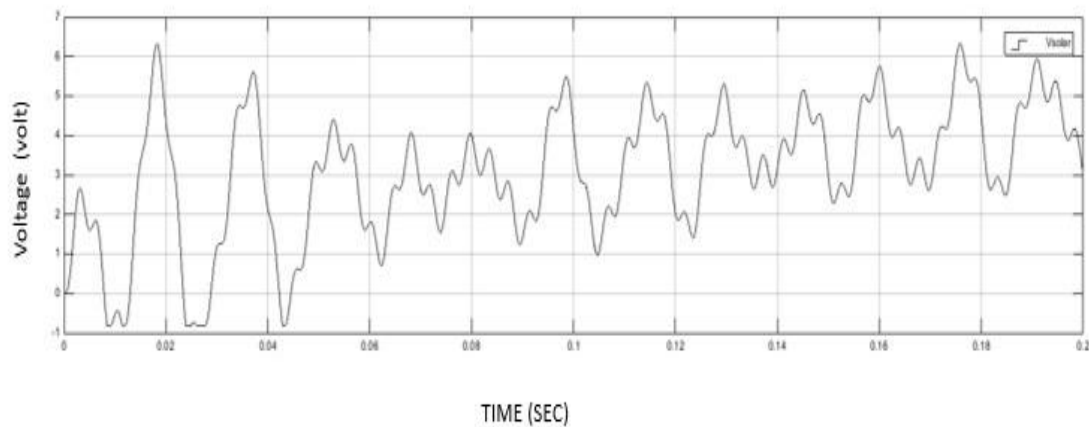**C. Simulation performance of Hybrid Solar-Wind Model**

Figure 7 Hybrid Solar-Wind Model output Voltage for PV constant 600 and wind speed 12m/s

D. Simulation performance of Multilevel Inverter Model
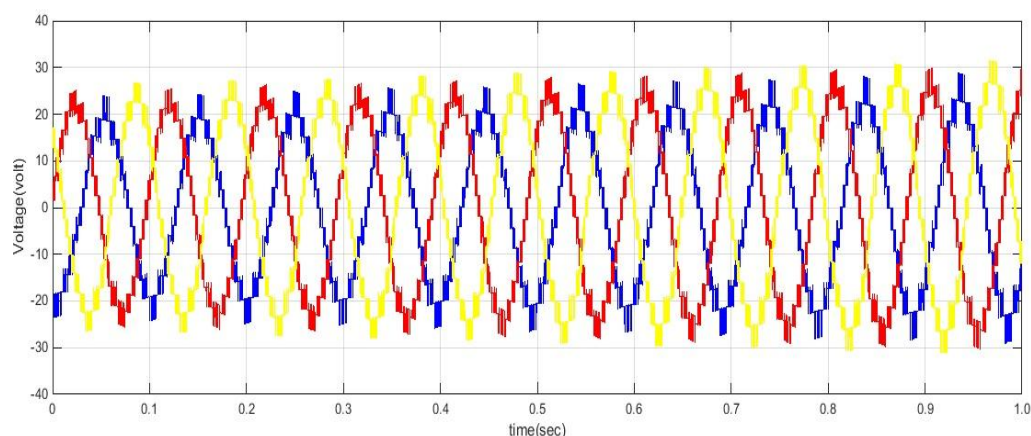

Figure 8 Multilevel Inverter output Voltage

VI. Conclusion

Solar-Wind Hybrid Systems is the best feasible economic solutions for lowering electricity bills; also they help in avoiding the high costs of extending utility power lines to remote locations, prevent power interruptions, and provide a non-polluting source of electricity. There is a definite need for optimizing the cost of the hybrid systems based on the various operating and design parameters. In this paper, cost optimization is exercised to minimize the cost of Wind-Solar hybrid system for the given requirement of drip irrigation pumping. The major advantage of wind – solar hybrid energy system is that when used together, the reliability of the system is enhanced. Additionally, the size of battery storage can be reduced. Considering the current industry costs of various subsystem components in order to meet the energy requirement. Remote communities which cannot be reached by electricity grids, except at prohibitive costs, or which do not have easy access to conventional commercial fuels, can easily adopt these hybrid systems for irrigation. This project will there by promote the use of hybrid renewable energy system as a power source for drip irrigation.

References

[1]. T. Salmi, M. Bouzguenda, A. Gagtli, "MATLAB/Simulink based modeling of solar photovoltaic cell," International journal of renewable energy research, vol.2, no.2, 2012.
[2]. S. Meenakshi, K.Rajambal, S. Elangovan "Intelligent controller for stand-alone hybrid generation system," IEEE, May. 2006.
[3]. Nabil A. Ahmed, Masafumi Miyatake, "A stand-alone hybrid generation system combining solar photovoltaic and wind turbine with simple maximum power point tracking control," IPEMC 2006, IEEE, 2006.
[4]. M. G. Villalva, J. R. Gazoli, "Modeling and circuit based simulation of photovoltaic arrays," Brazilian power electronics conference (COBEP), 2009.
[5]. Marcelo Gradella Villalva, Jonas Rafel Gazoli, "Comprehensive approach to modeling and simulation of photovoltaic arrays," IEEE transaction on power electronics, vol.24, no.5, May 2009.
[6]. Hiren Patel and Vivek Agarwal, "Matlab based modeling to study the effect of partial shading on PV array characteristics," IEEE transaction on energy conversion, vol.23, no.1, March 2008.
[7]. Mohammed Abdulazeez, Ires Iskender, "Simulation and experimental study of shading effect on series and parallel connected PV modules," IEEE transaction on energy conversion, vol.27, no.2, March 2008.
[8]. SiyuGuo, Timothly Michael Walsh, "Analyzing partial shading of PV module by circuit modeling," IEEE 2011.
[9]. Zhou Xuesong, Song Daichun, Ma Youjie, Chen Deshu, "The simulation and design for MPPT of PV system based on Incremental conductance method," Wase International conference on information engineering, 2010.
[10]. Azadeh Safari, Saad Mekhilef, "Simulation and Hardware Implementation of Incremental Conductance MPPT with Direct Control Method Using Cuk Converter," IEEE transaction on industrial electronics, vol. 58, no. 4, april 2011.
[11]. Mihnea Rosu-Hamzescu, Sergiu Oprea, "Practical guide to implementing Solar panel MPPT algorithm," Microchip technology Inc, 2013. 58
[12]. M. Gengaraj, J. Jasper Gnanachandran, "Modeling of a standalone photovoltaic system with charge controller for battery energy storage system," International Journal of Electrical Engineering, vol.6, no. 3, 2013.
[13]. T. Taftichat, K. Agbossou, "Output power maximization of a permanent magnet synchronous generator based stand-alone wind turbine system," IEEE ISIE July 9-6 2006.
[14]. Roger Gules, Juliano De pellegrin Pacheco, "Maximum power point tracking system with Parallel connection for PV stand-alone application," IEEE transaction on industrial electronics, vol.55, no.7, July 2008.
[15]. S. Rahmani, Ab. Hamadi, A. Ndtoungou, "Performance evaluation of a PMSG-based variable speed wind generation system using maximum power point tracking," IEEE electrical power and energy conference 2012.
[16]. Majid Jamil, Ravi Gupta, "A review of power converter topology used with PMSG based wind power generation," IEEE, 2012.
[17]. Eftichios Koutroulis, Kostas Kalaitzakis, "Design of a maximum power tracking system for wind-energy conversion application," IEEE Transaction on industrial electronics, vol. 53, no.2, April 2006.
[18]. C. Lin, S. yang, G.W. Wu, "Study of a non-isolated bidirectional dc-dc converter," IET power electronics. vol.6, 2013.
[19]. M. Ahmadi, K. Shenai, "New, Efficient, low-stress buck-boost bidirectional dc-dc converter," IEEE, 2012.
[20]. Zhilling Liao, Xinbo Ruan, "Control strategy of bi-directional dc-dc converter for a novel stand-alone photovoltaic power system," IEEE vehicle power and propulsion conference (VPPC), September 2008.