Grid connected hybrid renewable energy system for vehicles charging station and street lightning system

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Abstract - *Electrical energy generation from renewable energy sources such as the sun, wind, water, tidal etc., are widely adopted due to increase in electricity consumption. Development of renewable energy usage in towns and villages areas is an important factor and also its integration with the grid. The integration of renewable energy sources to grid with high efficiency is possible and also difficulty in transmission and distribution of power in towns & villages can be resolved with this paper. Hybrid renewable energy system can be used to reserve the non-renewable fossil fuels. The Photovoltaic-wind hybrid system returns the lowest unit cost values to sustain the same level of Shortage of Power Supply Possibility as compared to standalone solar and wind systems. The objective of this paper is to present the modeling and analysis of a fresh seven-level inverter for PV and wind power plant application. This paper discusses grid connected, multilevel converter practice using renewable energy supply usage in towns & villages areas especially for electrical vehicles charging station & street lightning system. The aim of this paper is to group and review these recent contributions in order to establish the current state of the art and trends of the technology, recently as a very important alternative in the area of control technology. The advantage of this idea is to avoid daily running cost and make the system more independent*

Key Words: Multilevel Inverter, Renewable Energy System, Solar wind, hybrid, energy, photovoltaic etc.

1. INTRODUCTION

In recent years, there has been an increasing awareness in electrical energy generation from renewable energy sources such as wind, water, sun, tidal etc. as because they are naturally available, pollution free and inexhaustible. The government also attracting the peoples to use renewable energy by giving 50% subsidy. Now we are in the exact time to disconnect from non-renewable power generating system. The advantages of power generation from renewable energy sources are widely accepted. They are essentially unlimited and environmentally friendly. Among the other renewable energy sources possible to obtain electricity, solar energy has been one of the most active research areas in the past decade. The rapid change rate of growth in the worldwide increasing PV capacity is mainly due to increase in grid-connected inverter topologies. AC output voltage is created by switching the full bridge in an appropriate sequence. At present, individual photovoltaic and wind energy systems have been sponsored around the world on a reasonably larger scale. These individual systems can't provide uninterrupted source of energy as they are seasonable. For example, individual solar photovoltaic energy system can't deliver reliable power during non- sunny days. The individual wind energy system can't provide constant power because of significant fluctuations in the amount of wind speeds from hour to hour all over the year. Therefore, battery bank will be essential for these systems in order to store power. Generally, battery bank system is costly and the size has to be compact to a least possible for the renewable energy system to be cost effective. Grid connected hybrid energy system can be used to reduce energy storage requirements cost. The main objective of the paper is to implement a power system using multilevel inverter that is a hybrid of both Photovoltaic and wind energy for the purpose of both vehicles charging station & to supply power to street lightning system. The objectives of this paper 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. This proposed system is supreme solutions for not only vehicles charging station but for street lightning system applications in both rural and urban areas.

2. LITURATURE 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 study work is going on to improve the power efficiency of renewable energy sources to make it more reliable and beneficial. Hybrid energy generation system uses two or more than two sources not only to extract energy from different energy sources but also to boost the energy generation efficiency. From [2],[3] the working of PV-Wind hybrid system is understood, different topologies are 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 modeling are studied. Also, the behavior of PV modules at varying environmental conditions like solar irradiation and temperature are studied. Behavior 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]. The study of different type of bi-directional converters, its working and how to use them in battery charging and discharging system is carried out From [18]-[20].From [21]-[22], the modeling and analyzing of a seven-level inverter operate on photovoltaic and wind energy sources is studied. From [23], study of vehicles charging station and street lightning system is carried out.

3. THEORETICAL APPROACH OF HYBRID ENERGY SYSTEM

Hybrid energy system is the grouping of two renewable energy sources for providing energy to the vehicles charging station and street lightning system i.e "Energy system which is invented or designed to extract energy from 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.

3.1 Solar Energy

Solar energy is obtained from the radiation of the sun. Solar energy is present on the earth infinitely and in plenty manner, freely available. It doesn't produce any pollution. It is free of cost. Only problem with solar system it can't produce energy in worse weather condition but it has superior efficiency than any other energy sources. It only need initial cost. It has long life span and has lower emission.

3.2 Wind Energy

Wind energy is obtained from wind for that we use wind mill. The wind energy requires less cost for electricity generation. Initial and maintenance cost is less. Wind energy is available almost 24 hours of the day. Electricity generation from wind is depending upon the wind speed.

The major drawback of using standalone solar or wind renewable energy system is that unavailability of power for all time. For overcoming this, we practice grid connected solar and wind system together. So that any one power source fails other will take care of the system power generation and if both fails then power will be continue from either grid or battery bank system. 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. 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.

3.3 Major System Components for grid connected hybrid renewable energy system

The functional and operational requirements will determine which components the system will include. It may contain major system components as multilevel power inverter, power charge controller, PV modules, wind turbine, MPPT system, battery bank system, and sometimes the specified electrical loads such as charging station & street lightning loads.

a) PV Modules: - Convert sunlight instantly into DC electric power.

b) Wind turbine: - extracts energy from wind by rotation of the blades of the wind turbine. Power generated from wind is depend on wind speed. Generally power is fluctuating so we require battery bank system to store it.

c) MPPT: - To track maximum power by solar array from solar radiation.

d) Multilevel Inverter: - Converts DC power extracted from hybrid renewable energy system into standard AC power for use in specified application, also it is coordinating with utility power whenever the electrical grid is distributing electricity.

e) Battery Bank: - store energy when there is an surplus coming in and distribute it back out when there is a electricity demand. A solar PV panel continues to recharge batteries each day to keep battery full charge.

f) Charge Controller - Avoids battery overcharging and prolongs the battery life of your PV system. Also supervise and control of balance of system components; wiring system, overcurrent protection, surge protection, connect & disconnect devices and other power processing equipment.

g) System Sizing: - The size of the PV system that will meet your expectations depends on your specific needs, site location and weather.

h) PV System Maintenance: - PV systems require very little maintenance. Practically maintenance-free.

i) Vehicles charging station: - to recharge the electrical vehicles by hybrid renewable energy system.

j) Street lightning system: - lighted by supply obtained from hybrid renewable energy system.

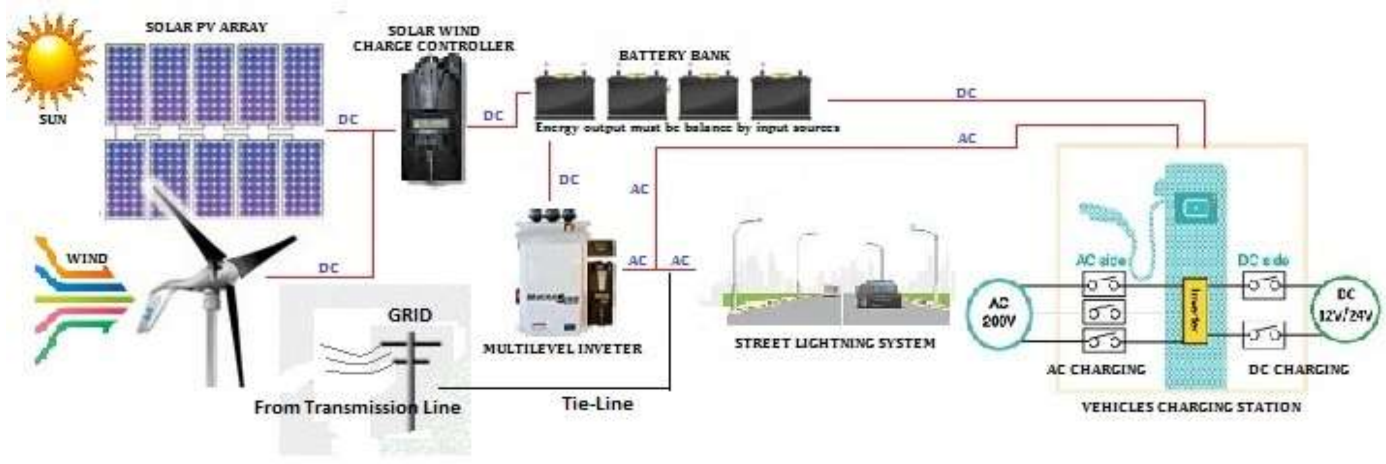

Figure 1: Grid Connected, Hybrid Solar-wind Energy system of electrical vehicles charging station & street lightning system

4. PROPOSED METHODOLOGY

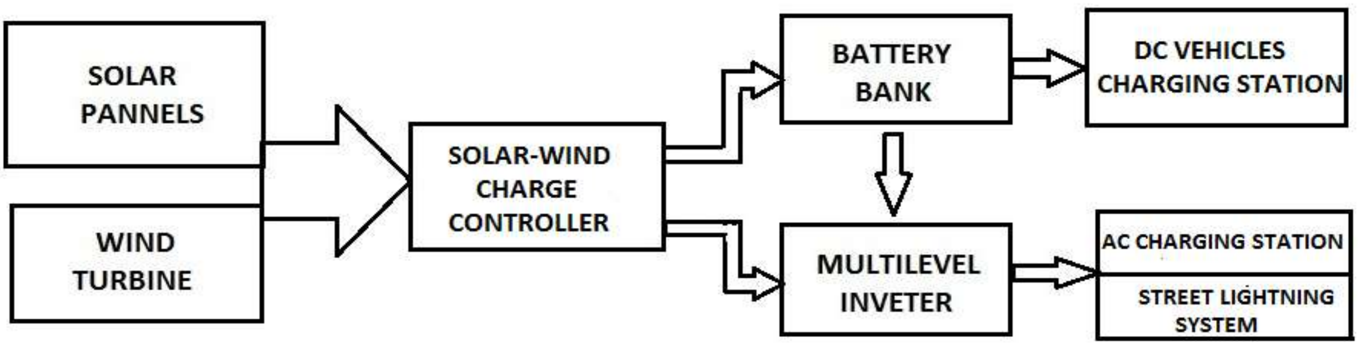

Figure 2: Proposed Block diagram of grid connected Hybrid Solar-wind Energy system vehicles charging station & street lightning system

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 number of solar panels used.

4.1 Calculations for Solar 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

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

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

The electronic torque is given by

$$T_e = 1.5\rho\left[\lambda i_d + \left(L_d - L_q\right) i_q i_d\right] \ldots\ldots(3)$$

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 modeling equation .

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

From stator side the equations are

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

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

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

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

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

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

From rotor side the equation are

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

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

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

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

For the air gap flux linkage the equations are

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

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

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.

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

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

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

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

With,

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

4.2 Calculations for wind 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:

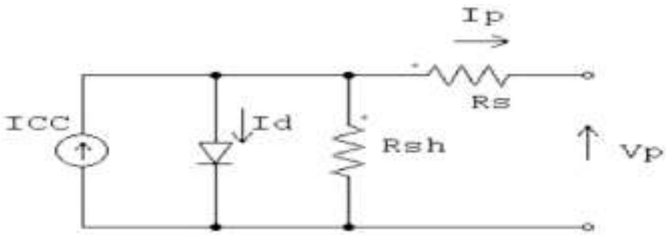

Figure 3: Circuit diagram of PV solar system

As shown figure 5.1.1 output current of solar panel

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

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.

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

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:

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

Also the diode voltage is given as ,

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

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:

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

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

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

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-

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

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.

5. SIMULATION PERFORMANCE OF PROPOSED SYSTEM

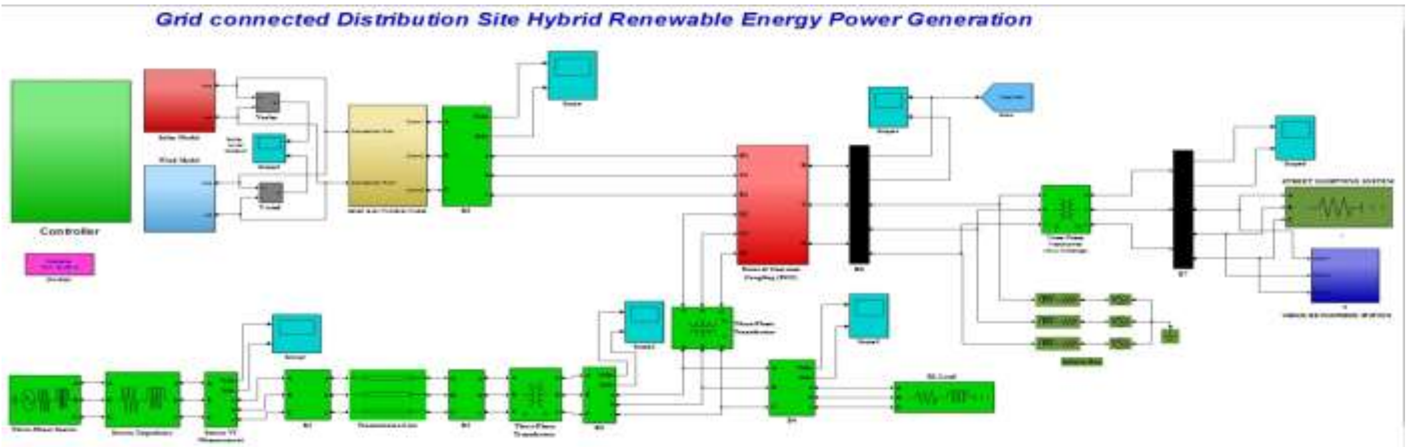

Figure 4: Simulation of Grid connected hybrid renewable energy power generation for Vehicle charging station & Street Lightning system

5.1 Simulation performance for PV System

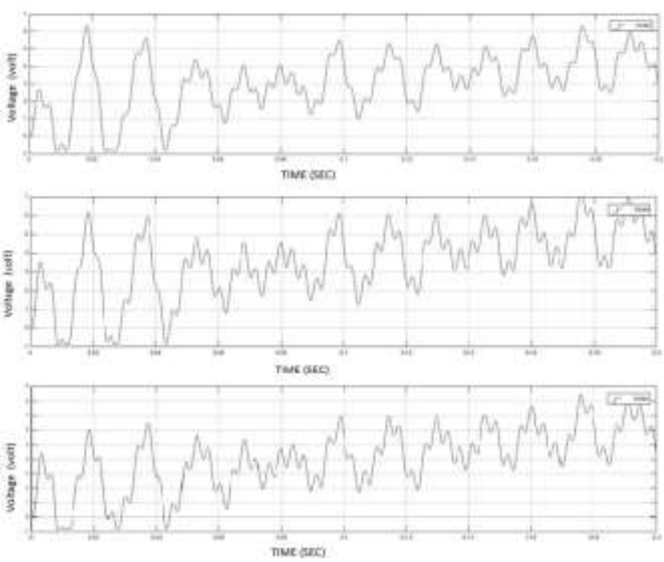

Figure 5: PV solar system output Voltage for 600, 800, 1000 constant values respectively

5.2 Simulation performance for wind System

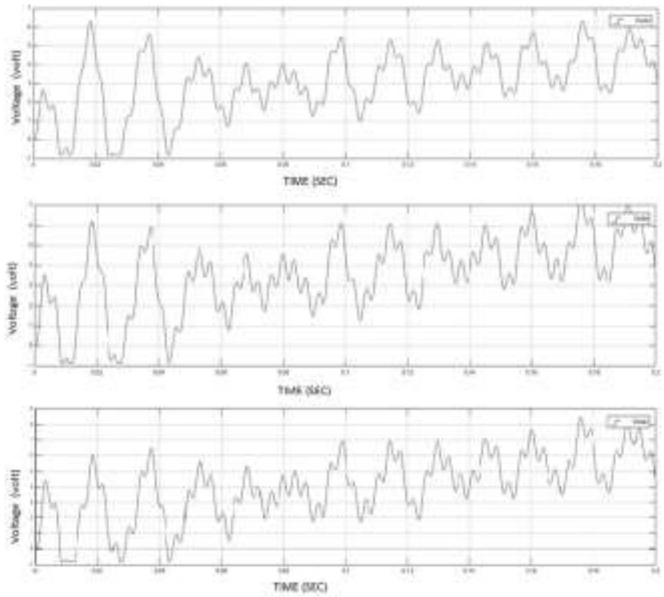

Figure 6: Wind system output Voltage for wind speed of 12 m/s , 15 m/s, 18m/s respectively

5.3 Simulation performance of Hybrid Solar-Wind Model

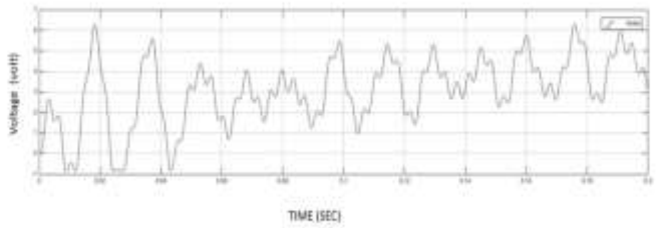

Figure 7: Hybrid Solar-Wind Model output Voltage for PV constant 600 and wind speed 12m/s

5.4 Simulation performance of Multilevel Inverter Model

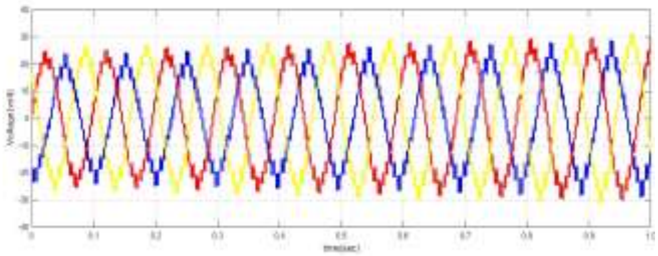

Figure 8: Multilevel Inverter output Voltage

5.5 Simulation performance of Transmission line

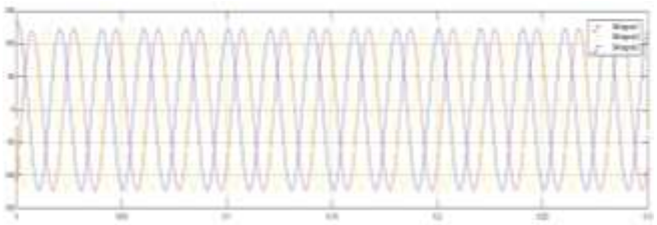

Figure 9: output voltage of transmission line

5.6 Simulation performance of grid Connected Hybrid Renewable energy system & transmission Line system

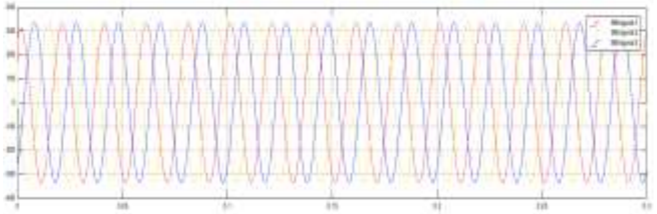

Figure 10: output voltage of Grid connected hybrid renewable energy power generation for Vehicle charging station & Street Lightning system

6. 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 vehicles charging station & street lightning system. The major advantage of hybrid 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. This paper will therefore to promote the use of hybrid renewable energy system as a power source for future generation electrical vehicle charging station & street lightning system.

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