Analysis and Design of Driver Circuit with Hybrid Wind-Solar Power Systems for Street Lighting

B. Aji Selvam[1] Shajini G Inbakani[2] T. Shilaja[3]
[1,2,3]Assistant Professor
[1,2,3]Rajas International Institute of Technology for Women, Tamilnadu, India

Abstract— In this proposed system, we discuss the universal issues about energy management for renewable resource, Wind / Photovoltaic (PV) hybrid power system in order to improve energy efficiency with LED's as the light source and placing the wind turbine in addition to solar. The use of LED allows energy saving, high luminous efficiency and high useful life to the proposed system. And in the same way the position of the turbine plays a major role, we had overcome that design for effective power production. By placing the short armed turbine in the horizontal path due to the too and fro motion of the vehicles air pressure is developed on the blades of the turbine. The pressure is developed from both the directions keeps the turbine in continuous motion of all the vehicles such as Trucks, Lorries and Buses, etc., Due to this, an uninterrupted power generation by solar at day time and whenever the vehicles crosses the path both at day and night the turbine rotates and energy is generated. This would put down the electricity bill and reduce the pollution rate to a certain limit.

Key words: Renewable Resource, Turbine Design, Power LED's, Street Light, Energy Management, Dual Converter, Electrical Generator, DC Battery Source

I. INTRODUCTION

Solar and wind energy is more effective and conventional form of renewable energy available at most it does not depends on any factor, solar energy begins when the day begin and wind is available with a too and fro motion of the vehicle at streets. Much research's are on going to overcome power crisis. The demand in country is hiking each and every day. But, the available power does not meet the requirement. Renewable energy resources must be utilized as much as possible to cut down the demand rate and it's non-polluting. At present, the issue is how to utilize and manage these resources. This paper is proposed to overcome and enhance the power management as said [3], at highways, by acquiring the available energy sources at highways. The proposed system has some advantages such as the energy generated can be utilized not only by street lights but also in traffic signal, and direction and distance indicators.

II. WORKING OF WIND ENERGY

Wind farms are erected based on the availability of atmospheric pressure of wind in a specific region. There are certain criteria's and design procedure to erect wind mills as discussed in [8]. At Highways there is availability of wind by the motion of moving vehicles. When a free moving air particle is disturbed by forceful object succeeding in its path a pressure is developed at the body of the object and it is delivered to the surrounding near objects. By this phenomenon wind turbine is placed on the top of street light. The wind turbines are not placed in vertical path, but horizontally.

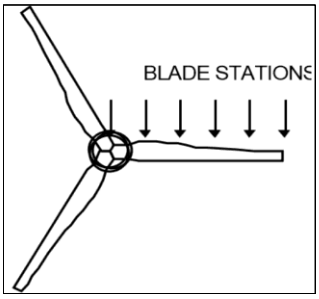

Fig. 1: Top View of Wind Generating System

As, show above in fig.1, this design will keep the blades in rotational motion since the vehicle are directed towards left and right direction and hence a forceful wind can be obtained when two vehicles crosses the blade evenly. The blades are connected to synchronous generator to maintain the rotational RPM (Rotation per minute) as constant and its performance characteristics discussed in [13].

A. *Material and methods*

A wind turbine is composed of several composite parts; but the blades, made of fiber-reinforced epoxy or unsaturated polyester, represent the largest use of material. Other turbine parts made of polyester include the nacelle and the hub. The dominant processing method is vacuum resin infusion. It generates low VOCs and can evenly wet out large parts with a controlled amount of resin, thus facilitating production of lighter and less expensive blades. Prepare molding with a woven or unidirectional glass fabric is more costly but offers greater consistency because it already contains the matrix material (typically epoxy).Typically composed of 70% to 75% glass by weight; these aerodynamically designed blades must meet very strict mechanical requirements such as high rigidity and resistance to torsion and fatigue. High static and dynamic loads over a wide temperature range typical service life. A standard 35- to 40-meter blade for a 1.5-MW turbine weighs 6 to 7 tons.

Both epoxy and polyester, and to a lesser extent vinyl ester, shared the wind blade business in the early days but epoxy earned preferred status as blades grew longer. Polyester is easier to process and is less expensive, but epoxy offers stronger mechanical performance particularly tensile and flexural strength for blades longer than 26 m (85 ft.). Unlike epoxy, polyester needs no post-curing but the blades are generally heavier. E-glass is by far the most used reinforcement, while more costly carbon fiber is employed on a limited basis for greater stiffness and reduced weight in longer blades

B. *Bigger, Stiffer, Lighter*

To reduce the cost of wind energy; developers want to maximize the amount of wind power they can capture. This demand for turbines with larger MW capacity and a corresponding increase in blade length. Over the last decade, average wind turbine capacity has doubled, thus cutting by

50% the number of turbines and blades necessary to generate a certain amount of power. The average turbine generating capacity is moving from 1.5 MW to 2 to 2.5 MW. The present and future trends of the manufacturing are discussed in [14].

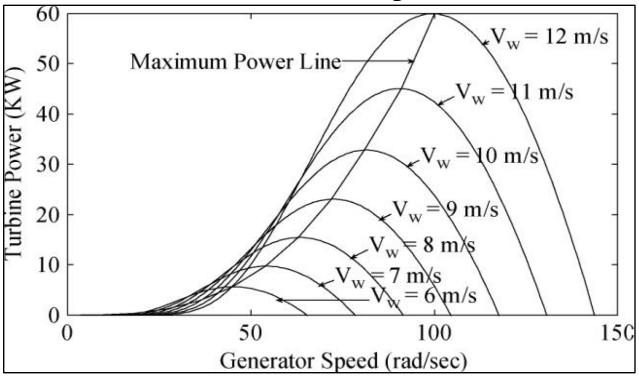

Fig. 2: Mechanical power output of the wind turbine versus SCIG$_w$ speed for different wind speeds

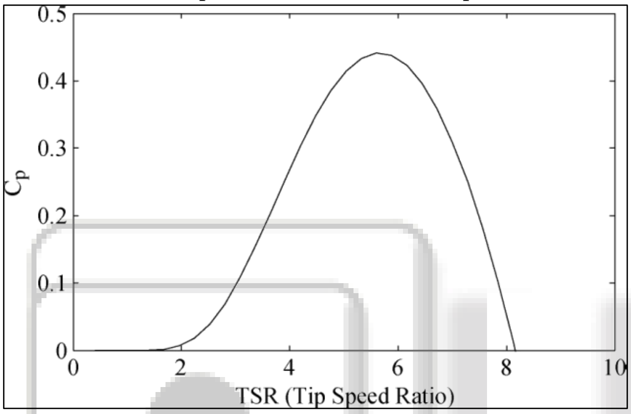

Fig. 3: Coefficient of performance (Cp) versus tip speed ratio (λ) for wind turbine

Blade Size in meters	Blade Size in Feet	Power Generated
35 – 40 m	131.2	1.5 MW
43 m	142	2 – 2.5 MW
50 – 60 m	196.8	7.5MW
3.2m	10.496	2 KW
2m	6.56	450W

Table 1: Blade size and output

As show above on Fig.2, it gives the generator speed (rad//sec) corresponding to the turbine power (kW). The speed and the power varies with each m/s of the turbine varies. The maximum power line indicates the peak power obtained from the turbine motion. And, the fig.3, show the Coefficient of performance (Cp) versus tip speed ratio (λ) for wind turbine. As shown in the table .1, above shows the maximum to minimum power generate from the wind. Many industry observers believe larger turbines will require carbon fiber to provide the necessary stiffness and light weight. In vacuum infusion, carbon fiber is hampered by its inability to wet out efficiently, though more experienced blade makers have learned to overcome this problem. Consequently, more costly prepreg molding is the preferred and most efficient method to utilize carbon fiber. Carbon-fiber makers argue that new capacity puts supply more in balance today. In the fig.4, shows the pictorial representation of the motion of the turbine with the wind pressure.

As show in fig.5, the turbines rotates when the pressure is developed the median of the turbine is coupled with synchronous generator

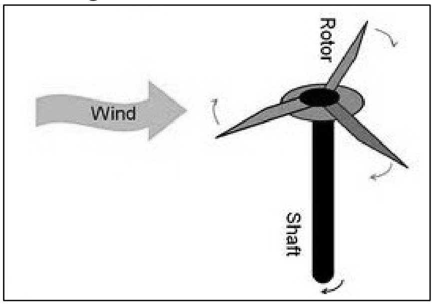

Fig. 4: Motion of Horizontally Placed Blades

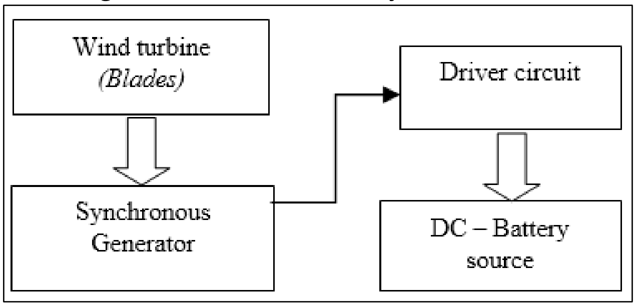

Fig. 5: Block Diagram of working of wind energy generation

An AC output is obtained is given to the driver circuit were the AC input in converted to DC and the power is stored.

III. Working of Solar

The solar energy is an uninterrupted source available for the entire nation at least for a few hours. Solar power is available (9am to 6pm) during the day hours. Recently the researchers has made a record by utilizing 44.4% of the energy from solar with Gallium Arsenide [4], [9], [10], at highways there is none street lights placed in a shady area, but only in the middle. Though the solar panel is in middle there will no fluctuation in the power generated by panel it will remain as a default output.

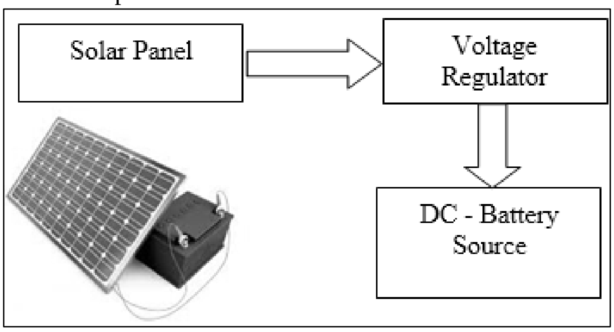

Fig. 6: Block Diagram of working of solar energy generation

As show in fig.6, the output of the solar energy is taken to a voltage regulator to maintain a constant voltage. The regulated voltage is stored in a DC-Battery source.

IV. Operation of Light Source

The energy obtained in to run loads (all are light source). The loads are street light, traffic signal, direction indicator. All the loads are light loads. It's important to choose the type of lamps to be used. Currently at most of the Highway street lights, they prefer sodium vapor lamp or halogen lamp or CFL in some areas as said in [1], because it has a better scattering property. The use of these lamps consumes more power based on luminance.

A. Lights and Luminance

Each and every lamp varies from other based on high luminance its preferred for street lighting as show in the table.2, below, it give a clear view about the kinds of lamps used in street light with different lumen capacity as per the required watts for luminance.

S.no	Type of light With various composition	Typical luminous efficiency (Lumen/watt)
1	Mercury Vapor lamp	35 – 60
2	Low pressure Sodium vapor lamp	100 – 200
3	High pressure sodium vapor lamp	85 – 150
4	Halogen lamp	16 – 24
5	LED lamps	30 – 90

Table 2: Types of lamp and its lumens/watt

The sodium vapor lamp consumes 100 - 200W power for an hour

Power consumed per day = 4800 W

Power consumed per month = 14, 4000 W.

Annually = 17, 52,000 W.

The use of Power LED's reduces this power consumption being utilized, the luminance effect of power led is almost equivalent and better the present days lighting system. The brightness of LEDs various based on the material used as discussed in [7], using two types of phosphor-converted white high brightness Led's can be used. This power consuming can be reduced to a larger limit. The power consumption is minimized and rest of the power can be utilized for other purposes. The heating of lamp is another major factor which we need to consider it determines the life and ability of lamps brightness as said in [6], at temperature between -25'c/125'c, junction temperature increases, with different materials the degradation rate various, most of the failure comes under the same phenomenon. The rectangular design of LED's are quite brilliant and spread the lights evenly throughout the place

B. Shape of Power LED

The power led gives a better outcome than the normal LED's there are various shapes and designs available for effective brightness and scattering of light over the required area, as the design given in [1]. There are various designs like square, rectangular, circular, strips and soon. The emission of light various from each design available in the manufacturing

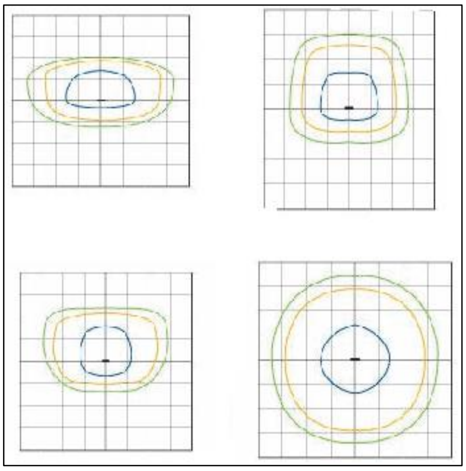

Fig. 7: LED Fixture Type Illumination Spread

The above fig .7, these are the various designs for better luminance.

V. CONVERTER CIRCUIT

The supply is from both sources v_1 is the supply from the wind and v_2 is the supply from the solar the mode of operation of the circuit is, as said in [11], [12]. A battery source is placed in between both the input sources v_1 and v_2, and source currents iL_1 and iL_2 are flowing from the source

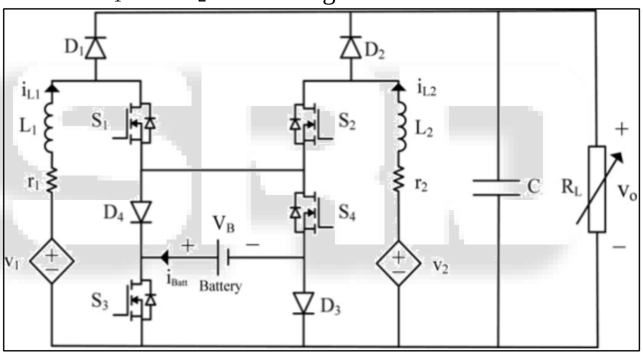

Fig. 8: Circuit diagram of Converter

As show in the Fig.8, The two Inductors L_1 and L_2 make the Input power ports as two current type sources. It results in drawing smooth currents from the sources. R L is the load resistance and switches S_1 – S_4 are the main controllable element that controls the power flow of the hybrid power system

First case, in this operation mode, the sources v_1 and v_2 supplies the load without battery. This is the Basic Operation mode of the converter. From the converter structure, there are two options to conduct Input – power sources currents iL_1 and iL_2 without passing through the battery, path1: $S_4 – D_3$, path2: $S_3 – D_4$. First path is chosen in this operation mode.

Based on the balance theory, equations are

L_1: $d_1T (v_1 – r_1 i_{L1}) + (1- d_1) T (v_1 – r_1 i_{L1} - v_o)$

$= 0 \longrightarrow v_0 = v_1 – r_1 i_{L1} / 1- d_1$ (1)

L_2: $d_2T (v_2 – r_2 i_{L2}) + (1- d_2) T (v_2 – r_2 i_{L2} - v_o)$

$= 0 \longrightarrow v_0 = v_2 – r_2 i_{L2} / 1- d_2$ (2)

C: $(1- d_1) T i_{L1} + (1- d_2) T i_{L2} = T (v_o/R_L)$ (3)

Battery

$i_{Batt} = 0 - P_{Batt} = 0$ (4)

Second case, when load is acting in this operation mode, the sources v_1 and v_2 supplies the load with the battery discharging state. From the converter structure, turning ON switches S3 and S4 simultaneously causes iL1 and iL2 to conduct through the path of S4, the battery and S3 which results in discharging of the battery.

L_1: $d_4 T (v_1 - r_1 i_{L1} + v_b) + (d_1 - d_4) T (v_1 - r_1 i_{L1}) + (1 - d_1) T (v_1 - r_1 i_{L1} - v_o) = 0$ (5)

$= 0 \longrightarrow v_0 = v_1 - r_1 i_{L1} + d_4 v_b / 1 - d_1$ (6)

L_2: $d_4 T (v_2 - r_2 i_{L2} + v_b) + (d_2 - d_4) T (v_2 - i_{L2}) + T (v_2 - r_2 i_{L2} - v_o) = 0$

$L_2 = 0 \longrightarrow v_0 = v_2 - r_2 i_{L2} + v_b / 1 - d_2$ (7)

C: $(1 - d_1) T i_{L1} + (1 - d_2) T i_{L2} = T (v_o/R_L)$ (8)

Battery

$i_{Batt} = [d_4(i_{L1} + i_{L2})]$

$P_{Batt} = - v_b [d_4 (i_{L1} + i_{L2})]$ (9)

Third case, in this operation mode, the sources v1 and v2 supplies the load while the battery is in charging state. From the converter structure, switches S3 and S4 are turned OFF, by turning ON S1 and S2, currents iL1 and iL2 are conducted through the path of D4, the battery, and D3. Hence the condition of battery charging is provided.

L_1: $d_3 T (v_1 - r_1 i_{L1}) + (d_1 - d_3) T (v_1 - r_1 i_{L1} - v_b) + (1 - d_1) T (v_1 - r_1 i_{L1} - v_o) = 0$ (10)

$L_1 = 0 \longrightarrow v_0 = v_1 - r_1 i_{L1} (d_1 - d_3) v_b / 1 - d_1$ (11)

L_2: $d_2 T (v_2 - r_2 i_{L2} + (d_2 - d_3) T (v_2 - i_{L2} r_2 - v_b) + T (v_2 - r_2 i_{L2} - v_o) = 0$

$= 0 \longrightarrow v_0 = v_2 - r_2 i_{L2} (d_1 - d_3) v_b / 1 - d_2$ (12)

C: $(1 - d_1) T i_{L1} + (1 - d_2) T i_{L2} = T (v_o/R_L)$ (13)

Battery

$i_{batt} = - (d_1 - d_3) i_{L1} - (d_2 - d_3) i_{L1}$

$P_{batt} = -v_b (-d_3) v (i_{L1} + i_{L2}) + d_1 i_{L1} + d_2 i_{L2}$ (14)

VI. Operation and Functioning

In this proposed hybrid system solar and wind energy is made hybrid the power obtained from the sources are converted to a DC and stored in a battery both the outputs are uneven the rotation of the wind turbine may vary; it depends on the speed of the vehicle crossing the area at a particular instance. The blades of the turbine are made up of polymer or fiber as said in [1]. The wind energy generation system is placed at the corners edges of the streets or near the traffic signal were we can find a steady flow of vehicle. Use of Light weight blades can produce rotational motion at low wind.

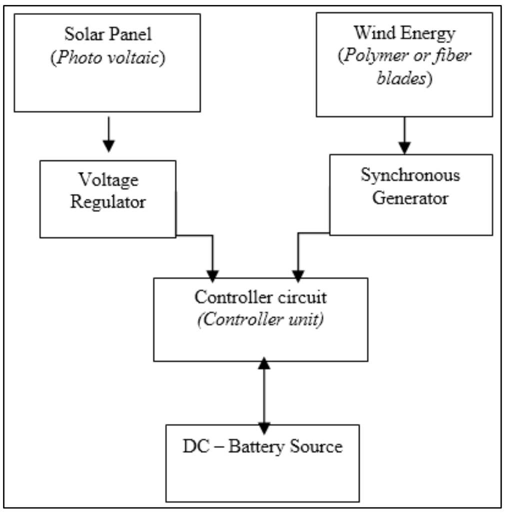

Fig. 9: Flow chart of working of Hybrid power system in Street lights

The solar output also depends on the intensity of the light. The lights are replaced by power led's for an effective output and low power consumptions. A switching circuit is made when there are voltage generation from solar the street lights gets TURNED OFF. In the absence of solar power the lights are TURNED ON.

This power can also be synthesized by traffic signals, direction and distance indicator. Due to this power the above said can be reduced.

As shown in Fig.9, all the switching process are carried out in the controller unit alternate charging and discharging processes is carried out with the available resources guidelines of using the using the street lights gives idea about the betterment operation and management of the street light as said in [5].

VII. Experimental Results

The performance of the wind-solar hybrid system is shown in Fig.10, with balanced linear load at wind speed of 11 m/s. The corresponding rotor speed set point is at 99.6 rad/s, and its stator frequency is 47.08 Hz. Since the power generated by the system is more than the required active power for the electrical loads, the battery is absorbing the surplus power to maintain the frequency of the load voltage constant.

Further, the reactive power required by the load is supplied by the load-side converter to maintain the magnitude of the load voltage constant. Thus, under these conditions, both the magnitude and the frequency of the load voltage are maintained constant

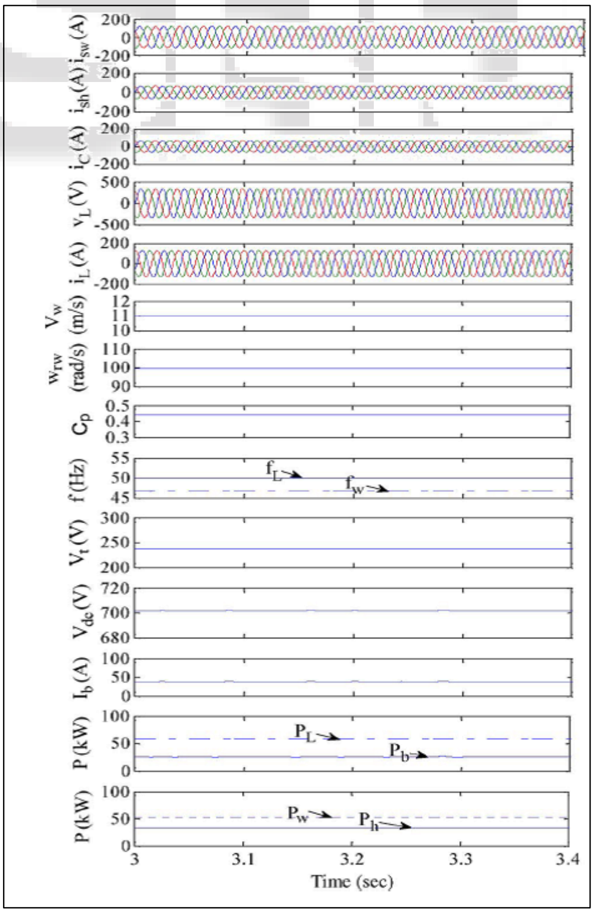

Fig. 10: Performance of hybrid system with balanced linear load at wind speed of 11 m/s

VIII. CONCLUSION AND FUTURE WORK

In this paper, the renewable energy's wind and solar have ability to complement each other. The solar panels are placed in between two street lights and interconnected for two loads in this scheme the power converters which interact with the controller is used to control set of operations(Based on presence and absence of vehicles the brightness or the supply can be cut down). By interconnecting all the sources to be made common and load sharing can be made. The power to the loads can be equally shared. Thus the unequal and power can be regularized. Using this method, the initial investment is saved and the total energy loss in the conversion to be reduced. This can be also erected in the path on rail roads were high pressure of wind is developed by the motion of the train.

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