Design and Implementation of Wind-Solar-Grid Hybrid Vehicles

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Abstract: ***In this paper, we introduce the design and implementation of electric vehicle from renewable energy sources like solar energy, wind energy etc. Which could improve reduction of air pollution and minimizing foreign currency of our country. This project is to design, charging and controlling circuit of electrically operated Auto rickshaw for public utilities.***

Keywords: solar energy, wind energy, hydro power plant (grid), controlling circuit, lead acid battery

1. Introduction

Now a day we can generate electricity from hydro power technology, nuclear power plant, solar radiation, thermal energy, fuel energy, wind power plant and so on. Our project concentrates from wind power, solar panels generation and store electricity and charging electric vehicles.

We can put the wind turbine and solar panels at the top of the car, when the car is starting or moving there is high wind energy to rotate the wind turbine at that time we can generate electricity from this wind power which is used as a prime mover of a generator so that we can charge the battery or we can store electricity with additional battery.

When the car is starting or moving the generator is generate electricity, we use AC generator so we can rectified this AC voltage in to DC voltage in the aid of rectifier circuits and we can control this dc voltage by different electronic equipment's after that we can feed this DC voltage to the automotive battery.

2. Components of Wind-Solar-Hybrid Electric Vehicles

In our project, the components we use for hybrid wind, solar and grid powered three wheel vehicle are:

- ✓ Wind power generator and charge controller circuit
- ✓ Solar panel and charge controller
- ✓ DC motor (henzman DC motor)
- ✓ Battery
- ✓ Rectifier
- ✓ Converter

3. Energy Generated by Wind Power

Most wind turbine manufacturers rate their turbines by the amount of power they can safely produce at a particular wind speed, usually chosen between 24 mph (10.5 m/s) and 36 mph (16 m/ s) with gear box but in my system its optional because vehicles is very fast during transportation, so we can get full generator speed.

The formula for calculating the power from a wind turbine is:

$$\text{Power} = k\, C_p\, 1/2\, \rho\, A\, V^3$$

Where:

- ✓ P = Power output, kilowatts
- ✓ Cp = Maximum power coefficient, ranging from 0.25 to 0.45, dimension less (theoretical maximum = 0.59)
- ✓ ρ = Air density, lb/ft3
- ✓ A = Rotor swept area, ft2 or π D2/4 (D is the rotor diameter in ft, π = 3.1416)
- ✓ V = Wind speed Generated by moving vehicle, mph
- ✓ k = 0.000133 A constant to yield power in kilowatts.

To get a preliminary estimate of the performance of a particular wind turbine, use the formula below.

$$AEO = 0.01328\, D^2\, V^3$$

Where:

- ✓ AEO = Annual energy output, kWh/year
- ✓ D = Rotor diameter, feet
- ✓ V = Annual average wind speed Generated by moving vehicle, mph

4. Selection of Solar Panel Size

The number of PV modules in parallel (Npv) is given by

$$N_{pv} = \frac{\text{daily energy consuption in wh}}{\text{energy generated in one modul}}.$$

Where:

- ✓ NPV = number of PV module in parallel

The number of modules in series (Ns) is given by

$$N_s = \frac{Vs}{Vm}.$$

Where:

- ✓ NS = number of PV module in series

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- ✓ VS= System voltage
- ✓ Vm =output voltage from PV module

5. Battery Bank & Capacity Analysis

Some of the factors for design criteria are:

- ✓ Load energy consumption analysis
- ✓ Allowed Depth of Discharge DOD
- ✓ Number of days in autonomy
- ✓ Operating temperature
- ✓ System efficiency loses
- ✓ Recommended charging rate or battery charge acceptance rate

We can calculate battery capacity by the following formula:

$$CB = \left(\frac{L\times Ta}{DOD\times Dt\times Be\times We\times Pc}\right)/V_{sysm}.$$

Where:

- ✓ CB = battery capacity
- ✓ L = daily mean energy consumption
- ✓ DOD = maximum depth of discharge
- ✓ Ta = number of autonomy days
- ✓ Dt = rate for temperature
- ✓ Pc= efficiency of power conversion
- ✓ Be= battery efficiency
- ✓ We = efficiency of wiring
- ✓ Vsyem =System voltage

Calculate the number of ampere hours required per day from the battery (Ahpd)

$$A_{hpd} = \frac{L}{Vsysm}$$

Calculate number of battery is connected to in parallels (Nbp)

$$N_{bp} = \frac{CB}{A_{hpd}}.$$

Number of battery connected to in seriously (Nbs)

$$N_{bs} = \frac{Vsysm}{Vbattery}.$$

6. System Design of Hybrid Electrically Operated Vehicles

Specification of hybrid solar, wind-solar-grid power E-Rickshaw

- ✓ Mass of the body (MB) = 160 KG
- ✓ Total mass of passenger and driver (MP) =260KG
- ✓ Efficiency of DC motor = 90%
- ✓ Voltage of DC motor (VM) = 48V
- ✓ Maximum vehicle speed = 25KM/H
- ✓ Battery efficiency = 90%
- ✓ Gradient angle $\alpha=2^o$
- ✓ Aerodynamic drag coefficient CD = 0.3
- ✓ Frontal area AF = 0.5m3
- ✓ Rolling resistance coefficient Co =0.006
- ✓ Gravitational constant g = 9.8m/s^2
- ✓ Average speed of the wind VW = 14.33KM/hr. or 3.981 m/sec.
- ✓ Radius of the wheel r = 0.09m
- ✓ Density of the air = 0.85 KG/m3

7. Analysis of the Forces Acting On the Vehicle

Aerodynamics force: Force due to viscous resistance of the air against the motion of a vehicle.

FA = 0.5ρAfCd (V+VW) ^{2}
FA=(0.5x0.85x0.5x0.7x(8.33+3.981)^2)
FA = 22.54N

Gradient forces: Therefore the gradients force on the vehicle becomes

Fg = Mtgsinα
Mt = M_P+ M_B
Mt = 160+260
Mt = 420 kg
Fg = 420x9.8xsin (2)
Fg = 143.792 N

Rolling resistances/ frictional force: Calculate rolling resistance by using equation,

Fr = $C_o$mtgcosα
Fr = 0.006x420x9.8cos (2)
Fr = 24.705 N
Calculate acceleration of the vehicle,
α =w^2$C_o$sinα
Calculate angular speed vehicle speed (v) is 25km/h,
W = V/r
W =6.94/0.09
W = 77 rad/sec.
So angular speed of the motor is;

$$W = \frac{1rpm\ x\ 77rad/sec}{0.104719755rad/sec}$$

W = 735 rpm
α= (77)^{2}x0.006xsin (2)
α= 0.92m/s^2
mα = 0.92x420kg
mα= 386.4 N

8. Torque and Power of the Motor

Firstly the load torques has been determined from the predefined specifications. In this design we assume that maximum load is concentrated on the back (rear wheels), i.e. 80% of total load is carried out by the actuated wheels meaning each active wheel handle 80% of the total load and the reaming 20% load is concentrated on the front wheels.

T = r F_T

First find total acting force on the vehicle from equation;

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$F_T = \mu (F_A + Fg + Fr + m\alpha)$
$F_T = 0.4(22.54+143.792+24.705+386.4)$
$F_T = 230N$
T = 230x0.09 = 20.7 N

Therefore, for the two wheels actuated by the rear wheel:

$T_1 = T_2 = 20.7$ N

Then ones we know the maximum load we select a motor that would handle this much of load. Assuming that friction is negligible, meaning viscous friction and Columbus friction almost zero; i.e. If the power on the shaft is greater than the power on the driven unit, the driven unit will accelerate. Since there is also 20% of the remaining load also distributed to the front wheel let's take. Then rating power is calculated as induced torque multiplied by rated speed. The rating of motor torque is equal to 24 Nm.

$Pm = WT_m$ = 24NMx 77rad/sec = 1848W

With the product of rated voltage and rated current, the rated current being determined select the voltage of the motor 48v and the rating of motor is 1800w.

$$I = \frac{PM}{V} = \frac{1800W}{48V} = 37.5\ A$$

So our motor has a specification of:

- ✓ Rated power = 1800W
- ✓ Rated speed = 1000rpm
- ✓ Rated current = 37.5A
- ✓ Rated voltage = 48V

9. Sizing of Solar PV Modules

We select 350W rated PV panel 1m by 1m area. So we can put three (3) 1m by 1m solar panels at the top and the back of the rickshaw. So we can generate 1050W power from these three solar panels by nine (9) sun shine hour per day.

From solar PV module we get half of the energy supply of electrically operated rickshaw, which is we can drive or operate for four (4) hours.

Daily load = 4hrs x DC power rating
= 4 x 2200 = 8800wh
4hrs battery power capacity = 8800/0.9
=9777w
Daily power generated in one module panel
= 9hrs x 350w = 3150w
So, calculate no of PV panel
Npv = 9777/3150 = 3.1= 3 panels

10. Specification & Rating of Wind Generator

- ✓ Rotor Diameter: 0.75 meter
- ✓ Rotor Type: 3-Blade upwind
- ✓ Blade Material: Glass Reinforced, UV resistant Nylon
- ✓ Rated Output: 650watts @ 8m/s (18mph)
- ✓ Peak Output: 800watts
- ✓ Cut-in speed: 3m/s (6.7mph)
- ✓ Weight: 6Kg
- ✓ Generator Type: single Phase permanent magnet AC generator
- ✓ Mounting Pole: 48.3 or 50.0mm outer diameter (3mm wall thickness)
- ✓ Output Voltage: 48 V

So we can generate from wind power generator daily

= 650w x 8hrs = 5200wh
5200/2200 = 2.30

We can operate the vehicle 2 hours and 30 minutes from wind power generator.

11. Sizing of Battery Storage of the System

Table 1: Daily load of a vehicle

Appliance	No of appliance	DC power (W)	Duty cycle (hr/day)	Daily load (Whr/day)
Henz man DCM	1	2150	8	17,200
Front main Lamp	1	10	3	30
Parking lamp	2	3	1	6
Internal lamp	1	3	3	9
Turn lamp	4	5	1	20
Stop lamp	2	5	1	10
Clacks	1	48	1	48
Audio player (tape)	1	50	4	200
TOTAL				17,500wh

In this project design select 2.15kw henz man DC motor depended on our design calculation the motor is derive 4hrs by solar panel, 2:30hrs by wind turbine generator and 1:30hrs using grid powered (the battery directly charged from electric power supply) and by observe two and three wheels automotive service to estimate the load.

$$CB = \frac{\frac{L \times Ta}{DOD \times Be \times We \times Pc}}{Vsysm}$$

CB=[(17500x1)/(0.5x0.9x0.95x0.9)]/24
= 1,898Ah

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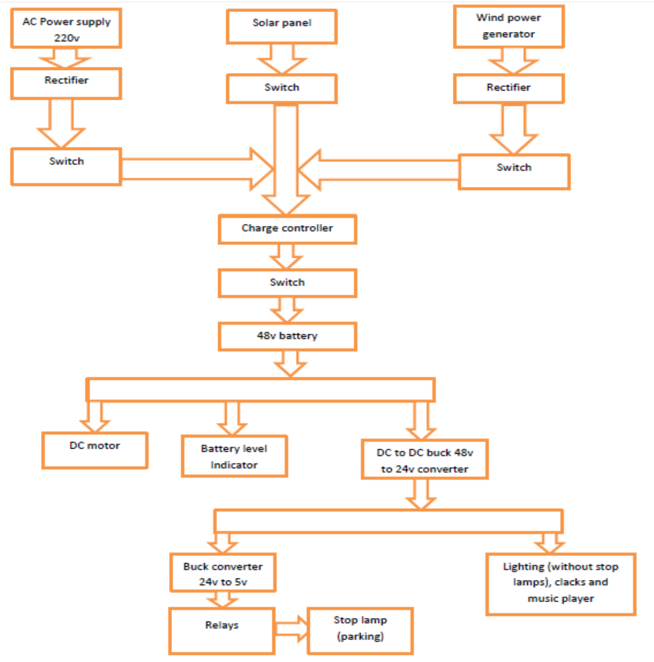

Figure 1: Block diagram of the system

12. Simulation Result of Wind Turbine Generator Controlling Circuit

This generator output variation is due to the wind speed that means the generator output is directly proportional to the wind speed. If, the wind speed is increase the generator output voltage is increase and if the wind speed is decrease the generator output voltage is decrease because the generator prime mover is wind energy.

But without relative motion or prime mover other characteristics of a generator is constant that characteristics is conductor of a generator and magnetic flux of a generator. We use permanent magnet generator for this project. In this project as we mention before we operate three conditions, this are **normal voltage** condition (22.5v-25v), **under voltage** condition (less than 22.5v) and **over voltage** condition (greater than or equal to 25.5v).

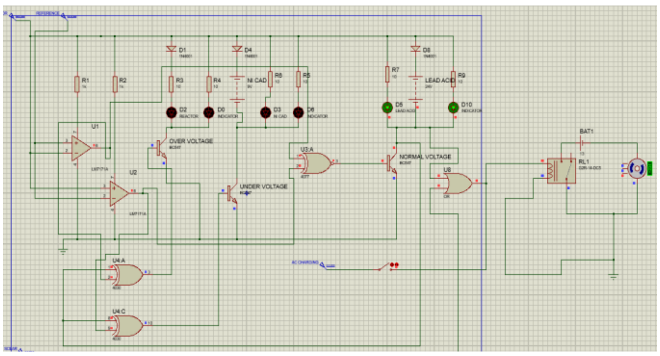

Figure 2: Simulation result for wind power generator controlling circuit

13. Simulation Result of Solar Panel Controlling Circuit

This solar panels output variation is due to the sun radiation strength that means the solar panels output is directly proportional to the sun radiation strength. When the sun radiation strength is good we can generate normal voltage conditions that is greater than or equal to 21v and when the sun radiation strength is poor the solar panel output is generated low voltage condition that is less than or equal to 20v. So in this solar panel we have two different simulation results that is **normal voltage (greater than 21v)** condition and **under voltage(less than 20v)** condition.

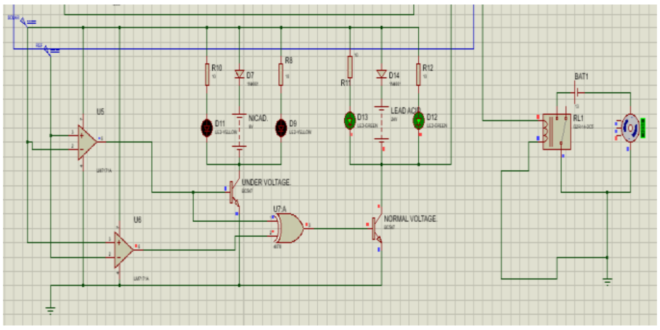

Figure 3: Simulation result for solar panels controlling circuit

14. Simulation Result of Grid (AC) Power Supply

The lead acid battery is charged by 24v DC so this AC 220v is rectified for suitable voltage for charging the lead acid battery.

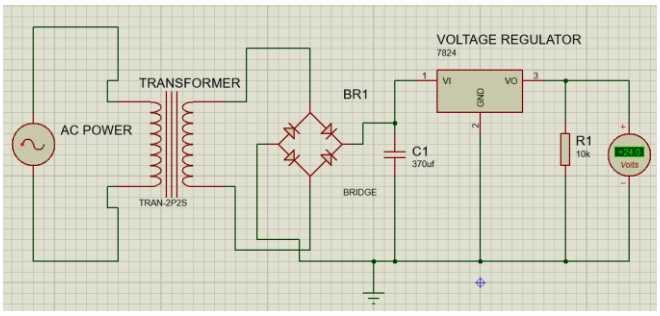

Figure 4: Simulation result for AC power charging circuit

15. Conclusion

We conclude that in this project we have studied and simulate on design of charging and controlling circuit of electrically operated rickshaw. The objective is to operate electrically operated rickshaw in the aid of lead acid battery storage by integrating solar panel, wind power generator and AC power when the vehicle is moving. AC generator is feet at the top of the vehicle and the top & back of the vehicle is covered by solar panels. Based on our project, op amps is reliable to use as a wind power generator and solar panels output voltage comparator because the cost and operation is better compared to PLC and microcontroller. So, the result shows we can operate electrically operated rickshaw by integrating wind power generator, solar panels and AC power supply by the aid of lead acid battery for store electricity.

The wind power generator result is show that the system is compared the output voltage of the generator in three

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levels, that is under voltage (less than or equal to 22.5v), normal condition (the voltage is between 22.5v and 25v) and over voltage (greater or equal to 25.5v). under voltage condition the NI CAD battery is charged, when the generator output voltage is at normal condition LEAD ACID battery is charged and finally in the case of over voltage the dissipated resistor is directly connected to the generator output to control the generator speed and to prevent circuit from over voltage. This wind power generator output voltage controller circuit is performed the above tasks or conditions done automatically.

The solar panel result is show that the system is compared the output voltage of the solar panels in two levels, that is under voltage (less than or equal to 20v), normal condition (the voltage is greater than 21v). Under voltage condition the NI CAD battery is charged, when the solar panel output voltage is at normal condition LEAD ACID battery is charged. This solar panel output voltage controller circuit is performed the above tasks or conditions done automatically.

The AC power supply is show that the input voltage is 220v AC and the output voltage is 24v DC so we can charge directly the lead acid battery by using this rectified voltage.

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