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Automatic Power Generation Vehicle

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Abstract: **An "Automatic Power Generation Vehicle (APGs)", is a vehicle which relies not only on batteries but also an wind energy which drives the turbine blades and rotates the generator which produces electric current. It has greater advantage over electric vehicle in which the battery needs to be recharged again and again in a short period of time. Our objective is to design an APG that is initially powered by battery and after that while in running condition the vehicle is powered by the wind turbine. It provides an advantage that there is no environmental pollution and no need of charging the battery frequently. APG vehicle increases the efficiency with the help of wind energy thereby achieving better performance and economy. Electric vehicle is powered by battery alone is not suitable for long journey because its need frequent charging for the battery. Thus APG vehicle is best suited for urban and rural travel.**

Keywords: **Automatic Power Generation Vehicle (APGs), Wind turbine, Electric vehicle, Urban and Rural Travel.**

1. INTRODUCTION

Electric vehicle is best suitable for non-pollutant vehicle. But the power stations for electric vehicle are comparatively less in many countries. Frequently recharging the battery is difficult without electric power stations. So we decided to build an APG vehicle which is generate their required power by itself using savonius type wind turbine while running condition.

At present, new domains of application of ecologically friendly power systems appear intensively. This process represents an attempt to withstand current environmental challenges and, in particular, results in development of new principles of design of wind turbines. An extensive enough review of existing wind power systems is given in [1].

One of methods to improve performance of wind turbines is the development of airfoils with better aerodynamic char-acteristics [2,3] .

An interesting and prospective direction is the using of an electromagnetic gear [4] to transmit the torque from turbine blades to a rotor of a generator (instead of mechanical gear). At present, wind power units are actively developed where an element interacting with the flow (wing) performs oscilla- tory motion instead of rotation. Sometimes such devices are called "wave-type wind turbines"(which means the wave-like motion of the wing). In particular, such a device using bionic principles of motion is described in [5] .

A schematic diagram for the Automatic Power Generation vehicle (APG) is shown in figure 1. The APG vehicle is initially run by battery after its attaining a certain speed the wind turbine produces the required amount of power. Then the power is given to the electric motor.

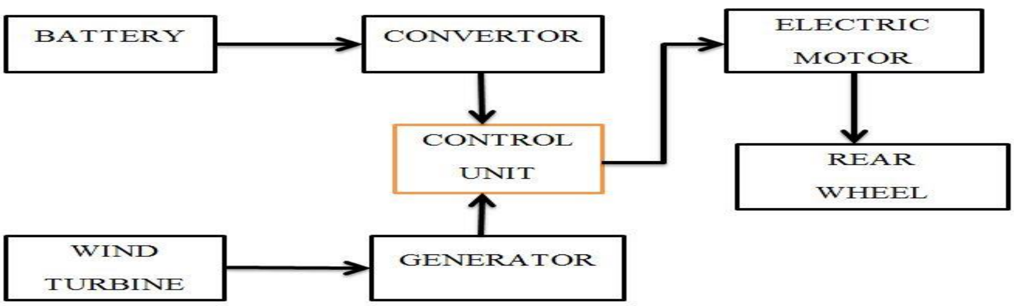

Figure 1: Schematic diagram of APG

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2. MATHEMATICAL CALCULATION

Aircraft design theory states where the thrust force is directly proportional to drag force as,

$$F_T = KF_D$$

Where,

F_T= Thrust force.

F_D= Drag force.

K = coefficient.

The above equation says that whenever there is increasing in thrust force simultaneous increase in drag force with coefficient. So utilises the drag force for producing power using savonius type wind turbine.

3. NUMERICAL CALCULATION

3.1 Overall specification

Overall length of vehicle = 1.8m

Overall width of vehicle = 0.65m

Area of the vehicle = length x height =1.17m^2

Curb weight = 75kg

Weight of the rider = 80kg

Gross weight = 75+80 =155kg

Wheel radius = 0.2286m

3.2 Drag force calculation

A drag force is the resistance force caused by the motion of a body through a fluid, such as water or air. A drag force acts opposite to the direction of oncoming flow velocity where as,

Coefficient of drag, C_d = 0.34

Density of air, ρ_{air} = 1.2kg/m^3

Cross-sectional area, A_c = height x width =0.8821m^2

Drag force, f_d = $\frac{1}{2}$ x ρ_{air} x A_c x C_d x v^2 = 17.995N

Where, v= velocity=10$\frac{m}{s}$

From, the above value suggest that the min velocity of vehicle produces 18N force using that drag force design a turbine for the required power.

3.3 Rolling resistance

The force that resists the motion of a body rolling on a surface called the rolling resistance or rolling friction.

Coefficient of rolling resistance, μ_π = 0.015

Rolling resistance force, F_π = μ_π x weight x 9.81

= 22.808N

From, the above value it clearly shows that min rolling friction developed is 23N.

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3.4 Inertial resistance

The extra resistance of a porous medium to fluid flow, beyond that predicted the Darcy's law caused by local acceleration within the tortuous pore volume.

(0-40kmph) t_{40} = 20s

Acceleration(acc.) $= \frac{V}{t} = 0.555 \frac{m}{s^2}$

Inertial resistance force, F_I = acc. X weight

= 129.17N

3.5 Required force and torque

Total force at starting

$F_{start} = F_I + F_\pi$

F_{start} =151.978

Torque required at starting

$T_{start} = F_{start}$ x wheel radius

T_{start} = 34.74Nm

Total force at average speed

$F_{avg} = F_\pi + F_d$

F_{avg} = 72.813N

Torque required at average speed

$T_{avg} = F_{avg}$ x wheel radius

T_{avg} = 16.65Nm

From, the above force and torque calculation at initial speed and average speed shows that at the time of starting required torque is more due to that amps drawn for the battery is more after reaching a certain speed the required torque is less due to that less amps is drawn so we use wind turbine power after certain speed.

3.6 Battery range and capacity

The numerical calculation of battery range and capacity shows that required distance and time for recharging a battery

Capacity of battery =12V- 35A.hr =420Whr

At continuous speed 40 km/hr

Distance = (usable capacity of battery) / (required whr/km)

= (420 x 0.8 x 0.55)/(12 x(20/40))

= 30.8km

Time = distance/speed

=0.77 hr

The above calculation shows that if we are using the electric vehicle at the distance of 30 km the battery needs charging to overcome this problem we attach a wind turbine. At the time of half the speed of vehicle the wind turbine produces a required power due to torque required at average speed is less, so required current drawn is less so easily motor is powered by wind turbine.

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
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3.7 Calculation for wind turbine

The number of wind turbine is two, so the required power is half of the power. Here the vertical axis wind turbine is used it doesn't affect the flow of the vehicle.

Power discharging from battery = 184.8 Whr

Min power produced in 1 turbine = 92.4Whr

Power = 0.5 x $\rho A V^3$

92.4 = 0.5 x 1.2 x A x 1000

A =0.154m^2

For vertical axis wind turbine,

Here the height of the turbine is constant due to constraint in the vehicle it as h=0.3m

A = πDh

D =163mm

Mass of the turbine = 0.816kg

Weight of turbine = 8.005N

3.8 Stress developed in turbine

Stress developed due to gravity,

$\sigma_g = (W r_{cg})(\frac{h}{2}) / (I)$

σ_g = 667.08 N/m^2

Tip speed ratio is the ratio between the tangential speed of the tip of a blade and the actual speed of the wind.

$\lambda = \omega D/(2V\infty)$

$\lambda = 1$

These are the theoretical value which is obtain from the equations.

4. COMPONENTS USED

4.1 Electric motor

Permanent magnet DC motor, the field poles of this motor are essentially made of permanent magnet. A PMDC motor mainly consists of two parts. A stator and an armature. Here the stator which is a steel cylinder. The magnets are mounted in the inner periphery of this cylinder.

The permanent magnets are mounted in such a way that the N-pole and S-pole of each magnet are alternatively faced towards armature as shown in the figure below. That means, if N-pole of one magnet is faced towards armature then S-pole of very next magnet is faced towards armature. In addition to holding the magnet on its inner periphery, the steel cylindrical stator also serves as low reluctance return path for the magnetic flux. Although field coil is not required in permanent magnet DC motor but still it is sometimes found that they are used along with permanent magnet. This is because if permanent magnets lose their strength, these lost magnetic strengths can be compensated by field excitation through these field coils. Generally, rare earth hard magnetic materials are used for these permanent magnet.

Rotor:

The rotor of pmdc motor is similar to other DC motor. The rotor or armature of permanent magnet DC motor also consists of core, windings and commutator. Armature core is made of number of varnish insulated, slotted circular lamination of steel sheets.

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By fixing these circular steel sheets one by one, a cylindrical shaped slotted armature core is formed. The varnish insulated laminated steel sheets are used to reduce eddy current loss in armature of permanent magnet DC motor. These slots on the outer periphery of the armature core are used for housing armature conductors in them. The armature conductors are connected in a suitable manner which gives rise to armature winding. The end terminals of the winding are connected to the commutator segments placed on the motor shaft. Like other DC motor, carbon or graphite brushes are placed with spring pressure on the commutator segments to supply current to the armature.

A. Working Principle of Permanent Magnet DC Motor or PMDC Motor

As we said earlier the working principle of PMDC motor is just similar to the general working principle of DC motor. That is when a carrying conductor comes inside a magnetic field, a mechanical force will be experienced by the conductor and the direction of this force is governed by Fleming's left hand rule. As in a permanent magnet DC motor, the armature is placed inside the magnetic field of permanent magnet; the armature rotates in the direction of the generated force. Here each conductor of the armature experiences the mechanical force F = B.I.L Newton where, B is the magnetic field strength in Tesla (weber / m^2), I is the current in Ampere flowing through that conductor and L is length of the conductor in metre comes under the magnetic field. Each conductor of the armature experiences a force and the compilation of those forces produces a torque, which tends to rotate the armature.

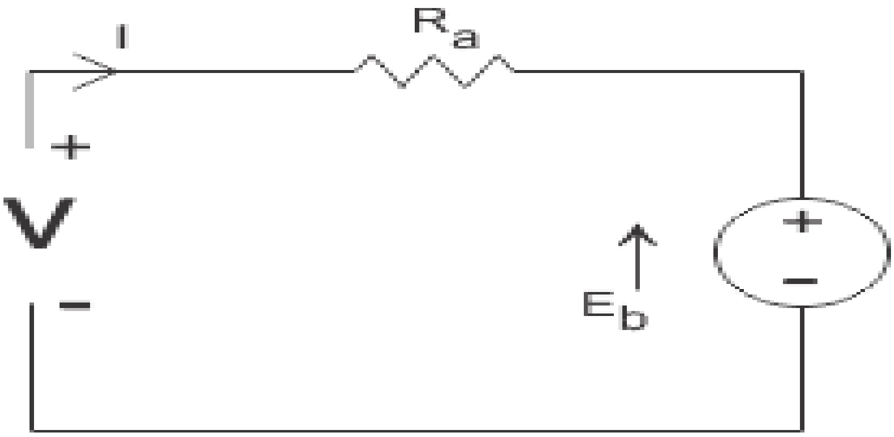

Figure 2: Equivalent Circuit of Permanent Magnet DC Motor or PMDC Motor

As in PMDC motor the field is produced by permanent magnet, there is no need of drawing field coils in the equivalent circuit of permanent magnet DC motor. The supply voltage to the armature will have armature resistance drop and rest of the supply voltage is countered by back emf of the motor. Hence voltage equation of the motor is given by,

$$V = IR + E_b$$

Where,

I is armature current and R is armature resistance of the motor.

E_b is the back emf and V is the supply voltage.

4.2 Dc generator

A DC generator can be used as a DC motor without any constructional changes and vice versa is also possible. Thus, a DC generator or a DC motor can be broadly termed as a **DC machine**. These basic constructional details are also valid for the **construction of a DC motor**. Hence, let's call this point as **construction of a DC machine** instead of just 'construction of a dc generator'.

The figure 3 shows the constructional details of a simple **4-pole DC machine**. A DC machine consists two basic parts; stator and rotor. Basic constructional parts of a DC machine are described below.

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 5, Issue 1, pp: (24-34), Month: January - March 2018, Available at: www.paperpublications.org

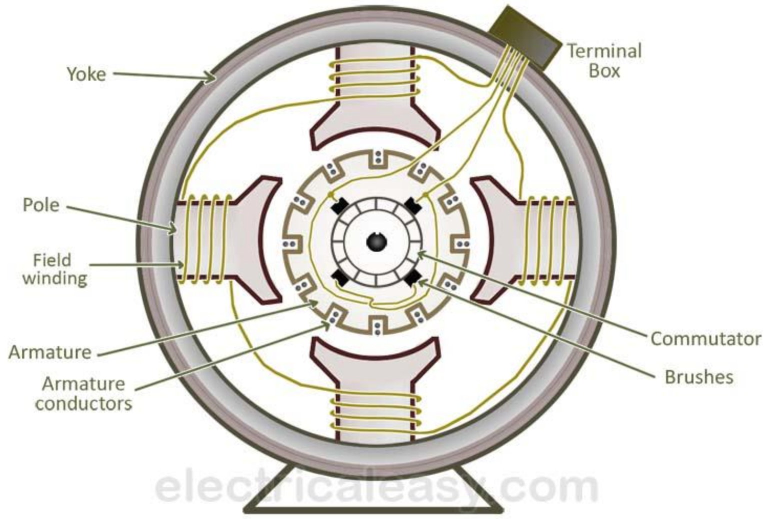

Figure 3: Construction of DC generator

Yoke: The outer frame of a dc machine is called as yoke. It is made up of cast iron or steel. It not only provides mechanical strength to the whole assembly but also carries the magnetic flux produced by the field winding.

Poles and pole shoes: Poles are joined to the yoke with the help of bolts or welding. They carry field winding and pole shoes are fastened to them. Pole shoes serve two purposes; (i) they support field coils and (ii) spread out the flux in air gap uniformly.

Field winding: They are usually made of copper. Field coils are former wound and placed on each pole and are connected in series. They are wound in such a way that, when energized, they form alternate North and South poles.

Armature core: Armature core is the rotor of the machine. It is cylindrical in shape with slots to carry armature winding. The armature is built up of thin laminated circular steel disks for reducing eddy current losses. It may be provided with air ducts for the axial air flow for cooling purposes. Armature is keyed to the shaft.

Armature winding: It is usually a former wound copper coil which rests in armature slots. The armature conductors are insulated from each other and also from the armature core. Armature winding can be wound by one of the two methods; lap winding or wave winding. Double layer lap or wave windings are generally used. A double layer winding means that each armature slot will carry two different coils.

Commutator and brushes: Physical connection to the armature winding is made through a commutator-brush arrangement. The function of a commutator, in a dc generator, is to collect the current generated in armature conductors. Whereas, in case of a dc motor, commutator helps in providing current to the armature conductors. A commutator consists of a set of copper segments which are insulated from each other. The number of segments is equal to the number of armature coils. Each segment is connected to an armature coil and the commutator is keyed to the shaft. Brushes are usually made from carbon or graphite. They rest on commutator segments and slide on the segments when the commutator rotates keeping the physical contact to collect or supply the current.

Working Principle of A DC Generator:

According to Faraday’s laws of electromagnetic induction, whenever a conductor is placed in a varying magnetic field (OR a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor. The magnitude of induced emf can be calculated from the emf equation of dc generator. If the conductor is provided with the closed path, the induced current will circulate within the path. In a DC generator, field coils produce an electromagnetic field and the armature conductors are rotated into the field. Thus, an electromagnetically induced emf is generated in the armature conductors. The direction of induced current is given by Fleming’s right hand rule.

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 5, Issue 1, pp: (24-34), Month: January - March 2018, Available at: www.paperpublications.org

Need of a Split ring commutator:

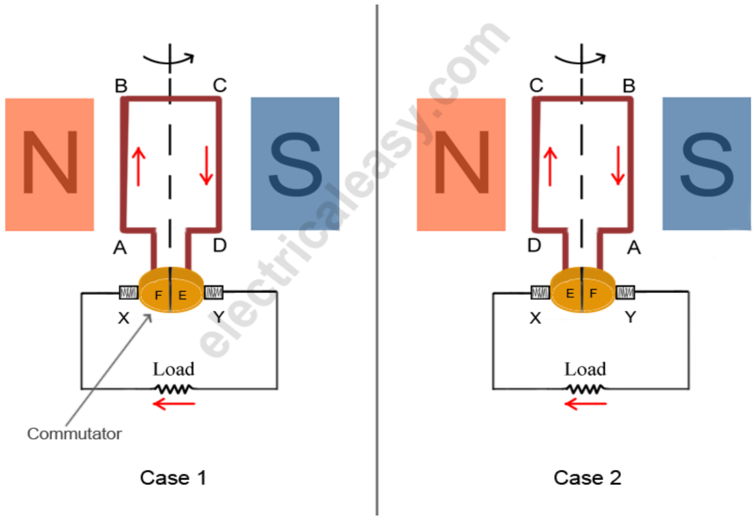

Figure 4: direction of current flow

According to Fleming's right hand rule, the direction of induced current changes whenever the direction of motion of the conductor changes. Let's consider an armature rotating clockwise and a conductor at the left is moving upward. When the armature completes a half rotation, the direction of motion of that particular conductor will be reversed to downward. Hence, the direction of current in every armature conductor will be alternating. If you look at the above figure, you will know how the direction of the induced current is alternating in an armature conductor. But with a split ring commutator, connections of the armature conductors also gets reversed when the current reversal occurs. And therefore, we get unidirectional current at the terminals.

4.3 Boost converter

Switched mode supplies can be used for many purposes including DC to DC converters. Often, although a DC supply, such as a battery may be available, its available voltage is not suitable for the system being supplied. For example, the motors used in driving electric automobiles require much higher voltages, in the region of 500V, than could be supplied by a battery alone. Even if banks of batteries were used, the extra weight and space taken up would be too great to be practical. The answer to this problem is to use fewer batteries and to boost the available DC voltage to the required level by using a boost converter. Another problem with batteries, large or small, is that their output voltage varies as the available charge is used up, and at some point the battery voltage becomes too low to power the circuit being supplied. However, if this low output level can be boosted back up to a useful level again, by using a boost converter, the life of the battery can be extended.

The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos and DC generators. The boost converter is different to the Buck Converter in that it's output voltage is equal to, or greater than its input voltage. However it is important to remember that, as power (P) = voltage (V) x current (I), if the output voltage is increased, the available output current must decrease.

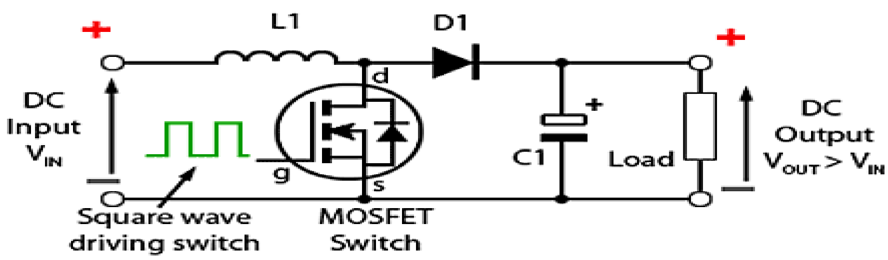

Figure 5: Basic Boost Converter Circuit

Figure 5 illustrates the basic circuit of a Boost converter. However, in this example the switching transistor is a power MOSFET, both Bipolar power transistors and MOSFETs are used in power switching, the choice being determined by the

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current, voltage, switching speed and cost considerations. The rest of the components are the same as those used in the buck converter illustrated in Fig. 3.1.2, except that their positions have been rearranged.

Boost converter Operation

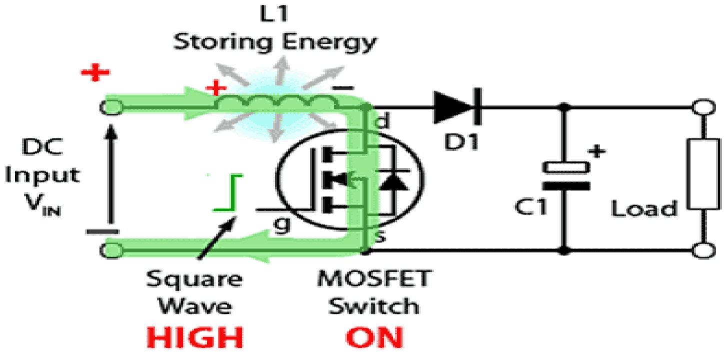

Figure 6: Boost Converter Operation at Switch On

Figure 6 illustrates the circuit action during the initial high period of the high frequency square wave applied to the MOSFET gate at start up. During this time MOSFET conducts, placing a short circuit from the right hand side of L1 to the negative input supply terminal. Therefore a current flows between the positive and negative supply terminals through L1, which stores energy in its magnetic field. There is virtually no current flowing in the remainder of the circuit as the combination of D1, C1 and the load represent a much higher impedance than the path directly through the heavily conducting MOSFET.

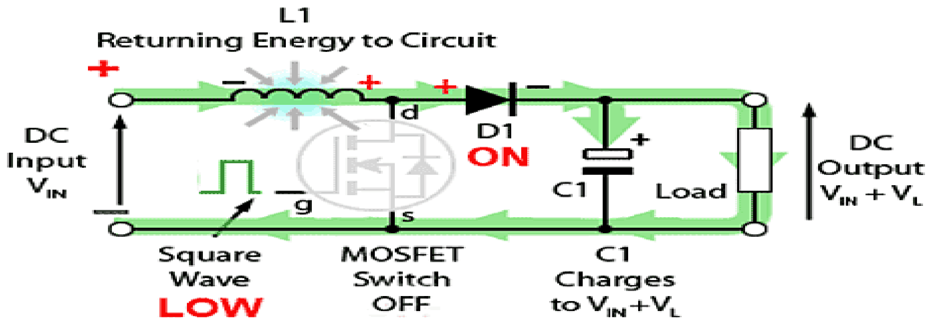

Figure 7: Current Path with MOSFET Off

Figure 7 shows the current path during the low period of the switching square wave cycle. As the MOSFET is rapidly turned off the sudden drop in current causes L1 to produce a back e.m.f. in the opposite polarity to the voltage across L1 during the on period, to keep current flowing. This results in two voltages, the supply voltage $V_{IN}$and the back e.m.f.(V_L) across L1 in series with each other.

This higher voltage (V_{IN} +V_L), now that there is no current path through the MOSFET, forward biases D1. The resulting current through D1 charges up C1 to V_{IN} +V_L minus the small forward voltage drop across D1, and also supplies the load.

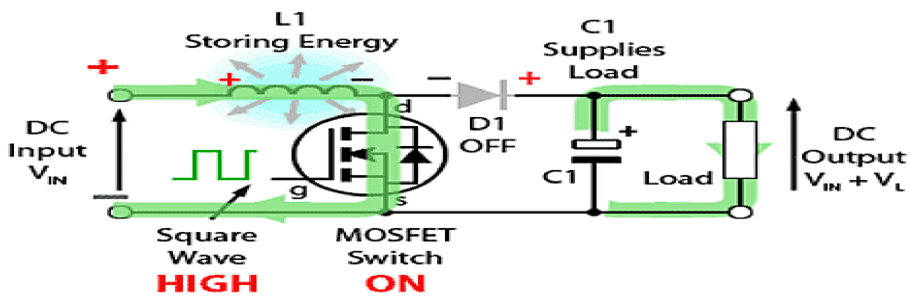

Figure8: Current Path with MOSFET On

Figure 8 shows the circuit action during MOSFET on periods after the initial start up. Each time the MOSFET conducts, the cathode of D1 is more positive than its anode, due to the charge on C1. D1 is therefore turned off so the output of the

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circuit is isolated from the input, however the load continues to be supplied with $V_{IN} + V_L$ from the charge on C1. Although the charge C1 drains away through the load during this period, C1 is recharged each time the MOSFET switches off, so maintaining an almost steady output voltage across the load.

5. ANALYSIS OF WIND TURBINE

5.1 Centrifugal stress analysis

Turbine blades are subjected to stress from centrifugal force (turbine stages can rotate at tens of thousands of revolutions per minute (RPM)) and fluid forces that can cause fracture, yielding, or creep failures.The high temperatures can also make the blades susceptible to corrosion failures.

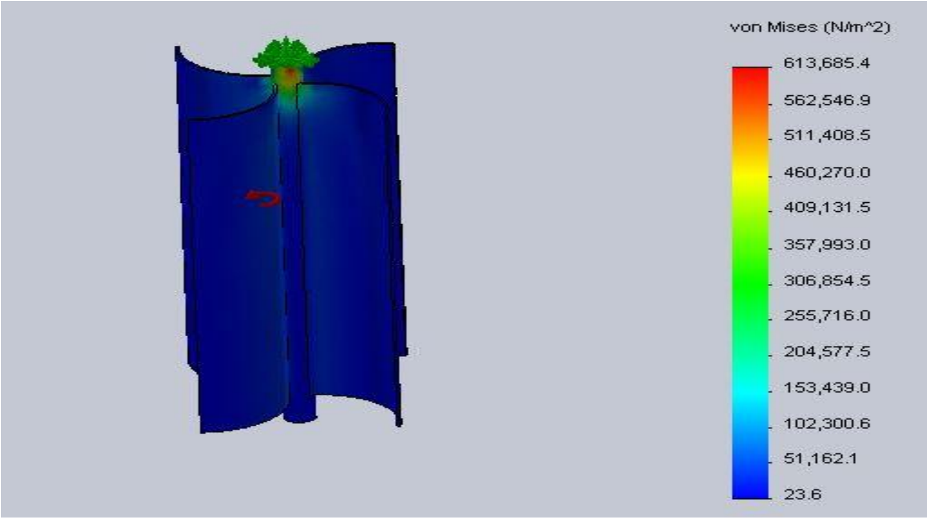

Figure 9: Centrifugal stresses in turbine

Figure 9 shows that the centrifugal stresses developed over the turbine is safe limit. The analysis were done in the solidworks software.

5.2 CFD analysis

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions.

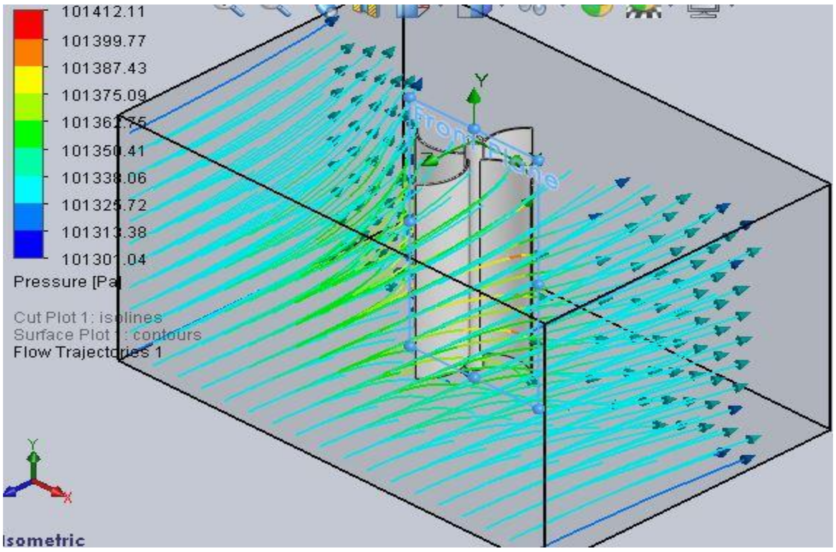

Figure 10: Flow analysis of turbine

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Figure 10 shows that intial rotation of vertical axis wind turbine requires high pressure which is shown in figure 11. The above diagram shows that the deviation of flow after striking the wind turbine.

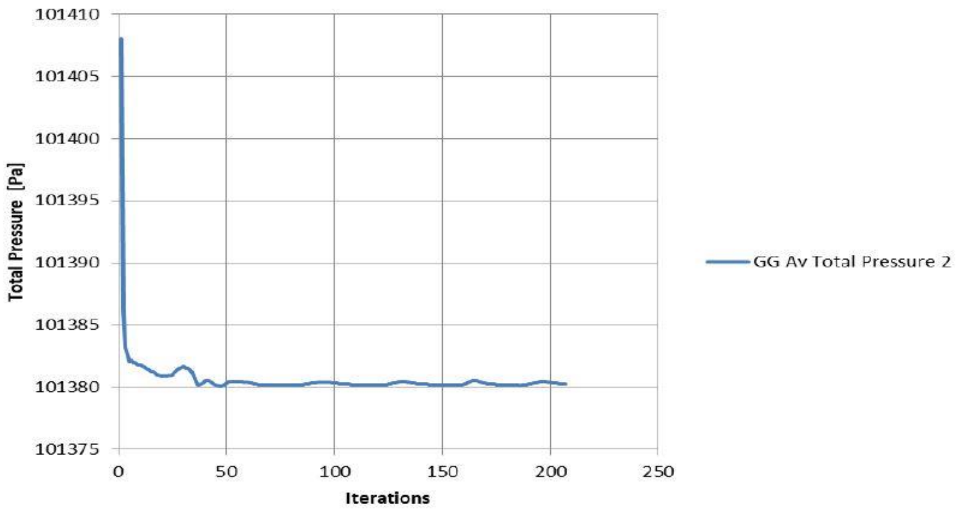

Figure 11: Pressure drop after strikes the blade

Initial rotation of turbine requires high pressure after starts rotating pressure is gradually reduced to atmospheric pressure shows in figure 11.

6. WORKING OF APG

Automatic power generating vehicle initially running with the help of battery power due to high torque and high amps drawn to the motor. Then the vehicle attains a speed of 20km/hr its starts producing power with the help of booster circuit. Then the required power is directly connected to the electric motor using dc controller at the time of running condition required torque is comparatively less so the required voltage produced from the wind turbine is enough to run the motor. The figure 12 shows that the pictorial representation of APG.

Figure 12: Automatic Power Generating vehicle

During the electricity demand over the countries these Automatic Power generating vehicle is best suitable. The minimum maximum value obtained from the cfd analysis were shown in table 1.

Table 1: Minimum maximum table

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
GG Av Static Pressure 1	[Pa]	101333.125	101333.116	101333.0234	101333.1724	100	Yes	0.028825957	0.274925785
GG Av Total Pressure 1	[Pa]	101380.248	101380.277	101380.1578	101380.4576	100	Yes	0.012291044	0.094372488
GG Av Dynamic Pressure 1	[Pa]	47.11309647	47.15116465	46.98380315	47.42419602	100	Yes	0.035469023	0.291256501
GG Av Temperature (Fluid)	[K]	300.0007761	300.0008174	300.0007242	300.0010395	100	Yes	5.22058E-05	0.000100279
GG Av Static Pressure 2	[Pa]	101333.125	101333.116	101333.0234	101333.1724	100	Yes	0.028825957	0.274925785
GG Av Total Pressure 2	[Pa]	101380.248	101380.277	101380.1578	101380.4576	100	Yes	0.012291044	0.094372488
GG Av Dynamic Pressure 2	[Pa]	47.11309647	47.15116465	46.98380315	47.42419602	100	Yes	0.035469023	0.291256501
GG Av Temperature (Fluid)	[K]	300.0007761	300.0008174	300.0007242	300.0010395	100	Yes	5.22058E-05	0.000100279
GG Av Static Pressure 3	[Pa]	101333.125	101333.116	101333.0234	101333.1724	100	Yes	0.028825957	0.274925785
GG Av Total Pressure 3	[Pa]	101380.248	101380.277	101380.1578	101380.4576	100	Yes	0.012291044	0.094372488
GG Av Dynamic Pressure 3	[Pa]	47.11309647	47.15116465	46.98380315	47.42419602	100	Yes	0.035469023	0.291256501
GG Av Temperature (Fluid)	[K]	300.0007761	300.0008174	300.0007242	300.0010395	100	Yes	5.22058E-05	0.000100279
GG Av Density 1	[kg/m^3]	1.176512645	1.176512376	1.176510746	1.176513279	100	Yes	5.24647E-07	3.30557E-06
GG Mass Flow Rate 1	[kg/s]	-0.004725705	-0.004723178	-0.004726494	-0.004715089	100	Yes	9.30682E-07	0.001
GG Av Velocity 1	[m/s]	8.280967137	8.285265814	8.247290972	8.33900173	100	Yes	0.007851553	0.0392417
GG Av Mach Number 1	[ ]	0.023857206	0.02386959	0.023760187	0.024024401	100	Yes	2.26198E-05	0.000113055
GG Av Turbulence Length 1	[m]	0.001141171	0.001140964	0.001124979	0.001154522	100	Yes	6.57173E-06	1.20517E-05
GG Av Turbulence Intensity	[%]	1.686614925	1.701421195	1.611344559	1.766816058	100	Yes	0.10340098	0.104270881
GG Av Turbulent Energy 1	[J/kg]	0.030076706	0.030335704	0.02999543	0.030591817	100	Yes	0.000596387	0.001931501
GG Av Turbulent Dissipatio	[W/kg]	2.665267036	2.683633708	2.665267036	2.701358806	100	Yes	0.03609177	0.127355289
GG Normal Force 1	[N]	1.213853037	1.212142754	1.202823456	1.216707725	100	Yes	0.003545019	0.231991389

Iterations: 207
Analysis interval: 31

7. CONCLUSION

This paper discussed a Automatic Power Generating vehicle which generates their power by itself while running condition. The prototype of the vehicle developed has very good functionality. The modified electric vehicle can be switched from electric vehicle mode to power generating mode. During electric vehicle mode of operation the motor speed is fixed at 380 RPM (12v, 16ah) which maximum speed is 33km/hr. So the power generated at 33km/hr which is 12v and 4ah. The decrease in ah is not affect the speed of motor it only affect the torque developed in the motor. So APG vehicle is best suitable for urbal and rural area driving.

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