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V2G Based Solar Electric Vehicle Drive Train

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ABSTRACT: In India, after 2030 all conventional vehicles are going to be replaced with electric vehicles. This work aims at to make an electric vehicle and also bringing Vehicle to Grid (V2G) concept to support the grid during different requirements. This paper proposes a proper method for the certain calculation of the V2G based solar powered electric vehicle transmission unit. Based on the vehicle's desired performances, the electric motor power, torque and output can be calculated. The liability of the mechanical parameters such as road load resistance, gear ratio, weight of the car, tractive efforts, wheel diameter, motor gear box coupling efficiency and many more plays a very decisive role in the calculation consideration of electrical vehicle.

KEYWORDS:V2G concept, Tractive efforts, Gear ratio, Motor gearbox coupling efficiency, Gradeability.

I.INTRODUCTION

The Electric vehicle (EV) is very similar to the road vehicle which involves with electric propulsion. Greenhouse gas emission from transportation is one of the major environmental issues and its emission rate is increasing at faster rate. So solar power for transportation can solve this problem. The aim of proposed work is to contribute a technology that supports Green energy. Electric vehicles are at least twice as efficient as conventional vehicle. However, the motors have different characteristics such as method of operation, rating, size, variation in speed and working principle. To obtain desirable characteristics the torque requirement from the vehicle is same.

II.V2G CONCEPT

The energy demand of Kerala is rising day by day and generation of electricity is not sufficient to meet this demand. So that we are forced to buy energy from our neighbouringstates. As a consequence, the price of energy rises steeply.Our aim is to reduce this energy demand using a method that results in zero emission and at lower energy prices. We are planning to make an electric vehicle with vehicle to grid concept (V2G) such that energy demand during the peak hours can be reduced to a great extend. During day time, the vehicle gets charged through solar. There is also an option to charge the vehicle from grid termed as grid to vehicle concept(G2V). Meanwhile during peak time, as demand in grid increases, the vehicle can provide energy to required loads.So our product can acts as both an electric vehicle and an energy provider thereby reducing the peak demand and energy price.

A.MOTOR

We are using 1kW 48V BLDC motor with 12:1 gear ratio.

B. BATTERY

We are using 12 volt 60Ah Lead acid battery for Direct current. Four batteries connected in series to get 48 volt DC voltage. Our specification – 48 volt, 60Ah.

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C. INVERTER

We are using 12V, 300VA (VSI) inverter. It convert 12V DC into 240 V AC for house hold appliance. We are makes an external source of energy when the vehicle is in standby condition. It provide protection for automatic shutdown for DC over voltage, overload, over temperature and AC over frequency.

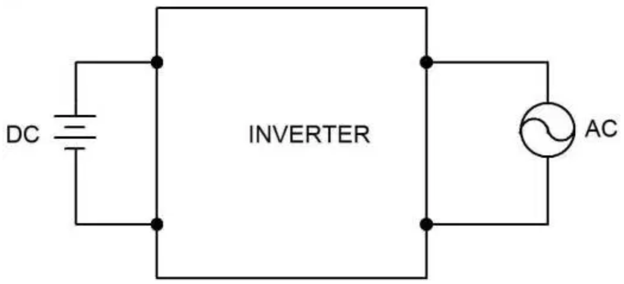

Fig 1. Block Diagram

III. MOTOR AND DRIVE

A. BLDC MOTOR

The brushless DC (BLDC) motor is becoming increasingly popular in sectors such as automotive (particularly electric vehicles (EV)), HVAC, white goodsand industrial because it does away with the mechanical commutator used in traditional motors, replacing it with an electronic device that improves the reliability and durability of the unit. Another advantage of a BLDC motor is that it can be made smaller and lighter than a brush type with the same power output, making the former suitable for applications where space is tight. Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors), or synchronous DC motors, are synchronous motors powered by DC electricity via an inverter or switching power supply which produces an AC electric current to drive each phase of the motor via a closed loop controller. The controller provides pulses of current to the motor windings that control the speed and torque of the motor.The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor.

Fig 2 .BLDC Motor

B. HALL EFFECT SENSOR

A hall effect sensor is a device that is used to measure the magnitude of a magnetic field. Its output voltage is directly proportional to the magnetic field strength through it. They are used for proximity sensing, positioning, speed detection and current sensing application. Speed in a BLDC motor is directly proportional to the voltage applied to the stator. The sensor that are used to detect the position of rotor are also used to detect speed by measuring the time it takes for sensor to switch. BLDC motor typically have 3 hall effect sensor mounted either to the stator or to the rotor. Since the commutation of BLDC motor is controlled electronically, the stator windings should be energized in sequence in order

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to rotate the motor. Before energizing a particular stator winding, acknowledgement of stator position is necessary. So the hall effect sensor embedded in stator senses the rotor position.

C. CONTROLLER

A motor controller is a device or group of devices that serves to govern in some predetermined manner for the performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and faults. Here the primary function is convert 48V DC to a controlled three phase supply.

Fig 3. BLDC Motor Controller

It enables the electronic commutation of motor. The controller generally controls all the functions of the motor such as speed control, changing the direction, controller may be of microcontroller based or a combination of logic circuit. The brushes of BLDC motor controller transmits the power to rotor windings which, when energized, turn in a fixed magnetic field. By varying the three phase output to motor windings the controller controls speed and other functions.

D. FOOT THROTTLE

A good quality accelerator is hard to find. Apart from our other hall effect foot throttle(the all metal one) ,it has been one of the more difficult part for as to source as they tend to only find use in more specialized fields. This unit is made from a heavy duty injection molded plastic coupled together with a heavy steel base plate and high tensile steel springs. It is held together by heavy steel locking pins at each end on both swivel points and is supplied with a 1.3m cable length with a standard hall effect connector. The length of wire is covered with a good quality semi rigid plastic sheet which allows the cable to bend without kinking and breaking the wires, so it is suitable for use in high vibration or movement applications.The throttle is used for controlling the acceleration of motor. It may be varistor or electromagnetic type. It consist of 3 output terminal, they are a +5V from the controller, variable output to the controller and the ground to the controller.The throttle actually varies the +5V from the controller in between 0-5V respective of the pressure we applied on it. By varying the output to the controller, the controller varies the three phase frequency controlled output and thereby controls the speed.The term throttle has come to refer, informally, to any mechanism by which the power or speed of an engine is regulated.

Fig 4. Foot Throttle

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The term throttle has come to refer, informally, to any mechanism by which the power or speed of an engine is regulated. The accelerator pedal motion is communicated via the throttle cable, which is mechanically connected to the throttle linkages which in turn rotate the throttle plate. When the driver presses on accelerator pedal the throttle plate rotates within the throttle body, opening the throttle passage to allow more air into the intake manifold, immediately drawn inside by its vacuum. Usually a sensor measures the change and communicates it to the ECU.

Technical specifications

- Input voltage : 5V
- Output : 0.8 - 4.2V
- Output rated load current : 10mA
- Output type : Voltage
- Pedal rotation angle : 15 degrees
- Maximum load current : 10mA
- Pedal starting force : 2kg ± 0.6kg
- Pedal stop force : 3.6kg ± 0.6

IV.GEAR TRANSMISSION

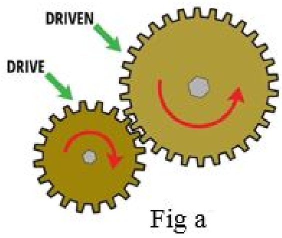

Fig a

The gear directly coupled into the motor is called Drive wheel and the gear connected to the vehicles final wheel transmission is called Driven wheel. Normally the electric vehicles have different set of gear ratio. Here we are using 1:12 gear ratio. Fig b, Fig c and Fig d represents the coupling of the gear.

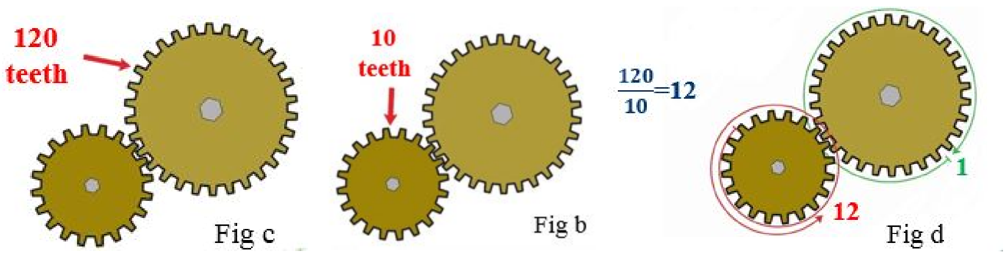

Fig c Fig b Fig d

According to our requirement, we are choose 1:12 gear ratio. If N_1 is the rpm of the 1st gear and N_2 is the rpm of 2nd gear.

$$\frac{N_2}{N_1} = \frac{1}{12} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

We are using 3000 rpm BLDC motor. To find out the speed of the vehicle by using the equation,

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$$k = d * r * 0.001885. \ldots \ldots \ldots (4.2)$$

Where,
k = Kilometer Per Hour(km/hr)
d = Wheel Diameter(cm)
r = Revolution Per Minute(RPM)

Gear transmission is used for control the speed and torque of the motor according to our requirement. The torque and speed are inversely proportional. In low speed we have get high torque. The torque speed relation is given below,

$$P = T * \omega. \ldots \ldots \ldots \ldots (4.3)$$

$$\omega = \frac{2 * \pi * n}{60} \ldots \ldots \ldots \ldots (4.4)$$

Where,
P = Power in Kilowatt
T = Torque in Nm
ω = Angular velocity
N = rpm

Fig 5. BLDC Motor, Gear Box and Differential

V.BASIC TERMS AND FORMULAS

A. TOTAL TRACTIVE EFFORTS(TTE)
Tractive efforts is defined as the tractive force of a vehicle exerts on a surface or the amount of tractive force is parallel to the direction of motor.

B. TRACTION OR TRACTIVE FORCE
Tractive force is the force used for generate the variation between tangential surface and body. Tractive force is nothing but the net force present at wheels.
To calculate this type of force, use this formula:

$$\text{Tractive Force} = \frac{(\text{Motor torque} \times \text{gear ratio} \times \text{Motor efficiency})}{\text{Radius of wheel}}$$

$$= \frac{Tm \times G \times \eta t}{Rr} \ldots \ldots \ldots \ldots \ldots (5.1)$$

Where,
Tm: Torque at the motor

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ηt: Transmission(Motor) efficiency
G: Gear ratio
Rr: Rolling radius of wheel

C. ROAD LOAD RESISTANCE
ROLLING RESISTANCE
Rolling resistance is the resistive force of vehicle which opposes the rolling of the wheels, which is caused due to non-elastic effects at the tire-road surface. it is calculated by the formula:

$$Rr = KW\cos\theta \, . \, . \, . \, . \, . \, . \, . \, (5.2)$$

Where,
K: Coefficient of rolling resistance
W: Vehicle weight in N
θ: Inclination angle

AERODYNAMIC RESISTANCE
It is the resistive force which opposes the motion of vehicle through the air.

$$AR = \frac{1}{2}\rho * V^2 * Cd \, . \, . \, . \, . \, . \, . \, . \, . \, . \, (5.3)$$

Where,
ρ: Density of air
Cd: Drag coefficient
A: Frontal projected area
V: velocity in m/s

GRADIENT RESISTANCE
The angle of inclination of the road surface is proportional to a weight of component which acts against the direction of motion.

$$Rg = W * \sin\theta . \, . \, . \, . \, . \, . \, . \, . \, . \, . \, . \, (5.4)$$

D. ACCELERATION
It is the rate of change of velocity of an object with respect to time. It is the ability of vehicle that how fast or quickly it reaches the maximum speed with respect to time pull force is more than road load resistance but lesser than tractive force

E. GRADEABILITY
The term gradeability refers when the driver should be relaxed while the vehicle moves on slop or inclination. The total pull force requires to move a vehicle in a vertical direction is generally refers to gradeability. It is known as the grade angle that the electric vehicle can move with a constant speed.

$$G = \frac{100 * T * R}{r - GVW} - RR . \, . \, . \, . \, . \, . \, . \, . \, (5.5)$$

Where,
100 = A constant expression
T = Torque of motor
R = Total gear reduction in both axle and transmission
r = Rolling radius of loaded driving vehicle
GVW = Gross Vehicle Weight
RR = Rolling Resistance in percentage

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VI.POWER TRAIN CALCULATION

A.RELATION BETWEEN TORQUE, SPEED AND POWER

$$P = \frac{2\pi NT}{60} \text{. . . . . (6.1)}$$

Where,
N is the speed in RPM
T is the motor torque in N-M
P is the power in KW.
In our specification
N = 3000 rpm
P = 1000 KW

$$T = \frac{1000*60}{2\pi*3000} = 3.18 \text{ Nm. . . . . (6.2)}$$

B. EQUATION FOR RPM AT DIFFERENT STAGES OF TRANSMISSION

The output rpm of motor having 90% efficiency:
As motor is 90% efficient, N1 is given as

$$N_1 = \frac{90N}{100} = \frac{90*3000}{100} = 2700 \text{ rpm . . . . (6.3)}$$

N = Motor Speed in rpm = 3000 rpm

C. OUTPUT RPM OF GEARBOX

The output of the gearbox is given by the basic formula

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} ; N_2 = N_1 \frac{D_1}{D_2} \text{. . . . . (6.4)}$$

Where,
D2:D1 is gear ratio and is given as D2:D1 = 1: 12
1:12 is a gear ratio to be assumed for an electrical vehicle

$$N_2 = \frac{N_1}{12} = \frac{2700}{12} = 225 \text{ rpm. . . . . (6.5)}$$

Also considering 0.9 as reduction ratio in gearbox

$$N_3 = N_2 *0.9 = 225*0.9 = 203 \text{ rpm. . . (6.6)}$$

D. TORQUE AT THE WHEEL

$$Tw = \frac{60 *P}{2\pi N_3} = \frac{60*1000}{2\pi*203} = 47 \text{ Nm . . . . . (6.7)}$$

E. TOTAL TRACTIVE EFFORT(TTE)

Tractive force is nothing but the net force present at wheels.

$$\text{Tractive Force} = \frac{(\text{Motor torque} \times \text{gear ratio} \times \text{Motor efficiency})}{\text{Radius of wheel}}$$

$$= \frac{Tm \times G \times \eta t}{Rr} \text{. . . . . (6.8)}$$

Where,
Tm: Torque at the motor

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ηt: Transmission(Motor) efficiency
G: Gear ratio
Rr: Rolling radius of wheel

Our specifications
Tm= 3.18 Nm
ηt = 90%
G = 12
Rr = 0.2921 m

$$\frac{\mathrm{Tm} \times \mathrm{G} \times \eta\mathrm{t}}{\mathrm{Rr}} = \frac{3.18 * 12 * 0.9}{0.2921} = 117.57\ Nm$$

VII. BLDC MOTOR CHARACTERISTICS

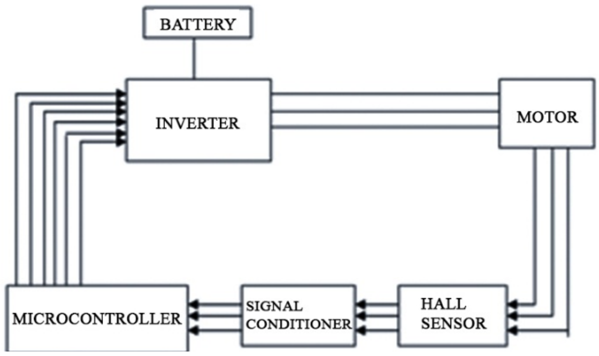

Fig 6. Closed loop Control

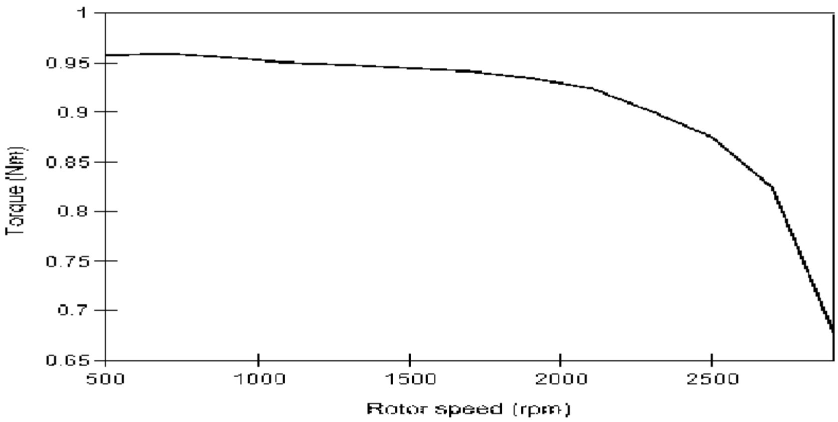

Fig 7. BLDC Motor Speed Torque Characteristics

VIII. FUTURE SCOPE

The world is quickly adopting to electric vehicles and in the next couple of decades, EVs are going to be more main stream than internal combustion vehicles. The government of India had a plan of converting the entire fleet of vehicles to fully electric by 2030, which is barely 12 years away..The electric vehicles are the future of our world.The efficiency and performance of an electric vehicle can be improved by adopting various methods.The fast charging stations can reduce the time of charging the vehicle.The replacement of batteries with super capacitors and ultra

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capacitors will increase the range of electric vehicle and reduce the range anxiety.The techniques like regenerative breaking will help us to recover the inertia during breaking and can be used for charging battery.By the help of these technologies used in the electric vehicle we can improve the entire system.

IX. EXPERIMENTAL RESULT

By considering the weight and required driving torque, we used a 1kW,3000 rpm,48 V BLDC motor.The battery used was 12 V,60Ah lead acid battery with solar and plug in charging method.The motor is coupled with a gear box of gear ratio 1:12 .

X. CONCLUSION

The project is mainly concentrated on motor and drive design for the solar based electric vehicle.We are designing a motor and drive for a vehicle weighing 150Kg.Motor is controlled by a 48V BLDC controller.The electrical energy supplied by four 12V,60Ah batteries connected in series.Vehicle can attain a maximum speed of 50 Kmph .The motor has a rated output power of 1000 watts and an input voltage of 48V.The rated torque is 30Nm.We are using transmission for the propulsion for improving efficiency, mileage and speed regulation.Overall cost of the BLDC motor with controller is lesser than the induction motor.

This work aims at contributing towards the application of electric vehicles and also bringing Vehicle to Grid (V2G) concept to support the grid during different requirements.Another speciality of our electric vehicle is thatthe vehicle will support another vehicle as a donour.Also by implementing V2G concept we can reduce the peak time load on grid.So in short we aims at a pollution less transportation and utilization of non-conventional energy.

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