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Permanent Magnet Brushless DC Motor coupled with rear Axle in Hybrid Car

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Abstract: - As the conventional energy resources are depleting there is an urgent need for switching to renewable energy resources as well as increasing its functionality. This paper proposes a design of coupling of brushless DC motor with a modified rear axle for a normal car. The Permanent magnet brushless DC motor is a high efficient in operation with high torque in range. The comparative investigation on the efficiency, weight, cost, cooling, maximum speed, and fault tolerance, safety, and reliability is carried out for switched reluctance motor, induction motor, permanent magnet blushless dc motor, and brushed dc motor drives, in order to find most appropriate electric motor drives for electric vehicle applications. The study shows permanent magnet brushless dc motor drives are the prior choice for electric vehicles. With ever-increasing concerns on our environment, there is a fast growing interest in electric vehicles (EVs) and hybrid EVs (HEVs) from automakers, governments, and customers. As electric drives are the core of both EVs and HEVs, it is a pressing need for researchers to develop advanced electric-drive systems. In this paper, an overview of permanent-magnet (PM) brushless(BL) drives for EVs and HEVs is presented, with emphasis on machine topologies, drive operations, and control strategies.

Key Words:— *Permanent magnet brushless ,DC motor hybrid EVs (HEVs), Electric vehicles (EVs).*

I. INTRODUCTION

A hybrid electric vehicle (HEV) is a type of hybrid vehicle that combines a conventional internal combustion engine (ICE) system with an electric propulsion system (hybrid vehicle drivetrain). The presence of the electric powertrain is intended to achieve either better fuel economy than a conventional vehicle or better performance. There is a variety of HEV types, and the degree to which each functions as an electric vehicle (EV) also varies. The most common form of HEV is the hybrid electric car, although hybrid electric trucks (pickups and tractors) and buses also exist. Modern HEVs make use of efficiency-improving technologies such as regenerative brakes which convert the vehicle's kinetic energy to electric energy, which is stored in a battery or super capacitor. Some varieties of HEV use an internal combustion engine to turn an electrical generator, which either recharges the vehicle's batteries or directly powers its electric drive motors; this combination is known as a motor–generator. Many HEVs reduce idle emissions by shutting down the engine at idle and restarting it when needed; this is known as a start-stop system. A hybrid-electric produces less tailpipe emissions than a compassrably sized gasoline car, since the hybrid's gasoline engine is usually smaller than that of a gasoline-powered vehicle. If the engine is not used to drive the car directly, it can be geared to run at maximum efficiency, further improving fuel economy. Types by degree of hybridization further information: Mild hybrid Full hybrid, sometimes also called a strong hybrid, is a vehicle that can run only on a combustion engine, only on an electric motor, or a combination of both. Ford's hybrid system, Toyota's Hybrid Synergy Drive and General Motors/Chrysler's Two-Mode Hybrid technologies are full hybrid systems. The Toyota Prius, Ford Escape Hybrid, and Ford Fusion Hybrid are examples of full hybrids, as these cars can be moved forward on battery power alone. A large, high-capacity battery pack is needed for battery-only operation. These vehicles have a split power path allowing greater flexibility in the drivetrain by interconverting mechanical and electrical power, at some cost in complexity. Mild hybrid is a vehicle that cannot be driven solely on its electric motor, because the electric motor does not have enough power to propel the vehicle on its own. Mild hybrids include only some of the features found in hybrid technology, and usually achieve limited fuel consumption savings, up to 15 percent in urban driving and 8 to 10 percent overall cycle. A mild hybrid is essentially a conventional vehicle with oversize starter motor, allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly and cleanly. The motor is often mounted between the engine and transmission, taking the place of the torque converter, and is used to supply additional propulsion energy when accelerating. Accessories can continue to run on electrical power while the gasoline engine is off, and as in other hybrid designs, the motor is used for regenerative braking to recapture energy. As compared to full hybrids, mild hybrids have smaller batteries and a smaller, weaker motor/generator, which allows manufacturers to reduce cost and weight. Honda's early hybrids including the first generation Insight used this design leveraging their reputation for design of small, efficient gasoline engines; their system is dubbed Integrated Motor Assist (IMA). Starting with the 2006 Civic Hybrid, the IMA system now can propel the vehicle solely on electric power during medium speed cruising. Due to their high efficiency and power density, high speed permanent magnet brushless machines are emerging as a key.

II. Classification Of Hybrids

A. Types by Power Train

Hybrid vehicle drivetrain Hybrid electric vehicles can be classified according to the way in which power is supplied to the drivetrain: In parallel hybrids, the ICE and the electric motor are both connected to the mechanical transmission and can simultaneously transmit power to drive the wheels, usually through a conventional transmission. Honda's Integrated Motor Assist (IMA) system as found in the Insight, Civic, Accord, as well as the GM Belted Alternator/Starter (BAS Hybrid) system found in the Chevrolet Malibu hybrids are examples of production parallel hybrids. The internal combustion engine of many parallel hybrids can also act as a generator for supplemental recharging. As of 2013, commercialized parallel hybrids use a full size combustion engine with a single, small (<20 kW) electric motor and small battery pack as the electric motor is designed to supplement the main engine, not to be the sole source of motive power from launch. But after 2015 parallel hybrids with over 50 kW are available, enabling electric driving at moderate acceleration. Parallel hybrids are more efficient than comparable non-hybrid vehicles especially during urban stop-and-go conditions where the electric motor is permitted to contribute and during highway operation. In series hybrids, only the electric motor drives the drivetrain, and a smaller ICE (also called range extender) works as a generator to power the electric motor or to recharge the batteries. They also usually have a larger battery pack than parallel hybrids, making them more expensive. Once the batteries are low, the small combustion engine can generate power at its optimum settings at all times, making them more efficient in extensive city driving. Power-split hybrids have the benefits of a combination of series and parallel characteristics. As a result, they are more efficient overall, because series hybrids tend to be more efficient at lower speeds and parallel tend to be more efficient at high speeds; however, the cost of power-split hybrid is higher than a pure parallel. Examples of power-split (referred to by some as "series-parallel") hybrid powertrains include 2007 models of Ford, General Motors, Lexus, Nissan, and Toyota. In each of the hybrids above it is common to user.

B. Types by Degree of Hybridization

Mild hybrid Full hybrid, sometimes also called a strong hybrid, is a vehicle that can run only on a combustion engine, only on an electric motor, or a combination of both. Ford's hybrid system, Toyota's Hybrid Synergy Drive and General Motors/Chrysler's Two Mode Hybrid technologies are full hybrid systems. The Toyota Prius, Ford Escape Hybrid, and Ford Fusion Hybrid are examples of full hybrids, as these cars can be moved forward on battery power alone. A large, high-capacity battery pack is needed for battery-only operation. These vehicles have a split power path allowing greater flexibility in the drivetrain by interconverting mechanical and electrical power, at some cost in complexity. Mild hybrid, is a vehicle that cannot be driven solely on its electric motor, because the electric motor does not have enough power to propel the vehicle on its own. Mild hybrids include only some of the features found in hybrid technology, and usually achieve limited fuel consumption savings, up to 15 percent in urban driving and 8 to 10 percent overall cycle. A mild hybrid is essentially a conventional vehicle with oversize starter motor, allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly and cleanly. The motor is often mounted between the engine and transmission, taking the place of the torque converter, and is used to supply additional opulsion energy when accelerating. Accessories can continue to run on electrical power while the gasoline engine is off, and as in other hybrid designs, the motor is used for regenerative braking to recapture energy. As compared to full hybrids, mild hybrids have smaller batteries and a smaller, weaker motor/generator, which allows manufacturers to reduce cost and weight.

C. Plug-In Hybrids (PHEVs)

Plug-in hybrid A plug-in hybrid electric vehicle(PHEV), also known as a plug-in hybrid, is a hybrid electric vehicle with rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source. A PHEV shares the characteristics of both a conventional hybrid electric vehicle, having an electric motor and an internal combustion engine; and of an all-electric vehicle, also having a plug to connect to the electrical grid. PHEVs have a much larger all-electric range as compared to conventional gasoline-electric hybrids, and also eliminate the "range anxiety" associated with all-electric vehicles, because the combustion engine works as a backup when the batteries are depleted.

D. Flex-Fuel Hybrid

In December 2018, Toyota do Brasil announced the development of the world's first commercial hybrid electric car with flex-fuel engine capable of running with electricity and ethanol fuel or gasoline. The flexible fuel hybrid technology was developed in partnership with several Brazilian federal universities, and a prototype was tested for six months using a Toyota Prius as development mule. Toyota announced plans to start series production of a flex hybrid electric car for the Brazilian market in the second half of 2019.

E. Heat Engine

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work. It is classified into two types,

a. External combustion engine
b. Internal combustion engine

F. External Combustion Engine

In this engine, the products of combustion of air and fuel transfer heat to a second fluid which is the working fluid of the cycle.

III. Literature Survey

An effective comparison of the performances of the four main electric propulsion systems, namely the dc motor, the induction motor (IM), the permanent magnet synchronous motor, and the switched reluctance motor. The main conclusion drawn by the proposed comparative study is that it is the cage IM that better fulfils the major requirements of the HEV electric propulsion. The operation of PMBLDC motors requires rotor-position sensing for controlling the winding currents. The sensor less control would need estimation of rotor position from the voltage and current signals, which are easily sensed.

IV. Block Diagram

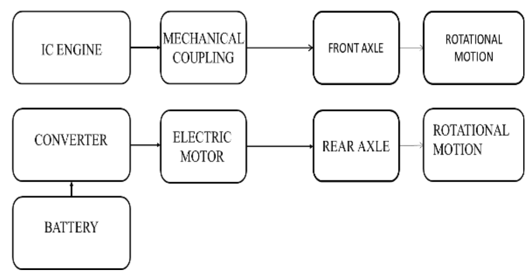


Fig.1. Block Diagram of Power Split-HEV

Brushless DC motors (BLDC):

This have been a much focused area for numerous motor manufacturers as these motors are increasingly the preferred choice in many applications, especially in the field of motor control technology. BLDC motors are superior to brushed DC motors in many ways, such as ability to operate at high speeds, high efficiency, and better heat dissipation. They are an indispensable part of modern drive technology, most commonly employed for actuating drives, machine tools, electric propulsion, robotics, computer peripherals and also for electrical power generation. With the development of sensor less technology besides digital control, these motors become so effective in terms of total system cost, size and reliability.

Rotor:

The rotor of a typical BLDC motor is made out of permanent magnets. Depending upon the application requirements, the number of poles in the rotor may vary. Increasing the number of poles does give better torque but at the cost of reducing the maximum possible speed. Another rotor parameter that impacts the maximum torque is the material used for the construction of permanent magnet; the higher the flux density of the material, the higher the torque.

Stator:

The BLDC motor stator is made out of laminated steel stacked up to carry the windings. Windings in a stator can be arranged in two patterns; i.e. a star pattern (Y) or delta pattern (Δ). The major difference between the two patterns is that the Y pattern gives high torque at low RPM and the Δ pattern gives low torque at low RPM. This is because in the Δ configuration, half of the voltage is applied across the winding that is not driven, thus increasing losses and, in turn, efficiency and torque. A slot less core has lower inductance, thus it can run at very high speeds. Because of the absence of teeth in the lamination stack, requirements for the cogging torque also go down, thus making them an ideal fit for low speeds too (when permanent magnets on rotor and tooth on the stator align with each other then, because of the interaction between the two, an undesirable cogging torque develops and causes ripples in speed). The main disadvantage of a slot less core is higher cost because it requires more winding to compensate for the larger air gap. Proper selection of the laminated steel and windings for the construction of stator are crucial to motor performance. An improper selection may lead to multiple problems during production.

A. Internal Combustion Engine (ICE):

In an internal combustion engine, the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. The force is applied typically to pistons, turbine blades, rotor or a nozzle. This force moves the component over a distance, transforming chemical energy into useful work. The first commercially successful internal combustion engine was created by Étienne Lenoir around 1859.

The first modern internal combustion engine was created in 1876 by Nikolaus Otto (see Otto engine). The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar four-stroke and two stroke piston engines, along with variants, such as the six-stroke piston engine and the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described. Firearms are also a form of internal combustion engine. In contrast, in external combustion engines, such as steam or Stirling engines, energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized water or even liquid sodium, heated in a boiler. ICEs are usually powered by energy-dense fuels such as gasoline or diesel fuel, liquids derived from fossil fuels.

B. Torque and Efficiency:

Torque and Efficiency:

For the study of electric motors, torque is a very important term. By definition, torque is the tendency of force to rotate an object about its axis.

Torque(Newton–Meters)= Force (Newton)*Distance(Meters)

Thus, to increase the torque, either force has to be increased – which requires stronger magnets or more current – or distance must be increased – for which bigger magnets will be required. Efficiency is critical for motor design because it determines the amount of power consumed. A higher efficiency motor will also require less material to generate the required torque.

Efficiency = Output power / Input power %.

Where,

Output Power = Torque *Angular Velocity, and

Input power = voltage * current.

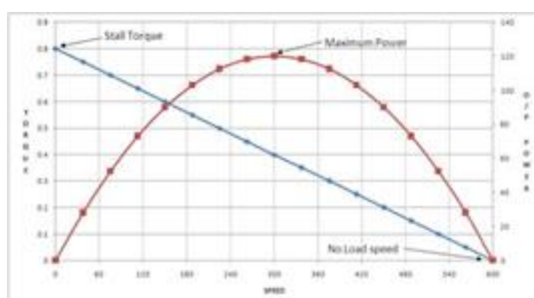


Fig.2. Speed-Torque-Power Curve

With an increase in speed, the torque reduces (considering the input power is constant).
Maximum power can be delivered when the speed is half of the "no load" speed and torque is half of the stall torque.

C. Advantages of BLDC Motor

BLDC motor has several advantages over conventional DC motors and some of these are

- It has no mechanical commutator and associated problems.
- High efficiency due to the use of permanent magnet rotor.
- High speed of operation even in loaded and unloaded conditions due to the absence of brushes that limits the speed.
- Smaller motor geometry and lighter in weight than both brushed type DC and induction AC motors.
- Long life as no inspection and maintenance is required for commutator system.
- Higher dynamic response due to low inertia and carrying windings in the stator
- Less electromagnetic interference.
- Quite operation (or low noise) due to absence of brushes

D. Disadvantages of PMBLDC MOTOR

- Electronic controller required control this motor is expensive.
- Not much availability of many integrated electronic control solutions, especially for tiny BLDC motors.
- Need of additional sensors.

E. Applications of Brushless DC Motors (BLDC)

- Computer hard drives and DVD/CD players.
- Electric vehicles, hybrid vehicles, and electric bicycles.
- Industrial robots, CNC machine tools, and simple belt driven systems.
- Washing machines, compressors and dryers.
- Fans, pumps and blowers

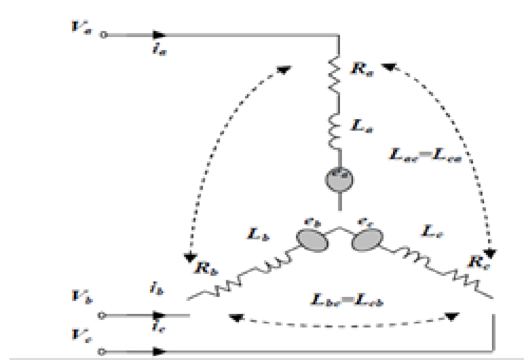
V. RESULT ANALYSIS

A. Mathematical (Dynamic) Model

State variable model is mathematical model which created from analysis of PMBLDC motor characteristic. From the state variable, the mathematical model [3,6] is converted by using [7,8] into discrete time form where trapezoidal algorithm is used. The trapezoidal is the preferred

algorithm because of its highest accuracy level and lowest simulation time. A combination of the forward and Backward-Euler algorithms generates the trapezoidal algorithm. Trapezoidal algorithm is a technique usually used to evaluate differential of bounded functions [9]. State variable model is also known as state-space model. Advantages of the state-space method over the existing methods are that no convergence, initialization, instability problems, and no restrictions such as the number and configuration of nonlinear elements. This model needs to be transformed to discrete time because differential equation in state-space can be solved easily. Developing the model of PMBLDC motor is to investigate torque behavior. When the input currents and motor flux

linkages are perfect, no torque pulsations are produced in the motor. However, imperfections in the currents arise due to finite commutation time while imperfections in the flux linkage can arise due to the phase spread, finite slot numbers and manufacturing tolerances [10]. Since both the magnet and the stainless steel retaining sleeves of the PMBLDC motor have high resistivity, rotor induced currents can be neglected and no damper windings are modeled. Because of the fact that the induced emfs are non-sinusoidal in this motor, phase variables are chosen for the model development. For a symmetrical windings and balanced system of PMBLDC motor.



B. Torque Ripple:

The biggest disadvantage of the BLDC motor drive configuration is the physical inability to generate the ideal rectangular pulse currents. As shown in the Fig. 2, the currents must make the required transitions instantaneously. In reality, the transitions require finite time. As a result, torque ripple is created at each commutation on point during the finite transition time of each phase current. This torque ripple is known as commutation torque ripple. In addition to significant commutation torque ripple, the BLDC motor configuration produces torque ripple whenever the back-emf or current shapes deviate from their ideal characteristics shown in Fig. 2. Because torque ripple is difficult to eliminate in the BLDC motor configuration, it is seldom used in applications where minimum torque ripple is required. However, in velocity applications such as fans and pumps where motor speed and inertia are sufficiently high, torque ripple has little affect because of the inherent filtering provided by the inertia.

C. Torque Production

The back-emf and the required currents in order to produce constant torque are shown in Fig. 2 in an ideal machine. That the torque is given by the product of the back-emf and stator current waveform divided by the speed. The back-emf divided by the speed is a constant and represents the flux linkage λ which has the same waveform as the back-emf. The flux linkage is horizontal (constant) for 1200 and for constant torque, it is necessary to supply a rectangular shaped current to the phase during this period. When the flux linkage is negative, a negative current is needed in order to produce constant positive torque. In addition, at any given instant, only two phases conduct current with the phase carrying the

VI. Conclusion

The present circumstances in electrical engineering are in a diversified approach. Brushless dc motors are more formal usage in high-production applications since of their higher ability using low inertia machines, higher torque in low-speed range, high power density, low Maintenance and less rumor than other motors. In this paper BLDC motor mathematical model is improved. Finally, the achievement of BLDC motor is analyzed by using Matlab/Simulink and Modelling results are instant. The parameters of BLDC motor instant a very essential factor in sketch of the BLDC motor drive system, so it is necessary to predict the exact values of all the parameters, which is resolved by the waveforms. In future IOT method can be implanted instead of using MATLAB/SIMULINK for better analyzing the performance of BLDC motor.

VII. Future Scope

Due to increasing demand in fuel consumption in the field of automobiles and for the betterment for the future there leads a greater demand in electric vehicles and this pays a greater efficient way of transportation.

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