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Selection of Drive System for Electric Vehicle

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ABSTRACT

In daily life travelling become vital for human being. Time taken for travelling should be less and also it should be economical and easily available. The growing use of travelling vehicles has increased the problem of air pollution, global warming issue and increased use of petroleum. Transportation accounts for about 24% of India's carbon emissions and is a major source for air pollution in several cities across the country. Electrification of transportation is essential for clean air in cities. The awareness of human against energetic and environmental problems is in need of the research in alternative solutions for the automotive field i.e. multiple fuelling, electrification and hybridization. Electric vehicles in India are having growing demand and in future electric or hybrid vehicles with electricity as option will take over in India. Currently we are using different types of drive systems for electric vehicles. This paper focus on discussion about different types of drive systems (motors) used in electric vehicle with their performance, limitations, comparison of different types of drive systems and selection of suitable drive system to improve performance of electric vehicle.

Keywords: *Electric vehicle, Motor, drive system, Switched reluctance motor.*

1.INTRODUCTION

In A vehicle propelled by an electric motor, rather than a traditional petrol or diesel engine is called as electric vehicle. The electric motor is powered by rechargeable batteries that can be charged using household mains electricity via an electric vehicle charge point at home or at a more powerful electric vehicle charge station at work or in the street. Battery electric vehicles use electricity, which is stored in a battery pack to power an electric motor and turn the wheels.
Electrical vehicles are classified as follow: [11]

i) Hybrid Electric Vehicle (HEV): In this type of vehicle, ICE and electric motor combined within drive train. Electric motor supports to ICE for the purpose of fuel economy/electric drive. Vehicle is either propelled by IC engine or electric drive.
ii) Plug-in Hybrid Electric Vehicle (PHEV): PHEV is having battery of larger size as compared to that of HEV and it allows recharging of battery through charging stations or home-outlets. ICE can be used produce the electricity for electric drive directly or to recharge the battery. If battery is charged fully, it can be operated in fully electric mode.
iii) Full Electric Vehicle (FEV): FEV runs simply on electric drive system. Batteries of this vehicle are of larger size and can be recharged at charging station or at home. FEV. act as zero-emission vehicles.

2.NEED OF ELECTRIC VEHICLE

Electric vehicles become popular in less time because of following advantages:

- Battery Electric Vehicle (BEV) is having very few moving parts as compared to that of in conventional gasoline-powered vehicle.
- Electric Vehicles are environment friendly because these vehicles don't emit smoke. [2]
- These vehicles are not having need for liquid fuels or oil changes. [2]
- Electricity is very cheaper (more than 10 times) than fossil fuels for same power extraction in India.[2]
- Maintenance cost of electric vehicles is negligible when compared to IC Engine vehicles. [2]
- In India there are no big fossil fuel sources, so we have to import petroleum oils continuously. [2]
- As per scientific research, all the fossil fuels will be exhausted by 35-40 years. [2]
- Petrol prices are highest in India itself. [2]
- EV's have a better emissions profile than internal combustion vehicle. [2]
- EV's helps to reduce effect on environment and climate change by fossil fuel used by conventional vehicles
- Electric motors are not having requirement of any conventional fuel because those are powered by rechargeable batteries.
- EV's are having silent operation [11]
- If war is declared against Islamic Nations for any reason, then supply of petroleum will be stopped. [2]
- There are fast growing transportation power requirement problems in India.[2]
- Electric vehicles are not having problem of acceleration and speed of the vehicle because whatever speed and acceleration is required, it can be obtained by increasing the power of the electric motor.[2]

3.GOVERNMENT INITIATIVE IN INDIA

Government of India is going to promote the mass adoption of electric vehicles through the FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) scheme. As per Society of Manufacturers of Electric Vehicles, total EV sales figure in India are 22000

for FY 2015-16, 25000 for FY 2016-17 and 56000 for FY 2017-18.As per the information on official website of FAME-India scheme, total 278704 number of electric vehicles sold up to April-2019 ,total 278546 number of incentives claimed and total incentive amount is Rs.3433318600. [17]

4.CHALLENGES OR PROBLEMS OF ELECTRIC VEHICLES

Many manufacturers responded positively to government scheme but in reality, end-users are not satisfied with Electric vehicle performance. Electric vehicles are facing following problems:

- Batteries are too costly.[2]
- Higher cost of EV which depends mainly on EV Battery and the range of battery cycle life [3]
- Frequent recharging is a major drawback. [2]
- Recharging time is high and waiting for recharging is a big pain. [2]
- Life of batteries. [2]
- Need of testing and improvement of performance of batteries.
- Need of design of motors with low cost, high acceleration, low weight, high efficiency-high torque at low speeds.
- Design of intelligent controller

5.DRIVE SYSTEM FOR ELECTRIC VEHICLE

Full Electric vehicle consist of three main components as follow:

- Battery
- Electric Motor
- Motor controller

Electric motors are used to drive the Electric Vehicles. In electric vehicles, electric motor act as the sole propulsion unit while in Hybrid vehicles, electric motor and IC engine together in series or in parallel combination provide the propulsion power. Major advantage of electric motor over IC engine is that, its full torque at low speed and the instantaneous power rating can be two or three times the rated power of the motor. These characteristics helps to provide excellent acceleration of vehicle with a nominally rated motor.

Requirement of EV's on Electric Motor Drives are as follow:[4]

1) High instant power and a high-power density

2)High torque at low speed for starting and climbing, as well as a high power at high speed for cruising

3) Very wide speed range with constant-power region;

4) Fast torque response

5) High efficiency over the wide speed range with constant torque and constant power regions

6)High efficiency for regenerative braking

7) Downsizing, weight reduction, and lower moment of inertia

8) High reliability and robustness for various vehicle operating conditions

9) Reasonable cost

10) Fault tolerance

11) Suppression of electromagnetic interface (EMI) of motor controllers.

12) Wide speed control range

Major electric motor with their advantages and limitations are discussed below:

INDUCTION MOTOR:

Most of the heavy electric vehicles use three phase induction motors. The most famous and most selling electric car in India that is REVA (now MAHINDA REVA) uses AC 3 Phase Induction motors. Induction motor drives are best suited because of their following advantages:

Advantages:

- Simple Construction [5]
- Low cost [5]
- High speed
- High reliability [4]
- Low torque ripple/noise [5]
- Established converter/manufacturing technology [5]
- Absence of position sensors [5]
- Ability to operate in hostile environment [4]
- The absence of brush friction helps the motors to increase the maximum speed limit, and the higher speed rating helps to develop high output. [4]

Limitations:

- Use of three phase drive unit means that the control mechanism is more complicated than that are employed for DC dives [4]
- The controllers of induction motors are at higher cost than the ones of DC motors [4]
- The presence of a breakdown torque limits its extended constant-power [4]
- Any attempt to operate the motor at the maximum current beyond this speed will stall the motor.[4]
- Extended speed range operation beyond base speed is followed by weakening of flux, once the motor has reached its rated power capability.[6]

Apart from above limitations, following two development helped engineers to use Induction motor and Synchronous motor:

i)Development of Large-scale integrated LSI circuits and powerful devices i.e. IGBT (Insulated Gate Bipolar Transistor) made numerical control very popular and also made design of more compact inverters possible.

ii) Power density of Induction motors have been increased because of development of permanent magnets using rare earth metals. It also made possible to obtain high torque from compact units.

PERMANENT MAGNET SYNCHRONOUS MOTORS [4]

Permanent Magnet Synchronous Motors are considered useful for such vehicles that have to start and stop very often in a slow traffic in cities, because of high efficiency at low speeds. It is possible to increase the power density of motors by using high magnetic flux density permanent magnets.

BRUSHED DC MOTOR

Initially DC motors were often used for driving a vehicle because we could use direct current supplied from batteries without conversion. But afterwards due to problem of short life of brushes and heavy weight, induction motors were preferred.

Advantages:

- Brushed DC motor have simple controller.[7]

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- Ability to achieve high torque at low speed [4]
- Torque-speed characteristic suitable for traction requirement [4]
- Motor speed is adjusted through varying voltage.[4]

Limitations:

- Bulky construction [4]
- Lower efficiency than brushless DC motor [7]
- Low reliability [4]
- Higher need of maintenance due to the presence of the mechanical commutator and brushes. [4]
- Brushes results in increase in size of motor as well as it becomes difficult to mount the motor into the fork of bicycle [7]
- Heavy weight [4]
- Difficult to downsize [4]
- Expensive [4]
- Friction between brushes and commutator restricts the maximum motor speed.[4]

BRUSHLESS DC MOTOR (BLDC) MOTOR

As the name suggest BLDC motors does not have brushes and they are commuted electronically. BLDC motors are similar to PMAC machines having trapezoidal back-emf waveforms. The trapezoidal-shaped back-emf waveforms in these machines are due to the concentrated windings of the machine used instead of the sinusoidally distributed windings used in the PMSMs. The motor basically operates like a DC motor with its electronic controller hence the motor is called the brushless DC motor.

Advantages: [8,9,7,10,4]

BLDC motor is preferred because of

- No maintenance,
- High efficiency than brushed motor
- Low noise
- High starting torque
- High no-load speed
- Because of the absence of brushes, we don't find sparking in BLDC motor which increases the life of motor
- Easy Speed Control
- Longer life time
- High power density

Limitations:

- More complex controller than brushed DC motor [7]
- BLDC motors of high-power rating is not available easily [7] BLDC motor and its controller should be matched to each-other.
- Coupling the motor with the gearbox of the existing vehicle is tiresome and time consuming.
- Magnetic field produced by permanent magnets is not adjustable. There is need to of adjustable strength of magnetic field so that when electric vehicle requires maximum torque particularly at low speeds, magnetic field will be at maximum strength.
- Heavy weight [4]
- Magnet is expensive and motors are costly [4]
- PM BLDC motors are not having brushes to limit speed, but there is problem of fixing intensity of the magnet because it restricts the maximum speed if the motors are having an inner-rotor type construction.[7]
- BLDC motor is having limited field weakening capability. It is because of the presence of the PM field which can only be weakened through production of a stator field component opposing the rotor magnetic field. [4]

HUB MOTORS

Hub motors are preferred for light weight electric vehicle. It is the compact electric motor placed inside the wheel and is directly connected to the rotating wheel. It generates high torque at low rpm. [6]

SWITCHED RELUCTANCE MOTOR [4]

Switched reluctance motors are also hopeful though they are only a very few vehicle applications. SRM makes possible the gearless operation in Electric Vehicle propulsion. These motors are robust as well as very inexpensive. Switched reluctance motors have no windings, magnets or cages on the rotor which helps to increase the torque/inertia ratio and rotor operating temperature. [12]

Advantages:

- Simple and rugged construction
- Fault –tolerant operation
- Simple control than the field-oriented control of induction machines. [12]
- Outstanding torque-speed characteristic i.e. torque-speed characteristics of SRM drives is best suited to EV load characteristics
- It can inherently operate with an extremely long constant-power range.
- High speed operation capability
- High torque-inertia ratio
- It is having very simple rotor structure because of no windings, magnets, commutators or brushes.
- In addition, on the rotor makes SRM is relatively easy to cool and insensitive to high temperatures because of absence of magnetic sources (i.e., windings or permanent magnets) on the rotor.
- An extended range of 2-3 times the base speed is usually possible using an Appropriate control becomes possible to obtain an extended range of 2-3 times the base speed.
- Cost effective due to magnet less structure.
- Desirable flux controllable characteristics.

Limitations:

- They have to suffer from torque ripple [4]
- Acoustic noise. However, these are not potential problems that prohibit its use for EVs application. [4]
- Absence of Permanent magnets imposes the excitation burden on the stator windings and converters, which increases the KVA requirement of converter.[12]
- Compared with BLDC motors per-unit stator copper losses are higher and reduces the efficiency and torque per ampere. [12]
- Comparison of different major types of motors: [6]

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Type of Motor	Advantages	Limitations
Induction Motor	Simple construction, Low Maintenance, High reliability, Low cost, Ability of operating in hostile environment.	Higher cost of controller than that of DC motor, Presence of breakdown limits its extended constant power operation, Less efficiency than Permanent magnet and Switched Reluctance Motor
Switched Reluctance Motor	Simple control, Simple and rugged construction, Fault tolerant operation, Higher starting torque, It can operate with an extremely long distance power range,	Suffer from Torque ripple, Acoustic noise is present
Brushed DC Motor	High torque at low speed, Easy to control and suitable to propel the vehicle	Low efficiency, Bulky construction, High maintenance cost, Low reliability, Heavy and expensive
Brushless DC Motor	High efficiency and power density, Longer life, Higher starting torque, High power to volume ratio, no load speed is high, Small energy loss.	High initial cost, High magnet cost, suffer from field weakening capability, Poor high-speed capability, Mechanical strength of magnet is difficult

Table I given below lists weight factors in efficiency, weight, and cost of four types of motor drives, where 5 marks represent the highest efficiency, lowest weight, and lowest cost, respectively.[4]

Index	DC motor drives	IM drives	PM BLDC motor drives	SRM drives
Efficiency	2	4	5	4.5
Weight	2	4	4.5	5
Cost	5	4	3	4
Total	9	12	12.5	13.5

The given table indicates that DC motor drives are suitable to use in electric vehicles because of their low cost. PM BLDC motor drives are best choice because of good efficiency. SRM drives are having light weight among as compared to other four types of motor drives for EVs. SRM drives are the best choice for EVs if we the select the motor drives by considering three factors that are weight, efficiency and cost . SRM drives also have the superiority in the aspects of cooling, maximum speed, fault tolerance and reliability.

Nasser Hashemnia and Behzad Asaei [13] mentioned that permanent magnet and the brushless DC motors are more attractive in EV applications because of less pollution, less fuel consumption and more power to volume ratio. S. S. Bharatkar, Raju Yanamshetti, D. Chatterjee, A. K. Ganguli [14] concluded that BLDC motor and induction motor are best suited for electric vehicular applications but induction motor requires more complicated controller as compared to BLDC motor and induction motors are rugged and less costly as compared to BLDC motors.

Christopher H.T. Lee, James L. Kirtley, Jr. and M. Angle [16] discussed that Permanent Magnet motors suffers from the problem of high PM material costs and uncontrollable PM flux densities, hence magnet less switched reluctance (SR) motor drives which offer satisfactory cost-effectiveness and desirable flux controllability becomes more popular. However, because of double saliency with concentrated stator windings and singly excited structure, SRM has larger torque ripple and noise than conventional motors. Torque ripple should be minimized to avoid speed fluctuations at low speed.

6.CURRENT SCENARIO

Currently as per the study of technical catalogues of various electric vehicles in market, almost 90% of two and three wheelers are using BLDC motors and not having information about technical data sheets. Most of the motors are China make motors and having monopoly in market because of lack of technical awareness in India. Electric cars are using BLDC motors, three phase induction motors, permanent magnet (PM) motors. Switched Reluctance motors and brushless DC motors. Mostly motors are having requirement of magnets and hence having more cos There is need of more research work on motor having magnet less construction (i.e. SRM) to avoid problem in future because of lack of magnets.

8.CONCLUSION

Electric motor is major part of electric vehicle and plays an important role in driving the vehicle. Currently we are using different motors like induction motors, permanent magnet (PM) motors, Switched Reluctance motors and brushless DC motors etc. according to type and use of electric vehicle. Almost all Two and three-wheeler electric vehicles using BLDC motors available without technical data sheet and imported from china. Literature review concluded that there is no single motor suitable for all electric vehicle applications. Comparison of different motors for electric vehicle applications concluded that Switched reluctance motors are fulfilling almost all characteristics required for electric vehicle application and also having magnet less construction, but still it is having less use for this purpose. Switched reluctance motor having requirement of more research work for applications in electric vehicles.

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