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Electrical Motors for Electric Vehicle: An Overview

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ABSTRACT: An Electric Vehicle is a vehicle controlled by an electric motor which runs utilizing the power in the batteries. Electric Vehicle was fabricated soon after the first DC power motor was introduced and consequently has longer history. Pertaining to the growing innovation in Electric Vehicle system, it has turned out to be critical to get a far reaching comprehension of the criteria connected in determination of electric motors. It is observed that the use of electric motor has been varied from manufacture to manufacture. An expanding biological mindfulness and the lack of non-renewable energy source assets are solid motivations to grow progressively effective vehicles, with lower fuel utilization however without lessening driving solace indicate references by Thanh Anh Huynh et Al, 2018. Hence, various types of electric motors are currently utilized depending upon the power requirement. In this paper, authors provide a comparison of the most popular classes of electric motors being used over the period of time in context with the efficiency, power density, reliability, and size.

Keywords: Electric Vehicle, Power density, Efficiency, Reliability, Economy

I. INTRODUCTION

Electric power strength is the principle supply of electricity for impetus of an automobile in the electric vehicle technology. In electric powered cars, electrical strength is changed over into mechanical (rotational) strength. This rotational strength is carried out to a vehicle wheel through the best possible transmitting device which thus reasons drive. An electric vehicle motor gives the vital power to the vehicle drive, thereby making it the core of electric vehicles. Choice of the electric motor for an electric vehicle (EV) framework is a significant advance.

There are various electric vehicles available in market. These vehicles incorporate different motors for different functionalities. In this paper we will be specifically talking about the electric cars and the electric motor functions will be intended to drive the power train of the electric car. Electric motors are intended for their particular use in electric vehicles. Electric vehicles may ignite AC/DC motors according to configuration or relying upon the expected utilization of electric vehicle. There has been an immense research in the field of electric motors and various kinds of DC and AC motors have been created throughout the years.

This provides electric vehicle manufacturers an extensive variety of different electric motors to browse according to their necessity. Determination of a specific sort of an electric vehicle motor must be done prudently as motor qualities influence the general execution of a vehicle. Indicate references by T.Porselvi et Al., 2017.

Numerous criteria, for example, efficiency, cost, reliability, innovation and controllability must be contemplated. From the industrial application perspective, the most widely recognized motors utilized in the electric vehicles are: DC motors (shunt and series), permanent magnet synchronous motors, brushless DC motors and Squirrel Cage Induction Motors. A study of qualities of motors utilized in the EVs is displayed. As to extent of research, the rest of motor types including the induction, brushless DC and permanent magnet synchronous motors are extraordinarily prevailing. Indicate references by Dr. Sab Safi, 2015.

II. LITERATURE REVIEW

The paper presented by Thanh Anh Huynh, 2018 assesses the electromagnetic and thermal execution of a few traction motors for EVs. Two differing driving cycles are used for the examination of the motors, one for urban and the other for freeway driving. The electromagnetic execution to be assessed incorporates most prominent motor torque output for vehicle

accelerating speed and the flux weakening capacity with respect to wide operating extent under current and voltage limits.

Diverse sorts of electric motors are thought about by Swaraj Jape, Archana Thosar, 2017 based on specific parameters which ought to be thought about for choosing specific motor compose for EV application. Examination has been classified on a few parameters.

Gagandeep Luthra, 2017 has given accentuation towards electric motor drives that are indispensable parts of the electric vehicle. Here an exertion is arranged to look at changed kinds and the attributes of electric motor drives utilized in the electric vehicle.

Ahmed A. AbdElhafez et. Al., 2017 thinks about various machine techniques: traditional techniques as induction machine, permanent magnet and SR and DC machine techniques for High Speed Traction application. The correlation tends to various plan criteria for HST zone as cost, quality, proficiency, fault- torque, adaptation to non-critical failure capacity and power density.

The paper presented by Xiangdong Liu, et. Al., 2015 plays out a plan and relative investigation of IPMSMs with various rotor topologies. The exploration results demonstrate that V-shape PMs with the IPMSM is more satisfying with complete thought. Besides, the V-shape PMs with IPMSM is explored thoroughly.

Adrian Bălţăţanu and Leonard Marin Florea, 2013 have exhibited a near examination of electric motors that are right now utilized in vehicle drive frameworks.

Juan de Santiago et. Al., 2012 presents a basic survey of the drivelines in every Electric Vehicle (EVs). The motor methodologies with best contender to be utilized in EVs are displayed. The focal points and inconveniences of every electric motor compose are discussed through a framework point of view. A study of the electric motor utilized in business EVs is introduced. The review appears that auto makers are exceptionally moderate with regards to presenting new advances.

In this paper David G. Dorrell et. Al., 2010 depicts an exam concerning various motor outlines for a utility directed by way of the execution of a modern hybrid electric vehicle force. An induction motor and SRM are taken. Torque over a extensive pace run is needed (base velocity of 1500 rpm and extreme velocity of 6000 rpm) and the key point is that the aggregate torque in keeping with extent is utilized. The productivity is taken into consideration and proficiency plots are proposed.

Three distinctive electric traction motor drives are thought about by Gianmario Pellegrino, 2009 as far as yield power and proficiency at same drift measurements and inverter estimate. Induction motor, surface mounted permanent magnet (SPM) and internal permanent magnet (IPM) synchronous motor drives are examined, in context with typical vehicle determination.

Nasser Hashernnia and Behzad Asaei, 2008 have proposed that distinctive electric motors are considered to analyze their advantages and the most reasonable benefit is utilized in the electric vehicle (EV) applications. It is presumed that in spite of the fact that the induction motors innovation is of course more developed, the brushless DC and permanent magnet motors are more reasonable than others for the EV applications.

Ali Emadi et. Al., 2008 in this paper, has done a concise auditing the existing patterns and futuristic vehicle systems; also capacity of power electronic subsystems are depicted. The necessities of power electronic parts and electric motor drives for the fruitful advancement of these vehicles are likewise displayed.

The traction motor and the drive are utilized for the whole torque/speed operational range. In perspective of this reality, the paper presented by Sheldon S. Williamson et. Al, 2007 goes for displaying the inverter and motor efficiencies and losses for city and expressway driving schedules. An induction motor is utilized for a medium-sized power vehicle that is displayed in the Advanced Vehicle Simulate or Programming.

The paper presented by Z.Q.Zhu, 2007 surveys the relative benefits of inductance, SRM, and permanent magnet (PM) brushless machines and drives for application in electric and fuel cell vehicles, giving specific emphasis on PM brushless machines. Essential operational attributes and plan necessities, i.e. a high power/torque density, good productivity up wide working reach, and an extreme acceleration capacity, and in addition the most recent advancements, are depicted.

Mounir Zeraoulia et. Al., 2005 depicts a similar report permitting the choice of a proper electric drive framework for a parallel Hybrid Electric Vehicle (HEV). The investigation depends on a thorough audit of the best in class classification furthermore, on an incredible relationship of the displays of the four principle electric traction frameworks that are the dc motors, the induction motors, the permanent magnet synchronous motors, and the switched reluctance motors.

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Another five-phase, surface-infix permanent magnet brushless DC motor drive is presented by Jinyun Gan, et. Al. 2000. The motor drive points of interests of both the PM brushless dc drive and the dc series motor drive. The machine design and operation ethic are odd to a point that the magnetic field circulation and stable execution are dissected by the Finite-Element Method (FEM).

The reason for the paper presented by Khwaja M. Rahman and Mehrdad Ehsani, 1996 is to do an examination of a few most regularly utilized motors. In this investigation, inductance motor is observed as most appropriate for vehicle application. Permanent magnet motors, attributable to their prohibitive speed run, are observed to be not as reasonable for vehicle applications.

In the current EV improvement programs, both Induction Motor drives and permanent magnet brushless dc motor drives have discovered their pertinence. SRM engines have been contemplated as an inherent drive for electric vehicles. With the end goal to give a specialized help to creating and choosing impetus frameworks for futuristic electric vehicles, a similar investigation of AC drives for EVs is completed by L. Chang, 1994.

Different types of electric motors in regards to their number of poles are explained by John G.W. West, 1994. DC motors can have two, four or six poles contingent upon power yield and voltage and may have series or parallel field tracts, the latter being chopper controlled to get a scope of consistent power task by field debilitating up to around 4000 rpm most extreme speed. Inter-poles are for the most part utilized more than 10 kW yield.

Electric Motors Used In Electric Vehicles: An Overview

Today, majority of the electric cars are utilizing DC motors (4 kW and less power). Induction Motor is an exceptionally well known AC motor. A considerable lot of the advanced power EV (more than 5kW), utilize Induction Motors. Typically a vector drive is utilized to give torque and acceleration management. Directly, BLDC motor applications find in low power EV. Battery is a primary energy depository device in EV. As of late monstrous works are being accounted for in-battery improvement such as Li-particle is being presently utilized by new age of EV. Distinctive sort of motors show diverse qualities, making it vital to assess motors on some fundamental guidelines to pick a specific type of motor for an electric vehicle. Electric motors utilized in electric vehicle ought to possess imperative properties as in easy plan, high vitality, low upkeep cost, and great control. Motors generally utilized by electric vehicle producers are DC motors, Induction motors, Synchronous motors, Switched Reluctance motors and Permanent magnet brushless motors.

Table 1. Recent electric vehicles manufactured by top producers and the electric motors used

Product Name	Manufacturer	Year	Types of Motors used
Chevrolet Bolt EV	Chevrolet	2018	Permanent magnet motor
Focus Electric	Ford	2018	Permanent magnet motor
Mitsubishi i-MiEV ES	Mitsubishi		

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		2017
Permanent magnet Synchronous motor		
Nissan Leaf		
		Nissan
		2017
Permanent magnet Synchronous motor		
Volkswagen Golf Electric		
		Volkswagen
		2014
Permanent magnet motor		
Fiat 500e		
		Fiat
		2014
Permanent magnet motor		
Tesla Model S		
		Tesla
		2012
Induction motor		
Toyota Prius		
		Toyota
		1997
Permanent magnet motor		

Direct Current Motors

DC brushed motors can accomplish high torque at low velocities, shaping them to be appropriate for traction framework. However, poor power density is a downside of brushed DC motor for accounting in electric vehicles. DC brushless motors in the contrary provide better efficiency and have less maintenance. Indicate references by Swaraj Ravindra Jape and Archana Thosar, 2017. Truly, a DC (Direct Current) drive has been utilized conspicuously in the E.V's on account of the fact that they give speed control and perfect torque- speed necessities. Excursion motors for electric vehicles are aligned in two sections, switching motors and motors without commutation.

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Switching motors are essentially conventional DC motors, including, series and shunt excitation.

DC motors have been the subject of interest since long as a result of straightforward control and decoupling of motion and torque. Obviously, DC motors are still great contender for low power applications. Indicate references by Adrian Bălţăţanu, 2013. The commutator really goes about as a strong inverter; therefore, power electronic gadgets can be simple and economic. Indicate references by Nasser Hashernnia and Behzad Asaei, 2008.

Induction Motors

Three phase induction motors are generally utilized in electric vehicles in view of immense proficiency, great speed control and no commutator. 3-phase AC supply is associated with stator winding, thereby building up the rotating magnetic field. A.C Induction Motor Drive is ideally utilized in E.V. They are generally acknowledged these days due to being the commutator less compose. This accounts for their high reliability and a maintenance free task. Vector Control, which is one of the strategies to enhance the dynamic execution of the electric drive framework, can be applied here too. Vector Control gives an extensive variety of speed when compared with the base speed. Indicate references by Gagandeep Luthra, 2017. The device all in all is low accelerated, which diminishes unwavering quality and productivity. Indicate references by Ahmed A. AbdElhafez et. Al., 2010.

Permanent Magnet Synchronous (PMS) Motors

In synchronous motor, rotor pivots at synchronous speed. The rotor is energized from a DC supply, although the stator is associated with a 3-phase AC supply. PMS motors are also known as brushless AC motors. Regarding the vitality productivity, the most effective motor is the Permanent Magnet (PM) Brushless Motor Drive, pursued by Induction Motor having relatively comparable effectiveness. As a matter of fact, numerous vehicle makers, (for example, Nissan, Honda and Toyota) have effectively utilized these motors. These motors take in a few points of interest vise higher power thickness, higher proficiency what's more, the more powerful dissemination of warmth into the condition by Nasser Hashernnia and Behzad Asaei, 2008.

Permanent Magnet Brushless DC and AC Motors

One more sort of motors in options to utilize is the permanent magnet brushless dc motor. These are accessed by for all intents and purposes transforming the stator and rotor of the permanent magnet dc motor. Despite the fact that their setup is relative to the PMS motors, the BLDC motors are fed by an AC supply that is rectangular in nature as opposed to a sinusoidal supply. Another benefit of PM BLDC motors is their capacity to deliver a greater torque when contrasted with other motors at similar apex amount of current and voltage.

Switched Reluctance Motors (SRM)

SRMs utilize rotor position switches to invigorate the separate phase windings in sequence. A wide speed extend is conceivable. Rotor aims to proceed to a place of slightest reluctance in this way inducing torque. SRMs possess qualities viz., large beginning torque, & great innate adaptation to non-critical failure ability, thereby being reasonable for EV use. Activity in steady power is shaped conceivable by the phase progressing of current in stator conduction edge down to the point that covering between the progressive phases happens. Indicate references by Khwaja M. Rahman and Mehrdad Ehsani, 1996.

Comparative Analysis

The motive of this paper is to establish a correlation among the different electric motors used in electric cars by manufacturers and the factors that are considered to choose any of the motor to be best suited to them. The observation has been made on the specific parameters.

Power Density

Power Density is capacity-to-weight proportion of any electric motor and is normally computed utilizing the motor apex power. Power density for any motor is acquired by subdividing the apex power yield (in kW) by mass (in kg). Measurement unit of power density is kW/kg. PM motor appreciates most astounding power density and that is because of the nearness of high power density permanent magnets. The PMS machine delivers the highest power thickness; allowing a powerful machine and little substance in the confined establishment field of a car's motor cell by Thomas Finken et. Al., 2008. At that point PM brushless motors turn to be best pursued by IM and SRM both. Again, dc motors possess the most reduced power density. Indicate references by John G.W. West, 1994. PM is accepted to pick up the unmistakable attributes for EV application, as this

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machine has most elevated power density by AbdElhafez et. Al., 2017.

Energy Efficiency

Electric motor efficiency provides us connection among electrical and mechanical yield. Every single electric motor is generally intended to work at maximal efficiency at measured output. It is observed that BLDC motor gives the best energy efficiency (greater than 95%) followed by Induction Motors (greater than 90 %) Indicate references by Ahmed A. AbdElhafez, 2017. BLDC Motors have the most elevated efficiency in light of the fact of the nonappearance of rotor losses by Behzad Asaei, 2017. BLDC endeavors the greatest proficiency in a characterized velocity run as indicated in reference by Thomas Finken, 2008. As far as efficiency is concerned, the most productive motors are the PMBLDC motors. The induction being next, and then the SRMs possess nearly indistinguishable efficacy. Among every one of the motors utilized in the EVD framework, slightest effective are DC motors by Gaurav Nanda and Narayan C. Kar, 2006.

Reliability :

Presently comparing based on fidelity of the Electric Motor that is breakdowns and support ought to be least, utmost reliable ones are IM and SRM as indicated by Gagandeep Luthra, Gaurav Nanda and Narayan C. Kar, 2017. It is pursued by PM motors. Slightest dependable is the DC Motor. DC motor brushes and switches enter current in the armature, along these lines and hence are less decisive and ill-equipped for maintenance free task. Induction motors abide by the vital competitor due to their fidelity by A. Pennycott, 2013.

Cost Factor :

One of the vital difficulties in front of electric car producers is providing customer an EV belonging to same class as fuel vehicle yet inside a moderate cost. The ultimate to be utilized here are the IM pursued by the DC and SRM Motors. The induction engines are accepted by most manufacturers for the EV applications since they are economical. For large capacity motor, the price of DC motor is much higher than that of AC motor of same capacity. If two motors are with the same power capacity are compared, a higher speed, lower torque motor will cost less than a lower speed, higher torque motor. A motor with a higher operating voltage and lower current requirement will have a lower cost than that with lower operating voltage and higher current. Rotor design is probably the most important factor in making the DC motor more expensive as in reference by Nasser Hashernnia 2008. The least expensive AC motor may be of lower quality than available DC motors with high power rating as indicated by Dr. Sab Safi. PMDC motors contain permanent magnets which are not economic. The amount of magnet required is approximately proportional to the power. Induction motors contain only copper windings and iron pole pieces. Indicate references by David G. Dorrell, 2010.

III. THEORETICAL ANALYSIS

An attempt has been made to analyze five diverse electric motors for electric vehicle application on various paradigms. Relative assessments shall demonstrate the accompanying highlights

- DC motors are difficult to control, provide large torque at curtailed speeds yet possess major support cost, expansive structure, and deficient efficacy.
- BLDC motors have advanced power density, high productivity and small size, yet up keeping costs and controller expenses are huge.
- 3-phase IM give productivity over 91%. They have extreme fidelity, low power density and substantial area, ease furthermore, and average acceleration. BLDC motors and 3-phase IM are the two most preferred engines by EV makers.
- Synchronous machines have greater proficiency at lesser accelerations and enhance battery usage and propulsive extent. Synchronous motor is favoured wherever steady torque is needed.
- SRMs give an extraordinary option with motor/controller cost being very less, reliability, good efficiency, and adaptation to internal failure capacity.

Figure 1.1 Cumulative Correlations of IM, SRM and BLDC/BLAC Motors – Power Density

Figure 1.2 Cumulative Correlations of IM, SRM and BLDC/BLAC Motors – Efficiency

Figure 1.3 Cumulative Correlations of IM, SRM and BLDC/BLAC Motors – Reliability

Fig. 1.3 Cumulative Correlations of IM, SRM and BLD/BLAC Motors - Reliability

Figure 1.4 Cumulative Correlations of IM, SRM and BLDC/BLAC Motors – Cost Factor

IV. CONCLUSION

From the above attributes of the different motors utilized in electric vehicles, an endeavor has been made to give the readers a superior point of view of various motors to be utilized in the EVD frameworks.

To Sum up :

- The most generally utilized motors are the induction motors and the PM brushless motors.
- Induction motors are the savviest among the motors thought about.
- Taking efficiency into account, the utmost effective are the PM BLDC motors.
- DC motors have a standout amongst the most developed innovations as a great deal of research has been done on them throughout the years.

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