COMPARISON OF CHARACTERISTICS OF VARIOUS MOTOR DRIVES CURRENTLY USED IN ELECTRIC VEHICLE PROPULSION SYSTEM

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Abstract - With an all-time increasing demand of typical fossil fuel based vehicles, we are facing an imminent danger of our environment being more polluted in the coming years. Every year more vehicles are added to roads and the total number is believed to surpass 2.0 Billion by 2035. Around 25% of the total industrial CO2 is done by vehicular emissions alone which have been responsible for acid deposition, stratospheric ozone depletion, and climate change worldwide. In India, where the population is very large the vehicular pollution will pose a serious threat to the environment in coming years. E.V's (Electric Vehicle) offer one of the ways to prevent these vehicular emissions as these are popularly known as zero emission vehicles. This paper emphasis on the electric motor drives which are integral components of the electric vehicle. Here an effort has been made to compare different types and the characteristics of electric motor drives used in the electric vehicle. Also, a tabular presentation has been made to compare different types of electric motors used in electric vehicles. Hence, concluding with the classification of specific motor drives best suited for certain characteristics.

Index Terms - Electric Vehicles, Electric Motor Drive, Electric Motors, Fossil Fuel, Propulsion.

I. INTRODUCTION

An Electric Vehicle (EV) is a type of vehicle which employs the use of one or more electric motors for the propulsion. An electric vehicle may be powered by a collector system by electricity from off-vehicle sources or may be self-contained with a battery or generator to convert fuel to electricity [1]. An EV can be of various types and can be classified into categories like battery-powered, hybrid or fuel cell method EVs. Electric Motors give these an instant torque resulting in a quick and smooth acceleration. These cars are around 3 times more efficient than a normal internal combustion engine car. Some of the primary components of this vehicle are electric direct current (D.C) motor, electronic controller, and battery pack.
D.C motor is the primary mover of the vehicle. An electronic controller is normally known as the "brain" which actually controls the amount of power to be transmitted to the electric motor from the battery pack. The battery pack is the energy source of the vehicle, stored in the form of chemical energy and later converted into the electric energy. Typically, it takes around 4 to 5 hours for a battery pack to fully recharge. The battery pack, electronic controller and the electric motor must have low weight and high efficiency. Despite all of these advantages, there is still a whole pile of issues concerned with them like - selection of motors, cost, energy efficiency, range, etc. There are some issues concerned regarding its commercialization. In India, around 40 % of NOx and 25 % of CO2 emitted into the atmosphere is contributed by transportation sector alone. One of the options available to us is Electric or Hybrid Vehicle which popularly known as zero emission vehicles can make the air much cleaner and solve this environmental problem. The technology being talked out here is not something new as it marks its very existence since the 19th century. But due to some limitations in design and some of the conspiracies involved it eventually vanished from the market. The block diagram Fig 1. shows the basic working of an E.V.

Also, a lot of new developments and research work is taking place to improve the various energy sources like in nickel-based and lithium based batteries. Fuel cells or Water Cells are also gaining popularity as well. Fuel Cell vehicles just operate on a slightly different mechanism. Unlike the battery pack, there is a Hydrogen Storage Unit. A process termed as Electrolysis occurs where Hydrogen is converted into water (H2O) and Oxygen (O2) along with the creation of electricity. This electricity is supplied to electric motors which really move the car. And only water is generated as a waste product unlike Carbon Dioxide or Nitrous Oxides.

But the overall performance and efficiency of an E.V mostly depend on a type of motor drive used. E.V's actually use various types of motors based on their propulsion system like - DC, Permanent Magnet (PM), Induction, Switched Reluctance, Synchronous Reluctance motor drives.

In this paper, a classification has been made along with

the several characteristics of various motor drives. And a comparison has also been made for the various motors been used as part of the motor drive system in the E.V.

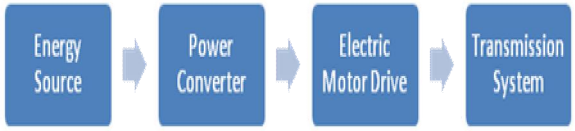

Fig. 1. Basic electric vehicle propulsion system.

II. VARIOUS TYPES OF ELECTRIC MOTOR DRIVES

The electric motor drive used in an E.V can't be compared with drives used in industrial plants or manufacturing processes because an E.V motor drive needs to face different circumstances like - frequent start/stop, usage in different environments. The comparison with a normal Industrial Drive would not be justified as the normal industrial drives operate at a rated speed. A motor drive consists of three components which are an electric motor, electronic controller, and a converter. To satisfy the need of an E.V the electric motor drive must have high torque generating capacity, high acceleration, and a high power intensity. Since an E.V need to run on any terrain and in harsh environments it must have high torque when operating at slow speeds with a high efficiency as well. Also, the efficiency must be high with respect to the regenerative braking capacity since the battery needs to be charged as well when dealing with harsh environments. The torque being generated also depends on the speed at which the E.V is generated. The maximum available torque at a time in an E.V depends inversely on the operational speed.

Some of the E.V models by different manufacturers are given in Table 1. along with the electric motor used. Since each company uses a different electric motor drive for its propulsion system accordingly.

Now, some of the technical specifications of electric vehicles like the Honda E.V Plus. It uses a permanent magnet brushless motor along with nickel-metal-hydride (NiMH) battery pack. It gives a maximum speed of around 80 mph and covers a range of 80-100 miles in a single charge. The General Motors (GM) EVI uses an induction motor with a maximum range of 55-95 miles in a single charge with a Lead Acid Battery and 75-130 when on Ni-MH battery pack. Mostly all the electric vehicles give same range and speed. But one of the major factors hindering their growth is the cost factor. Being so expensive these are generally non-affordable by a common man. It points to note and an urge to more Research and Development work on this technology.

Table 1: Different Models of Electric Vehicles (E.V).

Company	EV Model Name	EV Motor Used
General Motors	GM EV 1	Induction Motor
Honda	Honda EV Plus	PM Brushless Motor
Fiat	Fiat Panda Electra	Series DC Motor
Toyota	Toyota RAV 4	PM Brushless Motor
Mazda	Mazda Bongo	Shunt DC Motor

A. Direct Current (D.C) Drive

Historically, a D.C (Direct Current) drive has been used prominently in the E.V's because they provide simple speed control and ideal torque-speed requirements. The ideal torque suits the traction and terrain requirements in an E.V. But there is a little difference between the D.C and Permanent Magnet Drive. But if we replace the field winding and pole with high energy permanent magnet's, then we get permanent magnet dc motors which permit a considerable reduction in the stator diameter [2]. Owing to its low permeability the commutation can be considerably improved by a small reduction in the size or diameter of the armature.

Disadvantage:-

1. Their commutators and brushes make them less reliable. So, it is not suitable for a maintenance free function.

B. Alternating Current (A.C) Drive

With the recent advancements in the technology A.C, the motor drive is now much more preferred than a D.C drive.

Advantages:-

1. More Reliable.
2. Greater Efficiency
3. Less Maintenance
4. High Power Density

The A.C machines like induction motors and brushless permanent magnet motors do not have brushes and their rotors are robust because commutator and/or rings do not exist [3]. Since these above advantages are of the prime importance in an E.V propulsion system, the A.C Induction Motor Drive is now preferably used in E.V. Induction Motors are widely accepted nowadays because of being the commutatorless motor type. This accounts for their high reliability and a maintenance free operation. Vector Control, which is

one of the methods to improve the dynamic performance of the electric propulsion system, can be applied here as well. Briefly talking Vector Control provides a wide range of speed as compared to the base speed.

C. Permanent Magnet (P.M) Brushless A.C Motor Drive

These are also known as Permanent Magnet (P.M) Synchronous drive. This is also one of the electric motor drive widely used today. Along with all the drives, this drive gives a direct competition to the Induction Motor Drive.

Some of the reasons are:-

1. Magnetic Field excitement by using High Energy Permanent Magnets. That leads to an overall reduction in the weight and volume in a cross sectional area for a given value of the output power. This thus leads to a higher value of the power density.
2. Owing to no rotor copper losses, the efficiency is much higher in this electric motor drive.
3. Heat can be evenly distributed which rises in the Stator.
4. The reliability is quite high which reduces the chances of any mechanical breakdown, overheating, breakdown, etc.

D. Permanent Magnet (P.M) Brushless D.C Motor Drive

This type of motor drive is obtained by simply inverting the rotor and the stator of the permanent magnet D.C Motor. Even though the configuration of both of them is almost similar, the Permanent Magnet Brushless D.C Motors are fed by a rectangular A.C supply rather than a Sinusoidal supply in the case of the Permanent Magnet (P.M) Synchronous motors.

Advantages:-

1. Elimination of the Brushes.
2. Ability to produce a larger Torque than the others at the same values of Current and Voltage.
3. High Power Density.
4. Great Efficiency.

These above advantages make Permanent Magnet (P.M) Brushless D.C Motor Drive an ideal choice for being used in the Electric Vehicle Propulsion System.

E. Switched Reluctance Motor Drive

Although accepted quite late in the application of electric motor drive, this type of drive is supposed to have a tremendous potential in the field of electric vehicle propulsion system.

Advantages:-

1. Simple Construction
2. Very Low Manufacturing Cost
3. Outstanding Torque-Speed Characteristics for use in the E.V propulsion system.

But in spite of these advantages, there are many issues concerned with the use of this drive. Some of them are discussed below.

Disadvantages:-

1. The control mechanism is very complex because of the heavy saturation of the pole tips.
2. Noise and the Vibration problem.
3. Level of the efficiency and power density is quite low as compared with other drives.

III. COMPARISON OF DIFFERENT MOTORS DRIVES

In this sub-section of the paper, a comparison has been made amongst various electric motor drives used in an electric vehicle. The comparison has been made on the certain parameters like -energy efficiency, power density, the maturity of the technology, reliability, and the cost factor.

In terms of the energy efficiency, the most efficient motor drive is the Permanent Magnet (P.M) Brushless Motor Drive. Followed by Induction and Switched Reluctance Motor Drive both having almost similar efficiency but the least efficient being the D.C Motor Drive. In terms of the maturity of the technology for being used in the propulsion system, induction motor and dc motor drives score the highest and these two technologies are slightly more mature than that of permanent magnet brushless and switched reluctance motors [4,5]. One of the reasons being that a lot of Research and Development work has been done on the Induction and D.C Motor technology over the past.

Now comparing on the basis of reliability of the Electric Motor Drive i.e. breakdowns and maintenance should be minimum. The most reliable are the Induction and Switched Reluctance Motor Drive, followed by Permanent Magnet (P.M) Brushless Motor Drive. Again the least reliable is the Direct Current (D.C) Motor Drive. Considering the Power Density, the Permanent Magnet (P.M) Brushless Motors leads followed by Induction and Switched Reluctance motors. Here once again the D.C Motor Drive has the lowest Power Density.

One of the most important parameter and a characteristic considered while choosing a Motor Drive for Electric Vehicle Propulsion System is none other than the cost factor. It can be stated as the most

important factor because to keep a thing commercially viable the associated cost needs to be kept the minimum. The best to be used here are the Induction Motors followed by the D.C and Switched Reluctance Motor Drives.

IV. CLASSIFICATION OF DIFFERENT MOTORS USED IN ELECTRIC VEHICLES

As we know, Electric Vehicles (E.V) uses different types of motors in their propulsion system. Following is a tabular presentation of comparison of different types of Electric Motor.

1. The Table 2. gives a comparison between the BDC (Brush D.C Motor) & BLDC (Brushless D.C Motor).
2. The Table 3. gives a comparison between the D.C & A.C Induction Motor.

Table2: Comparison between BDC (Brush D.C Motor) & BLDC (Brushless D.C Motor)

S.No	Aspect	BDC Motor	BLDC Motor
1.	Maintenance Required	Periodic Maintenance needed	Less maintenance needed
2.	Speed/Torque	Moderately flat. At higher speeds, brush friction increases, thus reducing useful Torque.	Flat, enables operation at all speeds with rated load.
3.	Noise Generation	High	Low

Table 3: Comparison between D.C & A.C Induction Motor

S.No	Aspect	D.C Motors	A.C Induction Motor
1.	Power Sources	D.C (Direct Current)	A.C (Alternating Current)
2.	Components	Brushes & Commutator Used	Brushes & Commutator Not Used
3.	Speed Control	By varying the Armature Winding's Current.	By varying the Frequency, done with an Adjustable Frequency Drive Control.

CONCLUSION

Because From the above discussion of the various parameters as well as the characteristics of the various Electric Motor Drives used in Electric Vehicles. An attempt has been made to classify various Electric Motor Drives according to their characteristics and mode of application. The main conclusions drawn from this classification paper are:-

1. The most widely accepted as well as used Electric Motor Drive is the Induction Motor Drive and Permanent Magnet (PM) Brushless Motor Drive.
2. The Induction Motor Drive is the most cost effective Motor Drive.
3. The most Energy Efficient is the Permanent Magnet (PM) Brushless Motor Drive.
4. Most mature technology is of the D.C Motor Drive as a lot of research work and development has been done on them over the past.
5. Most Reliable ones being the Induction Motor Drive and the Switch Reluctance Motor Drive.

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