Advantages of IPM Motor in Electrical Propulsion Over Other Motors for Electrical Vehicles

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Abstract - The paper presents a brief comparison between various motors in various aspects of the desired characteristics of a drive used in electricvehicles. The use of Interior Permanent Magnet(IPM) motor as a drive in Electric vehicles can be proved to be a smart decision because of the advantages it offer.

Keywords: IPM motor, Electric Vehicle, Field Weakening, Electric propulsion, rotor topologies.

I. INTRODUCTION

In our modern living, speed matters a lot. We want everything to be fast. While travelling also, one is always in a hurry to reach its destination. With the advancement in recent technology more attention is being paid to the electric vehicles (EVs). The demand in transportation technology has led to think about alternatives for the conventional propulsion system. The rising price of fuels and the fact that the resources are exhaustible have enhanced the need for electric propulsion system.

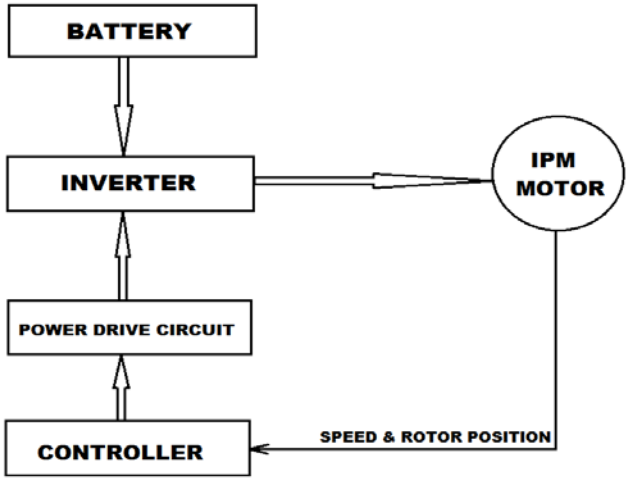

Fig.1 Block diagram showing Electric Propulsion System in Electric Vehicle

Though EVs were present since 1800's but the cost of batteries and low efficiency of the drive made its usage obsolete. Also the low cost of fuels and advancement in Internal Combustion engines dragged everyone's attention towards Internal Combustion engines. EVs consists of propulsion system whichprovides force to propel the vehicle. The motor used in such system converts the energy supplied by the battery into mechanical energy to provide traction power to the wheels. Latest examples of such EVs are Toyota Prius, Ford Escape, Chevy Volt; all these vehicles have another thing common in them: IPM motor.

IPM motor is a permanent magnet synchronous motor, which has permanent magnets buried inside the rotor that gives the motor a special characteristic of saliency.IPM (Interior Permanent Magnet) motor fulfil all the criteria needed for a traction motor. Some of its features are: - High efficiency, high torque, high power density and wide speed range. The reduction in the price of the rare earth based magnets has added to the popularity of IPM motor used in EVs.

The IPM motor has some inherent properties that makes it different from the other motors used as drives for EVs:

1. As the magnets are mounted inside the rotor the machine is more robust, thereby permitting a higher speed of operation.

2. Effective virtual air gap in the d axis is larger than that in the q-axis; which makes the machine a salient pole machine.

3. Magnets are not directly exposed to the magnetic field of the air gap, therefore better demagnetization withstand capabilities.

4. The torque developed by the IPM motor is also higher due to the addition of reluctance torque and torque due to magnets.

In this paper a review is given by comparing various aspects of different motors used in EVs and the advantages IPM motor give.

II. ADVANTAGES OF IPM OVER OTHER DRIVES

Every EVs must possess some characteristics like: high efficiency, high power density, wide speed range, ease in

speed control, robust model and low losses. There are various topologies of rotor of IPM motor used for the drives used in EVs. These topologies(segmented, V-shaped, W-shaped, conventional type)of rotor influence the function of the drive used inEVs [1]. Apart from that, various other parameters also affect the usage of drives.

In IPM motor the inductances does not remain constant throughout its operation, and changes with current. The w-shaped rotor has highest inductances. Also Ld<Lq thereby inducing a reluctance torque so that the overall torque increases. Also the ripple torque is reduced in the segmented and w-shaped PM rotor compared to the conventional rotor.

The inherent armature reaction of IPM motor also helps in reducing the flux, thereby increasing the speed beyond the base speed. The w-shaped rotor IPM rotor has the highest flux weakening capabilities. Therefore w-shaped rotor is a good option for use in EVs.

So by, improving the rotor shape, performance of IPM motor can be easily improved. The efficiency and power factor of IPM motor is found to be 35% more than the induction motor of same rating [2]. Analysis was done on Toyota hybrid system. This analysis revealed that the system efficiency was improved by the following ways: - during low speed range internal combustion engines were switched off and with the help of an intelligent controller IPM motor was used to provide the necessary power. The power of combustion engines was used to supply to the wheels and also some part is converted and stored as electrical energy in the battery.

The high-performance of the IPM motor can be achieved by orienting the stator phase excitation wrt to the rotor position with every load change [3]. Also, by using a closed loop structure of controlling, the torque can be changed instantaneously.

The IPM motor has the difficulty of maintaining or achieving a constant power region at higher speeds, as the voltage reduces [4]. A new rotor designed was developed in which the magnets were mounted on the surface in some portion of the rotor and rest portion was developed as a reluctance rotor.This new design though gave nearly same characteristics as the IPM motor but has a limitation that the characteristics were poor at low speed with the increase in I^2R losses. The difficulty in IPM motor during constant power region can be improved by increasing the voltage by using DC-DC voltage booster.

Though some of the desired characteristics can be fulfilled by the Induction motor (IM) but the inherent advantages of the IPM motor predominated its use in EVs. Speed range of IM is limited by its pull-out torque at higher speeds. As the speed increases, the voltage decrease and therefore the pull-out torque also decreases thereby limiting the speed range. Also the iron losses must be same as the copper losses to achieve maximum efficiency. As the copper losses remain constant, but iron losses increases up to base speed and then decrease, this affects the efficiency. Apart from that as the flux is reduced at higher speed the noise increases.

In switched reluctance motor the increment in the performance of the constant power region reduces the torque capability. Also the number of poles in rotor and stator affects the constant power performance of the motor.

The use of synchronous motors demands double excitation which can be removed by the singly fed brushless AC machines or IPM motor. SPM (Surface Mounted Magnet) motor has many disadvantages like; poor armature reaction, low speed range and not as robust as IPM motor.

So, from the above discussion we find that IPM motor is most suitable option for a drive in EVs. There are various materials used for the development of magnets but NdBFe are found suitable for high efficiency IPM motor [5]. Though IPM motor itself offer many advantages to be used in EVs but there is always a scope of increasing the efficiency to the desired one. This can be done by proper controller design in vector control of IPM motor, appropriate rotor design and intelligent ac-dc converter and dc-ac inverter for IPM drive.

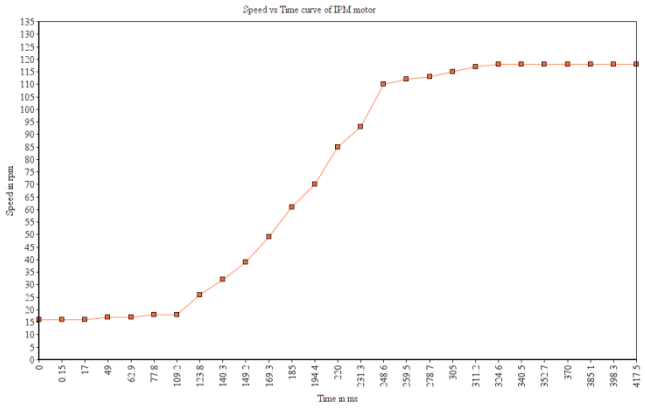

Fig-2

The figures (2) and (3) shows the speed and torque characteristics of a 2kW IPM motor at various frequencies.

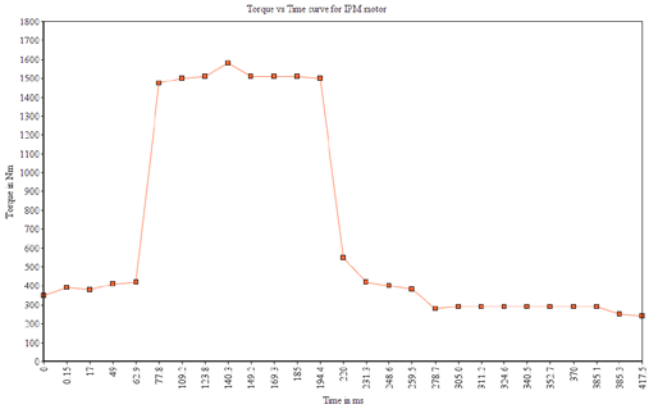

Fig-3

III. CONCLUSION

It can be concluded from all the above discussions that the advancement in the topologies of the rotor of IPM motor and proper designing of the power electronic circuits used in the drive can improve the efficiency and torque characteristics of an IPM motor. Also, the IPM motor offer better over loading capacity than other motors thereby enhancing its use as a drive in EVs.

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