International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Analysis of Different Types of Motors for the Use in Electric Vehicles

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Abstract – *Electric motors are regarded as the future and it is only imperative that we study more about how they can be made consumer-friendly in order to not only improve the adoption rate of electric vehicles but also improve the electrification of countries worldwide. An important aspect that needs to be studied is the type of motor that can provide us with the most value and price to performance ratio while considering its application in the field of electric vehicles. This paper provides a basic study and understanding of all the different motors available for usage in the field of electric vehicles and which kind of motors can prove to be a viable option with regards to usage in the field of electric vehicles.*

Key Words: **Electric vehicle, motor, comparison, dc motor, BLDC motor, induction motor**

1. INTRODUCTION

Electric vehicles are all the rage nowadays and for the right reasons. Electric vehicles have a ton of benefits and the hype is therefore justified. There is actually a lockdown that has been enforced in many parts of the world owing to the spread of Covid-19 and this has actually had some surprising results. Recent articles have surfaced online showing the comparison of various parts of some of the most polluted cities in India from a year before, more specifically from the 20th of March, 2018 compared to April 8th, 2020 [1]. The results are extremely substantial and the difference in the air quality and the visibility is night and day. This garnered a lot of media attention owing to the fact that the Covid-19 disease was already being covered intensely by many media channels alike. This also got a lot of environmentalists and scientists thinking as to why there was a drastic dip in the pollution levels all over the world. Some cities also claimed to have experienced a drop of around 50% in the total air pollution and this made headlines as well.

Air pollution accounts for approximately 27% of the total air pollution in India. Wikipedia states that 9 out of the 10 most polluted cities all around the world are from India and all of these cities house extremely unhealthy levels of air pollution. This is an alarming issue and needs to be addressed immediately or this can have horrendous repercussions. The World Health Organisation (WHO) has stated that around 4.2 million people die every year due to air pollution related diseases. Around 91% of the people all around the world live in an area that has an air quality that exceeds the limit set by the WHO. An effective way to curb this is to adopt electric vehicles and replace the already existing internal

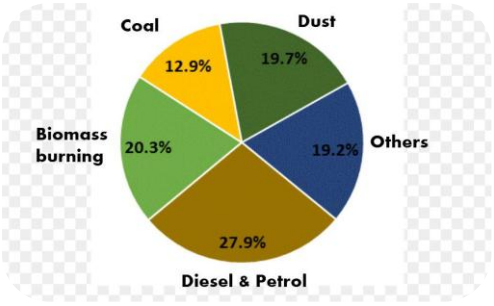

Fig -1: A graph showing the amount of total pollution caused due to different types of fuel being used.

combustion engine vehicles in a bid to not only reduce the pollution but also to enable the electrification of nations. This is what makes the study of electric vehicles and the technologies related to electric vehicles all the more important. The sheer number of lives that can be saved by the advancement and adoption of electric vehicles means that a low of manpower, time, effort and research must go into the development of newer and better technologies in the field of electric vehicles.

2. PARTS OF AN ELECTRIC VEHICLE

An electric vehicle is an extremely sophisticated machine and it has various parts in it that all work together to help in the propulsion of the vehicle [2]. A typical electric vehicle has the following parts:

- Battery: This is the source of the whole process. It provides the necessary electricity required to power up the electrical parts and components of the vehicle.
- Charging port: The charging port is a way to enable the charging of the vehicle. This is usually found in all-electric vehicles and plug-in hybrid electric vehicles. Hybrid electric vehicles usually do not possess a charging port as they primarily use the internal combustion engine present in them and charge the batteries only via regenerative braking. Regenerative braking is the term given to the phenomenon where the energy generated while the vehicle is being braked is transferred back to the batteries, thereby replenishing a part of the charge of the battery.
- DC/DC converter: The battery pack that is present in the vehicle is of high capacity and if fed directly to the other electrical components of the vehicle, the components have a tendency to fail. Thereby, we need some way to step down the voltage of the battery pack to a safe level so that the electrical

components can operate safely. This is where DC-DC converters come into the picture. A DC-DC converter is a device that alters the level of voltage to suit our application. The main types of DC-DC converters used primarily are the buck converter, boost converter, and the buck-boost converter [3]. The buck converter steps down the voltage, the boost converter steps up the voltage whereas the buck-boost converter is a combination of the buck converter and the boost converter. The buck-boost converter can either step up or step down the voltage.

- Electric traction motor: This is considered the main component of the electric vehicle. The electric motor is responsible for the propulsion of the vehicle and this is done by the motor using the power fed in by the battery and converting it into mechanical energy that is then supplied to the wheels to drive the vehicle forward.
- Onboard charger: The onboarding charger takes in the AC electricity that is being supplied to the vehicle via the charging port and converts it into DC for charging the battery pack. This component functions as a converter and also continuously monitors the voltage, current, power, and the speed of charging of the battery to make sure that the charging occurs reliably.
- Power electronics converter: A power electronic converter deals with the processing and the controlling of the flow of electrical energy to supply voltages and currents as per the requirement of the user. Power electronic converters usually employ devices such as Silicon Controlled Rectifiers (SCRs), Insulated Gate Bipolar Transistors (IGBTs), and Triode for Alternating Currents (TRIACs) [4]. All of these devices help in the manipulation of the voltage and current to produce conditioning power concerning a certain type of application as required by the user. In an electric vehicle, a power converter manages the flow of the electrical energy delivered by the battery and also helps in the control of the speed and the torque of the motor.
- Cooling systems: Since the car is a compact vehicle and there are a lot of systems working, as the load and the speed of the vehicle increases, the heat generated will also increase exponentially. If this heat is not funneled out properly, then this can cause a lot of issues in the mechanical parts of the vehicle and this is not desired. This is where cooling systems come into the picture. The cooling systems maintain a proper operating temperature for the motor, the engine, the power electronics as well as the other components.
- Transmission: The mechanical power that is generated by the motor needs to be transferred to the wheels to propel the vehicle forward. The transmission system transfers the mechanical power generated by the motor to the wheels, thereby helping in the propulsion. The transmission consists of the differential and the gear systems along with the axles and the wheels.

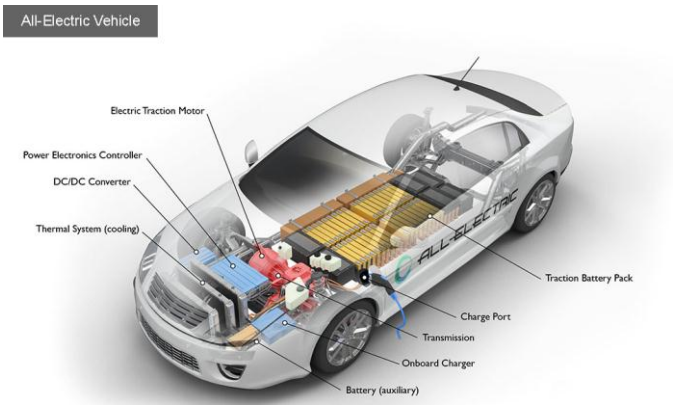

Fig -2: Parts of a typical electric vehicle

3. COMPARATIVE STUDY OF DIFFERENT MOTORS

Traction motors are the type of motors that help in the movement and propulsion of the vehicle. These kinds of motors are commonly found in electrically powered rails and electric vehicles such as electric cars as well as vehicles that employ an electric transmission system to transfer the power. The motor is the most important part of the electric vehicle. Therefore, the selection of the motor is extremely crucial and needs to be done with deliberation so that the vehicle can perform admirably. Many criteria's such as the cost, performance, efficiency, power density, maturity of the technology and how easy it is to control the motor play an important part in the selection of the motor. There are many types of motors available to us. Motors are broadly classified as DC and AC motors. Simply put, DC motors work on DC voltage and AC motors work on AC voltage. It is imperative that we study more about these motors in detail and find out more about the properties of each kind of motors and how suitable it would be to use the motor in an electric vehicle. It is also important to study how the motors compare to each other as each motor has its own set of properties and therefore, the best motors can be chosen by a comparative study.

3.1 DC motors:

A classical motor that has been used in motor control for a long time. The power that is involved in the electromechanical transmission is actually transferred to the rotor via stationary brushes that are in contact with the commutator segments. The construction of a DC motor is extremely simple and thus, it does not pose a lot of problems during the construction. The problems arise due to the way the construction has been made. The simplicity of the construction of the motor is also the motor's biggest issue as it poses a ton of maintenance issues. The presence of slip rings and brushes means that there is a tendency for sparking to occur and thereby causing maintenance issues.

On studying the speed-torque characteristics of the DC motor, we can see that it cannot be used as a traction motor. When the speed of the motor increases, the torque decreases exponentially [5]. The torque is extremely important as it is a measure of the accelerative capability of the vehicle. The torque generated by the motor plays an important role in the handling of the vehicle as well as the fuel economy, which is an extremely important factor to be considered. A better torque means that the vehicle can travel at a given speed with more ease as well as lesser revs which in turn means that the drive is less jerky and more enjoyable. That does not mean that the DC motor is not useful at all for electrical applications. In spite of its high maintenance and short life, the DC motor is suitable for low power applications such as electric wheel-chairs. Many of the golf carts actually use a DC motor for traction.

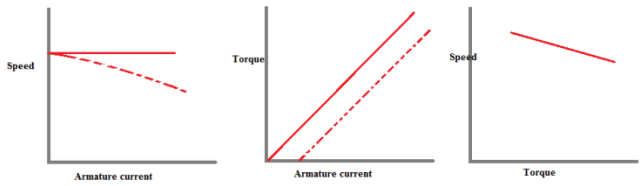

Fig -3: Characteristics of a DC motor

3.2 Induction motors:

These are some of the most popular AC motors. Induction motors are usually just called as AC motors owing to their popularity. Induction motors have a lot of advantages over DC motors mainly in the maintenance department. Induction motors have an extremely rugged construction which in turn means lesser maintenance. This ruggedness and low maintenance make the induction motor a perfect choice for usage in industrial settings. Induction motors also possess excellent speed torque characteristics. The construction of the motor is rugged as well as easy. The squirrel cage inductor motor does not even require a slip ring arrangement compared to a DC motor. Due to the lack of the brushes, the issues of maintenance and sparking are greatly reduced. This also reduces the cost of the motor. The efficiency of the induction motor is also pretty high in the range of 85-97% which is excellent. But that does not mean that induction motors are perfect. A low starting torque, an increase in the rotor losses at higher speeds, a reduction in efficiency as well as a lower efficiency when compared to permanent magnet synchronous due to the presence of rotor windings. Induction motors also has an extremely narrow speed across which useful power output can be obtained. Induction motors are actually used by Tesla in their cars such as the Tesla model S. Induction motors are commonly used in high power applications which explains its presence in electric vehicles. Induction motors also have a market share in variable speed drive applications such as air-conditioning systems, elevators and escalators.

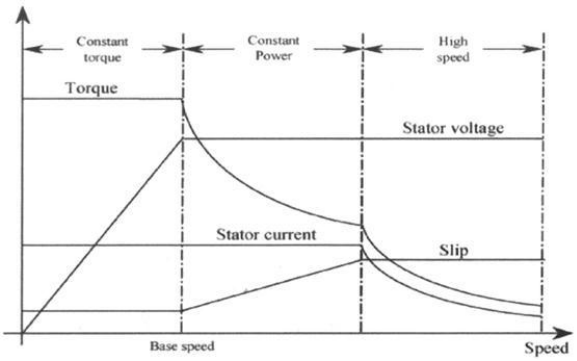

Fig -4: Characteristics of an Induction motor

3.3 Permanent magnet synchronous motors:

Permanent magnet synchronous motors are also another serious contender for the usage in electric vehicles and rightfully so. It is also a brushless motor thereby the robustness is increased and therefore the maintenance issues are extremely low. The main advantages of a permanent magnet synchronous motor are the high efficiency, the high reliability, uniform heat dissipation and the high power density. These motors are similar to induction motors in the respect that these motors have only a narrow speed range where it can operate and produce a useful power output. There also exists demagnetization issues which occur due to the heat or armature reaction from the motor. All of these disadvantages can be worked around by various methods but the biggest disadvantage of the permanent magnet synchronous motor is the cost. The permanent magnet synchronous motor makes use of rare-earth metals such as Neodymium which is extremely costly. Research done in 2011 and 2012 show the rapid increase in the prices of rare-earth metals such as Neodymium and Dysprosium. The increase in the prices of the rare-earth means that the prices of the manufacturing and production of electric vehicles are increased as well which is not feasible for both the OEM as well as the consumer.

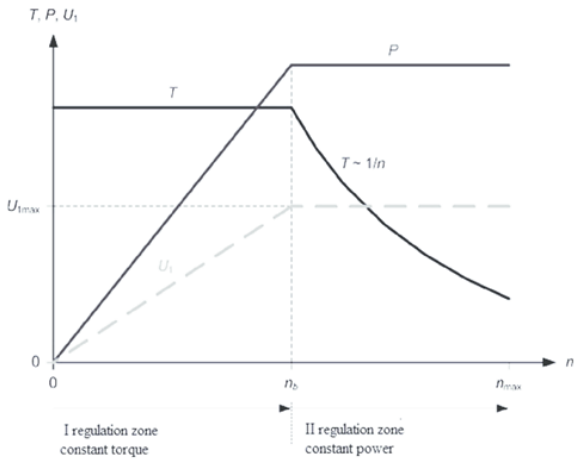

Fig -5: Characteristics of a PMS motor

3.4 Brushless DC motors (BLDC):

BLDC motors possess excellent speed torque characteristics, a wide operating speed range compared to induction motors, high power densities and lesser maintenance issues due to the lack of brushes. The lack of brushes also means that there are no sparking issues as well that conventional brushed DC motors usually suffer from. A BLDC technically can be considered as a type of synchronous motor as the magnetic field produced by the rotor and the stator rotate at the synchronous speed. The rotation occurs due to the pair poled being energized in a sequential manner such that the rotation is started and maintained. It is also lighter, easier to control, and less prone to failures that usually occur with other motors. The conventional DC motor is actually poor mechanically and the brushless DC motor is basically the conventional DC motor that has been turned inside out. In a BLDC motor, the high power winding is put on the stationary side of the motor and the field excitation is on the rotor using a permanent magnet. But with these benefits also come a slight increase in the price. BLDCs can be a viable option to be used in the electric vehicles in low power electric vehicles such as electric auto-rickshaws and two-wheelers.

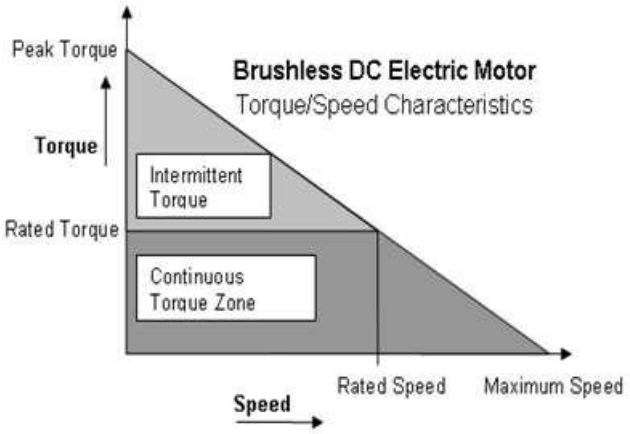

Fig -1: Torque speed characteristics of a BLDC motor

3.5 Switched Reluctance motor:

A type of motor that runs by the torque produced due to reluctance. One of the most unique aspects of this motor is the power delivery. Unlike conventional DC motors, the power is delivered to the stator instead of the rotor. This simplifies the mechanical design by a ton as the power is being delivered to a stationary part and not a moving part [6]. But this aspect of the design also means that there is a degree of complexity that is added to the construction of the motor. This means that there needs to be a switching mechanism that needs to be added to the motor, thereby giving the motor its name. The switched reluctance motors can be used as a viable option for Hybrid Electric Vehicles (HEV) due to the ease of the construction, excellent speed torque characteristics and a simple control process. The main disadvantages of this motor are the high noise and the high torque ripple.

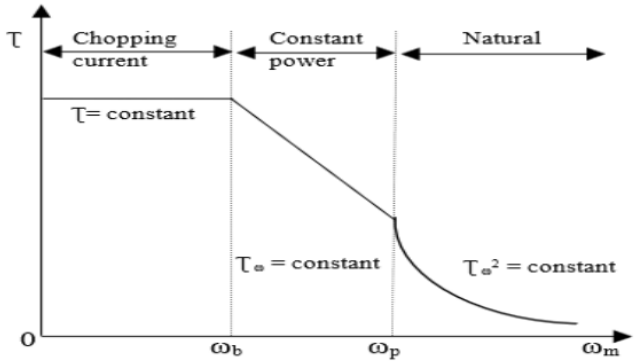

Fig -1: Characteristics of an SRM

4. CONCLUSION

Electric vehicles will only grow in global market share as the years progress and it is possible only if a lot of study and research is done in the field of electric vehicles. An electric vehicle has a lot of nuances and components that require a lot of study and deliberation but arguably the most important part of the electric vehicle is the electric traction motor. There are different options available for the usage in electric vehicle such as DC motor, BLDC motor, PMS motor, Induction motor and switched reluctance motor. A comparative study of the characteristics of these motors show that the induction motor is the best choice for high power electric vehicle applications such as the electric cars and trucks, as is shown by Tesla with most of their products. The brushless DC motor is a viable choice to be used in low power electric vehicles such as electric auto-rickshaws and two-wheelers.

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BIOGRAPHIES

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