Available online at: http://www.ijmtst.com/vol6issue04.html

International Journal for Modern Trends in Science and Technology

ISSN: 2455-3778 :: Volume: 06, Issue No: 04, April 2020

Overview of Electric Drive Motors Use in Electric Vehicles

Barve Nikita Rajendra[1] | Kishor V Bhadhane[1] | Avhad Nikita Vijay[1] | Yadav Prashant Ramsingar[1]

[1]Department of Electrical Engineering, Sandip Institute of Engineering and Management, Nashik, Maharashtra, India

To Cite this Article

Barve Nikita Rajendra, Kishor V Bhadhane, Avhad Nikita Vijay and Yadav Prashant Ramsingar, "Overview of Electric Drive Motors Use in Electric Vehicles", *International Journal for Modern Trends in Science and Technology*, Vol. 06, Issue 04, April 2020, pp.:308-314.

Article Info

Received on 27-March-2020, Revised on 24-April-2020, Accepted on 26-April-2020, Published on 30-April-2020.

ABSTRACT

This paper provides overview of present standing and future trends in electric vehicle technology in an exceedingly world wherever energy conservation and environmental protection are growing issues. The event of electric vehicle technology has taken associate accelerated pace, because the key part of EV, motor assumes a vital position within the performance of the vehicle. During this study, Induction Motor (IM), Brushless DC Motor (BLDC), Switched Reluctance Motor (SRM), Synchronous Reluctance Motor (synRM), permanent magnet Synchronous motor (PMSM), permanent magnet Brushless DC Motor (PMBLDC), Axial Flux Motor and their drives are mentioned. The benefits and drawbacks of every motor sort are mentioned from a system perspective. The relative investigation on the efficiency, weight, cost, cooling, maximum speed, fault-tolerance, safety &reliability is applied for motor drives, so as to search out most acceptable motor drives for EV applications.

KEYWORDS: *EV- Electric vehicle, HEV- Hybrid Electric Vehicle, IM- Induction Motor, BLDC –Brushless DC Motor, PMBLDC- Permanent Magnet Brushless DC Motor , SRM- Switched Reluctance Motor , synRM- Synchronous Reluctance Motor , PMSM- Permanent Magnet Synchronous Motor, AF-Axial Flux*

Copyright © 2014-2020 International Journal for Modern Trends in Science and Technology
All rights reserved.

I. INTRODUCTION

The electric vehicle (EV) in nearest future can become superb selection for a various transportation. It is usually recognized that in transportation there's requirement for the brand spanking new ways of reasonable, non-polluting personal transportation.

Electric vehicles (EVs) are more & more supported as an answer to energy conservation and because of this emission reduction. Electric vehicle may be a terrific for the town traffic while not providing harmful gases with low noise, because the main power supply, Motor is one in every of the foremost vital components in electric vehicles use in electric vehicle The choice of correct motor is incredibly vital to the electrical vehicles.

Varied styles of the electrical motors are utilized in electric vehicles within the past. The block diagram shown in Fig 1 illustrates a basic electric vehicle system [14].

The energy source, the power convertor, the sort of motor employed in the electric vehicle and therefore the transmission system of the electric vehicle are connected with one another.

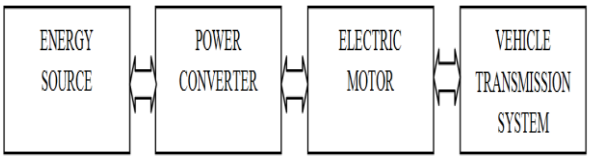

Fig. 1 Basic electric vehicle propulsion system

The overall performance of an electric vehicle depends significantly on the kind of motor drive being employed. Parameters are some physical characteristics of motors such as:

1. High torque density and power density
2. Terribly wide speed vary, covering low speed crawling and high speed cruising.
3. High efficiency over wide torque and speed range.
4. High torque capability for electric launch and hill climb.
5. Wide constant power performance capability.
6. High intermittent capability for passing.
7. High reliability and robustness for transport atmosphere.
8. Low acoustic noise.
9. Cheap value.[8]

So relying upon those parameters the varied drives used for EVs are mentioned during this paper

The supported the supply, we have a tendency to use two styles of drives that are DC or AC drive. The AC drives consisting of three phase permanent magnet synchronous motor (PMSM) is most well liked amongst them. The opposite wide used drives are three phase Induction motor (IM), Switched reluctance motor (SRM), Brushless DC motor (BLDC). during this paper a summary of has been created amongst several characteristics of electrical motor drives utilized in electric vehicles, together with a classification of assorted motors used as a part of the drive system.

II. Electric Motor Drives

A. *Induction Motor:*

Induction motors are ordinarily utilized in EV applications due to easy structure, reliability, robustness, less maintenance demand, low price and operation at poor environmental conditions. Its negative options like low efficiency compared with PM, high loss and low power factor. It's presently one among the most cost effective and most reliable electrical machines. Because of absence of wearing elements this motor is maintenance-free machine [1]

It characterizes high efficiency in wide operation vary near to 90% just in case of rotor aluminum cage or higher for motors with rotor copper cage. The upper efficiency of the motors with cooper cage comes from decreasing of rotor, mechanical and stray losses. In Fig. 2, the most characteristics of an induction motor are shown. Torque and field control is decoupled using vector control strategies [1, 7]. Speed range could also be extended using flux weakening within the constant power region and Continuation of break-down torque within the constant power region, reduction of efficiency and increment of losses at high speeds. To boot the operation temperature for copper cage motor is lower as compared to motors with aluminum cage providing the reduction of the motors dimensions and also the weight. The motor size reduction is very necessary within the electric vehicles application

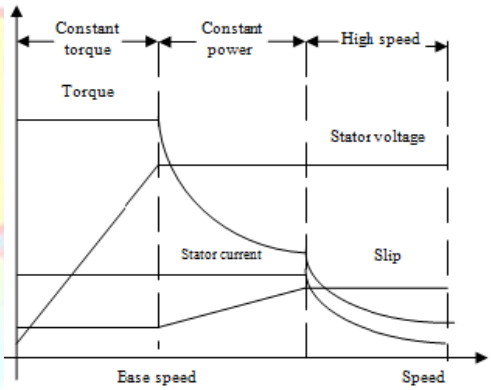

Fig.2. Torque speed characteristics of induction motor

Three-phase induction motors are the foremost wide used electrical motors, because of their ruggedness and low value. The induction motor will be operated directly from the mains, however variable speed and sometimes higher energy efficiency are achieved by means that of a frequency convertor. [3] Hence, IMs will be thought of as a promising PM-free, low cost, and high efficiency candidate for EV applications between the mains and therefore the motor.

B. *Synchronous reluctance motor:*

Among the varied typologies, the synchronous motors offer the simplest performance, in terms of high torque and power density, high speed capability, wide speed vary, high efficiency and mass saving. Therefore, the synchronous reluctance (REL) machines are getting of nice interest within the recent years. They represent valid alternatives to alternative machine sorts for

EVs and HEVs for their easy and rugged construction and for hazard-free operations.

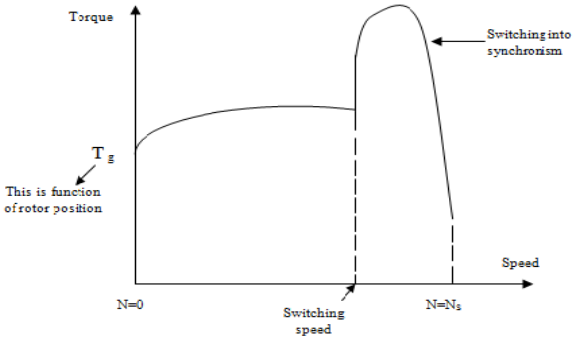

Fig.3. Torque speed characteristics of synchronous reluctance motor

Synchronous reluctance motor might produce 34% more torque than the induction motor with 29% more current [15]. A standard torque speed characteristic of a synchronous reluctance motor has been pictured in Fig.3 [20]. Torque supported the current doesn't depend upon temperature not like permanent magnet synchronous motor and induction motor. Price is cheaper than permanent magnet synchronous motor and induction motor.[10,16] A really good dynamic behavior of synchronous reluctance motor (synRM) drive was determined each in motoring and breaking mode and additionally low torque ripple determined.

C. Permanent magnet synchronous motor:

Permanent Magnet synchronous motor became at the highest of AC motors in high performance drive systems like EV. Permanent magnet Synchronous Motors have the potential to providing high torque-to-current ratio, high power-to-weight ratio, high efficiency and robustness. [9, 13] Because of the on top of favorable points, PMSMs are ordinarily utilized in latest variable speed AC drives, significantly in electric Vehicle applications. The growth of the PMSM in market is raised by its distinctive characteristic and sensible features of usage all told form of AC electrical motors that are as follows:

1. Small size, light weight, little moment of inertia, high power density and may be simply utilized in limit electrical vehicle space.
2. It does not want excitation current at basic speed, this could improve the power factor, decrease the stator copper loss by lower the current, and there is no rotor copper loss as a result of there is no excitation current therefore high efficiency, high power factor.

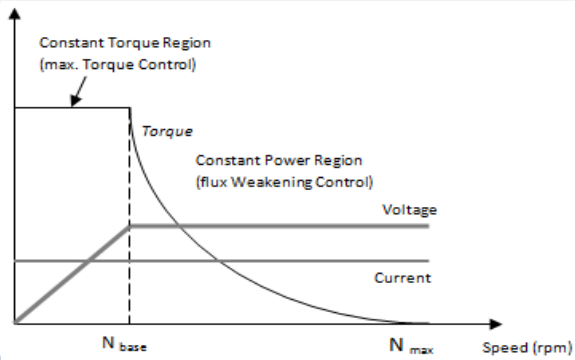

Fig.4. Torque, voltage, &current characteristics of the PMSM according to speed and control mode

In general, the PMSM for electric vehicles is controlled with maximum power control mode at constant torque region and field weakening control mode at constant power region, as shown in Fig.4 [17] PMSMs offer robustness additionally to electrical balance and certify dependable overall performance as PMSM improves the motor efficiency about by 10% it will increase the usage of PMSM in numerous applications. The fuel consumption of PMSM is extremely low, thus it's employed in green vehicles. The notice of green and electric vehicle improves the PMSM.

PMSM were an increasing variety of used in electric vehicle applications owing their high efficiency, excessive power density, compact structure and speedy dynamic response. High power to volume ratio and high efficiency are achieved by permanent magnet motors. [9]

D. Brushless DC motor:

From efficiency purpose of view, BLDC motor drives are the simplest alternative for electric vehicles. BLDC motors are very talked-about during a large choice of applications. when put next with a DC motor, it's easy structure, light weight, higher speed vary, noise less operation, maintenance free operation, giant beginning torque, precise and correct control and high dynamic response.[6] The BLDC motor uses an electric commutator previous to a mechanical commutator, therefore its additional reliable than the DC motor. During a BLDC motor, rotor magnets generate the rotor's magnetic flux; therefore BLDC motors attain higher efficiency.

Due to engaging options like easy operation and simple to control, the conventional brush DC motor has been wide utilized in several variable speed operation and servo control applications. However, the actual fact that it's equipped with brush and commutator has led to many disadvantages:

1. Spark might occur because of commutation that is dangerous for a few specific occasions.
2. Brushes might wear out because of longer muse.
3. Electromagnetic interference and noise drawback.
4. The space required for housing brushes might limit the chance of miniaturization or shape of motor.
5. It wants maintenance and also the operation values are going to be increased [7]

In contrast, the Brushless DC Motor (BLDCM) does not have the above mentioned drawbacks. Moreover, it also has advantages such as high efficiency, high power density, and maintenance free, etc. As shown in Fig. 5(a), the operational point is located at the intersection of the torque-speed curve with the load curve. Obviously the stall torque can be increased significantly when the motor is coupled with a gearbox, but this limits the operational speed as shown in Fig. 5(b) [18]

BLDC motors are often classified as synchronous motor. In BLDC motor, pole modification was done on the stator coil element. Its stator consists of coils and cores. Rotor is static magnets that are generated by permanent magnets. The BLDC motor utilized in this study was a motor with three phase electricity.

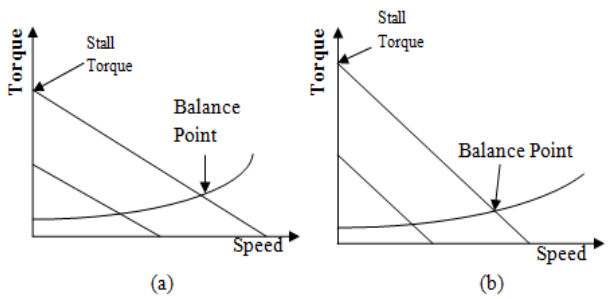

Fig.5. Torque versus speed, (a) coupled directly (b) With a gear

The characteristics of BLDC motor that makes it a far better various among varied alternative motors are increased speed torque characteristics, quick dynamic response, quiet operation, high power density, low maintenance; low rotor inertia because of permanent magnet so avoiding the rotor windings, reduced losses so exhibits high efficiency etc

E. Permanent magnet brushless DC motor:

Permanent-magnet brushless dc (BLDC) motors provide many benefits, together with high efficiency, low maintenance, bigger durability, compactness, and better power density. They're unremarkably utilized in varied commercial, military, and renewable energy applications. Normally totally different indices like power density, efficiency, speed ratio, cogging torque, and torque ripple, may be used as criteria to assess a motor's performance.

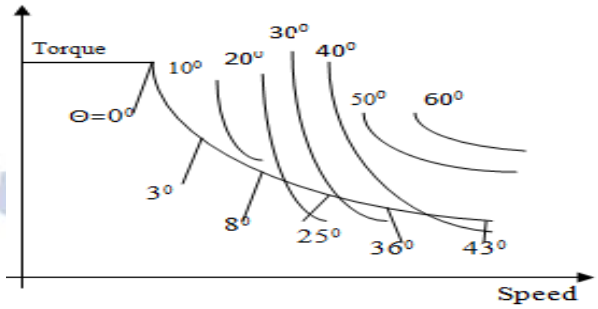

Fig: 6 Torque speed characteristics of PMBLDC

Power density and efficiency of PMBLDC motors are high. Their efficiency is more than IM because of not having rotor winding and rotor copper losses. These motors have a short constant power vary as a result of restricted field weakening capability ensuing from the presence of the PM Field which might be weakened by a stator field. The constant power region is short. The operation region at constant power may be extended by a conduction-angle control three to four times in Fig. 6 [1]

With the arrival of high-energy permanent-magnet (PM)materials, PM motors have become more and more attractive .Being regularly fuelled by new machine topologies and control methods, PM brushless (BL) drives are known to be the foremost promising to produce the on top of mentioned characteristics for contemporary EVs.[5]

F. Switch reluctance motor:

Wide torque-speed varies and high reliability is the first would like of the traction motor in electric vehicles. Switched Reluctance machine (SRM) offers various benefits like easy and robust construction, high speed and high durability, low cost, low weight and fault tolerance control capabilities, high reliability as every phase works severally. Competitive efficiency combines to create the switched reluctance motor (SRM) drive a strong individual for application in future electric vehicle (EV) propulsion systems. Considering mass manufacturing of EVs in future, it's to seek to hunt for an occasional price furthermore as high power density motor. Switched Reluctance Motor (SRM) has emerged as major competition for this application. [11] SRM provides benefits over different machines like high temperature loading

capability in temperature vary of 160⁰. A comparison is completed between proposed SRM and also the antecedently discussed Induction motor having around same outer geometrical dimension. Table I shows the comparison [23].

Table I. Comparison between Induction Motor and Switched Reluctance Motor

	320v		48v	
Parameters	SRM	IM	SRM	IM
Power	7.5kw	8.5kw	3.5kw	3kw
Max. speed	9000rpm	7000rpm	8000rpm	7000rpm
Max. efficiency	91%	90%	91%	90%
Current density	5	9	3.75	4.75
Cooling	Air cooled	Liquid cooled	Air cooled	Air cooled

The switched reluctance motor works on the principle of variable reluctance. The electromagnetic behavior is highly non-linear; the speed-Torque characteristic of motor is also shown in Fig.7 [21]. This non-linear nature of SRM operational in saturation makes analytical modeling extraordinarily troublesome. In most of the cases, SRM has windings on the stator, however no permanent magnet or windings on the rotor, which permit it to work at higher temperatures [19]. This property additionally leads to a lower manufacturing price, simple and rugged structure, permitting it to be designed with reduced dimensions. On the opposite hand, if any fault occurs in one phase or winding, the machine will continue its operation at a reduced load. For same power rating of SRM, extremely saturated machine can have relatively lesser convertor KVA demand. This is often an important advantage which will be helpful for pumps and fans, and can also be exploited within the EV industry. It needed additional conductor connections than the more conventional 3 ph.IM, PMSM, synRM, however there's a non-linear characteristic on SRM due to the magnetic saturation that produces it difficult to control the torque precisely. [1, 7]

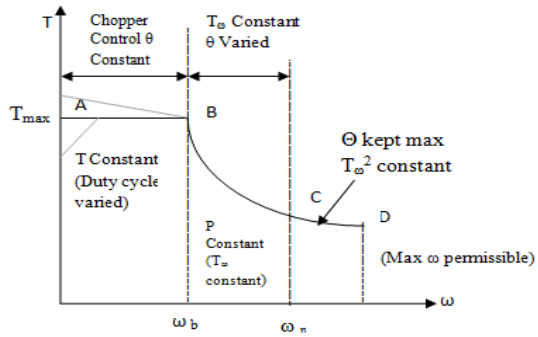

Fig.7. Torque speed characteristics of SRM

Various forms of permanent magnet machines have been used for small and medium size EVs, however the value of permanent magnets is increasing, therefore there's a limitation to use permanent magnets for heavy duty vehicles. Therefore, the SRM and also the induction machines is futurist for the EV applications due to their rugged and value effective characteristic.

G. *Axial Flux Motor:*

For electric car propulsion systems, the wheel motor is an application that needs the electrical machine has form flexibility, compactness, robustness, high efficiency, and high torque. Axial flux machines are an interesting resolution, wherever the motor is directly coupled to, or inside, the drive wheels. The axial flux permanent magnet motor with two rotors is extremely compact and may be integrated within the wheel. [4]The electrical motor will be dc or ac and also the controller is related to the motor type. The multi-motor systems are two with two or more motors and every motor is directly mounted within the wheels or directly connected to the wheel. With this answer, the mechanical differential, and even the reduction gear, will be unneeded. We are going to decision this solution "wheel motor" [4]

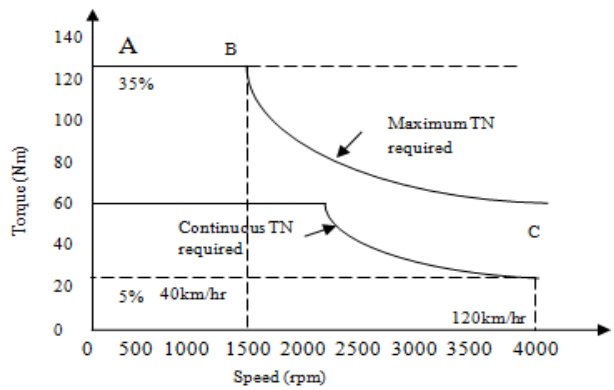

Fig.8. Torque speed characteristics of axial flux motor

The torque versus speed is shown in Fig.8 [22]. Hence, AF machines will notice their advantageous

applications in low-speed, high-torque electrical drives. Additionally, AF machines' mechanical configuration is well matched to be used as wheel motors.

III. Market Survey

Research is concentrated on low-emission and fuel-efficient cars in response to environmental considerations and strict emission legislation levels. The development of the battery technology that was led by the electronic industry has revived the interest of full EVs. The market has become a lot of mature with a position marketplace for zero-emission cars. The pure EV has two market tendencies. On the one hand, models designed for commuting purposes with low battery weight and short range. These are light-weight town vehicles with a restricted speed for town traffic. On the opposite hand, there are long vary electric cars with high-capacity batteries. The weight and value of the batteries orient this product to the high-performance market. [12]

Table II shows a survey on EVs on the market. Information is obtained from manufacturers and direct surveys. The list isn't finishing as various and distinguished models are missing. Information could also be inaccurate and missing as manufacturers are indisposed to convey technical information. For these reasons, the survey has solely a qualitative worth. [12]

Table II: Data of the Most Representative EV Models on the Market

Model	Motor Used	Top Speed	Max. Power	Max. Torque
Mitsubishi I Miev	PM	130km/h	47KW	196Nm
Ford Focus Ev	IM	135km/h	107KW	250Nm
Hyundai Kona Electric	PMSM	167km/h	132BHP	395Nm
Mahindra E Verito	IM	86km/h	41.5BHP@3500rpm	91Nm@3000rpm
Tesla Model S	IM	249km/h	825BHP	1300Nm
Mahindra E2o NXT	3ph IM	60km/h	25.5BHP@3750rpm	53Nm@3400rpm
Tata Tigor EV	3ph IM	80km/h	40.23BHP@4500rpm	105Nm@2500rpm
Tata Nexon EV 2020	3ph PMSM	120km/h	130.7BHP	245Nm
Kona Electric Car	PMSM	167km/h	134BHP	395Nm
Tata Altroz	PM	100km/h	88.76BHP@4000rpm	200Nm@1250-3000rpm
Mahindra EKUV 100	3ph IM	160km/h	39.6BHP@3500rpm	91Nm@1050rpm
Nissan Leaf	PM	150km/h	110KW@3283-9795rpm	320Nm@3283rpm
Tata Indica Vista EV	PM	60km/h	74BHP@4000rpm	190Nm@1750-3000rpm
Wheego Whip Life	IM	105km/h	15KW	129Nm

IV. CONCLUSION

In this study, electric motor drives are mentioned and their features like the efficiency, weight, cost, cooling, maximum speed, and fault-tolerance, safety, and reliability and therefore be taken into consideration the aspect of efficiency, PM BLDC motor drives are higher than SRM drive, IM drive and brushed DC motor drive. IMs are still the predominant technology even with but 75% of efficiency DC motors are still in use in some small vehicles. Therefore, PM BLDC drives are ideally suitable for these days EV applications.

References

[1] A Survey On Comparison Of Electric Motor Types And Drives Used For Electric Vehicles MerveYildirim,; Mehmet Polat,; HasanKürüm

[2] A Comparison Of Different Types Of Motors Used For Low Speed Electric Vehicles: Experiments And Simulations WANG Yue; GAO Dawei

[3] Efficiency Analysis Of Induction Motor Control Strategies Using A System-Level EV Model RasulTarvirdilu-Asl; Jennifer Bauman; *Member, IEEE*

[4] Axial Flux Machines Drives: A New Viable Solution For Electric Cars Francesco Profumo, *Senior Member, Ieee,* Zheng Zhang, And Alberto Tenconi

[5] Performance Analysis Of Permanent Magnet Brushless Motors For Mobility Scooters Yu-Chuan Lu, Ming-Yang Cheng, Chun-Hsien Wu

[6] Selection Of Electric Motor Drives For Electric Vehicles X. D. Xue, K. W. E. Cheng, And N. C. Cheung

[7] Comparative Study Of Using Different Electric Motors In The Electric Vehicles Nasser Hashernnia; BehzadAsaei

[8] Overview Of Permanent-Magnet Brushless Drives For Electric And Hybrid Electric Vehicles K. T. Chau, *Senior Member, IEEE*, C. C. Chan, *Fellow, IEEE*

[9] Permanent Magnet Synchronous Motor For Electric Vehicle Applications Ms. Loganayaki A, Student; Dr. Bharani Kumar R, Professor

[10] A Survey Of Synchronous Reluctance Machine Used In Electric Vehicle H. Wu1*, D. Depernet ; V. Lanfranchi

[11] A Review On Switched Reluctance Machines For Electric Vehicles N. Zabihi, Member, IEEE; R. Gouws

[12] Electrical Motor Drivelines In Commercial All-Electric Vehicles: A Review Juan De Santiago, Hans Bernhoff, BoelEkergård, Sandra Eriksson, SenadFerhatovic, Rafael Waters, *Student Member, IEEE*, And Mats Leijon, *Member, IEEE*

[13] Development Of Permanent Magnet Synchronous Motor Used In Electric Vehicle *XuYanliang, XuJiaqun, Wan Wenbin And Tang Renyuan*

[14] A Survey And Comparison Of Characteristics Of Motor Drives Used In Electric Vehicles Gaurav Nanda Narayan C. Kar Member, IEEE

[15] Synchronous Reluctance Motor Drive For Electric Vehicles Including Cross-Magnetic Saturation P. Gonçalves, S. M. A. Cruz, F. J. T. E. Ferreira, A. M. S. Mendes, Anibal T. De Almeida

[16] Compare Motors Of Toyota Prius And Synchronous Reluctance For Using In Electric Vehicle And Hybrid Electric Vehicle AlirezaSiadatan Mehdi KholousiAdabH.Kashian

[17] A Novel Magnetic Flux Weakening Method Of Permanent Magnet Synchronous Motor For Electric Vehicles Ki-Chan Kim

[18] Torque Control of Brushless Dc Motors Applied To Electric Vehicles C. L. Chu M. C. Tsai And H. Y. Chen

[19] A Review on Switched Reluctance Machines For Electric Vehicles N. Zabihi, Member, Ieee, And R. Gouws

[20] Https://Www.Electricalengineeringinfo.Com/2016/12/Construction-And-Working-Principle-Of-Reluctance-Motor-Applications.Html

[21] Ee6703 Unit 3 – Switched Reluctance Motors (Srm) 1 Prepared By : U.Nagabalan., Ap/Eee Constructional Features – Rotary And Linear Srm - Principle Of Operation – Torque Production – Steady State Performance Prediction- Analytical Method -Power Converters And Their Controllers – Methods Of Rotor Position Sensing – Sensor Less Operation – Characteristics And Closed Loop Control – Applications.

[22] Optimal Design Of An Axial-Flux Permanent-Magnet Motor For An Electric Vehicle Based On Driving ScenariosBy ,Yee Pien Yang [1,2,*] AndGuan Yu Shih [3]

[23] Design and Development of Switched Reluctance Motor for Electric Vehicle Application Shubham R Patel*, Nikita Gandhi**, Naga Chaithanya**, Dr. B. N. Chaudhari* and AkshayNirgude*

[24] A Control and Protection Model for the Distributed Generation and Energy Storage Systems in Microgrids, MS Ballal, KV Bhadane, RM Moharil, HM Suryawanshi, Journal of Power Electronics 16 (2), 748-759.

[25] Investigation for causes of poor power quality in grid connected wind energy-A review KV Bhadane, MS Ballal, RM Moharil 2012 Asia-Pacific Power and Energy Engineering Conference, 1-6