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

Electrical Vehicle: Revolution in Transport Industry

Akash Bhagawan Pawar[1], Arati Ramesh Mane[2], Hitesh Shankar Patil[3]

Sumpreet Singh[4], Takadir S. Pinjari[5]

[1,2,3] B. E. student in Electrical Engineering, Trinity College of Engineering and Research, Pune.
[4,5]Assistant Professor, Dept. of Electrical Engineering, Trinity College of Engineering and Research, Pune, Maharashtra, India - 411048

Abstract: *Electric vehicles are becoming well liked transportation in recent times. As per the scenario, Electric vehicle drives offer a variety of benefits over ICE vehicles, especially in terms of lower local emissions, higher energy efficiency, and decreased dependency upon oil. Yet there are significant barriers to the rapid adoption of electrical cars, including the restrictions of battery technology, high purchase costs, and therefore the lack of recharging infrastructure. However, there are some major obstacles for EVs to beat before totally replacing ICE vehicles. This paper mainly focuses on some important information about EV like Types of EV, Electrical machines &batteries. The objective of this paper is to provide current Electrical Vehicle technologies & future of EV.*

Key Words: Types Electric Vehicle (EVs), Batteries & specifications, Motor used in EVs

1. Introduction

The technology of electric vehicles (EVs) and batteries continue to enhance but there are some drawbacks like high cost, limited range, performance issues, long charge time, and a scarcity of charging stations is dwindling. Since electric vehicles have zero tailpipe emissions, we will anticipate to cleaner air when there are more electric vehicles on the road 3. Cleaner air means less disease within the world, which suggests less stress on public health systems, hospitals, and so on. Additionally, fewer greenhouse emission emissions will save the ozonosphere and reduce our carbon footprint. If we can't stop heating, we will certainly hamper the onset, and EVs are nothing if not an honest start. With no gas to shop for, or oil to vary. To refuel, you merely connect reception, at work, or opportunity charge on the road 5. As another bonus to EV charging, the facility going into your batteries is increasingly produced by renewable sources. Non-renewable electricity charging your electric vehicles is generated domestically. Add a solar battery to your home or work and your commute could buy it. If you drive an electric vehicle you're obviously planning for the longer term.

Nowadays EVs are gaining popularity & there are many reasons behind it. The important one is to scale back greenhouse emission as penetration of EVs in transportation is increasing. EVs are often considered as a mixture of various subsystems interact with one another to form EV work. EVs are often solely driven by stored electric power, some can generate this energy from an ICE, and therefore there also are some vehicles that employ both the ICE and the electrical motors together 18. The overall classification of EVs is discussed which provides present scenario about technology, the most important issue could also be having to vary out your battery, but most models today accompany a good warranty 8. Batteries can last up to fifteen years during a mild climate, and anyway you toss it, that's pretty good value. During this different sort of batteries utilized in electric vehicles also are explained 10. BEVs are different from conventional vehicles as they are doing not consist engine, engines are replaced by motors. Hence, the paper gives description of varied motors used for the BEVs 9.

2. Types of Electric Vehicles (EVs)

There are four main types of EV-

- Hybrid Electric Vehicle (HEV)
- Plug-in-hybrid Electrical Vehicle (PHEV)
- Fuel cell electric vehicle (FCEV)
- Battery Electric Vehicle (BEV)

2.1 Hybrid Electric Vehicle (HEV)

The combination of conventional internal combustion engine (ICE) system with an electric propulsion system known as a hybrid electric vehicle (HEV) 1. The presence of the electrical Powertrain is meant to realize either better fuel economy than a standard vehicle or better performance. HEV uses an electrical system when power demand is low. It's advantageous for low speed applications. Thanks to a reduction in fuel consumption, it also reduces fuel consumption. ICE can agitate batteries & hence HEV can regenerate energy by braking 8. HEV uses ICE because the main drive & electric propulsion for performance enhancement. The figure 1 shows the energy flow in HEV. At starter acts as a generator which produce the facility which is stored in batteries. During passing motor & ICE both drives the motor as requirement of speed are more 2. During the braking gearing runs motor as a generator to charge the battery by regenerative braking. The facility flow is stopped when the vehicle is stopped.

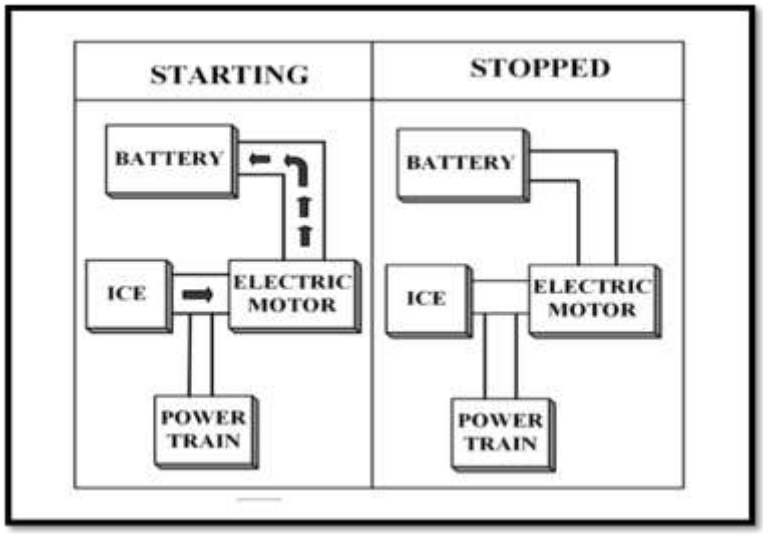

Fig -1: Direction of power flow during start & when stopped 8

2.2 Plug-in-hybrid Electrical Vehicle (PHEV)

PHEV contains both ICE & electrical machine. It is similar to HEV, only difference is PHEV uses electric propulsion as its main driving force3. This is the reason why they require bigger capacity batteries than the HEV. PHEV starts with electric operation; it runs on electricity & when the battery is discharged or low in charge ICE provided to EV to charge up the battery pack8. A PHEV can be charged through external supply. PHEV also provides the facility of Regenerative braking. The PHEV has the potential even more than conventional hybrids because a more limited use of the PHEV's internal combustion engine may allow the engine to be used at closer to its maximum efficiency 21.

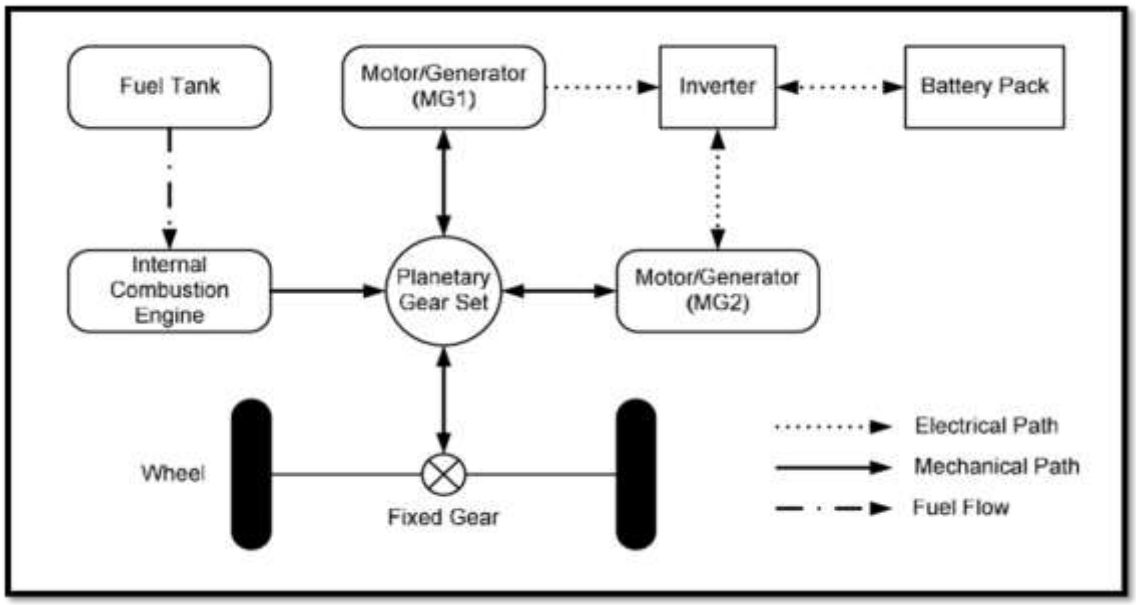

Fig - 2: Configuration of PHEV21

2.3 Fuel cell electric vehicle (FCEV)

The electric motor is driven by the fuel cells; hence the vehicle goes by such a name FCEV8. Chemical reactions take place in the fuel cell. They are also called as 'Hydrogen Fuel Cell EV' because hydrogen is the common choice for the reactions. FCV contains high pressure tanks in which hydrogen is carried out. Oxygen is also used for this reaction which is gained from the atmosphere. The energy generated by this reaction is stored in batteries and super capacitors. Water is only produced as a byproduct. Hence, the advantages of this type of vehicles are that they do not emit carbon in the atmosphere and refilling this vehicle take same time which is required for conventional vehicle to fill the gas 9. But there is concern of safety regarding flammable hydrogen may leak from the tank. The figure 3 shows the details of FCEV-

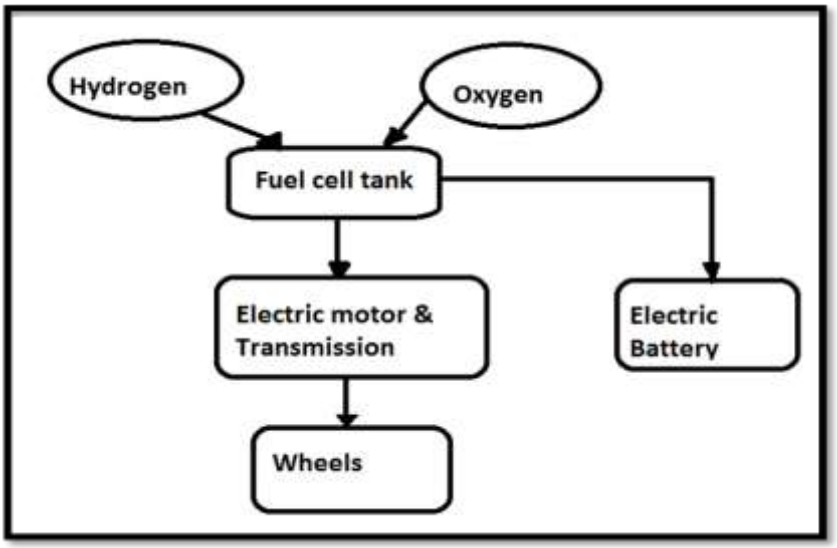

Fig - 3: Block diagram of Fuel Cell Electric Vehicle.

2.4 Battery Electric Vehicle (BEV)

Vehicles which are driven by only batteries are known as BEV. The electric motor is driven by only energy stored in the battery. Hence, it is clear that range of vehicle directly depends upon battery capacity 9. The speed covered by the vehicle depends upon battery type & age, road condition, vehicle configuration etc. When batteries are totally discharged, battery packs take lots of time to charge as compared to conventional ICE vehicle 8. This charging time depends upon charger configuration and its operating power level. The BEV is simple in construction & operation. They do not create any noise. These are the perfect vehicles to use in urban areas. Following figure 4 shows basics of BEV-

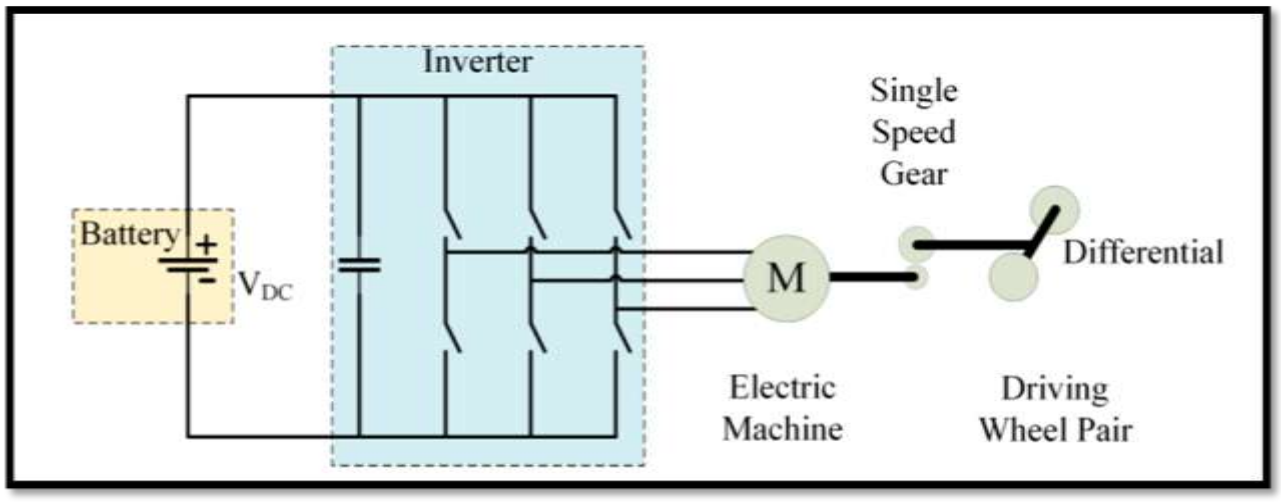

Fig - 4: Configuration of Battery Electric Vehicle 8

2.5 Comparison analysis

Table -1: Comparison between electric vehicles 138

Vehicle Type	Electric Vehicle (EV)	Fuel Cell (FCEV)	Plug-in-Hybrid (PHEV)	Hybrid (HEV)
Energy Source	Electric Only (Battery)	Fuel only	Main: Electric Sub: Gasoline	Main: Gasoline Sub: Electric
Propulsion mechanism	Motor	Motor	Combination of Motor + engine	Combination of Motor + engine
CO2 emission	None	None	Yes	Yes
Fuel facility location	Charging Stations		Gas Stations, Chargers	Gas Stations
Cruising distance	Short	Short	Long	Long

3. BATTERY

The battery is an important energy source that converts chemical energy into electrical energy and gives that energy to Electrical Vehicles. Batteries are classified into various types, and each battery has different specifications, but still some battery specifications failed to meet desired goal, so research in battery performance is in process 2. Selection of battery for Electrical vehicle is Electrical vehicle is one more important factor to get maximum output energy, longer life cycle, high efficiency, safe to use, comparatively light weight then all other batteries for same ratings, and many more. In battery most important factor is Specific Energy on which range of Electrical vehicle is depend, high specific energy gives maximum range. So, mainly Specific energy will be taken into consideration while selection of battery for Electrical vehicles4.

3.1 Types of Batteries:

There are various types of battery technologies used in electric vehicle as follows:

- Lead-acid Battery
- Nickel Cadmium (NiCd) battery
- NiMH (Nickel-Metal Hydride) battery
- Lithium-ion (Li-ion) Battery

3.1.1 Lead-acid

The process of charging and discharging of Lead-acid battery is due to reaction between electrolyte and electrodes 10.They are very cheap and, most commonly used in electric vehicle in the past, but lead-acid battery should not be discharged below 50% of its total capacity, or it will reduce the battery life cycle 8. Similarly, Special care must have to take during charging, these types of batteries are never charged to their full capacity 11. Excessive charging responsible for the production of gases and depletion of the solution. Lead-acid have a lower specific energy than petroleum fuels, which is 30–40 Wh/kg and the efficiency of this type of batteries is near about 70–75%. The emission of hydrogen, oxygen, and sulfur is there in operation of charging and discharging of the battery. If battery is properly ventilated then operation of charging and discharging is safe. Charge retention of Lead-acid battery was good compared to rechargeable batteries4.

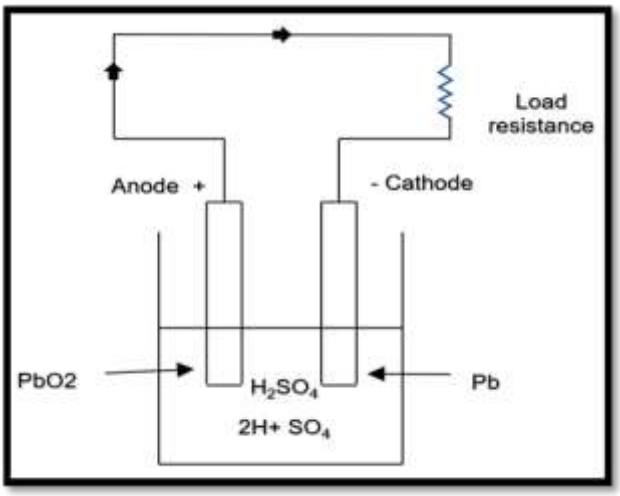

Fig -5: Basic Schematic diagram of Lead-acid battery

3.1.1 Nickel Cadmium (NiCd) battery

The Nickel Cadmium (NiCd) batteries are used where terms as a battery life cycle, price of battery, discharge rate are taken in consideration. The time required for charging of NiCd battery is very less, load current delivery is higher and overall cost per cycle is lowest, but this battery requires frequent maintenance 11. Nicd is the battery type that can operate in tough working condition with good performance; but the battery contains toxic metals due to which it effects on the environment 822. In this discharge rate is high just after charging in which the battery capacity will decrease about 10% in the first day, then it reduces to about 10% for next 30 days and battery self-discharge rate will increase with increase in temperature 4. Because of the presence of toxic metals and requirements of higher energy density people will prefer new developments in technology.

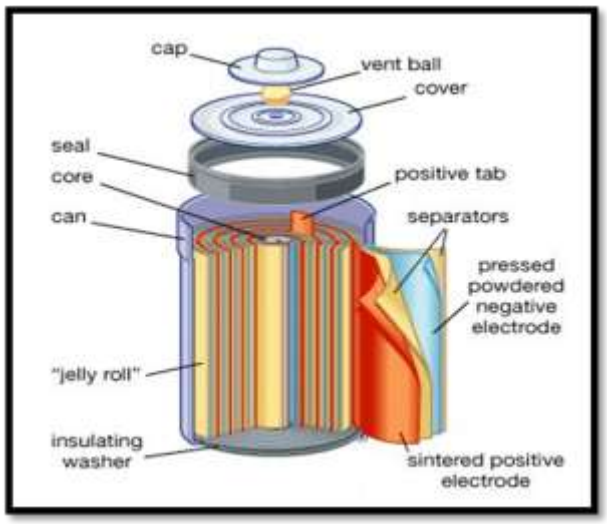

Fig -6: Nickel Cadmium (NiCd) battery 22

3.1.3 NiMH (Nickel-Metal Hydride) battery

After some research and development, the Nickel-metal hydride batteries give some additional advantage over NiCd battery. NiMH (Nickel-Metal Hydride) is less efficient in charging and discharging than NiCd batteries, but they give a higher energy (>30-40%) than NiCd 22 and if we use battery properly, then it operates safely with high voltage, wide temperature range due to which it has a longer life span 11. They also provide an option for recycling. On the other hand, performance decreases in a cold atmosphere, operation under heavy load, and a high self-discharging rate will result in the reduction of the life cycle. NiMH batteries are expensive and they require high maintenance. If we take NiMH battery and NiCd battery, then comparatively NiMH battery is suitable to use in EV because Nicd contains toxic metal which is harmful and it is not environmentally friendly4.

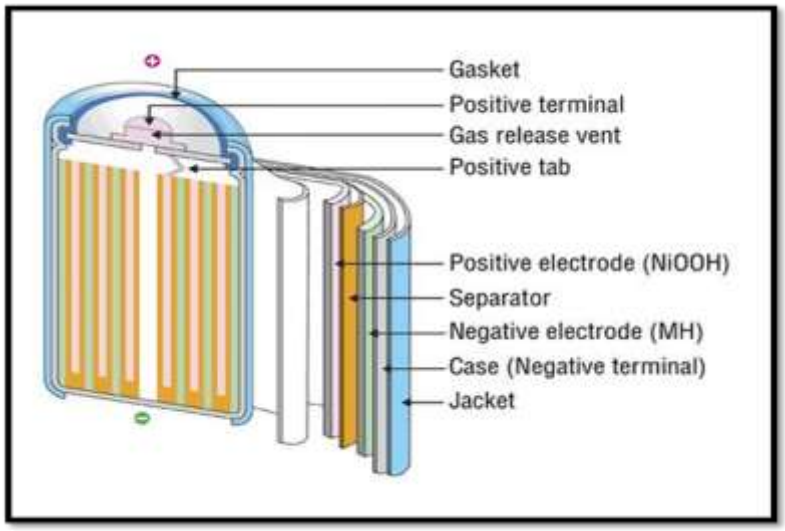

Fig -7: NiMH battery cell 22

3.1.4 Lithium-ion Battery

Lithium-ion batteries are basically rechargeable batteries, and they are commonly used for portable electronic and electrical vehicles. These types of batteries are mature technology than other batteries and suitable for electrical vehicles because of their main advantages like the lightest battery in weight, higher energy density, longer life than all other batteries

that's why it is the only battery that is used in recent electrical vehicles 26. The self-discharge rate of that battery is very less than compared to all batteries, it makes a most preferable battery for Electrical vehicles.

Lithium-ion batteries are very sensitive to overheating, overcharging, and deep discharging of the battery 7, it can damage the battery, so it is necessary to take special care during charging. For safe operation, the battery requires a protection circuit. Whenever Li-ion battery is used in an electric vehicle, then the user must use, 'Battery management system' for cell balancing purposes 4.(BMS helps to avoid peak voltage of cells, deep discharge, etc. and maintain battery output constant through its every operating cycle.)

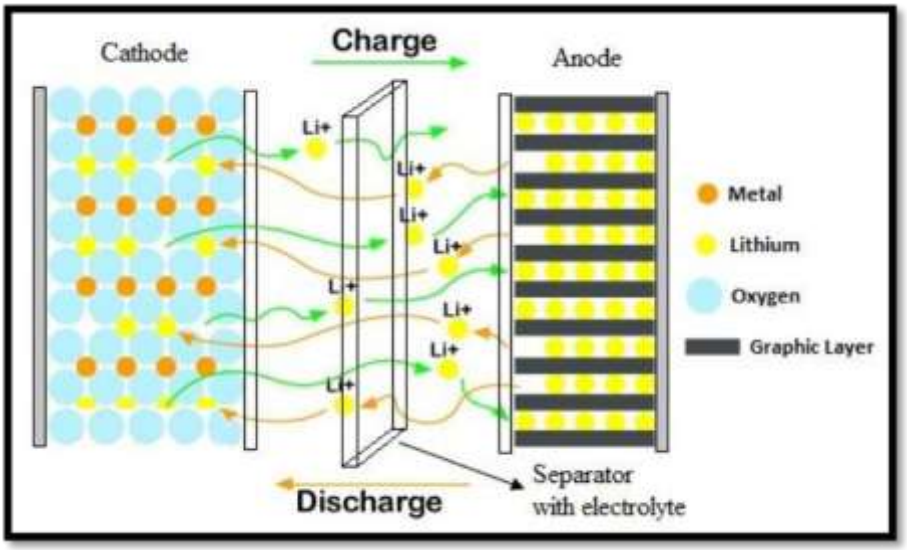

Fig -8: Schematic diagram of Lithium-ion battery With Charging and discharging 12

3.2 Comparison of Batteries:

The following comparison is based on the particular specification of batteries that can represent itself and will give the required information for the selection of battery technology for the Electrical vehicle system.

Table -2: Comparison of Battery types 781112

Names of parameters	Types of battery with specification			
	Lead acid	**Nicd**	**Ni-MH**	**Li-ion**
Specific energy (wh/kg)	20-40	40-65	45-80	90-190
Specific power (w/kg)	75-415	100-175	200-1500	500-2000
Nominal voltage(v)	2	1.25	1.25	3.6
Rated capacity (mAh)	20000	28000	23000	5300
Self-discharge/month (%)	5	20	30	10
Charging time (h)	8-16	1	2-4	2-4
Life cycle	200-2000	1500	300-500	500-1000

Peak drain (c)	5	20	5	2
Energy Efficiency (%)	70	60-90	75	80
Thermal Stability	Least stable	Least stable	Least stable	Most stable
Self-discharge	Low	Moderate	High	Very low
Overcharge tolerance	Moderate	Low	High	Very low
Maintenance requirement	3 to 6 months	30 to 60 days	60 to 90 days	Not req.
Internal resistance (includes peripheral circuits) in mΩ	100 to 200 6v pack	200 to 300 6v pack	<100 12v pack	150 to 250 7.2v pack
Operating temperature (discharge only)	-20 to 60°C	-40 to 60°C	-20 to 60°C	-20 to 60°C
Cost ($/kwh)	8.5	7.5	18.5	24

According to the above comparison, in all recent battery's technologies, Lithium-ion battery is the most suitable technology to use in Electrical Vehicles. Lithium-ion battery is the lightest battery in weight, higher energy density, longer life than all other batteries, and an only battery that can fulfill the requirements of Electrical vehicles 6.

4. MOTOR

There are mostly four preferable types of motors to propel the EV (Electrical Vehicle) are discussed. There is some requirements of EV's on electric motor drives that should be fulfill to drive the Electric Vehicle that requirements are efficiency, weight, cost, cooling, maximum speed, and fault-tolerance, safety, reliability, & overall performance is carried out for electric motor drives like Brushed DC Motor Drives, Permanent Magnet Blushless DC Motor, Induction Motor, & Permanent Magnet Synchronous Motor (PMSM) in order to find more appropriate electric motor drives for electric vehicle applications 1920.

4.1 Brushed DC Motor

Brushed DC motor working principle is based on the principle of that when a current carrying conductor is placed in a magnetic field the conductor experiences a mechanical force produces a torque, which turns the DC motor and this is the states with Fleming's left hand's rule, brushed DC motor rotor acts as a permanent magnet and stator as a rotating magnetic field 19.

However, Brushed DC Motor drives have a bulky construction, less efficiency, bulky construction, higher need of maintenance & less reliable due to the presence of the mechanical commutator and brushes. This construct brushed DC motors heavier and more expensive 16. Furthermore, friction between commutator& brushes to keep limits on the maximum motor speed.

4.2 BLDC Motor

To construct EV's (Electrical Vehicle) operation more reliable, more efficient & less noisy then use brushless DC motors. They are light weight than brushed DC motor with the same output. Brushes of DC motor wear out so we never use the operational demand long life & reliability BLDC is similar to DC motor & have a PM (Permanent Magnet) it is also called brush less because, it doesn't have the commutator and brushed arrangement 19.

The commutation is done by electrically brushless DCMOTOR are maintenance free BLDC have traction characteristics, high starting torque & high efficiency around 95%-98%. It has high starting torque, because it doesn't have any brushes so there will be no friction during the commutation the brushless DC motor are most preferred motor for electric vehicle application due to its traction 8.

4.2.1 Working:

The rotor of the BLDC motor is a permanent magnet, the stator has a Coil arrangement showing out-runner type BLDC motor in following figure. To energize the coil the DC supply is applied due to which coil act as an electromagnet.

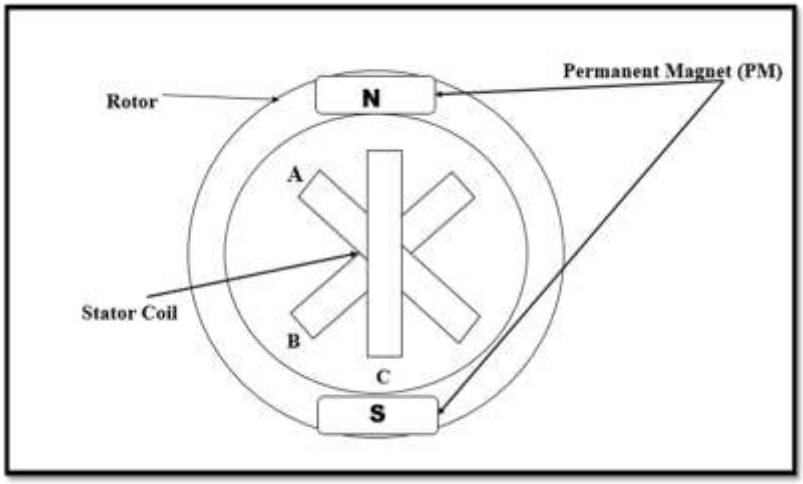

Fig -9: Coil arrangement of Out-runner type BLDC Motor

The operation of BLDC is based on the simple force interaction between the permanent magnet & the electromagnet 8. In this condition when the coil A is energized the alternative poles of the rotor & stator are interested in one another because the rotor nears coil A, coil B energize, as the rotor near coil B, coil C is energized & vice versa, this process is repeated & the rotor continues to rotate.

In BLDC uses an electronic controller for the purpose to get continuous rotation from rotor & randomly stator coil energizing, A sensor determines the position of the rotor & based on this intelligence the controller chooses which coils to energize. The arrangement of electronic sensor shown in fig no: 02. Mostly a Hall Effect sensor is used for this application 20.

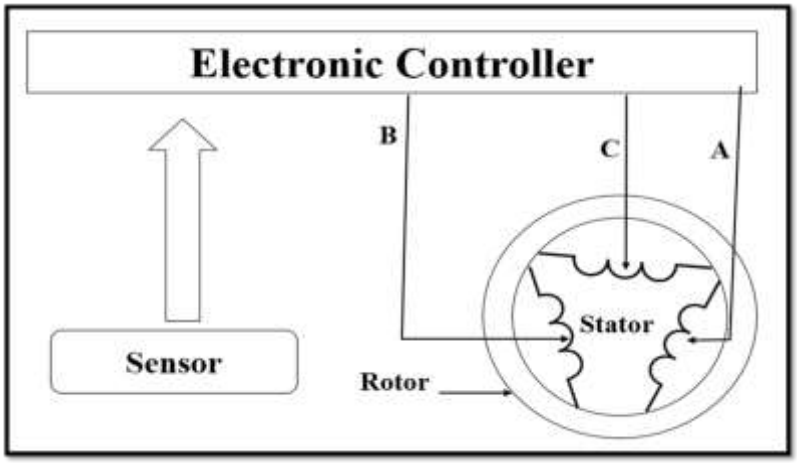

Fig -10: Block diagram of Electronic Controller arrangement with sensor for BLDC Motor

4.2.2 There are two types of BLDC motor:

4.2.2.1 Out-runners Type BLDC Motors

This type rotor of the motor is an out of doors & stator is inside, it's also called as HUB motor because the wheel is directly connected to the outside rotor. This type of motor does not require an exterior gearing system 15. This motor makes the overall vehicle less bulky as doesn't require any gear system, it eliminates space monitoring the motor as well this motor widely uses or preferred by electric manufactures like cycle & two wheelers also 13.

4.2.2.2 In-runner Type BLDC Motor

In this type rotor of motor is inside & stator is an outside, this motor required to extend transition system to transfer the power of wheel because of this the outer runner configuration is less bulky when compare to internal configuration many three wheelers uses this motor as well as the two wheelers like anther 450 so, the working principle of the same as the out runner motor but the cases magnets are inside 8, the rotor is inside as energies the coil the magnets get will attract and the rotation will be there.

4.3 Induction motor

The motor works on the principle of rotating magnetic field, so what is RMF (rotating magnetic field) when the wire is carrying current it produces a magnetic field around it 8, when three wires are connected to each other 120° apart & 3 phase given to them all three wires will create a magnetic field around IM variation in AC current takes different orientation & RMF is seen. The rotational speed of these magnetic field is known as synchronous speed 14.

4.4 Permanent Magnet Synchronous Motor (PMSM)

This motor is similar to BLDC motor which has permanent magnet all the rotor these motors have traction characteristics like high power density & high efficiency. PSSM (Permanent Magnet Synchronous Motor) are available for high power ratting. This is the best choice for high performance application like car & buses many more 18.

4.4.1 Working:

The speed characteristics achieved by constant & a rotating magnetic field; the rotor produces a constant magnetic field & the stator produce rotating magnetic field theory is an interaction between rotating magnetic field & rotor.

The field coil stator excited by 3 phase AC supply this process revolving magnetic field which rotates at synchronous speed20. The rotor is a permanent magnet that produces a constant magnetic field, when there is rotating magnetic field the opposite poles of rotating magnetic field & rotor will attract each other & they get mechanically locked so, the rotor will rotate at the same speed of rotating magnetic field & will get motion of the rotor which will propel the vehicle 8.

Synchronous speed derived as:
NS=(120F/P)

- NS= speed of the rotor in RPM.
- F=Frequency.
- P= numbers of poles.

So, if we can control the frequency of electricity supply then the speed of the synchronous speed motor accurately controlled.

4.5 Comparison of Electrical Motors used in electrical vehicle:

Table -3: Comparison of Electrical Motors 820

Feature	Brush DC Motor	Brushless DC Motor	Induction Motor	Permanent Magnet Synchronous Motor
Speed torque characteristics	Moderate loss in torque at higher speeds because of losses in brushes	Flat-operation at all speeds with rated load	Non linear	Speed is constant irrespective of loads ability to control power
Commutation method	Mechanical contact between brushes & commutator	Using solid switched	Special starting circuit is required.	Using solid switched
Detecting method of rotors position	Automatically detected by brushes & commutator	Hall sensors, optical encoder.	NA	NA.
Required Controller	No controller is required for a fixed speed & it is required for variable speed	A controller is always required to control the commutation sequence	Controller isn't required for a fixed speed & it is required for variable speed	Controller isn't required for a fixed speed & it is required for variable speed
Direction reversal	Reversing the terminal voltage	Reversing the switching sequence	By reversing any two phase of motor input	By reversing any two phase of motor input
Mechanical structure	Field magnet on the rotor & stator are made up of permanent magnet or an electromagnet	Rotor is permanent magnet & stator has a Coil arrangement	Stator has winding & AC lines are connected to the stator	Stator is Field Coil & Rotor is a Permanent Magnet
Direction reversal	Reversing the terminal voltage	Reversing the switching sequence	By reversing any two phase of motor input	By reversing any two phase of motor input
Electrical noise	High because of brushes	Less	Less	Less
Maintenance	Periodic maintenance because of brushes	No or Less maintenance	Less maintenance	No or Less maintenance
Efficiency	Moderate, losses due to brushes	High, No brushes	Low heat & current losses in both rotor & stator, high efficiency motors are also available (higher cost)	High, No brushes

System cost	low	High, because external controller requirement	Low	High, because external controller requirement or PM are expensive.

5. CONCLUSION

The goal of this paper is to target the key components of EV. EVs can be classified as BEV, HEV, PHEV. BEV have become mainstream in the future as having great potential of becoming the future of transport while saving this planet from imminent calamities caused by global warming. Current EVs use batteries as the main energy source. Battery technology has felt significant changes, the lead-acid technology is long gone, as is that the NiMH type. Li-ion batteries are currently in use, but even they're ineffectual enough to produce the quantity of energy required to appease the consumers littered with 'range anxiety' in most cases. Therefore, the most focus of research during this area has got to be creating batteries with more capacity, and also with better power densities. Differing kinds of motors may be employed for EV use. The prominent ones can be listed as induction motor, permanent magnet synchronous motor, and synchronous reluctance motor. Induction motors are being extensively these days, they can also dominate in the future because of their independence on rare-earth material permanent magnets.

REFERENCES

1. N. Penina, Y. V. Turygin and V. Racek, "Comparative analysis of different types of hybrid electric vehicles," 13th Mechatronika 2010, Trencianske Teplice, 2010, pp. 102-104.
2. Ghosh, Aritra. (2020). Possibilities and Challenges for the Inclusion of the Electric Vehicle (EV) to Reduce the Carbon Footprint in the Transport Sector: A Review. Energies. 13. 2602. 10.3390/en13102602.
3. H. Zakaria, M. Hamid, E. M. Abdellatif and A. Imane, "Recent Advancements and Developments for Electric Vehicle Technology," 2019 International Conference of Computer Science and Renewable Energies (ICCSRE), Agadir, Morocco, 2019, pp. 1-6, doi: 10.1109/ICCSRE.2019.8807726.
4. V. V. Shimin, V. A. Shah and M. M. Lokhande, "Electric vehicle batteries: A selection based on PROMETHEE method," 2016 IEEE 7th Power India International Conference (PIICON), Bikaner, 2016, pp. 1-6, doi: 10.1109/POWERI.2016.8077224.
5. G. Suciu and A. Pasat, "Challenges and opportunities for batteries of electric vehicles," 2017 10th International Symposium on Advanced Topics in Electrical Engineering (ATEE), Bucharest, 2017, pp. 113-117, doi: 10.1109/ATEE.2017.7905058.
6. X. Chen, W. Shen, T. T. Vo, Z. Cao and A. Kapoor, "An overview of lithium-ion batteries for electric vehicles," 2012 10th International Power & Energy Conference (IPEC), Ho Chi Minh City, 2012, pp. 230-235, doi: 10.1109/ASSCC.2012.6523269.
7. E.M.G. Rodrigues, R. Godina, G.J. Osório, J.M. Lujano-Rojas, J.C.O. Matias, J.P.S. Catalão University of Beira Interior, Covilhã, Portugal, and INESC-ID, IST, University of Lisbon, Lisbon, Portugal" Comparison of different Battery Types for Electric Vehicles.
8. Un-Noor, F.; Padmanaban, S.; Mihet-Popa, L.; Mollah, M.N.; Hossain, E. A Comprehensive Study of Key Electric Vehicle (EV) Components, Technologies, Challenges, Impacts, and Future Direction of Development. Energies 2017, 10, 1217.
9. Flah, Aymen & Lassaad, Sbita & Mahmoudi, Chokri. (2014). Overview of Electric Vehicle Concept and Power Management Strategies. 2014 International Conference on Electrical Sciences and Technologies in Maghreb, CISTEM 2014. 10.1109/CISTEM.2014.7077026.
10. K. W. E. Cheng, "Recent development on electric vehicles," 2009 3rd International Conference on Power Electronics Systems and Applications (PESA), Hong Kong, 2009, pp. 1-5.
11. E.M.G. Rodrigues, R. Godina, G.J. Osório, J.M. Lujano-Rojas, J.C.O. Matias, J.P.S. Catalão University of Beira Interior, Covilhã, Portugal, and INESC-ID, IST, University of Lisbon, Lisbon, Portugal "Comparison of Battery Models for Energy Storage Applications on Insular Grids"
12. M. A. Hannan1, Senior Member, IEEE, M. M. Hoque2, Student Member, IEEE, Aini Hussain3, Yushaizad Yusof3, P. J. Ker1," State-of-the-Art and Energy Management System of Lithium-Ion Batteries in Electric Vehicle Applications: Issues and Recommendations."

13. Porselv, T., Jayanty Ashok and Anjan Kumar. “Selection of Power Rating of an Electric Motor for Electric Vehicles.” (2017).
14. X. D. Xue, K. W. E. Cheng and N. C. Cheung, "Selection of eLECTRIC mOTOR dRIVES for electric vehicles," 2008 Australasian Universities Power Engineering Conference, Sydney, NSW, 2008, pp. 1-6.
15. Nadolski, Roman & Ludwinek, Krzysztof & Staszak, Jan & Jaśkiewicz, Marek. (2012). Utilization of BLDC motor in electrical vehicles. Przeglad Elektrotechniczny. 88.
16. Racewicz, Szymon & Kazimierczuk, Paweł & Kolator, Bronisław Andrzej & Olszewski, Andrzej. (2018). Use of 3 kW BLDC motor for light two-wheeled electric vehicle construction. IOP Conference Series: Materials Science and Engineering. 421. 042067. 10.1088/1757-899X/421/4/042067.
17. M. Yildirim, M. Polat and H. Kürüm, "A survey on comparison of electric motor types and drives used for electric vehicles," 2014 16th International Power Electronics and Motion Control Conference and Exposition, Antalya, 2014, pp. 218-223, doi: 10.1109/EPEPEMC.2014.6980715.
18. Bhatt, Pooja and Mehar, Hemant and Sahajwani, Manish, Electrical Motors for Electric Vehicle – A Comparative Study (April 3, 2019). Proceedings of Recent Advances in Interdisciplinary Trends in Engineering & Applications (RAITEA) 2019.
19. Jape, Swaraj & Thosar, Archana. (2017). COMPARISON OF ELECTRIC MOTORS FOR ELECTRIC VEHICLE APPLICATION. International Journal of Research in Engineering and Technology. 06. 12-17. 10.15623/ijret.2017.0609004.
20. S. Derammelaere, M. Haemers, J. De Viaene, F. Verbelen and K. Stockman, "A quantitative comparison between BLDC, PMSM, brushed DC and stepping motor technologies," 2016 19th International Conference on Electrical Machines and Systems (ICEMS), Chiba, 2016, pp. 1-5.
21. Wu, Guoyuan & Boriboonsomsin, Kanok & Barth, Matthew. (2014). Development and Evaluation of an Intelligent Energy-Management Strategy for Plug-in Hybrid Electric Vehicles. Intelligent Transportation Systems, IEEE Transactions on. 15. 1091-1100. 10.1109/TITS.2013.2294342.
22. Petr Krivik and Petr Baca (January 23rd 2013). Electrochemical Energy Storage, Energy Storage - Technologies and Applications, Ahmed Faheem Zobaa, IntechOpen, DOI: 10.5772/52222. Available from: https://www.intechopen.com/books/energy-storage-technologies-and-applications/electrochemical_energy_storage

BIOGRAPHIES

Akash Bhagawan Pawar
B. E. student in Electrical Engineering, TCOER, Pune, Maharashtra,
India - 411048

Arati Ramesh Mane
B. E. student in Electrical Engineering, TCOER, Pune, Maharashtra,
India – 411048

Hitesh Shankar Patil
B. E. student in Electrical Engineering, TCOER, Pune, Maharashtra,
India - 411048

Sumpreet Singh
Assistant Professor, Dept. of Electrical Engineering,
TCOER, Pune, Maharashtra,
India – 411048

Takadir S. Pinjari
Assistant Professor, Dept. of Electrical Engineering,
TCOER, Pune, Maharashtra,
India - 411048