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Trends and Performance Measures of Electric Vehicles in Market

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Abstract:
The unfolding changeover from internal combustion engine to electric vehicle is emerging at a rapid phase due to various factors such as outpouring environmental pollution, clean and sustainable transportation, climatic changes and scarcity of fossil fuel. The competent motors which provide substantial output in terms power and energy are in need for electric vehicle (EV) to replace internal combustion engine (ICE). This paper delivers various types of EV's and its drive unit type used to propel the vehicle and investigation of most widely used electric motor in context with its efficiency, power and cost. Also performance parameter of electric vehicle produced by original equipment manufacturer (OEM) is compared.

Keywords: *Electric vehicle, PMSM.*

1. INTRODUCTION:

Electric vehicle is proposed to replace internal combustion engine (ICE) due to various factors. Around 30% energy from combustion reaction in ICE is converted into mechanical power and almost 70% of energy is wasted as combustion loss. [1] Exhaust gases from ICE such as carbon dioxide, nitrogen oxide, hydrocarbons and carbon monoxide may increase air pollution and cause global warming. These emissions blocks earth radiation emission back into outer space which in turn increase the global temperature drastically. It also leads to rise in sea level. Toxic emissions from ICE also leads to severe air pollution in cities and it may cause respiratory disorders, lung cancer etc. scarcity of fossil fuel is major/ important reason for emerging electric vehicles or hybrid electric vehicle.[9] Electric vehicles uses electric motor for traction purpose or to advance the efficiency in design of conventional vehicle. Electric vehicle has higher efficiency, lower or zero emission, low fuel cost compared to internal combustion engine.[3]

2. TYPES OF ELECTRIC VEHICLE

Electric vehicles are categorized on the basis of either type of energy converter used to drive the vehicle or vehicle power and function as follows

- Hybrid electric vehicles-HEV
- Plug-in hybrid electric vehicles -PHEV
- Battery electric vehicle or All-electric vehicles - EV

PHEV and EV can be together called as plug-in electric vehicle.[3,5]

A. Hybrid electric vehicle (HEV)

HEVs can be powered by single or group of EM-electric motor that utilizes power from a battery bank and by a conventional diesel internal combustion engine (ICE) i.e propulsion is based on combined action of electric motor and ICE. The battery can be boosted both by the ICE and also through regenerative braking. In regenerative braking, energy which is normally wasted during braking is grabbed by EM-electric motor as generator and then stored in the bank of battery.

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Stored energy from battery can also be used for some power supplementary loads such as headlamps, microphones and speakers thus reduce engine be inactive when vehicle is not running. HEV is mostly commonly preferred for short distance nd low speed vehicle. It has superior fuel economy and minor emission than conventional ICE.

Classification of HEV based on degree of hybridization:

i. **Micro hybrids**: In this type EM of range 2.5 KW at 12 V is used. Electric motor is used only during start and stop operation hence only 5% to 10% energy saving is possible. C3 Citroen is one of the viable example.

ii. **Mild Hybrids**: uses EM of about 10-20 KW at 100-200 V. 20%-30% of energy saving is possible which compensates the higher preliminary cost as compared to ICE. Honda Civic and Honda Insight are the commercial models.

iii. **Full Hybrid**: In this type EM of about 55 KW at 210-300 V is used. Energy saving of 30%-50% are possible. Recovered energy can be saved either in battery and/or using super capacitor, during coasting and regenerative braking. Example Toyota Prius.

HEVs TOPOLOGY:

The three fundamental power train architectures are designed based on the way in which energy converters are combined to accelerate the vehicle are listed as follows [9]

a) **Series HEV**: In this topology, drive train and electric motor are directly connected and vehicle is propelled. ICE drives an electric generator which supplies electric power to battery and motor.

b) **Parallel HEV**: In this topology, dual power paths are possible for drive train. For short distance trip, the vehicle is driven by electric, while for long drives ICE is preferred. Propulsion in parallel HEVs can be the consequence of generated torque concurrently by an ICE and EM. Electric motor can assist engine while Climbing hills and during vehicle accelerations.

c) **Dual mode HEV (Series- Parallel mode):** In this topology, alternator is connected to the IC engine that charges the battery. Under ordinary circumstance, ICE turns both the drive train and generator, which in turn feed the Bank of battery through ECU. Requested acceleration can be attained during full throttle acceleration as battery powers EM and in turn the motor assists ICE for the operation.

B. Plug-In Hybrid Electric Vehicles (PHEV)

In PHEV uses fuel such as gasoline to power an ICE and also use batteries to power an electric motor. [7]

Table I : Elucidation Chart of Various Types of Electric Vehicles With Respect to ICE

S. No	Characteristics	ICE	HEV	PHEV	EV
1	Propulsion System	ICE based	ICE & Electric drive based	ICE & Electric drive based	Electric drive based
2	Storage Of energy	Fuel tank	Fuel tank Ultra capacitor Battery banks Flywheel converter	Fuel tank Flywheel converter Battery bank Ultra capacitor	Battery bank Ultra capacitor Flywheel converter
3	Source of Energy	Petrol / gasoline	Petrol and electric energy	Petrol and electrical energy	Electrical energy
4	Commercialized	Yes	Yes	Partially	yes

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5	Pollutants from vehicle	Very high	Very low	Low	No
6	Bulky	Yes	Yes	Yes	No
7	Fuel cost saving	Expensive	Less expensive	Less expensive	Less expensive

Batteries in PHEV can be charged by an AC utility grid or by ICE and energy obtained by motor operating as a generator in regenerative Mode while applying brake. Battery packs used in PHEVs are comparatively larger than HEVs. While driving PHEV in the cities, it uses power from the battery until there is a charge in it. When battery is almost drained or condition of blackout occurs due to the rapid acceleration phase, usage of air conditioner then ICE comes in to play to power the vehicle. PHEV produce zero emission when working on battery power alone and it consume a reduced amount of fuel and produce negligible emissions compared to conventional vehicle, even when ICE is operating. The distance travelled for each charge cycle determines the gasoline consumption of PHEV. Its usage o gasoline fuel alone without plugging in will result in the same efficiency as that of the similar sized HEV.

C. All-electric vehicles (EVs) or Battery electric vehicle

In EVs, it used of group of electric motors for powering the differential drive. The motors are supplied by energy through the batteries. It does have any ICE but propulsion is only due to electric motors. The batteries are charged through plugging in to AC utility grid. BEVs use battery banks to store the energy in terms of electrical power to supply the motors which in turn converts the electrical energy in to mechanical energy to drive the differential wheels through transmission module. With EVs only shorter driving ranges are possible compared to conventional vehicle. According to driving conditions and driving habits, EV range can varies. Temperature variation may reduce EV range because battery banks must power not only motor but also climate control system. Over Speed, rash driving, and over loading the vehicle can also reduce range.BEV is less attractive compared to HEV because of dependency on only battery as a source, charging time, running time, performance.

BEV TOPOLOGY:

The electric motor is driven by the power converter through ECU control. The power converter is supplied by the energy from the bank of battery. EM shaft drives the respective wheel with the aid of a differential Gear arrangement controlled by the transmission control module. Electronic converter unit consists of DC converter and driver circuit for the motor. Selection of converter is based on motor type, motor rating, battery specifications and power rating. To achieve maximum efficiency, Kinetic energy generated while applying brakes should be utilized by converting it into electrical energy by the operation of motor as a generator in regenerative mode. Thus the energy is stored in the battery which in turn is an advantage. Topology and control strategy of power converter decides motor type, ratings and battery technology. In order to obtain effective regenerative power, electronic converter must be capable of controlling the flow of power from battery to motor and vice-versa. For quick charging of battery with recovered kinetic energy from brake pedals, a super capacitor or a flywheel should be used as intermediate energy storage.

3. CHARGING TECHNOLOGY

Charging stations are equipped with DC charging utility to boost the battery banks of PEVs. The Battery management system exchanges information with the vehicle through Electronic control unit to check and assure that it provides an suitable power with safety constraints. Charging system for PEV is classified into two types as Alternating current stage

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1 and Alternating current stage 2 which supply AC power to vehicle. Onboard equipment in vehicle converts AC into Direct Current which is required to charge the battery banks. For fast charging, DC fast charging can be adopted for direct charging of the vehicle. The inductive charging equipment is used to charge PEV by using Electromagnetic field to transfer energy. Based on type or level of charging, charging times ranges from 20 minutes to 20 hours or more. Charging times also depends on battery type, its capacity and size of internal charger. Installation of charging units can be done in suburban, place of work and public places. Financial incentives for charging stations are also provided by some government.

4. ELECTRIC MOTORS USED IN EV:

Among various electric motors available PMSM,SRM and IM are commonly preferred in electric vehicle and also in hybrid electric vehicles. [10] Induction motors are vastly used in electric vehicles because of its higher efficiency, better speed regulation ,nocommutators and less maintenance. Maximum torque at starting which is essential for electric vehicle can be achieved by using control methods like v/f method. Drawbacks of IM includes, complex control methods and inverter circuit. From table I and Table II it inferred that permanent magnet synchronous motor is seems to be best option for upcoming electric vehicles and in HEVs because of its superior power density & higher efficiency. High power density is possible with Interior PMSM as it as extra reluctant torque compared to Surface Mounted PMSM.[2] One of the major disadvantage of PMSM is its high overall cost especially due to usage of permanent magnets their construction. Motor design which does not include rare-earth magnet in their construction such as Switched Reluctance Machines (SRM) which has salient structure both in stator & rotor but no winding or magnet in rotor may replace PMSM in near future. [6] In SRM, H-bridge converter topology is used replacing Voltage Source Inverter (VSI) which is common in other motors. Some of the advantages of SRMs includes, less cost, simple structure, flexibility of control, fault tolerance capability and better efficiency. According to cost and simplicity, SRM seems to be best option but it also includes some drawbacks such as higher ripple current in the DC bus, higher electromagnetic radiation (EMI), high torque ripple, huge acoustic noise and moderate power density.

Table- II: Characteristics comparison of Electric motor.

FEATURES	Permanent Magnet Synchronous Motor	Induction motor	Switched Reluctance Motor
Efficiencies at constant torque region	91.3–95.8%	79-86%	85.1-89%
Overall technology cost	high	medium	Low

5. COMPARISON OF ELECTRIC CARS ON MARKET

An attempt is made to compare electrical parameters of some electric cars of 2019 model by original equipment manufacturers. It is observed from the comparison that high end car is having more torque compared to other electric vehicles. PMSM is commonly used in electric cars and the cost is comparatively low. Cumulative correlations of electric vehicle model in terms of battery size, peak power, maximum speed, energy consumption and torque are plotted in the graph and figured in [1-5].

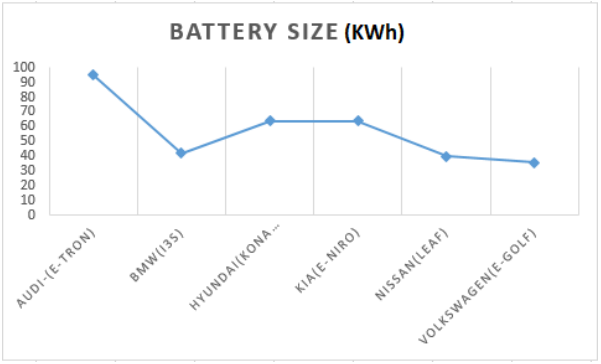

Fig. 1. Battery size comparison of electric cars

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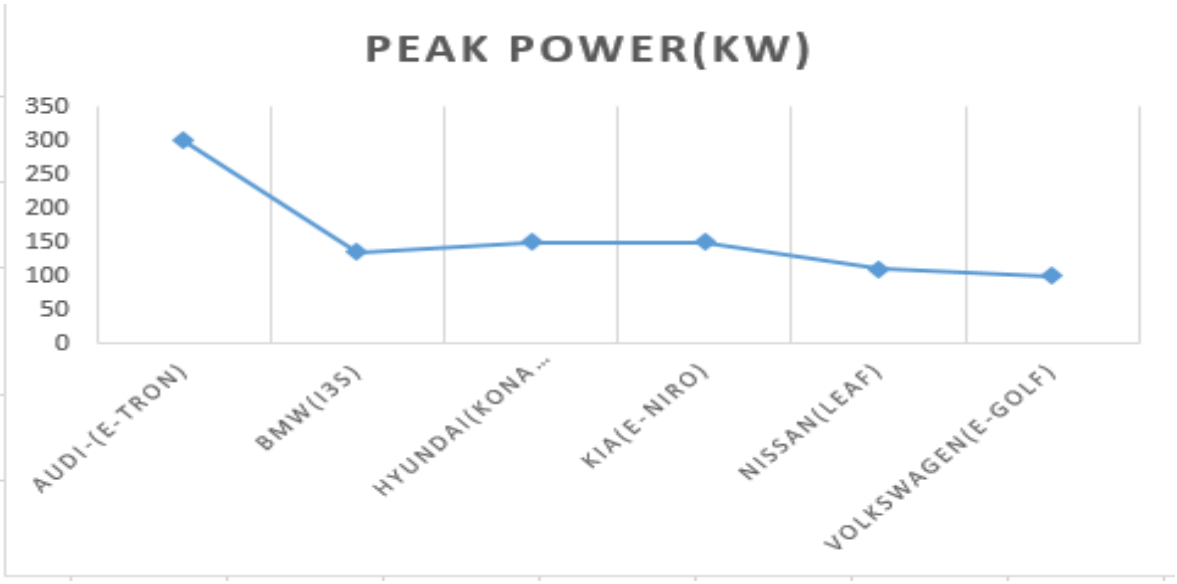

Fig. 2 Peak power comparison of electric cars

Table III : Study of parameters of various models of Electric Vehicles available in Market

S.no	Model(2019)	Battery size (KWh)	Peak power (Kw)	Top speed (mph)	Energy Consumption (Wh/mi)	Torque (Nm)	Motor type
1	Audi-(e-tron)	95	300	124	455	664	IM
2	BMW(i3s)	42.2	135	100	298	250	PMSM
3	Hyundai(kona electric)	64	150	104	281	395	PMSM
4	KIA(E-NIRO)	64	150	104	301	395	PMSM
5	NISSAN(LEAF)	40	110	90	301	320	PMSM
6	Volkswagen(e-golf)	35.8	100	93	283	290	PMSM

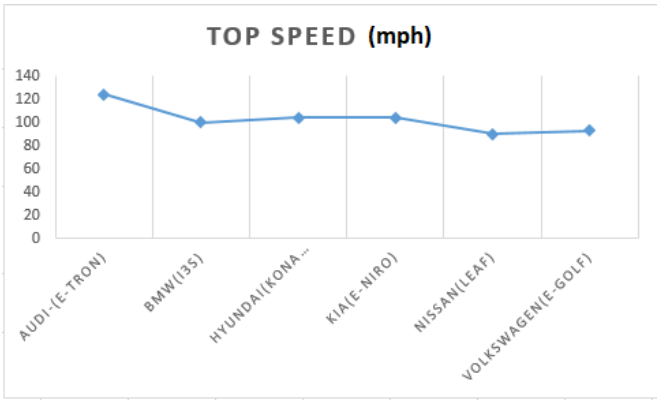

Fig. 3 maximum speed comparison of electric cars

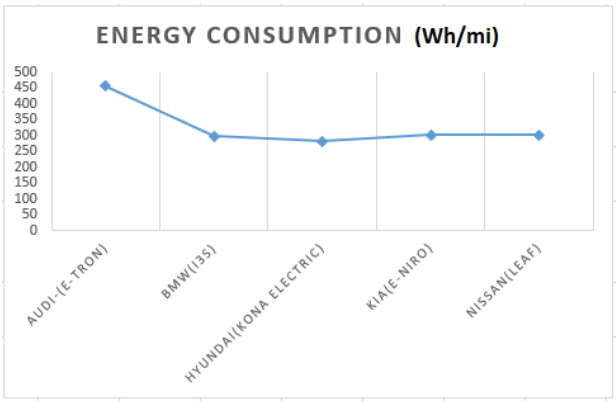

Fig. 4 Energy consumption comparison of electric cars

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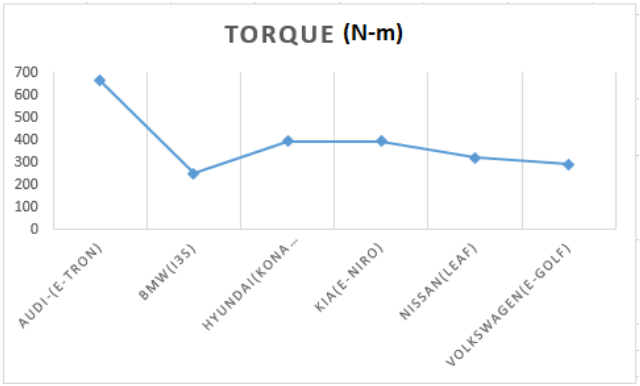

Fig. 5. Torque comparison of electric cars

6. CONCLUSION

Electric vehicles are flourishing in the recent years to procure solution for problems faced by the ICE such as pollution, hazardous emission and blackout of gasoline. These electric vehicles can be utilized for urban transportation and also in historical tourist places. The effective performance of electric vehicle demands right choice of the motor. In this Paper. We have elucidated the types of EVs available and also studied the electrical performance of the vehicle with different Motors. The Studies performed in this Paper inferred that PMSM is predominantly preferred by the manufactures because of its higher efficiency. On the contrary use of rare earth magnets in its design make its cost high. The improvement in the design of SRM and IM can reduce the overall cost of the EV in upcoming years.

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