"SAVE ENERGY'

Electric Times

EEE- AITS RAJAMPET

VOL.V. . . No.1 *MAY 2021* EDITORS : S.MUQTHIAR ALI::P.AYUB KHAN

Vision	MISSION
We envision the Department as one of the best in the region with a stimulating environment to make an impact on and lead in the field through its Education and Research.	The mission of the Department is to provide an excellent and comprehensive education in the field of Electrical & Electronics Engineering which in turn moulds the students for a wide range of careers and to exhibit a high level of professionalism, ethical behavior and social responsibility.

Student Article:

50 Hz vs 60 Hz

50 Hz and 60 Hz power sources are most often used in international power systems. Some countries (regions) commonly use 50Hz power grid while other countries use 60Hz power grid.

Alternating current (AC) is changing the direction of the current periodically. Cycle is the time of a cyclical change of the current. Frequency is the times of the current changes per second, unit Hertz (Hz). AC current direction changes 50 or 60 cycles per second, in accordance with 100 or 120 changes per second, then the frequency is 50 Hertz or 60 Hertz.

WHAT IS HERTZ?

Hertz, in short Hz, is the basic unit of frequency, to commemorate the discovery of electromagnetic waves by the German physicist Heinrich Rudolf Hertz. In 1888, German physicist Heinrich Rudolf Hertz (Feb-22, 1857 to Jan-1, 1894), the first person confirmed the existence of radio waves, and had a great contribution in Electromagnetism, so the SI unit of frequency Hertz is named for him.

WHAT IS Hz USED FOR?

Hz (Hertz) is the frequency unit of the vibration cycle time of electric, magnetic, acoustic and mechanical vibration, i.e. the number of times per second (cycle/sec).

WHAT IS 50 HERTZ?

50 Hertz (Hz) means the rotor of the generator turns 50 cycles per second, the current changes 50 times per second back and forth, direction changes 100 times. That means the voltage changes from positive to negative, and from negative to positive voltage, this process converts 50 times/second. The electricity 380V AC and 220V AC, are both 50 Hz frequencies.

The speed of 50 Hertz 2 poles synchronous generator is 3000 rpm. AC power frequency is determined by the pole number of the generator p and speed n, Hz = p*n/120. The grid standard frequency is 50 Hz, which is a constant value. For a 2-pole motor, the speed n = 50 * 120 / 2 = 3000rpm; for a 4-pole motor, the speed n = 50 * 120 / 4 = 1500rpm.

WHY USE 50 HERTZ?

When the frequency increases, the copper and steel consumptions of the generator and transformer decrease, along with the reduction of weight and cost, but will make the inductances of the electrical equipment and transmission line increase, reduce the capacitances and increase losses, thereby reducing the transmission efficiency. If the frequency is too low, the electrical equipment's materials will increase, along with heavy and high cost, and will make lights flashing obviously. Practices have proved using 50 Hz and 60 Hz frequencies are appropriate.

CAN A 50 HERTZ MOTOR RUN ON 60 HERTZ?

Since the formula for governing the synchronous speed of a three-phase motor is n = (120 * Hz)/p if this is a 4-pole motor then at 50 Hz the speed would be 1,500 RPM whereas at 60 Hz the speed would be 1,800 RPM. Since motors are constant torque machines then by applying the formula that HP = (torque*n)/5252 then you can see that with a 20

WHAT IS 60 HERTZ?

At 60 Hz, the rotor of the generator turns 60 cycles per second, the current changes 60 times per second back and forth, direction changes 100 times. That means the voltage changes from positive to negative, and from negative to positive voltage, this process converts 60 times/second. The electricity 480V AC and 110V AC, are both 60 Hz frequencies.

The speed of 60 Hz 2-pole synchronous generator is 3,600 RPM. AC power frequency is determined by the pole number of the generator p and speed n, freq. = p*n/120. The grid standard frequency is 60 Hz, which is a constant value. For a 2-pole motor, the speed n = 60 * 120 / 2 = 3,600 RPM; for a 4-pole motor, the speed n = 60 * 120 / 4 = 1,800 RPM.

1. **50 Hz vs 60 Hz**

50 Hz and 60 Hz power sources are most often used in international power systems. Some countries (regions) commonly use 50Hz power grid while other countries use 60Hz power grid.

Alternating current (AC) is changing the direction of the current periodically. Cycle is the time of a cyclical change of the current. Frequency is the times of the current changes per second, unit Hertz (Hz).

AC current direction changes 50 or 60 cycles per second, in accordance with 100 or 120 changes per second, then the frequency is 50 Hertz or 60 Hertz.

WHAT IS HERTZ?

Hertz, in short Hz, is the basic unit of frequency, to commemorate the discovery of electromagnetic waves by the German physicist Heinrich Rudolf Hertz. In 1888, German physicist Heinrich Rudolf Hertz (Feb-22, 1857 to Jan-1, 1894), the first person confirmed the existence of radio waves, and had a great contribution in Electromagnetism, so the SI unit of frequency Hertz is named for him.

WHAT IS Hz USED FOR?

Hz (Hertz) is the frequency unit of the vibration cycle time of electric, magnetic, acoustic and mechanical vibration, i.e. the number of times per second (cycle/sec).

WHAT IS 50 HERTZ?

50 Hertz (Hz) means the rotor of the generator turns 50 cycles per second, the current changes 50 times per second back and forth, direction changes 100 times. That means the voltage changes from positive to negative, and from negative to positive voltage, this process converts 50 times/second. The electricity 380V AC and 220V AC, are both 50 Hz frequencies.

The speed of 50 Hertz 2 poles synchronous generator is 3000 rpm. AC power frequency is determined by the pole number of the generator p and speed n, Hz = p*n/120. The grid standard frequency is 50 Hz, which is a constant value. For a 2-pole motor, the speed n = 50 * 120 / 2 = 3000rpm; for a 4-pole motor, the speed n = 50 * 120 / 4 = 1500rpm.

WHY USE 50 HERTZ?

When the frequency increases, the copper and steel consumptions of the generator and transformer decrease, along with the reduction of weight and cost, but will make the inductances of the electrical equipment and transmission line increase, reduce the capacitances and increase losses, thereby reducing the transmission efficiency. If the frequency is too low, the electrical equipment's materials will increase, along with heavy and high cost, and will make lights flashing obviously. Practices have proved using 50 Hz and 60 Hz frequencies are appropriate.

CAN A 50 HERTZ MOTOR RUN ON 60 HERTZ?

Since the formula for governing the synchronous speed of a three-phase motor is n = (120 * Hz)/p if this is a 4-pole motor then at 50 Hz the speed would be 1,500 RPM whereas at 60 Hz the speed would be 1,800 RPM. Since motors are constant torque machines then by applying the formula that HP = (torque*n)/5252 then you can see that with a 20% increase in speed the motor would also then be able to produce 20% more horsepower. The motor would be able to produce rated torque at both 50/60 Hz frequencies only apply if the V/Hz ratio is constant, meaning that at 50 Hz the supply voltage would need to be 380 V and at 60 Hz the supply voltage would need to be 460 V. In both cases the V/Hz ratio is 7.6V/Hz.

WHAT IS 60 HERTZ?

At 60 Hz, the rotor of the generator turns 60 cycles per second, the current changes 60 times per second back and forth, direction changes 100 times. That means the voltage changes from positive to negative, and from negative to positive voltage, this process converts 60 times/second. The electricity 480V AC and 110V AC, are both 60 Hz frequencies.

The speed of 60 Hz 2-pole synchronous generator is 3,600 RPM. AC power frequency is determined by the pole number of the generator p and speed n, freq. = p*n/120. The grid standard frequency is 60 Hz, which is a constant value. For a 2-pole motor, the speed n = 60 * 120 / 2 = 3,600 RPM; for a 4-pole motor, the speed n = 60 * 120 / 4 = 1,800 RPM.

HOW TO CHANGE 60 Hz TO 50 Hz

A frequency converter can convert fixed frequency (50 Hz or 60 Hz) AC power to variable frequency, variable voltage power through AC → DC → AC conversion, output pure sine wave, and adjustable frequency and voltage. It is different with variable frequency drive, which is special for motor speed control only, and also different with ordinary voltage stabilizer. Ideal AC power supply is stable frequency, stable voltage, resistance is approximately zero and the voltage waveform is pure sine wave (without distortion). Frequency converter output is very close to the ideal power supply, hence, more and more countries use frequency converter power supply as a standard power source in order to provide the best electrical power supply environment for appliances to estimate their technical performance.

50 Hz vs. 60 Hz IN OPERATING SPEED

The primary difference between 50 Hz (Hertz) and 60 Hz (Hertz) is simply that 60 Hz is 20% higher in frequency. For a generator or induction motor pump (in simple terms) it means 1,500/3,000 RPM or 1,800/3,600 RPM (for 60 Hz). The lower the frequency, the lower will be the iron losses and eddy current losses. Lower the frequency, speed of induction motor and generator will be lower. For example with 50 Hz, generator will be running at 3,000 RPM against 3,600 RPM with 60 Hz. Mechanical centrifugal forces will be 20% higher in case of 60 Hz (rotor winding retaining ring has to bear centrifugal force while designing).

But with higher frequency, output of generator and induction motors will be higher for same size of motor/generator because of 20% higher speed.

50 Hz VS 60 Hz ON EFFICIENCY

The design of such magnetic machines is such that they are really one or the other. It may work in some cases, but not always. To change between different power supply frequencies will certainly have an effect on efficiency, and may mean de-rating is necessary. There is little real difference between 50 Hz and 60 Hz systems, as long as the equipment is designed appropriately for the frequency.

It is more important to have a standard and stick with it. The more significant difference is that 60 Hz systems usually use 110V (120V) or thereabouts for the domestic power supply, while 50 Hz systems tend to use 220V, 230V etc. for different countries. This has the impact that house wiring needs to be twice the cross section for the 110V system for the same power. However the optimum system is accepted as around 230V (wire size and power required versus safety).

IS 60 Hz BETTER THAN 50 Hz?

It is no big difference between 50 Hz and 60 Hz, nothing is bad or good basically. For independent power equipment like ships, aircraft or isolated area like gas/oil installation, any frequency (like 400 Hz) can be designed based on suitability.

Source: http://www.gohz.com/difference-between-50hz-and-60hz-frequency

50 Hz OPERATION OF 60 Hz MOTORS

To obtain optimum performance, motors used for 50 Hz applications should be specifically engineered and manufactured for 50 Hz. Frequently, the delivery of 50 Hz products is such that an alternate course of action, utilizing 60 Hz products, is desirable.

The general guidelines for operating 60 Hz motors on 50 Hz systems relate to the fact that the volts per cycle have to remain constant with any change in frequency. Also, since the motor will operate at only five sixths of 60 Hz speed the output horsepower capability of 50 Hz is limited to a maximum of five sixths of nameplate H.P.

2. Review on Electric Vehicle, Battery Charger, Charging Station and Standards

Abstract: Electric vehicles are a new and upcoming technology in the transportation and power sector that have many benefits in terms of economic and environmental. This study presents a comprehensive review and evaluation of various types of electric vehicles and its associated equipment in particular battery charger and charging station. A comparison is made on the commercial and prototype electric vehicles in terms of electric range, battery size, charger power and charging time. The various types of charging stations and standards used for charging electric vehicles have been outlined and the impact of electric vehicle charging on utility distribution system is also discussed.

Keywords: Battery charger, charging station, electric vehicle, standards

INTRODUCTION

In light of high energy usage, environmental pollution and rising fossil fuel prices, current dependent on Internal Combustion Engine (ICE) technology must be reduced and alternative fuel which has the potential to solve environmental pollution; global warming and energy sustainability concerns must be explored. It is suggested that electricity is the most suitable energy carrier for transportation in the next 30 years when considering risk, emissions, availability, maintainability, efficiency and reliability (Chan and Chau, 2001). The invention of automobiles with ICE began in the late 19th century and the automotive industry ever since has seen only incremental changes. ICE remains the prime mover for automobiles with fossil fuel as the main fuel. The paradigm shift towards electrification drives the development of new types of propulsion systems based on electric. Figure 1 shows the paradigm shift from ICE vehicle to advanced electric-drive vehicles (Emadi, 2011). Transportation 1.0 and Car 1.0 refer to a stage or time in which transportation and cars employ fossil fuels as the main fuels, while Transportation 2.0 and Car 2.0 refer to paradigm-shifted stage in which increasing electrification in vehicles is foreseen.

Electric drive vehicles are very attractive due to low road emissions, can potentially strengthen the power system by providing ancillary services; have a lower operating cost compared to fossil fuels and are more energy efficient. Advanced electric drive vehicles can be categorized into Hybrid Electric Vehicles (HEVs), plug-in Hybrid Electric Vehicles (PHEVs) and all-electric vehicles (EVs). HEVs can be generally classified as series, parallel and series-parallel (combined hybrid) (Maggetto and Van Mierlo, 2000) as shown in Fig. 2 to 4 respectively. In a series HEV, traction power is delivered by the electric motor while the ICE drives an electric generator that produces power for charging the batteries and driving the electric motor as shown in Fig. 2 and 3 shows a parallel HEV in which the engine and electric motor are coupled to drive the vehicle which allows simultaneous operation of ICE and motor high speeds. Figure 4 shows a series-parallel configuration in which two electric machines are used to provide both parallel and series paths for the power. This means that ICE can be used to drive the vehicle together with the motor, or used for generating electricity to be stored in the battery, depending on the operating conditions and setup. HEVs can be further divided into micro hybrids, mild hybrids, power hybrids and energy hybrids depending on the hybridization factor. Hybridization factor is defined as the ratio of the peak of vehicle electrical power to that of total electrical and mechanical power (Zeraoulia *et al*., 2006). Micro hybrids have a hybridization factor of 5-10%; mild hybrids, 10-25% and power hybrids have much higher factor. An energy hybrid has an energy

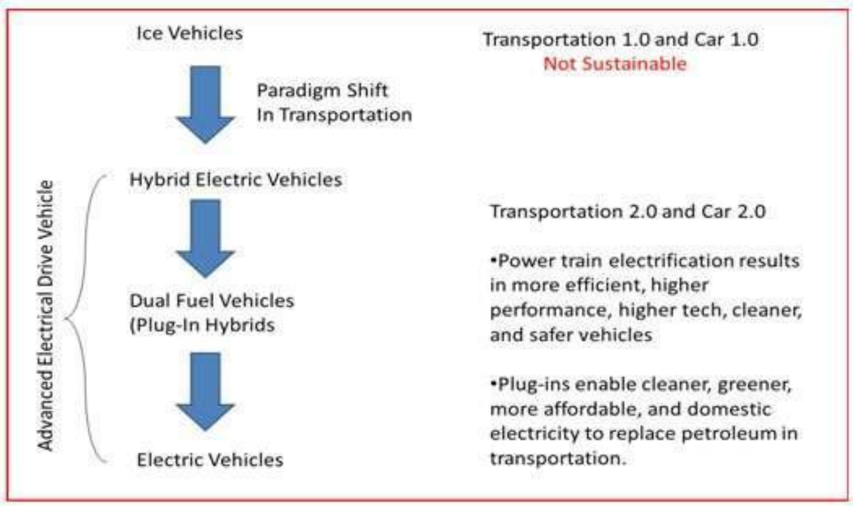

Fig.1: The paradigm shift in transportation from ICE vehicles to advanced electric-drive vehicles

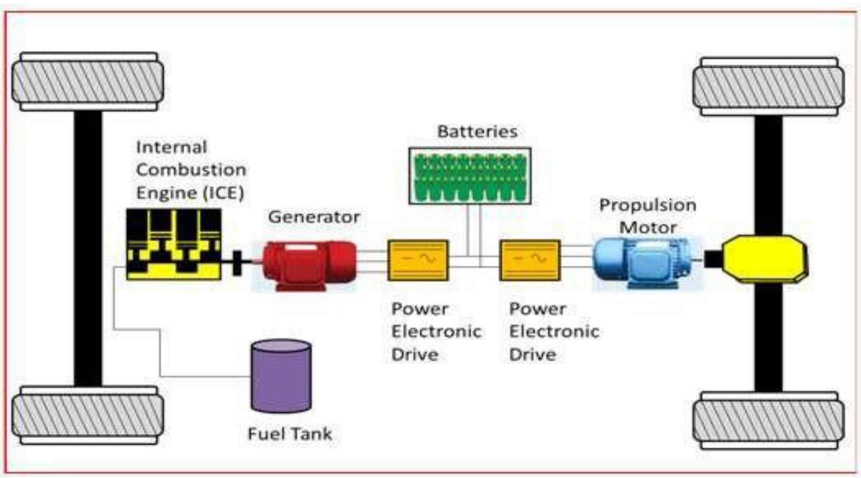

Fig. 2: A hybrid electric vehicle with a series hybrid power train

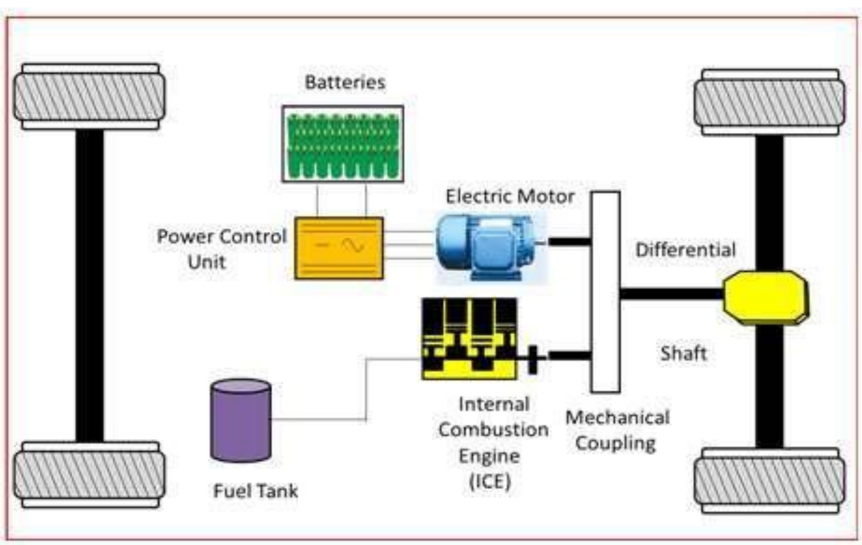

Fig. 3: A hybrid electric vehicle with a parallel hybrid power train

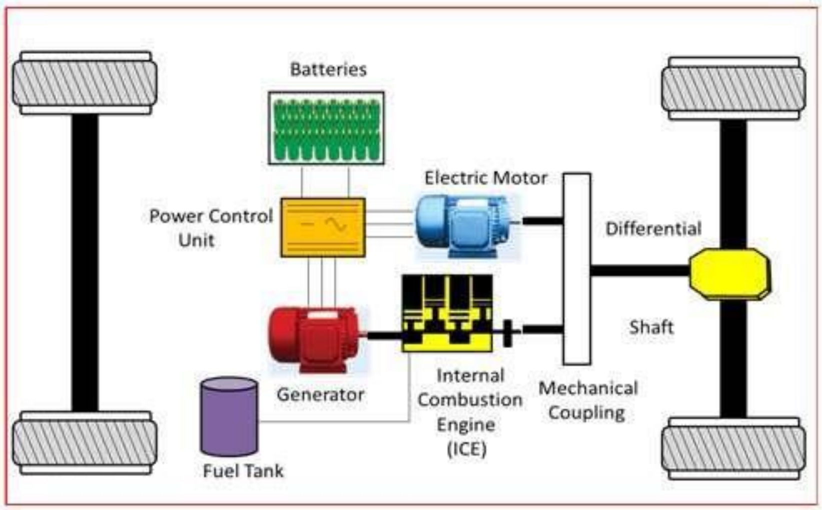

Fig. 4: A hybrid electric vehicle with a series-parallel hybrid power train

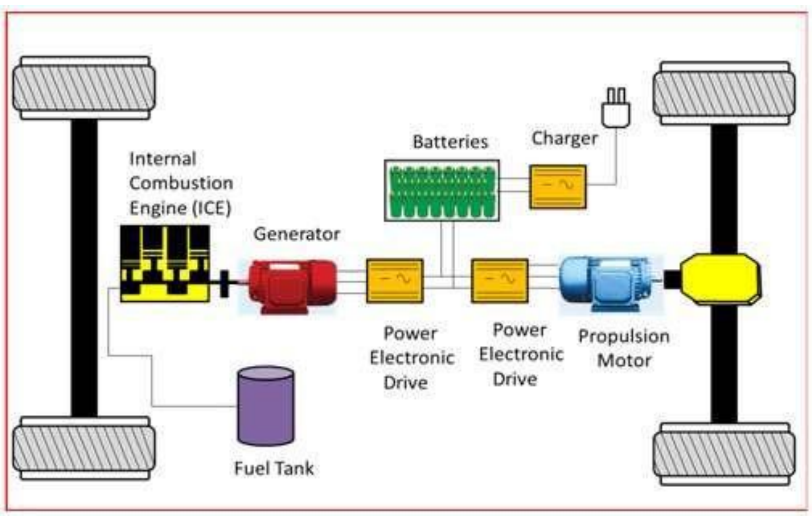

Fig. 5: A plug-in hybrid electric vehicle with a series hybrid power train

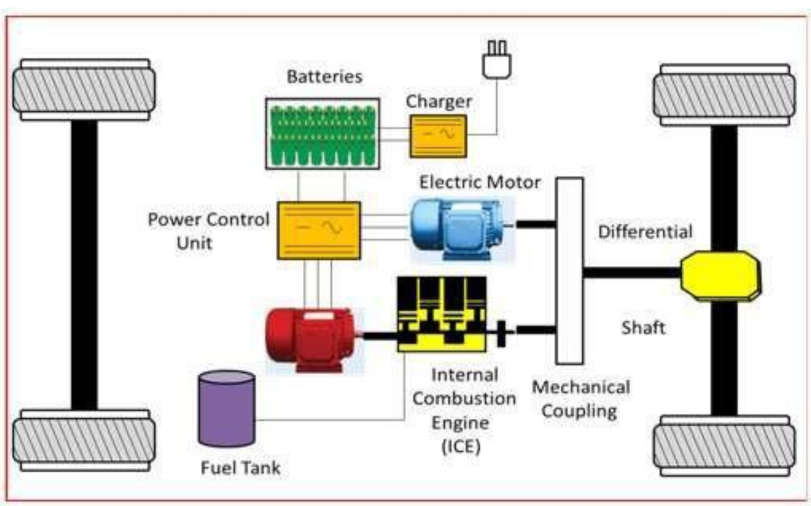

Fig.6: A plug-in hybrid electric vehicle with a series-parallel hybrid power train

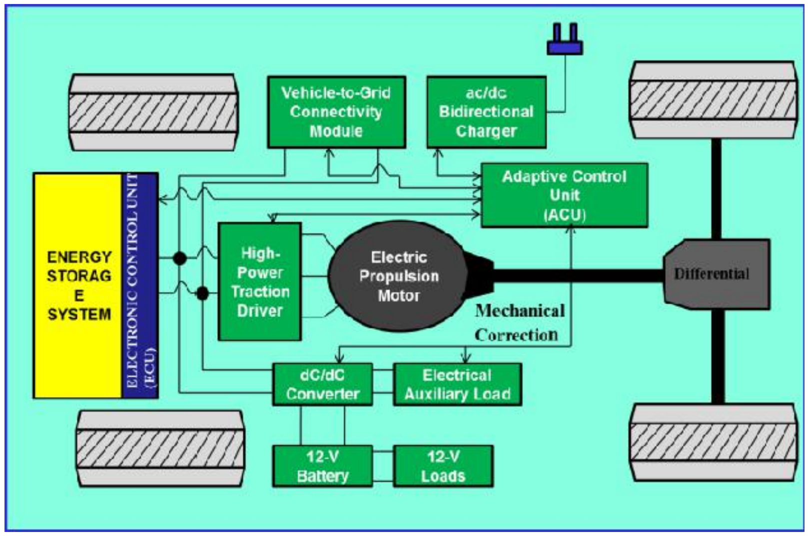

Fig.7: An all-electric power train with adaptive control unit

Table 1: Overview of technical data for commercial/ prototype electric vehicle

	Tesla Roadster (Berdichevsky *et al.*, 2006)	Nissan Leaf (Nissan, 2012)	GM Chevy Volt (Chevrolet 2012)	Toyota Plug-in Prius (Prius 2012)	Mitsubishi i-MiEV(Mitsubishi 2012)	Exora REEV (Che Din 2011)
Type	Battery	Battery	Plug-in hybrid	Plug-in hybrid	Battery	Plug-in hybrid
Electric range (Km)	394	161	56	24	160	97
Battery size (kWh)	53	24	16	4.4	16	13.5
Onboard charger (kW)	9.6	3.3	1.44	1.44	2.3	3.8
Quick charger (kW)	16.8	60	3.3	3.3	50	20
Charging time	Onboard: 6 h Quick: 3.5 h	Onboard: 6 h Quick: 0.5 h	Onboard 10 h Quick: 4 h	Onboard: 3 h Quick: 1.5 h	Onboard: 8 h Quick: 0.5 h	Onboard: 4 h Quick: 0.5 h
Type		Saga EV (Che Din 2011)	Mercedes-Benz Blue ZERO E-Cell plus (Mercedes 2012)	BMW i3(Autocar 2012)	Honda Fit/Jazz- V (Honda 2012)	Mazda Demio-EV (Mazda 2012)
Electric range (Km)		Battery	Plug-in hybrid	Battery	Battery	Battery
Battery size (kWh)		97	100	160	131	200
Onboard charger (kW)		15.9	18	22	20	20
Quick charger (kW)		3.1	3.3	7.7	6.6	3.3
Charging time		20	20	12	40	50
		Onboard:6-8 h Quick: 0.5 h	Onboard: 6 h Quick: 1 h	Onboard: 6 h Quick: 1 h	Onboard: 3 h Quick: 0.5 h	Onboard: 8 h Quick: 0.67 h

storage system larger than power hybrid. Among the hybrid car models are such as the Toyota Prius, Honda Insight, Honda Jazz and Honda CR-Z. Toyota Prius uses a series-parallel configuration while the Honda family is more close to parallel configuration but allowing battery charging through motor regenerative braking.

Plug-in Hybrid Electric Vehicles (PHEVs) is essentially an HEV with the option to recharge its energy storage system with electricity from the grid (Markel and Simpson, 2006). PHEVs have a high-energy-density energy storage system that can be externally charged and they can run solely on electric power longer than regular hybrids, resulting in better fuel economy. Just like HEVs, PHEVs can have series, parallel and series-parallel configurations. Figure 5 and 6 show a PHEV with series and series-parallel configuration, respectively. PHEVs make use of utility power as the batteries are usually charged overnight. The battery can also be charged onboard to increase the vehicle range. All electric vehicles have all-electric propulsion system. Unlike HEVs and PHEVs, EVs do not have an ICE to supply the additional power. A typical EV architecture is shown in Fig. 7. These EVs rely mainly on external charge from the utility power grid and these types of advanced electric-drive vehicles are expected to affect the electricity distribution network.

Power demand of EV is a function of voltage and current and its energy requirement depends on the battery size. The technical information on commercial and prototype EV sin terms of electric range, battery size, charger power and charging time is tabulated and summarized in Table 1. Such information is useful for determining the power demand required by EV. It is estimated that a single EC can increase electricity consumption of a household by 50% (WDI, 2008). Some EVs consumed more than 5 kW powers which is greater than the consumption of a typical residential house and this consumption is continuous up 10 h subject to the state of charge of the EV's battery. This power consumption is required for EV which is charged using the slow type on board charger. If EV is charged using rapid/fast charger, the power consumption can go as high as 60 kW. Most of the figures in Table 1 refer to the technical specification of the older version and prototype EVs. For the commercial or latest version of EVs, the power consumption can be different. From the literature, it is noted that for fast charging station, there is effort to standardize the chargers so that all cars can share the same charging station. In the future, fast charger can consume 62.5 kW (CHAdeMO, 2012) or 100 kW (SAE J1772-2010 2013).

This study presents the state-of-the-art of electric vehicle technology focusing on the types of electric vehicles, types of battery chargers and charging stations and identifying supply voltage, charging current and different standards that are being used in the US, Europe and Japan.

MATERIALS AND METHODS

Types of EV battery chargers: An EV battery charger is a combination of electronics used for recharging the battery banks in an EV or a plug-in HEV. EV chargers can be installed in houses, offices, shopping stores and public places to enable EV owners to charge their EV or plug-in HEVs. There are two types of charging based on their mode of energy transfer; conductive and inductive. Conductive type EV battery chargers have direct plug-in connection to the supply by using an extension power cord to plug from the wall outlet into the EV. It is popular, simple in design and higher efficiency.

The inductive type EV battery charger uses magnetic coupling as mode of energy transfer. Through inductive chargers, a charging station is used to transfer high voltage and current directly from the grid into an inductive paddle or pad with an electro-magnet that acts as half a transformer. The other half is situated inside the EV and once full contact is made between the two magnets, the current is allowed to flow across and into the battery, charging at a higher rate due to the charging stations direct power grid connection. Figure 8 illustrates the inductive charging concept showing the path of current from the wall socket to the battery. Figure 9 shows an example of charging a Nissan leaf EV via an inductive pad located below the car (Nissan, 2012). Figure 10 shows a closer look below a car with inductive charging pads in which one pad is fixed on the surface of the road and the other fixed under the car chassis.

The main advantage of inductive type EV battery charger is electrical safety under all weather conditions. However, its disadvantages are long charging time and relatively poor efficiency. In April 2011, carmaker BMW and electrical giant Siemens introduced trials with an inductive charging system to the public in London. Located in the bottom of the car and the ground, the system's air wide gap which is between 8 and 15 cm prevents efficiencies of more than 90%. In 2012, Qualcomm Inc started a trial on their wireless charging system called Inductive Power Transfer in London and this study is still ongoing.

Fig. 8: Concept of inductive charging via the two inductive pads

Fig. 9: A Nissan leaf charging via an inductive pad below the car

Fig. 10: A closer look under a car with inductive charging showing both the inductive pa s

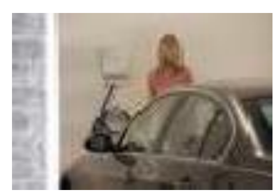

Fig. 11: Example of domestic charging stationer

Fig. 12: Example of off-street and robust charging post

Fig. 13: Example of rapid charging stat on

Table 2: IEC EV charging modes based on IEC 61851-1

Mode	Supply	Duration	Charger configuration	Example charger
Mode 1	AC	Slow	Standard household-type connector	1- or 3-phase plug
Mode 2	AC	Slow	Standard household-type socket-outlet with an in-cable protection device	the Park and Charge or the PARVE systems
Mode 3	AC	Slow/Fast	Specific EV socket-outlet and plug with control and protection function permanently installed	SAE J1772 and IEC 62196
Mode 4	DC	Fast	External charger	CHAdeMO

Table 3: Levels of EV charging according to SAE

Source	Level	Voltage	Phase	Max current	Max power (kW)	Time (h)
AC	Level 1	120	Single	16	1.9	6 - 24
	Level 2	240	Single	80 (typical 40)	19.2	2 - 8
	Level 3	TBD	TBD	TBD	TBD	TBD
DC	Level 1	200-450	DC	<= 80	<= 19.2	~ 20 min
	Level 2	200-450	DC	200	90	~ 15 min
	Level 3	TBD (may cover 200-600)	DC	TBD (may cover up to 400)	TBD (may cover up to240)	TBD

TBD-to be defined

Table 4: Types of coupler for EV charging

Type	Coupler	Example
Type 1	Single-phase vehicle coupler (vehicle connector and inlet)	Yazaki or SAE J1772-2009 (Japan, North America)
Type 2	Single- and three-phase vehicle coupler and mains plug and socket-outlet without shutters	VDE-AR-E 2623-2-2
Type 3	Single- and three-phase vehicle coupler and mains plug and socket-outlet with shutters	SCAME plug developed by the EV Plug Alliance.

Types of charging stations: EV charging stations when categorised in terms of voltage rating, power rating and place of application, can be classified into three different types of charging stations, namely, domestic charger at residential area, off-street and robust charger at commercial and office area and rapid charger at strategic location. Example pictures of these three chargers are depicted in Fig. 11 to 13.

In this document, the charging stations discussed will be focusing on conductive chargers due to the fact that the inductive charging method is still under development. According to Daimler's Head of Future Mobility, inductive chargers are at least 15 years away and the safety aspects of inductive charging for EVs have yet to be looked into in greater detail. Most rechargeable EVs and equipment can be charged from a domestic wall socket. However, a charging station may be required due to the following reasons:

- Charging can be provided for multiple EV owners at one time,
- The facility may have additional current or connection sensing mechanisms to disconnect power when the EV is not actually charging,
- Readily provide option for suppliers to monitor or charge for the electricity actually consumed.

Society of Automotive Engineers (SAE) and International Electro technical Commission (IEC) both have come up with standards which define EV charging. The term 'level' used by SAE and 'mode' used by IEC essentially means the same thing. According to IEC 61851-1, there are 4 modes for charging EVs as described in Table 2. However, SAE defines 6 levels of EV charging as shown in Table 3. Some information in the table is still to be defined (TBD) by the standard.

From Table 2, essentially 'Level 3' does not exist yet and the charging standard everybody has been thinking of as 'Level 3' is really either 'DC Level 1' or 'DC Level 2'.

Standards for EV charging stations: Different type of standard is being used in different region of the globe for charging of EV. This section is comparing different standard that are being used in USA, Europe and Japan. Standards that have been published are described as follows:

- **IEC 61851(IEC, 2010):** The IEC 61851 standard covers the overall EV conductive charging systems. In this standard, the IEC defines the four modes of EV charging that has been described above. This standard became the basis for IEC 62196. A few important sections in IEC 61851 are:

IEC 61851-1: This standard defines three cables and plug setups which can be used to charge EVs:

Case A: Where the cable is permanently attached to the EV

Case B: Where the cable is not permanently attached to anything

Case C: Where the cable is permanently attached to the charging station.

IEC 61851-23: This standard defines the requirements for DC fast charging stations in terms of electrical safety, harmonics, grid connections and communication architecture. The standard is expected to be published in November 2012.

Fig. 14: IEC 60309 style plugs mounted onto a wall socket

IEC 61851-24: This standard defines digital communication for DC charging control between the charging controller in the EV and the charging controller in the Electric Vehicle Supply Equipment. The standard is expected to be published in September 2013.

- **IEC 62196-Plugs, socket-outlets, vehicle connectors and vehicle inlets (IEC, 2011):** The IEC 62196 is the latest standard for EVs by IEC which is based on the IEC 61851 standard. A few important sections in IEC 62196 are:

IEC 62196-1: This standard is entitled 'Plugs, socket-outlets, vehicle couplers and vehicle inlets'. This standard contains the general requirements for EV connectors

IEC 62196-2: It standardizes three types of mains connecting systems, known as Types 1, 2 and 3 that are applied only to modes 1, 2 and 3. Which of these is appropriate depends largely upon the electrical infrastructure and regulatory conditions in each country. The coupler types for EV charging are outlined as in Table 4.

IEC 62196-3: This standard defines connectors and inlets for fast DC charging to be used with mode 4 charging according to IEC 61851-1. The standard is expected to be published in December 2013.

- **IEC 60309-Plugs, socket-outlets and couplers for industrial purposes (IEC, 2012):** IEC 60309, formerly known as IEC 309 is an international standard from the IEC for 'plugs, socket-outlets and couplers for industrial purposes'. The maximum limits under this standard include; voltage 690V AC or DC, current 125A, frequency 500 Hz and temperature range -25 to 40ºC. The two parts of IEC 60309 are:
  - **IEC 60309-1:** General requirements and
  - **IEC 60309-2:** Dimensional requirements. A few details outlined under this standard include i) a range of plugs and sockets of different sizes with differing numbers of pins, depending on the current supplied and the number of phases accommodated, ii) limited weather proofing and iii) color coded connectors depending on the voltage range and frequency e.g., yellow for 100-130 volts at 50-60 Hz. An example of IEC 60309 style plug mounted on to a wall socket is depicted in Fig. 14.
- **IEC 60364-electrical installations for buildings (IEC, 2005):** IEC 60364 'Electrical Installations for Buildings' is the standard on electrical installations of buildings. This is the standard attempting to harmonize national wiring standards in one IEC standard. The latest versions of many European wiring regulations (e.g., BS 7671 in the UK) follow the section structure of IEC 60364 very closely, but contain additional language to cater for historic national practice and to simplify field use and determination of compliance by electrical tradesmen and inspectors. National codes and site guides are meant to attain the common objectives of IEC 60364 and provide rules in a form that allows for guidance of persons installing and inspecting electrical systems. The standard has several parts described as:

Part 1: Fundamental principles, assessment of general characteristics, definitions

Part 4: Protection for safety (including sections on electric shock, thermal effects, over current, voltage disturbances and electromagnetic disturbances)

Part 5: Selection and erection of electrical equipment (including sections on common rules, wiring systems, isolation, switching and control, ear thing and safety services)

Part 6: Verification

Part 7: Requirements for special installations or locations (for range of locations such as bathrooms, swimming pools, rooms/cabins, construction sites, caravans, external lighting, mobile units and others).

- **SAE J1772:** This SAE Recommended Practice covers the general physical, electrical, functional and performance requirements to facilitate conductive charging of EV/PHEV vehicles in North America (SAE International, 2013). This document defines a common EV/PHEV and supply equipment vehicle conductive charging method including operational requirements and the functional and dimensional requirements for the vehicle inlet and mating connector.SAE J1772-2009 is the most recent standard in use and maintained by the SAE. The previous standard, SAE J772-2001 was manufactured by Avcon but is being phased out.

Details on SAE J1772-2009 are described as follows:

Fig. 15: SAE J1772-2009 connector

Fig.16: The new SAE J1772-2010 connector

- Based on a connector design from a company called Yazaki.
- Allows for both 120 V and 240 V quick charging with power delivery up to 16.8 kW at 70 amps.
- Companies participating in or supporting the revised 2009 SAE J1772 standard include GM, Chrysler, Ford, Toyota, Honda, Nissan and Tesla.
- Currently being used by Nissan Leaf (has both SAE J1772 and CHAdeMO protocol on board), Chevy Volt and other newer models
- Manufacturers of the charging interface include Coulomb Charge Point.
- The connector is shown in Fig. 15. The connector supports communication over power lines to identify the vehicle and control charging. It is designed to withstand up to 10,000 connection/ disconnection cycles and exposure to all kinds of elements. The connector lifespan given one connection/disconnection daily is estimated to be 27 years. The J1772 2009 standard includes several levels of shock protection, ensuring the safety of charging even in wet conditions.

Connection pins are isolated on the interior of the connector when mated, ensuring no physical access to those pins. When not mated there is no voltage at the pins.

In 2010, SAE developed a DC fast charging with a combined charging system or 'combo connector' for short. Details on SAE J1772-2010 are as follows:

- An adaptation of the existing J1772 connector.
- Charging port has two parts; upper section retains the configuration of the existing standard, meaning that slow-charging EVs already on the market can transition seamlessly to the new connector and lower section contains a second set of pins to accommodate fast-charging battery technology that was not commercially available before 2010.
- All together the combo connector will enable charging up to 500 volts, at 200A enabling a charger with a yield of 100kW.
- Final approval for this new standard is expected by August 2012 and SAE expects the eight US and German car makers to begin production of vehicles equipped with the new J1772 in 2013. Figure 16 shows the combo connector.

CHAdeMO: CHAdeMO is a trade name for global quick charging method that is proposed by the CHAdeMO Association as an industry standard (CHAdeMO, 2012). The CHAdeMO Association was founded by the Tokyo Electric Power Company, Nissan Motors, Mitsubishi Motors, Fuji Heavy Industries (the manufacturer of Subaru vehicles and Toyota Motor Corporation. Other members include automakers, charger makers, supporting businesses, administrative entities and others united towards the core business of developing quick charging infrastructures. CHAdeMO is an abbreviation for "CHArge de MOve" equivalent to "charge for moving" and is a pun for "O cha demo ikaga desuka" in Japanese, meaning "Let's have a tea while charging" in English. Under the CHAdeMO protocol, the charger sometimes also spelled CHΛdeMO is capable of delivering up to 62.5 kW of high voltage direct current. This type of high voltage high-current charging is called DC fast charge and is sometimes referred to as level 3 charging to contrast with less powerful AC charging levels. The approximate charging time is 15 min. Compatible vehicles with the CHAdeMO protocol include the Nissan LEAF, Mitsubishi i-MiEV, Subaru R1e (prototype) and Citroen C-ZERO.

The CHAdeMO connector has been designed for fail-safe operation. The CHAdeMO quick charger design has a controller that receives EV commands via a CAN bus and the quick charger sets the current to meet the EV's command value. Via this mechanism, optimal and fast charging becomes possible in response to battery performance. Currently, CHAdeMO chargers are very popular in Japan and Europe.

RESULTS AND DISCUSSION

Impact of EV charging on utility distribution systems: EV charging is considered as a big load to the utility. The worst case if all EVs are charged at the same time. However, this scenario will be unlikely to happen because of many factors. One of the factors is that the number of charging station is limited. As for the impact of EV battery chargers on the power supply system, it depends on the technology of the chargers. Older version of chargers is based on full-wave rectification using diodes and progressively, thyristors are used. Later designs use microprocessor-controlled charging technologies with several algorithms being implemented for parameter monitoring and control. Today, smart battery chargers are available which can interactively communicate with the utility system in order to receive and send information about the state of charge, energy availability, tariffs and management data in general. Such designs have resulted in reduction of harmonic distortion and power factor improvement. A survey of battery charger manufacturers from 1993 to 1995 shows that the average total harmonic distortion decreases from 50.1 to 6.12% (Gomez and Morcos, 2003).

The general effect of home battery chargers on distribution systems will be load increase and large increment of system voltage distortion. Another issue that should be considered is the coincidence between the charging start time and the eventual evening load peak period, which varies with customer and country (Autocar, 2012). However, the net effect of a population of EV chargers is not merely the numerical sum of the THDs, which involves both the magnitude and phase angles of individual harmonic components (Lambert, 2000). For higher harmonic orders, harmonic cancellation effect can take place.

Another issue of EV charging that has been investigated is on the lifetime of transformers. For calculation of transformer life reduction or the derating factor, parameters that are required are the winding eddy-current loss, harmonic current magnitudes and harmonic order values (IEEE, 1998). However, THD values do not give enough information for transformer temperature and life span calculations, as the harmonic order is very important for thermal effect evaluation. Two harmonics of the same magnitude, but having different order, can have dissimilar thermal effects. Therefore, as a conclusion, EV charging should be looked at not only in harmonics and voltage overload issues, but also its effects on distribution equipments such as transformers, cables, circuit breakers and fuses.

The degree of impact on power system depends on how much the EV penetrates the market. This penetration will depends on the battery cost, gasoline prices, charging infrastructure, competition from other vehicles and government policy. When referring to impact of EV to power grid, the regional or local penetration is of importance to utilities. Some parts of the region will be more severely impacted by the presence of EVs than others. Even within the same region, only certain part will need significant focus. The distribution of these EV will depend on promotional policies, incentives and the deployment of charging infrastructures.

CONCLUSION

Electric vehicles are expected to enter the world market such that by 2030, 10% of the vehicles will be of EV type. To have a better understanding on EV technology, this study outlines the various types of EV, battery chargers and charging stations. A comprehensive review has also been made on the standards currently adopted for charging EV worldwide. For better understanding on the state of the art EV technology, a comparison is made on the commercial and prototype electric vehicles in terms of electric range, battery size, charger power and charging time.

3. Battery Electric Vehicles Vs Internal Combustion Engine Vehicles

Abstract – We are all aware that the diesel transport is one of the world's major sources of black carbon. Not only it contains black carbon it also has significant warming effect, but it is also a major component of particulate matter, the air pollutant most closely associated with increased air-pollution related morbidity and mortality. According to The U.S. Environmental Protection Agency (EPA) "motorvehicles collectively cause 75% of carbon monoxide pollution in the U.S. The Environmental Defense Fund (EDF) estimates that on-road vehiclescauseone-third of theairpollutionthatproducessmogin the U.S., and transportation causes 27% of greenhouse gas emissions." As global warming has become a stringent issue, we need to embrace renewable energy programs which help us to reduce the global warming and achieve more sustainable transportationoptions. Pollution is one ofthe biggestreasonsthat people gravitate towards an electric vehicle. The environmental benefits surrounding electric cars are one of the most significant factors in switching from a fuel-powered engine to an electrical one. The total life cycle economic cost and environmental impact analysis of Lithium-ion battery electric vehicles (BEVs) versus internal combustion engine vehicles (ICEVs) are elaborately compared and discussed in this paper.

Key Words: Battery Electric Vehicles (BEVs), Internal Combustion Engine Vehicles (ICEVs), Lithium-Ion Battery (Li-Ion Battery), Rotating Magnetic Field (RMF)

1. INTRODUCTION

Electric cars have made big waves in the automobile world. As electric cars give pollution free, noise free and high performance it is expected that the electric vehicle can surely capture the market and make the IC engine counterpart obsolete by 2025.Because of the technology behind the induction motor, inverter and Lithium-Iron power source and synchronized wheel mechanism make the electric cars work with astounding performance. The working principle and feature of electric vehicle and IC engine vehicle are presented in this paper. Power is converted from the DC battery to AC for the electric motor. The accelerator pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor. The motor connects and turns the wheels through a cog. When the brakes are pressed or the electric car is decelerating, the motor becomes an alternator and produces power, which is sent back to the battery.

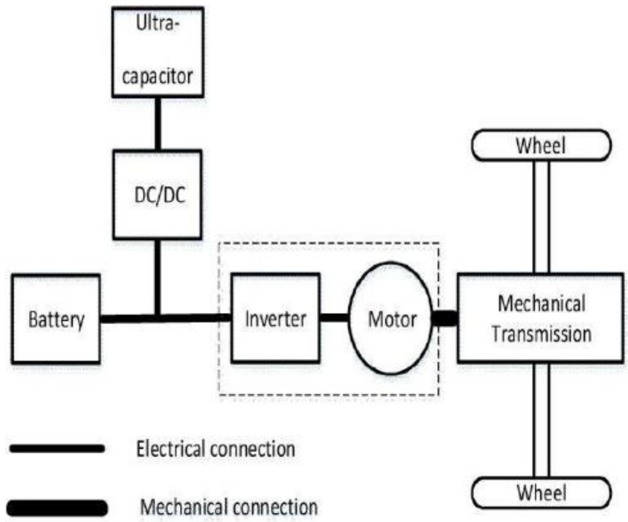

Figure 1: Block diagram of Battery operated Electric vehicle

1.1 Power source

Battery pack gives DC power so before giving supply to induction motor it has to be converted to AC. Hence inverter is connected with battery pack. This power electronics device not only converts DC into AC it also helps to adjust the AC power frequency. This is how the speed of the induction motor is easily controlled.

1.2 Battery: Lithium-ion battery

An Electric-Vehicle Battery EVB also known as a traction battery is a battery which is used to power the electric motors of a battery electric vehicle (BEV) or hybrid electric vehicle (HEV). These batteries are usually rechargeable (secondary) batteries, and are typically Lithium-Ion batteries. These batteries are specifically designed for a high ampere-hour (or kilowatt-hour) capacity.

Electric-vehicle batteries differ from starting, lighting, and ignition (SLI) batteries as they are designed to give power over sustained periods of time and are deep-cycle batteries. Batteries for electric vehicles are characterized by their relatively high power-to-weight ratio, specific energy and energy density; smaller, lighter batteries are desirable because they reduce the weight of the vehicle and therefore improve its performance. Compared to liquid fuels, most current battery technologies have much lower specific energy, and this often impacts the maximum all-electric range of the vehicles.

The most common battery types in modern electric vehicles are Lithium-Ion and lithium polymer, because of their high energy density compared to their weight. Other types of rechargeable batteries used in electric vehicles are lead–acid ("flooded", deep-cycle, and valve regulated lead acid), nickel-cadmium, nickel–metal hydride, and, less commonly, zinc–air, and sodium nickel chloride ("zebra") . The amount of electricity (i.e. electric charge) stored in batteries is measured in ampere hours or in coulombs, with the total energy often measured in kilowatt-hours

Most electric vehicles use lithium-ion batteries (Li-Ions or LIBs). Lithium Ion batteries have higher energy density, longer life span and higher power density than most other practical batteries. Complicating factors include safety, durability, thermal breakdown and cost. The energy density of lithium ion batteries currently used in electric vehicles is 100-180 Wh/Kg and the cost of cells is of the order of $400/kWh.

1.3 Induction. Motor

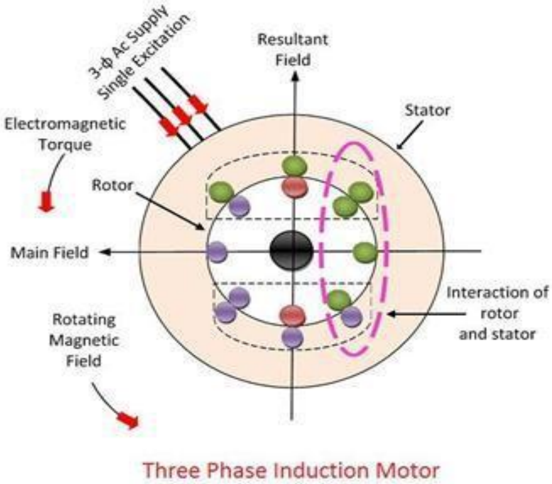

Figure 3: Induction Motor

When three phase AC supply is given to the stator of an induction motor, the three phase alternating current flowing in the stator coil produces rotating magnetic field. The flux from the stator cuts the short-circuited coil in the rotor. As the rotor coils are short-circuited, according to Faraday's law of electromagnetic induction, the current will start flowing through the coil of the rotor. When the current through the rotor coils flows, another flux gets generated in the rotor. Now there are two fluxes, one is stator flux, and another is rotor flux. The rotor flux will be lagging in respect of the stator flux. Because of that, the rotor will experience a torque which will make the rotor to rotate in the direction of the rotating magnetic field. This is the working principle of both single and three phase induction motors. The speed of the induction motor is directly proportional to the supply frequency. So just by varying the supply frequency with help of variable frequency drive the speed of the induction motor can be easily varied. This simple fact makes electric car speed control easy and reliable. The motor speed range can easily vary from 0 to 18000 rpm. This is the most significant advantages of electric vehicle over internal combustion engine vehicle.

1.4 Working Principles of BEV

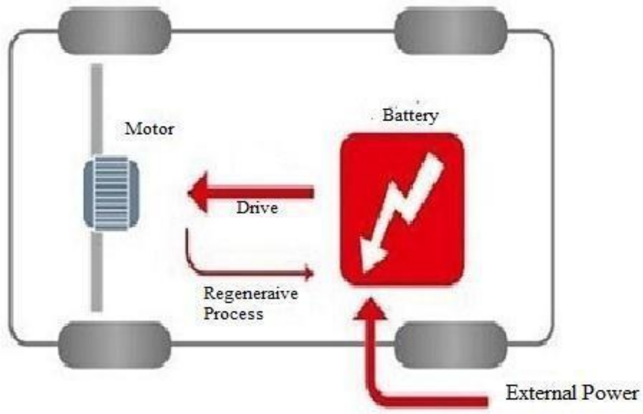

Figure 2: Working principle of BEV

The working principle and feature of electric vehicle and IC engine vehicle are presented in this paper. Power is converted from the DC battery to AC for the electric motor. The accelerator pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor. The motor connects and turns the wheels through a cog. When the brakes are pressed or the electric car is decelerating, the motor becomes an alternator and produces power, which is sent back to the battery.

1.5 Internal Combustion Engine

Figure 4: Internal Combustion Engine

The number of cylinders that an engine contains is an important factor in the overall performance of the engine. Each cylinder contains a piston that pumps inside of it and those pistons connect to and turn the crankshaft. Based on number of pistons the pumping, and more combustive events are taking place during any given moment. That means that more power can be generated in less time. In an internal combustion engine (ICE), the ignition and combustion of the fuel occur within the engine itself. Then it partially converts the energy from the combustion to work. After the piston compresses the fuel-air mixture the spark ignites it, causing combustion. Now the Internal combustion engine produces the required torque and power output with limited range of speed. Hence it requires a mechanical transmission to control the drive wheel speed. Moreover IC engine produces only linear motion and it doesn't produce direct rotational motion. Therefore IC engine rotation is not directly connected with drive wheel. Moreover the power output of IC engine is not uniform. Therefore it requires some accessories to get the even power output.

2. COMPARISON BETWEEN ELECTRIC VEHICLE AND CONVENTIONAL ICE VEHICLE

Table1: Comparison between Electric vehicle and conventional ICE vehicle.

Feature	Battery Electric vehicles	I.C. Engine vehicles
Powered by	Charged battery, ultra capacitors	Diesel, Petrol
Self weight	High due to battery's bank	Low as compared to EV
Power Transmission	Both mechanical as well as electrical	Mechanical only
Braking system	Regenerative braking	Mechanical only
Eco friendly	Yes	No
Running cost	Low	very high

3. RESULT AND DISCUSSION

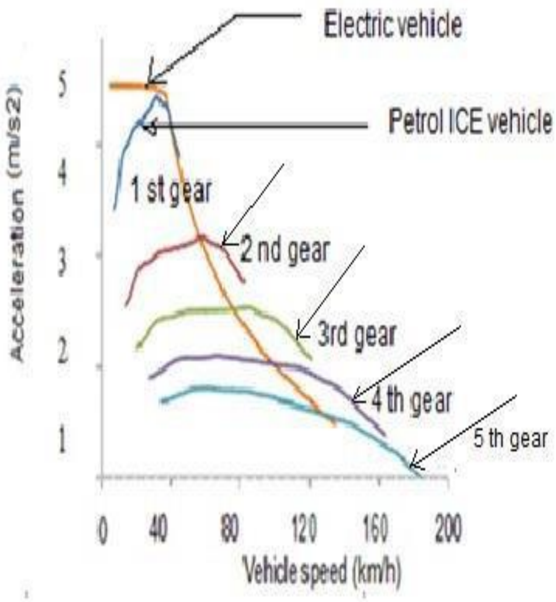

Figure 5: Acceleration versus Speed of EV and petrol ICE vehicles

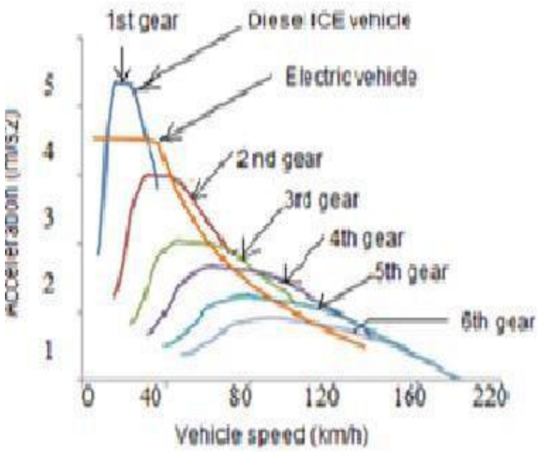

Figure 6: Acceleration versus Speed of EV and

Diesel ICE vehicles

Figure 5 shows that the EV attains higher values of acceleration until it reaches a speed of 38.5 km/h in comparison with the vehicle with petrol ICE. After reaching that speed the vehicle with the petrol ICE achieves higher values of acceleration until it reaches its maximum speed of motion in the first gear 45.24 km/h. After shifting from the first to the second gear a decline in its acceleration happens by which the EV attains higher acceleration until reaching a speed of 56.3 km/h. After attaining this speed the vehicle with the petrol ICE again attains higher acceleration values and retains them until it reaches the maximum speed on the horizontal road. The advantage of attaining better acceleration performance from starting from standing state to reaching a speed of 36 km/h is an important feature in many conditions such as for example, city driving, which becomes multiplied benefit if we add the previously explained characteristics of electric propulsion. Concerning that there are benefits from acceleration when moving in a speed range from zero to 38.5 km / h and from 45.25 to 56.3 km/h it can be concluded that the electric vehicle provides significant advantages in specific conditions such as driving in a city traffic. When compared to the vehicle propelled by the diesel ICE Figure 6, it is concluded that the EV achieves greater values of acceleration from starting the vehicle from standing to reaching a speed of 12.27 km/h, and also in the speed range of 30.7 km/h to 42.95 km/h .with, greater value of maximum engine torque. However, previously presented acceleration advantage of the EV is significant from the aspect of city traffic where faster starting the vehicle from standing and overtaking at certain speeds is important.

Torque is a measure of how much rotational force can be produced, whereas power is a measure of how hard an engine has to work to produce the rotational force. As shown below, the power and torque characteristics of a combustion engine means that although a conventional car might have a *top capacity* of 120 kW of power and 250 Newton metres of torque, this is only when the engine is running at high speeds.

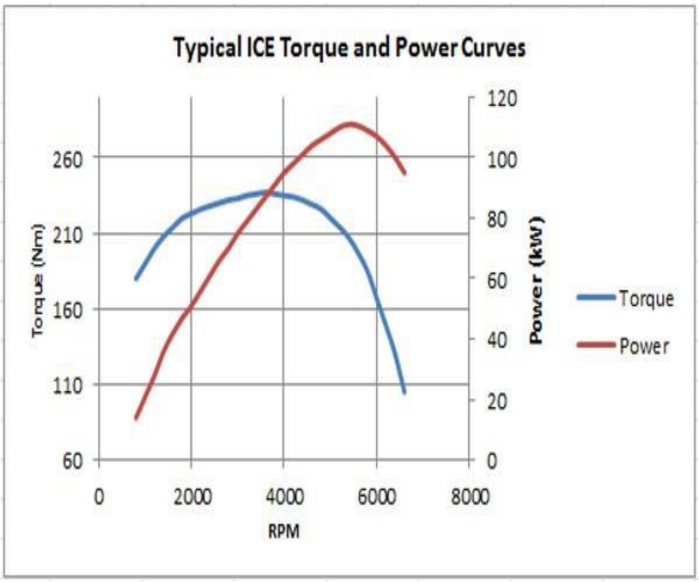

Figure 7: Torque versus Speed characteristics of ICE vehicle

In contrast, an electric motor provides full torque from zero kilo metres an hour, with a linear relationship between how fast the motor is spinning and the power required. These characteristics translate to a vehicle that is extremely fast at accelerating, with the ability to push load very quickly

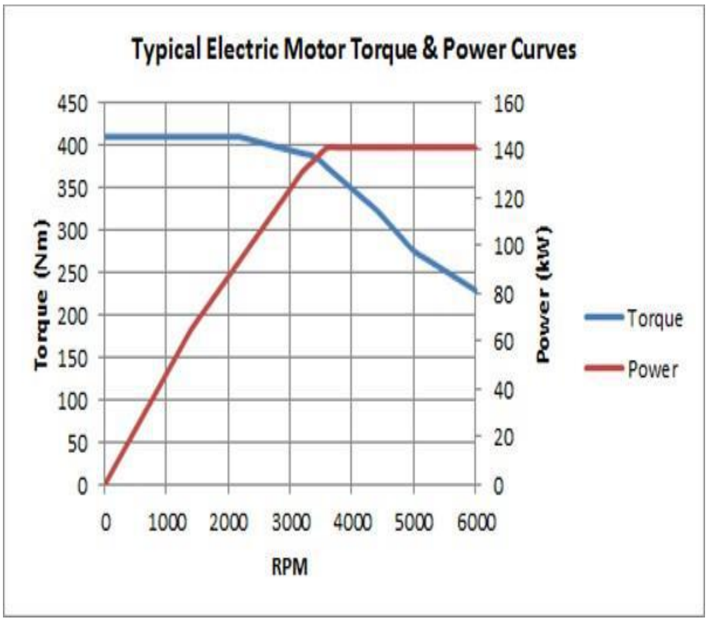

Figure 8: Torque versus Speed characteristics of BEV

4. CONCLUSION

BEV enjoys some distinct advantages. First, the electricity cost associated with operating a BEV over a distance of one mile is significantly lower than the gasoline cost required for operating a comparable ICEV over the same distance. Second, BEV cost less to maintain owing to the relative elegance and simplicity of a battery-electric motor system compared with the frequent maintenance required for operation of an internal combustion system. More over battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs) among these vehicles, the BEV does not require gasoline at any point during operation, relying solely upon pure electric battery power. Apart from that electric cars produce peak torque at zero RPM On the other hand internal combustion engines need to be spinning up at a much higher speed than electric motors before they produce peak torque.

4. Electric Vehicles : Boon Or Bane?

It all started with the **Mahindra Reva**. The Reva is a rechargeable electric vehicle running on battery. Automakers such as Honda and Toyota have their Accord and Camry hybrids available in the market. Mahindra has the e-Verito while Tata has the Tata e-Tigor. While most of the available vehicles are nothing but mild hybrids, automakers and the government need to team up and spread more awareness about the advantages of electric vehicles thus slowly starting the shift to all electric.

Advantages:

·**For Environment:**

1) By choosing to drive an EV you are helping to reduce harmful air pollution from exhaust emissions. An EV has zero exhaust emission

2) If you use renewable energy to recharge your EV, you can reduce your greenhouse gas emissions even further. You could recharge your EV from your solar PV system during the day instead of from the grid.

3) There is also a trend towards more Eco-friendly production and materials for EVs. The Ford Focus Electric is made up of recycled materials and the padding is made out of bio based materials. The Nissan Leaf's interior and bodywork are partly made out of green materials such as recycled water bottles, plastic bags, old car parts and even second hand home appliances

· **Cheaper**:

The electricity to charge an EV works out around a third as much per kilometer as buying petrol for the same vehicle

· **Health** :

Better air quality will lead to less health problems and costs caused by air pollution. EVs are also quieter than petrol/diesel vehicles, which means less noise pollution.

· **Energy Security**:

EVs are easy to power from local and renewable energy sources, reducing our dependence on foreign oil.

· **Popularity**:

EV's are growing in popularity. With popularity comes all new types of cars being put on the market that are each unique, providing you with a wealth of choices moving forward.

· **Low Maintenance**:

Electric cars runs on electrically powered engines and hence there is no need to lubricate the engines. Other expensive engine work is a thing of past. Therefore, the maintenance cost of these cars has come down. You don't need to send it to service station often as you do a normal gasoline powered car

Disadvantages:

Electric car sales are steadily growing, but the charging infrastructure that supports them still needs a lot of work and it's this fear of 'running out of juice' that's putting some people off an EV purchase.

· **Limited Choice:**

Car manufacturers have only recently caught the electric vehicle (EV) bug, so the choice of models remains limited.

· **Limited Availability Charging Infrastructure**:

Of those surveyed, 50% felt that there aren't enough charging stations for electric cars.

· **Not Suited for long Journeys**:

42% of respondents seeing a problem with using an EV for long journeys. High-end EVs, like the Tesla Model S 100d, have a range of up to 335 miles. Mid-range EVs, like the Chevrolet Bolt, are improving drastically and can go over 230 miles on a single charge. For some people these ranges genuinely won't be enough for their 'long journeys', but for others, they will.

· **Charging Time:**

The charge time of electric vehicles is still a major gripe for consumers, and 36% thought this was a disadvantage. For example:

3.7kW charge point: 7–8 hours

7kW charge point: 4–5 hours

DC fast chargers: up to 80% in 30 minutes

· **Cannot be charged at home**:

Being unable to charge an electric car at home was the fifth biggest disadvantage for 26% of respondents. **This can be a real problem if you don't have a driveway or garage.**

Way Forward:

For EVs to contribute effectively, we need commensurate efforts in developing an entire ecosystem.

· Increasing focus on incentivizing electric two-wheeler because two-wheeler account for 76% of the vehicles in the country and consume most of the fuel. A wide network of charging stations is imminent for attracting investment.

· Private investment in battery manufacturing plants and developing low cost production technology is needed.

· To generate more awareness, Edu-tech platforms should be leveraged like **DIYGuru.org** who is doing a pioneering work on **Industrial Revolution 4.0** Technologies including Electric vehicles.

· Acquiring lithium fields in Bolivia, Australia, and Chile could become as important as buying oil fields as India needs raw material to make batteries for electric vehicles.

· Providing waiver of road tax and registration fees, GST refunds and free parking spaces for EVs.

· New technologies like EV should be included as part of curriculum in graduation and post graduation courses as after setting up of charging infrastructure, challenge will also lie in repairing and maintenance of EVs. For that, collaboration with platforms like **Findmementor.com** where experts become mentors for budding talent, will help us in creating right ecosystem for EVs.

Genius is One Percent inspiration, Ninety-Nine Percent perspiration