IOP Conf. Series: Materials Science and Engineering **402** (2018) 012154 doi:10.1088/1757-899X/402/1/012154

# A survey on power levels of battery charging and infrastructure for plug-in electric and hybrid vehicles

**A Aswin[1,*] and S Senthilmurugan[2,*]**

UG Student[1], Asst.Professor[2], Dept. of EEE, SRM Institute of Science and Technology, Kattankulathur, Chennai, India.

*Corresponding Author: aswin97@gmail.com[1], sen.accet@gmail.com[2]

**Abstract**. Hybrid electric vehicle is an integration of conventional internal combustion engine and electric propulsion systems. Hybrid electric vehicles have tempted many people as their mode of transport which is going to be the next biggest global market in the upcoming years due to lack of fuel based energy and emission from the exhaust that ultimately leads global warming. Hybrid electric vehicles reduce the overall cost of fuel and have good economic impact on the global society. The development of hybrid electric vehicle is fast picking up its pace to be the next generation of the mode of transport. This paper explains the overview of hybrid electric vehicles, classification of hybrid electric vehicle, battery chargers, charging level infrastructure, Issues and opportunities.

## 1. Introduction

Transports have become the most common mode of commutation to different parts of the world. Four-wheel drive is the most important commutation tool inside any country. All four wheel drive has conventional internal combustion engines that have caused continuous serious issues of depletion of ozone layer due to global warming on account of air pollution. Electric vehicle and Hybrid electric vehicle (HEV) has replaced all typical internal combustion engine system. Hybrid electric vehicle performance and cost is far better than the former internal combustion engine. This ever-growing demand for hybrid electric vehicles has attracted many automobile industries and researchers to study and invest in hybrid electric systems. Plugin hybrid electric vehicle (PHEV) has advantage of driving long distance as it can effectively run with alternative resources of fuel. Interconnection of plug-in hybrid vehicle (PHEV) with the grid provides opportunities like ancillary services, reactive power and load balance. As a result plugin vehicle is integrated with the electric vehicle.

In US, it is an official target to put seven hundred thousand PHEVs to be on road which has been achieved at December 2017 and the same have been achieved to encourage electrical systems to be put on use by governments at every stage. Many organizations are adopting codes and standards with respect to utility or customer interface. Electric vehicle is not widely accepted by the society because of high cost, size, weight, volume, and battery charge level and battery charger infrastructure. The infrastructure of the battery charger depends on the cost, size of converters and power semi converters, electromagnetic interference and the safety standards. The major drawback associated with the battery charger is that they introduce harmonics into the grid system and this problem can be rectified by using rectifiers. Electric vehicles can operate in two modes namely vehicle to grid where vehicles inject energy back to the grid and grid to the vehicle

where the grid supplies energy to the vehicle, therefore a bi-directional communication is established between the electric vehicles and the electric utility.
Charging of electric vehicles takes place during late hours at our homes where the plug-in hybrid vehicle would be fit into a charging outlet for the level of primary charging, where the rate of charging is slow. Secondary charging level comprises of charging the electric vehicle both at public and private places and requires a charging outlet of 240 V. The summary of power charging are described in Table 1.

**Table 1.** Charging power levels.

| Types of Power levels | Charger position | Practical Application | Interface for Energy Supply | Desired Level of Power | Charging Period | Technology of Vehicle |
|---|---|---|---|---|---|---|
| Primary (US)-120 Vac (EU)-230 Vac | Onboard single-phase | Domestic application | Convenience outlet | 1400W (12A) | 240-660 minutes | PHEVs (5-15kWh) |
| | | | | 1900W (20A) | 660-2160 minutes | EVs (16-50kWh) |
| Secondary (US)-240 Vac (EU)-400 Vac | Onboard single or three phase | Retail outlets | Dedicated EVSE | 4000W (17A) | 60-240 minutes | PHEVs (5-15 kWh) |
| | | | | 8000W (32 A) | 120-180 minutes | EVs (16–30kWh) |
| | | | | 19200W(80A) | 120-180 minutes | EVs (3 –50kWh) |
| Tertiary (208-600 Vac) | Off-board Three-phase | Commercial, analogous to a filling station | Dedicated EVSE | 50000W | 24-60 minutes | EVs(20–50kWh) |
| | | | | 100000W | 12–30 minutes | |

Research and developments in secondary charging levels are taking place for semi-fast charging techniques which can be implemented in any environment. Single phase charging is used for primary and secondary level charging. Tertiary charging levels comprise of fast charging techniques and can be employed in commercial and public facilities which ultimately acts as filling outlets. Three-phase solutions are useful for high power and tertiary level chargers. Public places are projected to use secondary and tertiary chargers which are placed in shopping centers, hotels, parking lots, theatres, restaurants, etc.
The electric vehicle can be charged through conduction or induction. Charging through Conductive systems can be direct contact between the electric vehicle and charging inlet. Power can be transferred magnetically through inductive charger to electric vehicle at resonance since maximum power can be transferred at resonance. An off-board battery charger has limited restriction to weight and size.
The on-road plugin hybrid vehicles (PHEV) includes Toyota Prius and Chevrolet Volt. The on-road Electrical vehicles include Tesla Roadster Nissan Leaf i-MiEV, Mitsubishi. These are commercial ready for road vehicles with electrical different configurations, charging level, charging infrastructure and type of hybridization. These vehicles are costlier than the conventional IC engine systems, instead, it has got higher efficiency and they are go green vehicles.
These Electric vehicles are fast picking up its pace with the advent of technology. This update in automobile technology creates a revolution in the transportation system and automobile industries. This paper reviews the implementation and the current status of electric vehicles, battery chargers, battery charger infrastructure, charging level, issues and opportunities.

IOP Conf. Series: Materials Science and Engineering **402** (2018) 012154 doi:10.1088/1757-899X/402/1/012154

## 2. Types of Hybrid Electric Vehicles

### *2.1. Series Hybrid*

The series hybrid model consists of an ignition engine that drives the generator instead of powering the wheels directly. The car wheels get their power from the electric motors. The use of generators powers both the charging battery and wheels of the locomotive. When the demand for the power is more the motor extracts electricity directly from all batteries. Series hybrids are supported by ultra-capacitors which ultimately reduce the overall loss in the battery. Series Hybrid vehicles generates maximum energy at the time of acceleration and returns back the energy at the time of Regenerative Breaking. These Ultra capacitors are charged in reduced speed condition and nearly depleted at top speed conditions. The use of Ultra capacitors reduces the stress factor of the battery and the complex transmission between the wheel and the motor is reduced to a considerable extent. The Electric vehicles are designed to have motors connected to each wheel. Combination of motor and wheel has the disadvantage of mass increase and thereby affecting the performance of the ride and the advantage of the system is easy traction control.

### *2.2. Parallel Hybrid*

The parallel hybrid vehicle is an integration of an electric motor and an internal combustion engine (ICE) which is connected parallel to the mechanical transmission. Parallel Hybrid architecture includes both motor and electrical generator into one unit that is located amid the transmission and combustion engine. The battery gets recharged by Regenerative breaking. There is a mechanical interconnection between the motor and the wheel, the charging of the battery can't be done when the car is moving.

### *2.3. Combine Hybrid*

The combined hybrid vehicle is a fusion of both parallel and series hybrids. It is also known as series-parallel hybrids. The dual connection in-between the drive axle and the engine are electrical and mechanical in nature. The power to the wheels can be either electrical or mechanical in nature. Power split of the hybrid electric vehicle has a variety of performance mode.

At lower speeds, it acts as a series hybrid electric vehicle, but at higher speeds series powertrains are less likely preferred and the vehicle engine takes the lead. This model is quite costlier than parallel models as they require mechanical split power system, an extra generator, and require high computing power for dual control.

## 3. Degree of Hybridization

### *3.1. Strong Hybrid*

A strong Hybrid vehicle runs on engine only, battery only or a combination of both battery and engine. The battery pack with high capacity is needed for the operation of the battery. Vehicles like Prius, Lexus, Toyota and Auris are fully hybrid vehicles and can move forward with the help of battery power only. The brand name Toyota for the hybrid vehicle is hybrid synergy drive. This technology monitors the entire performance of the engine systems and evaluates whether a motor or combination of both are used for running the system. The internal combustion engine will shut down once the electric drive is capable of supplying enough power.

### *3.2. Medium Hybrid*

Medium hybrid vehicles use an engine for the usage of primary power source and an electric motor retaining Torque boosting characteristics connected in parallel to a traditional powertrain. The mode of Electric vehicle is restricted to a distinct time period and not a standard one. Medium hybrid vehicle absorbs less power and thereby reducing the size of the battery when compared to full hybrid vehicle. To restart the internal combustion an electric motor is used, having the same advantage of turning down the main engine when idle, the battery systems are used to power the equipment's. The electric motor acts like alternator at regenerative braking.

### *3.3. Micro Hybrid*

Micro Hybrid is an idle-stop system that is found to be in European small cars which consists of an AC generator that improves twice to a motor for a warmer restart of the engine through belt make it a micro-hybrid system. The typical power rating of micro-hybrids are 3000 to 5000 W and Mild Hybrid power rating varies from 7000-12000W.It consists of a generator- motor set placed in the Transmission of the vehicle at the engine crankshaft.
The mild hybrids projects an economic gain of 10%

### *3.4. Plug-in hybrid*

The vehicle belongs to plug-in hybridization type. This Hybrid vehicle consists of a battery which is rechargeable and can store the entire charge by interfacing the plug to an external power source. The plug-in hybrid vehicle has the peculiar feature of the conventional hybrid vehicle, which have motors and an internal combustion engine. All these plug-in electric vehicles are connected to the grid through the plug. The working and operating range of all plug-in vehicles are much larger when compared to the former ones. The internal combustion engine backups the system when battery charge level is depleted.

## 4. BATTERY CHARGERS

### *4.1. Infrastructure and Charger Power Levels*

Battery Charger power level includes mirror power, location, equipment, period of charging, cost and effect on the utilities. Implementing the electric vehicle supply equipment (EVSE) and battery charging infrastructure is an important work to be done due to the drawbacks of the charging period, distribution of charge, charging extent, policy demand, standardized charging points in the country and regulatory protocols and procedures. The presence of charging infrastructure reduce the availability on –Board storage requirements, costs, overall weight and the size of vehicles.
Electric Vehicle charging cords size, charge stands for both public and residential purposes, attachment plugs, vehicle connectors, safety circuits and power outlets ratings are major apparatus of electric vehicle supply equipment.

There are generally two type's configurations: a pedestal mounted box for supply and a specialized cord. The specifications of the cord and supply box differ from nation to nation depending on voltage, no.of cycles per second, transmission standards and electrical grid connection. With respect to the Electric Power Research Institute (EPRI), most of the plug-in vehicle is expected a charge in late night at residential places. For this reason, primary and secondary charging apparatus would be employed in residential places. Following the electric standards improves the efficiency of the battery, electric vehicles and thereby reducing the effects of electric vehicles on the distribution network.

*4.1.1. Primary level charging.* Primary Level charging is the poorest method of battery charging. In United States, primary charging uses a standard120V/15A single-phase grounded outlet for charging the connection. It uses a standard J1772 connector which connects the AC port to the electric vehicle. For residential and business sites, there is no additional charging system is needed. Poor off-peak levels seems to happen at bed time. The gross price of a domestic primary charger support is recorded to roughly cost about $500 - $880.

*4.1.2. Secondary level charging.* Secondary level battery charging infrastructure is the dedicated method for public and private facilities. Existing secondary Level apparatus provides a charging condition of 208V or 240V (at up to 80A, 19200 kW). This secondary level charger requires dedicated charging apparatus, a proper connection and installation for public or home charging, although vehicles like Tesla have the power electronics circuits on board to improve the efficiency. Most residential places have 240 V service availability, and Secondary charging devices can charge a Electrical vehicle battery throughout the night. Proprietor of Electric vehicles seems likely to prefer secondary level charging technology due to fast charging time and a particular vehicle-to-charger connection. An extra billing energy meter is installed to monitor the power consumption on regular basis. A residential secondary level charging has installation costs and infrastructure cost roughly about $2,150. The charging system of Tesla Roadster has been subjected to impose an extra cost of $3,000 in the bill. Secondary level chargers cost quite high but the charging capacity is fast and huge.

*4.1.3. Tertiary Level charging.* The tertiary Level charger is the commercial level turbocharger that can be implemented in city and highway refueling junctions, complement to gas stations. It works over a range of 480 V or higher and generally comprises of an off-board charger and a three-phase circuit to give constant conversion of ac-dc. Tertiary charging level is barely possible for domestic application. The hardware and Standards for dc plug cord are in development stage. The main potential issue is Cost of launching. The costs of Tertiary charging level infrastructure is $30,000 - $160,000 has been recorded. The maintenance work of charging station is an important factor.

The SAE J1772 standard suggests the Primary level and secondary level electric vehicle supply components could be implemented on the vehicle, while tertiary charger apparatus is situated outside the vehicle. Retail stations are supposed to use the secondary level or tertiary level to enable Turbocharging facilities in parking lots, restaurants, hotels, shopping centres, theatres, rest stops, etc. The minimum charge level is a benefit for utilities expecting to reduce the on-peak impact on the distribution network. High power rating machines have the latent to overload the distribution network at peak times. The charging levels are gathered in Table. 2 and shown in Figure. 1. Charging infrastructure and features are described in Table II for a few vehicles.

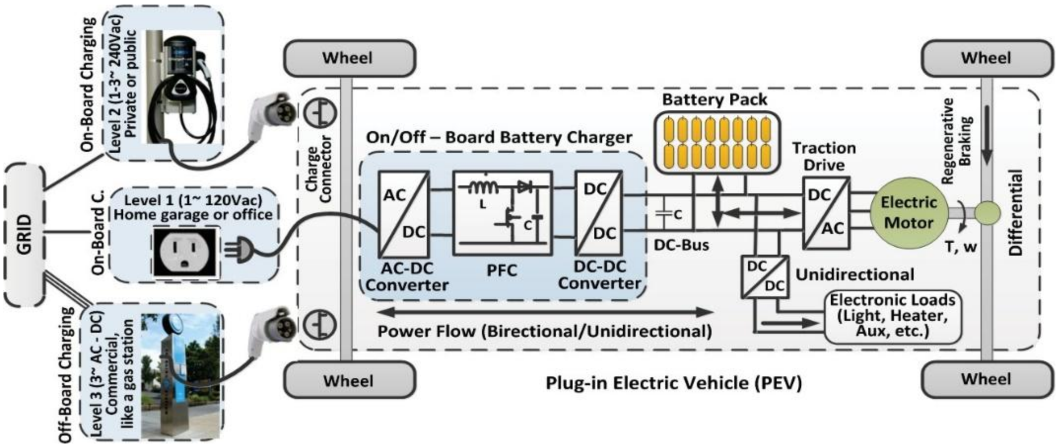


**Figure. 1.** Vehicle charging system and On/off board plug-in electric power levels.

**Table 2.** Infrastructures and charging characteristics of some manufactured PHEVS and EVS.

| Vehicles | Connector Type | Primary Charging | Secondary Charging | Tertiary Charging |
|---|---|---|---|---|

| | Battery Type Energy | All-Electric Range | | Demand (watts) | Charge period | Demand (watts) | Charge period | Demand (watts) | Charge period |
|---|---|---|---|---|---|---|---|---|---|
| Toyota Prius PHEV(2012) | Li-Ion 4.4kWh | 22.5 km | SAE J1772 | 140000 W | 180 Min | 3800 W (240V) | 150 minutes | NA | NA |
| Chevrolet Volt PHEV | Li-Ion 16kWh | 64 Km | SAE J1772 | 960–1400 W | 300-480 Min | 3800W | 120–180 minutes | NA | NA |
| Mitsubishi i-MiEV EV | Li-Ion 16kWh | 154 Km | SAE J1772 JARI/TEPCO | 1500 W | 420 Min | 3000W | 840 minutes | 50kW | 30 Minutes |
| Nissan Leaf EV | Li-Ion 24kWh | 160 Km | SAE J1772 JARI/TEPCO | 1800W | 12–16 Hours | 3300W | 360–480 minutes | 50 + kW | 15-30 Minutes |
| Tesla Roadster EV | Li-Ion 53kWh | 394 Km | SAE J1772 | 1800W | 30 + Hours | 9600–16800 W | 240–720 minutes | NA | NA |

The development of universal codes standards and infrastructure will improve the vehicle's efficiency and modernize the transport system and establishes a bidirectional communication between the owner and the electric vehicle, where the owner can control the electric vehicle remotely and safely.

### *4.2. Off-Board and On-Board Chargers*

The charger employed inside the vehicle which permits proprietor to charge their electrical vehicles anywhere, where a proper supply is available. The configuration of the onboard chargers is to minimize the power because of space, cost and weight factors which are employed to the vehicle's to charge the vehicles battery for a long time. The stand-alone (off-board) charger of the electric vehicle is less constrained by weight and size.

In forthcoming days Electrical vehicles can be benefited from frequent and fast to improve an effect of all-electric drive range. The period taken to charge can be reduced to less than 60 minutes. The demerits of Off-board charging includes the risk of vandalism, high cost of power electronics circuits, and include clutter in a public environment. The practical prototype of an off-board and onboard electric vehicle charging systems and power ratings can represent as given in Fig.1.This prototype of onboard charger consists of a DC-DC converter, AC-DC converter, power factor control circuit, electric motor, traction drive system etc. Research and development activities are taking place in these vital areas, such as designing the electric vehicle, designing the battery capacity and compatibility, size and the weight of the vehicle and effect of electric vehicles on the distribution network.

### *4.3. Integrated Chargers*

By reducing cost of the charger, weight, volume and design of implementing onboard charging systems into the electrical drive system have developed. The electric motor was first developed in 1985 to decrease the weight and size of the electric vehicle and it was patented by Cocconi and Rippel in 1990, 1992 and 1994.

The charging could be implemented on electric vehicles if traction and charging are not simultaneous processes. The motor windings can be used as integrated chargers for inductors. The motor drive inverter acts as a bidirectional ac-dc converter. An integrated charger is shown in Figure. 2.

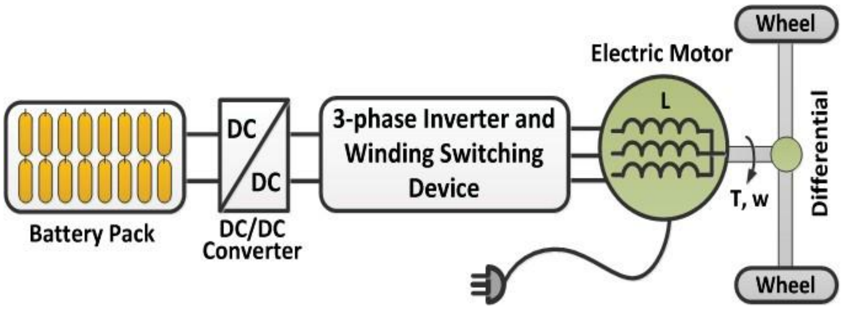


**Figure. 2** The basic layout of integrated EV charger.

The topology of integrated chargers is classified based on inverters (one or two) and the number of motors (one or two) .They have subdivision based on the motor type (permanent magnet motor (PM) switched reluctance motor (SRM) and induction motor (IM) with non-isolated or isolated circuits. The demerit of integrated chargers is the complexity of control and the circuit.

### *4.4. Unidirectional Chargers*

The traditional method of charging is unidirectional method. By using unidirectional chargers in electrical vehicles we cannot inject energy back into the distribution network .This type of chargers can be implemented by using Diode Bridge with filter and DC-DC converter. Nowadays, these type of converters are integrated into a one stage to minimize losses, weight, costs, and volume.

The handling of unidirectional chargers will makes it easy for the distribution network to handle highly loaded feeders because of many Electrical vehicles. For the local reactive power control the phase angle control of current without dischargeable battery can be implemented. The efficient charging actions are needed to maximize the benefits for the Research and development on unidirectional battery chargers. The unidirectional chargers having more penetration and high charging current will meet most of the objectives of distribution utilities while reducing performance, safety factors and cost combined with bidirectional chargers.

### *4.5. Bidirectional Chargers*

The bidirectional charger has two subdivisions: To regulate charge level of the battery and discharge current, a chopper has been employed and a grid-connected active bidirectional ac-dc converter that implements power factor. The charger draws sinusoidal current during battery charging with a predefined phase angle to control power and reactive power. During discharging mode, it would return current in the form of original sinusoidal wave. The bidirectional charger introduce battery energy back to the distribution system, charge from the distribution network, power stabilization and acts as vehicle-to-grid (V2G) operation condition. It is seems to be active Power factor correction.

While most of the research areas has focused on bi-directional power flow, there are serious obstacles which has to be overcome in order to implement. Two-way power flow should overwhelm battery degradation due to often cycling, metering issues, necessary hardware upgrades and the gross price of the charger with bidirectional power flow potentiality. Customers are in need of uninterrupted energy to make sure that vehicle state of charge before it is ready for a drive.

The extensive safety precautions are required for the successful implementation of bi directional power flow. The interconnection issues and Anti-islanding protection must also be implemented. Different chargers are used in this way.

### *4.6. Inductive and conductive chargers*

The conductive type of chargers employs metal contacts in both direction in most of the electronic devices, components and electrical appliances. The contactless power transfer is used for inductive charging in electric vehicle.

*4.6.1 Conductive charging.* The Conductive charging methods which it uses the direct contact between the charge inlet and electric vehicle. The charging cable can be fed from a charging station (tertiary, secondary) or a standard electrical output (primary level). In an electrical market there are different charging post available but this type of charging has been implemented to the Chevrolet Volt, Toyota Prius, and Tesla Roadster; they use primary and secondary chargers with basic infrastructure. Basic structure or dedicated off-board chargers are used in Mitsubishi i-MiEV and Nissan Leaf for conductive charging. The important demerit of this solution is that the operator needs to plug in the electrical cord, anyway this is a usual issue.

*4.6.2. Inductive Charging.* An inductive type of charger transfers their power magnetically through resonance because maximum power can be transferred through resonance. This charger has been employed for Primary and secondary level devices. Here no need of cords and cables. Merits comprises of convenience and the possibility of galvanic isolation. Demerits include cost of the new infrastructure and power, size, complexity, manufacturing, and relatively low efficiency.

The basic function of Inductive Power Transfer (IPT) are analogous to that of transformers, although most of the types possess high leakage flux and poor magnetic coupling. The secondary side of the transformer may be moving or stationary (roadway charging).An inductive coupled charger is shown in Figure.3

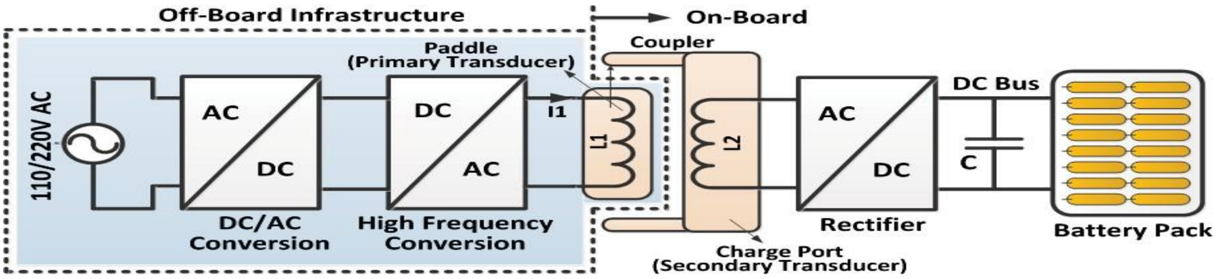


**Figure 3.** Typical inductively coupling stationary EV battery charging and GM EV1 system.

## 5. Merits And Demerits Of A Hybrid Electric Vehicle

### *5.1. Merits of a hybrid vehicle.*

*5.1.1. Eco friendly.* The biggest advantage of electric vehicle compared to the internal combustion engine type is that it reduces the carbon footprints which is the root of global warming. This makes hybrid electrical vehicles eco-friendly. This hybrid electric vehicle gives better mileage than the conventional vehicles. The electric vehicle operates on a dual powered engine (electric motor and gasoline engine) that cuts the rate at which the fuel is consumed and conserves energy.

*5.1.2. Financial aids:* Electric transports are benefitted by many incentives and credits that helps to make them economical to buy. It Lowers the annual tax bills and reduces the charges as compared to fuel vehicles.

*5.1.3. Less dependence on fossil fuels*: To avoid air pollution and to minimize the oil prices in the global market, the vehicle should be cleaner and requires less fuel.

*5.1.4. Regenerative braking system:* During the application of brakes the hybrid electric vehicles recharge the battery. An internal apparatus that acquires the energy outcome during braking and it uses to recharge the battery which in turn reduce the need for stopping to recharge the battery frequently and reduces the period of charging.

*5.1.5. Built from light substance:* Electric vehicles are constructed by super light equipment's which means energy required to operate is very less. The engine of the electrical vehicle smaller in size and light weight. It saves huge energy.

*5.1.6. High resale value:* With continuous increase in oil prices people are looking towards electric cars. As a result the green vehicles have started ruling the transport system and the resale value is much higher than the average resale value.

By owning a hybrid electric vehicle, has more advantage and the best one is budget and reasonable price.

### *5.2. Demerits of a hybrid electric vehicle*

*5.2.1. Expensive:* The demerit of owning a hybrid electric vehicle is that it can make our pocket empty. Hybrid vehicles are costlier than a traditional petrol, diesel car can cost around $5000 to $10000 more than the typical version.

*5.2.2. Low performance:* The hybrid electric vehicle employs a weightless electric engine and a couple of powerful batteries. Its consumes more space and weight in the car. Additional burden makes fuel inefficiency. By reducing the weight and battery size it reduce support to the suspension and the body.

*5.2.3. Huge Maintenance Costs*: The electric vehicle with dual powered engine, high maintenance cost and continuous up gradation in technology could make it tough for technicians to repair the electric vehicle.

*5.2.4. High Voltage in Batteries:* In case of an accident, the high voltage inside the battery can explode the car. There is a high probability of driver getting electrocuted.

## 6. CONCLUSION

This paper reviews the present scenario, degree of hybridization, types of hybrid vehicles, implementation of the chargers for the battery, infrastructure, and levels of power charging for Electric vehicles. Battery Performance do not depends on the design and types of the batteries but also on the charging infrastructure and characteristics of battery charger. Charging setup are classified into on-board and off-board types with bidirectional and one way power flow. Unidirectional charging decreases hardware fulfillments easy, tends to minimize battery degradation process and interconnection problems. The process battery energy injection is done by bidirectional charging, supplies battery energy outcome back into the grid. The onboard chargers limits power to match cost constraints, weight and space. These problems can be avoided by using an integrated charger and the electric drive system. The present charging infrastructure limits onboard storage of energy costs and its requirements. Onboard charging systems can be inductive or conductive in nature. The power transfer between the grid and the electric vehicle by direct contact through conductive charging and the power is transferred magnetically through inductive chargers. An infrastructure and power levels of charging are classified into three types: Primary, Secondary, and Tertiary levels. These system specifications and standards varies for different places. Different charging power levels and battery infrastructure specifications were presented and compared based on duration of charging, equipment necessary, the amount of power, cost, location, and suitability. The Triumph of Electric vehicles based on efficient and smart chargers, infrastructure decisions, standardization of requirements and increase in battery technologies.

## 7. References

[1] A.Y. Saber, and G.K. Venayagamoorthy 2015 One million plug-in electric vehicles on the road," Proc. IEEE Int'l. Conf. Intelligent Transportation Systems, ITSC **2009,** pp.141-147.
[2] US Department of Energy 2011 Office of Energy and Renewable Energy and the National Renewable Energy Lab.,Vehicle Technologies Program.
[3] M. A. Fasugba and P. T. Krein 2011 Gaining vehicle-to-grid benefits with unidirectional electric and plug-in hybrid vehicle chargers, Proc. IEEE Vehicle Power Propulsion Conf., VPPC**,** pp 1-6.
[4] Y. Du, S. Lukic, B. Jacobson, and A. Huang 2011 Review of High Power Isolated Bi-directional DC-DC Converters for PHEV/EV DC Charging Infrastructure, Proc. IEEE Energy Conv. Cong., 2011 IEEE**,** pp. 553-560.
[5] S. Haghbin, K. Khan, S. Lundmark, M. Alaküla, O. Carlson, M. Leksell, and O. Wallmark 2010. Integrated Chargers for EV's and PHEV's: Examples and New Solutions, in *Proc. Int'l. Conf. Electric Machines (ICEM)* 2010 IEEE**,** pp 1-6.
[6] CHAdeMO Association, 2011 Desirable characteristics of public quick charger.
[7] D. Aggeler, F. Canales, H. Zelaya - De La Parra, A. Coccia, N. Butcher, and O. Apeldoorn 2010 Ultra-Fast DC-Charge Infrastructures for EV-Mobility and Future Smart Grids, in Proc. IEEE ISGT Europe, 2010 IEEE, pp. 1-8.
[8] Takafumi Anegawa 2010 Development of Quick Charging System for Electric Vehicle, Tokyo Electric Power Company.
[9] Joseph Beretta 2010 Automotive Electricity, New York: John Wiley,.C.
[10] S. Acha, T. Green, and N. Shah 2010 Effects of optimised plug-in hybrid vehicle charging strategies on electric distribution network losses, *Conference and Exposition on Transmission and Distribution.*PES, Ed. Prague: IEEE.*2010 IEEE PES***,** pp. 1–6.
[11] A. Ramos-Paja, C. Bordons, A. Romero, R. Giral, andMartinez-Salamero 2009 Minimum fuel consumption strategy for PEM fuel cells, *IEEE Trans. on Industrial Electronics*, **56(3),** pp. 685-696.
[12] G. Putrus, P. Suwanapingkarl, D. Johnston, E. Bentley, and M. Narayana 2009 Impact of electric vehicles on power distribution networks, *IEEE Vehicle Power and Propulsion Conference.VPPC'09,* pp. 827–831.
[13] Q. Gong, Y. Li, and Z. Peng 2009 Power Management of Plug-in Hybrid Electric Vehicles Using Neural Network Based Trip Modeling, *Pro- ceedings of American Control Conference*. ACC'09 pp. 4601-4606.
[14] A. Emadi, Y. J. Lee, and K. Rajashekara 2008 Power electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles 2008 *IEEE Trans. on Industrial Electronics*, **55(6),** pp. 2237-2245
[15] M. B. Camara, H. Gualous, F. Gustin, and A. Berthon 2008 Design and new control of DC/DC converters to share energy between supercapacitors and batteries in hybrid vehicle, *IEEE Trans. on Vehicular Technology*.**57(5),** pp. 2721-2735
[16] C. Huston, G. K. Venayagamoorthy, and K. A. Corzine 2008 Intelligent scheduling of hybrid and electrich vehicle storage capacity in a parking lot for profit maximization in grid power transactions, IEEE Energy. **2030,** pp 1-8.
[17] M. E. Ortuzar, J. Moreno, and J. W. Dixon 2007 Ultracapacitor-based auxiliary energy system

for an electric vehicle: implementation and evaluation, *IEEE Trans. on Industrial Electronics*. **54(4),** pp. 2147- 2156.

[18] W. Short and P. Denholm 2006 A preliminary assessment of plug-in hybrid electric vehicles on wind energy markets ,National Renewable Energy Laboratory, Tech. Rep.

[19] W. Kempton and J. Tomic 2005 Vehicle-to-grid power fundamentals: Cal- culating capacity and net revenue, Journal of Power Sources. **144,** no. 1, pp. 268–279.

[20] S. Pay and Y. Baghzouz,2003 Effectiveness of Battery-Supercapacitor Combination in Electric Vehicles *, Proceedings of IEEE Power Tech Conference*. **3,** pp. 6-11.