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E vehicle conversion and Charging infrastructure

Mayank singh[1], Dr. Pankaj jain[2].

1. *Research scholar, School of energy and environment management, RGPV, Bhopal, mayank.singh2252@gmail.com*
2. *Associate Professor, School of energy and environment management, RGPV, Bhopal, M.P., India, pankajjainrgtu@gmail.com*

ABSTRACT

EV charging system is a system in which single or certain number of vehicles can be charged at a time under a single roof. EV runs on battery i.e., on D.C. power source therefore a convertor is required to convert available A.C. power into D.C. power to charge electric vehicle battery. D.C. fast charging stations are becoming more popular nowadays because they have capability to charge EV at a much faster rate than normal A.C. charging. Tesla motors in 2012 made first 480 volt D.C. charging system, which has a supply power range to approximately 250kW. Battery technology which is available now, has a capability to get charged less than an hour safely. Li-ion battery technology is breakthrough technology in EV industries. Due to high charge discharge cycle they are becoming more reliable and adaptive. High voltage charging is more preferred over low voltage charging because in high voltage system charging could be done at a much faster rate as energy transfer rate increases. A special switch system could be made so that same number of batteries can be charged at a much faster rate. Fast charging will lead to increased load on the grid hence special transmission system and equipments are required to handle such vast load. Solar charging infrastructure is a good option here as it provides large amount of power to be served at a source.

KEYWORDS: *EV-Electric vehicle, FC-fast charging, CCS- combined charging socket, Li-ion- Lithium ion, $LiFePO_4$- Lithium iron phosphate, BLDC-brushless direct current motor, DOD- Depth of discharge.*

I. ELECTRIC VEHICLE:

An electric vehicle (EV) is a vehicle that uses electric traction motors for motion. An electric vehicle is powered by self-contained battery, solar panels, fuel cells or an electric generator to convert fuel to electricity.

Fast charging and long life battery technology made it possible for easy adaption of electric vehicles. Nowadays battery up to 10 years life is available, hence frequent changing of EV battery is not needed. For example, TESLA MODEL S has a battery life of about 10 years, TATA NEXON EV battery has a battery life of up to 8 years, HYUNDAI KONA ELECTRIC EV has a battery life of about 8 years and similarly there are various EV which are having minimum 5 years warranty.

- **WHY TO OPT FOR EV RATHER THAN GAS POWER VEHICLES?**

One day all oil reserve will be vanished and therefore we have to think for the alternative fuel for powering the vehicle. Renewable energy

There are following reasons which advise for the use of EV:

- EV is a clean mode of travelling and transportation which has no tail pipe emission.
- EV has more boot space than other vehicles.
- Cost of running EV is very less.
- EV is very easy to use, as there is no need of using clutch and gear shifting and they are direct drive vehicles.
- EV motor drive has a efficiency of about 80-90% whereas gas vehicles are about 35% efficient.

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- Maintenance cost of EV is very less compared to gas vehicles.

- **WHAT HABIT DOES EV REQUIRES FROM US?**

EV requires only patience from the user, because EV requires some charging time to get completely charged. We can relate as an analogy between our cell phone and EV. As we are charging our phone and always plans for charging it before going outside, in the same way we have to think for the EV. While using it we should plan its charging and then we should use it. In this way we can become habitual for the EV. So the problem of long charging time can be avoided through this way.

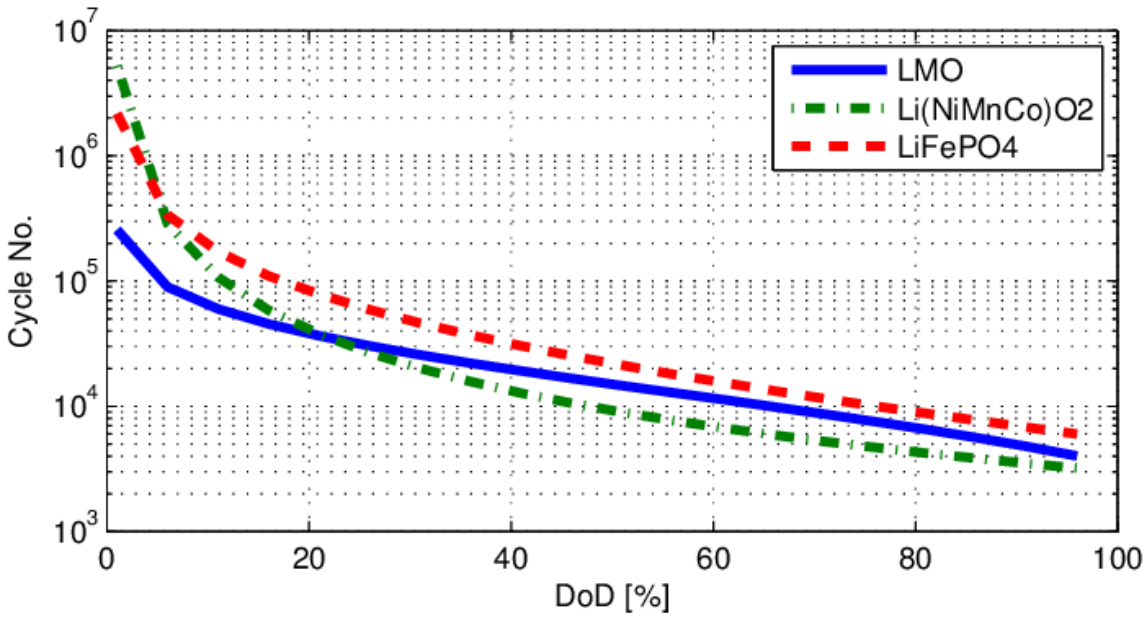
II. BATTERY USED IN EV:

Current proven battery technology, which are being used nowadays are discussed in this paper. Lithium ion batteries are generally used in present electric cars. TESLA MOTORS, which is world leader in EV industry, uses Li-ion battery. TESLA MODEL S uses high density PANASONIC 18650 3800mAh Li-ion cell. TATA NEXON EV, HYUNDAI KONA ELECTRIC, MAHINDRA e-VERITO, also uses Li-ion cells in their battery.

In general lithium ion cell could be charged with 1C rating i.e, if cell is of 3800 mAh capacity then this cell can be charged with 3.8A current in approximately about 1 hour.

These Li-ion cells have a discharge rate of 3C continuously.

$LiFePO_4$ cell are also good option for EV. These cells have more charge discharge cycle than Li-ion cells. Generally $LiFePO_4$ and Li-ion cells have about 2000 and 1000 charge discharge cycles.



In the above graph, it can be seen that $LiFePO_4$ cells have more charge discharge cycle than other lithium chemistry cells. If proper care is taken then and battery is charged after 80% DOD then battery would last more than 2000 charge discharge cycle.

- **TYPES OF BATTERY AVAILABLE IN INDIA ACCORDING TO VOLTAGE:**

In India, there are different kinds of E vehicle available in the market but among them popular EVs are E rickshaws, E bikes and custom conversion of old cycles and bikes into electric bikes. Now majority of them operates at following voltage systems which are discussed and compared as follows:

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i. 24 or 36 VOLT SYSTEM:

24 volt and 36 volt system are basically used in low power E bicycle. Power ranges from 250 watt to 350 watt in this system. Most commonly brushed DC motor and BLDC hub motor is used in this system. 24 or 36 volt, 250 or 350 watt E bicycle conversion kit is available in the market which is mostly used by the enthusiasts to convert their old bicycle into E bicycle. Li-ion battery gives the best performance in comparison to Lead acid battery because of its lightweight and fast charging property.

ii. 48 VOLT SYSTEM:

This system is mostly used in the E rickshaws and in few E bikes. Most of them run on Lead acid batteries and haves a range of 80-100km. Generally, Power of these E rickshaws ranges from 750 watt to 1200 watt. These E rickshaws have charging time of about 8 hours. These E rickshaws are popular because of its simplicity, low price, and low cost of running per km.

iii. 60 VOLT AND 72 VOLT SYSTEM:

This system is used in mostly sedan E cars and high performance E bikes. MAHINDRA E-VERITO, MAHINDRA e2O, TATA TIGOR ELECTRIC operate at 72 volt system. These electric cars have a range of about 120km-130km.

iv. 320 VOLT or HIGHER VOLTAGE SYSTEM:

Currently this system is used in SUV segment electric cars like TATA NEXON EV AND HYUNDAI KONA ELECTRIC having range of 312 km and 452 km respectively. While TESLA cars uses 380-405 voltage systems.

- **WHY HIGH VOLTAGE SYSTEM IS MORE PREFERRED OVER LOW VOLTAGE SYSTEM?**

  High voltage system is more preferred over low voltage system because for the same power, high voltage system decreases the value of required current hence due to this reason I^2R losses occurring inside the system are decreased. Also charging could be done at much faster rate, with low cost. In low voltage system, convertors used for fast charging are expensive and also large heat sink is required to dissipate the heat produced during conversion. But in high voltage system charging becomes fast and easy with less current to be handled.

III. CHARGING SYSTEM

For 24 volt, 36 volt, 48 volt, 60 volt, 72 volt system generally SMPS(Switched Mode Power Supply) based chargers are used. In E rickshaw for charging lead acid batteries transformer based chargers are used and in general these lead acid batteries are deep discharge batteries and charges at C/10 current. Li-ion battery based EV can be charged with 1C rating and hence they are more preferred over Lead acid batteries.

In India, domestic electricity system is based on single phase 230 volt AC and 400 volt AC three phase system. While charging EV on this electricity system through 15 Amp socket, maximum power which can be transferred to the battery per unit time is limited to 3.6 kW. Hence battery of 28kWh capacity will require at least 8 hour of time to get completely charge.

Hence for EV user, it is more desirable to add an extra metered connection for particularly EV so that about 30 Ampere current can be provided to charge it and same battery can be charged in about 4 hours. As in single phase 230 volt connection maximum power which can be fed to any electrical system is about 10 horsepower or about 7.5 kilowatt. Hence separate metered connection will be much more advantageous for charging EV.

In single phase 230 volt AC connection calculation is done as follows:

$$\text{Power} = \text{Voltage} \times \text{Current}$$

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$$P = V.I. \quad \text{eq. 1}$$

In case of 3-phase metered connection calculation done is as follows:

$$\text{Power} = (3)^{1/3} \times \text{Voltage} \times \text{Current} \times \text{Cos } \varphi$$

$$P = (3)^{1/3}.V.I. \text{ Cos } \varphi \quad \text{eq. 2}$$

Where, Cos φ = Power factor

Generally, Cos φ value is taken as 1

Therefore in 3-phase connection we calculate power as $P = (3)^{1/3} \times V \times I$.

➢ MOSTLY USED CHARGING CONNECTOR FOR EV CHARGING

In charging stations, charging sockets and connectors are available such that they are compatible with all the EV for charging them. Therefore standard has been set for the charging connectors so as to charge various types of EV through single charging connector. Various types of standardized charging socket are described as follows:

- **TYPE 2 CHARGING CONNECTOR**

TYPE 2 CHARGING CONNECTOR

This type of connector is capable of charging at a rate of 3kW to 50kW power. Tesla motors modified this connector and can charge at a rate of kW. Electric power is provided by single-phase or three-phase alternating current, or direct current. Cars are fitted with a standard male inlet connector, while charging stations are fitted with a female outlet, either directly on the outside of the charging station, or through a flexible cable with permanent connector attached on the end.

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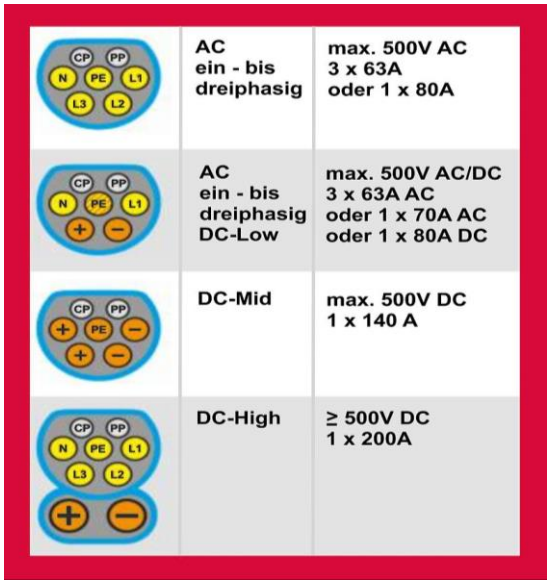

PIN INDICATION OF TYPE 2 CONNECTOR

The connectors contain, two small and five larger. The top row consists of two small contacts for signaling, the middle row contains three pins and the centre pin is used for earthing, while the outer two pins are used for the power supply, optionally in addition with the two pins on the bottom row which are also used for power supply. Three pins are always used for the same purposes which are described as follows:

- Proximity pilot (PP): pre-insertion signaling
- Control pilot (CP): post-insertion signaling
- Protective earthing(PE): full-current protective earthing system: 6-millimetre (0.24 in) diameter.

The allocation of four normal power supply pins varies depending on the mode of operation. They are allocated as one of:

- Neutral & line(L1) in single-phase AC system.
- Neutral & line phases (L1, L2, L3) in three-phase AC system.
- Neutral & line (L1), negative(−), and positive(+) in combined single-phase AC and low-current DC system.
- Negative (−) & positive (+) in low-current DC system.
- Negative (−, −) & positive (+, +) in mid-current DC system.

Communication takes place through the signaling pins between charger, cable, and vehicle to ensure that, the highest common denominator of voltage and current is selected.

- **CCS CHARGING CONNECTOR**

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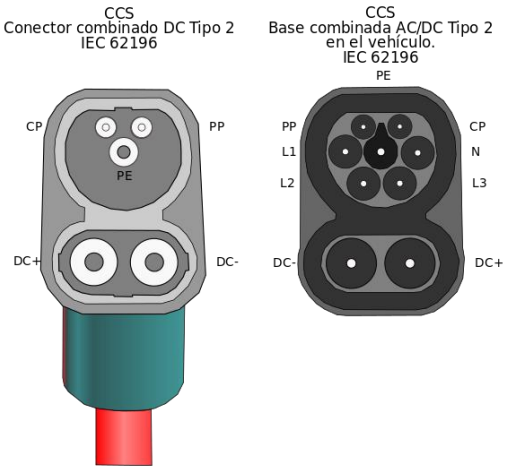

CCS CHARGING CONNECTOR

The Combined Charging System (CCS) is a standard system for charging electric vehicles. It uses both the Combo 1 and Combo 2 connectors to provide power at up to 350 kilowatts. These two connectors are the extension of both (Type 1&2) connectors, with two additional direct current (DC) contact points to allow high-power DC fast charging. CCS defines a single connector pattern on the vehicle side that offers enough area for both Type 1&2 connectors, along with space for two-pin DC connector, allowing charging current at up to 200 Amps. In this connector, it has both AC and DC fast charging pins. Hence fast charging through 480 volt DC system is possible, and there is no need of connecting extra fast charging cable.

- **HOW TO CHARGE EV BATTERY?**

Li-ion battery technology could be used till 100% DOD but, if we have to use it till 90% or 80% DOD. Discharging the battery till 80% and then charging will result in long life of the battery. It is also observed that if battery is charged till 90% or 95% maximum then it gives out its best performance. In this way we can keep battery of EV healthy and long lasting. During battery charging heat is produced, therefore additional cooling system is required to cool down the batteries for safety purpose.

IV. METHODOLOGY

For conversion of old car into electric car, simply engine is taken out from the car and direct driving motor is connected with gearbox through coupling. Here we have used jaw and spider coupling to connect motor and gearbox. Motor used is BLDC DC motor of 4.5kW power.

$LiFePO_4$ cells are used to make 48 volt battery pack of 84Ah. Kelly 7245 controller is used to operate and control the motor. Torque of the motor is approximately 14 NM. Foot throttle is used to control speed of the motor. Battery is just placed above the motor and near controller so as to minimize the conductor loss. It is important to note that, connecting wires should be of good quality and should be thick. Structure for motor fitting is made by 1 inch square pipe of 3mm thickness.

Gear ratio of Maruti 800 car:

1st gear- 43/12, 3.58.
2nd gear- 39/18, 2.166.
3rd gear- 32/24, 1.333.
4th gear- 27/30, 0.900.
Reverse gear- 37/22x22/11, 3.363.
Final ratio: 87/20, 4.350

Calculation of speed of the vehicle:

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Maximum RPM of the motor: 6000 RPM.
Diameter of the tyre: 15 inches = 38.10 cm= .3810 meters
Hence maximum speed of the vehicle in different gears is as follows:

$$S = \frac{\pi.D.N.60}{1000} \quad \textbf{eq. 3}$$

Where, S= speed of the vehicle in KMPH
D= diameter of the wheel in meters
N= number of rotation of wheel per minute

Final gear reduction in first gear:
3.58 x 4.350 = 15.573
Hence speed of the vehicle will be:
RPM of wheels in 1st gear: 6000/15.573= 381.436 RPM
Similarly, putting all values in speed calculation formula, speed in:
1st gear : 27.6 KMPH.
2nd gear : 45.73 KMPH.
3rd gear : 74.44 KMPH
4th gear : 110.06 KMPH

Solar PV modules of 200 watt power are used to charge 12 volt battery for auxiliary component operation. This solar PV module will lead in giving extra range of the car. A separate 20Ah battery is used to be used as a reserve source of power in the car. This reserve battery will help in adding extra range to the vehicle even in case if main battery is drained completely. This will also be very helpful during emergency when main battery don't have enough charge and vehicle require extra rang, in this situation reserve battery will provide extra range.

V. WORK DONE

General specifications:
Weight of the vehicle before conversion: 650 KG.
Weight of the vehicle after conversion: ~660 KG.
BLDC motor specifications:
Power: 4.5KW.
Torque: 14.3 NM @ 3000RPM.
Sensor used inside motor: Hall sensor.
Controller used: Kelly 7245 programmable controller.
Battery capacity: 3.9 KWh.
Operating voltage: 48 volt.
Size of wheel of Maruti 800: ~15 inches.

Engine is swept from the car and gearbox is remained attached with the car. Now with the gearbox shaft, coupling is used to connect motor with it. We have used jaw and spider coupling for the connection. Now main problem aroused due to misalignment of motor shaft and gearbox shaft. Centre of both the shaft are matched very carefully and both shaft are placed with 1mm gap between two couplings because if any misalignment occurred during run then this gap will mitigate the affect of misalignment. Due to misalignment chances of premature failure of spider could be observed hence extra spider is kept with the motor for safety purpose.

$LiFePO_4$ prismatic cells are used of 80Ah capacity. Nominal voltage of the cell is 3.25V and maximum charging voltage is limited to 3.65V. Overcharging of cell to higher voltage is strictly prohibited because it

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will lead to internal damage to the cells, and it will decrease the overall life of the cell. 15 cells are connected in series to obtain 48 volt battery. Each cell has a capacity of 80Ah there for overall capacity will be 80Ah of 48 volt battery. Battery charger of 15A is used to charge 80Ah battery pack in approximately 6 hours. Here experimental charging is also done with joining a 6A charger in parallel with 15A charger. Hence overall output of the two chargers will be about 21A. Hence then battery could be charged completely in 4 hours instead of 6 hours.

At peak power maximum current drawn from the battery by the motor is about 93A. Maximum power is required by the car is when car starts from the rest. Hence 1st gear is more preferred so as to provide momentum to the vehicle from rest with low power consumption.

THEORETICAL COMPARISON BETWEEN EV AND PETROL ENGINE CAR: TECHNICAL PARAMETERS:

PARAMETERS	TATA NEXON XMA PETROL	TATA NEXON EV XM
PRICE	Rs 8,44,500	Rs 13,99,000
POWER	120 PS	129 PS
TORQUE	170NM @4000 RPM	245 NM
WEIGHT	1305 KG	1400 KG
BOOT SPACE	350 L	350 L
RANGE	16 KM/L(average)	312 KM Per Charge
RUNNING COST	Rs 1,691 for 300 KM (approx.)	Rs 330 for 300 KM
SERVICE/MAINTEN--ANCE COST	Rs 21,800 for 50,000km (ref. (8))	Nearly zero maintenance cost as battery and motor warranty comes for 1,60,000 KM
TOTAL FUEL COST OR CHARGING COST(1,60,000 KMs)	Rs 9,49,334	Rs 1,33,120

Table 1- comparison between Tata nexon EV and Tata nexon

Assumptions:

- Price of petrol in august, 2020 is Rs 89 per litre.
- 1 Unit electricity cost in MP is Rs 6.5 per KWh (2020).
- Base model of automatic drive petrol version on TATA NEXON XMA and TATA NEXON EV XM are taken for reference and study.
- Cost of per km range on TATA NEXON EV is taken as Rs 1.1/km (ref-7, business today).

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- Total fuel cost is cost of fuel or charging till 1,60,000 KMs and is evaluated for 1,60,000 KM as TATA NEXON EV comes with the same warranty on motor and the battery.
- Average range of TATA NEXON EV is taken 250 KMs.
- Average fuel economy of TATA NEXON is taken as 15KMPL.
- Cost of petrol is taken as Rs89/Litre (August 2020).
- Energy required to charge the battery of TATA NEXON EV is taken as 32 KWh.

CONCLUSION:

Hence from all the discussions and results it can be concluded that, there are following bottlenecks for E vehicles which are described as follows:

- Without proper charging infrastructure, promotion and easy acceptance of E vehicle cannot be done.
- Better battery technology is required for safe and economic running of electric vehicle.
- Renewable energy like solar and wind energy could prove best charging source for electric vehicles.
- Induction motor are much preferred over BLDC as BLDC motor uses neodymium magnets and these magnet material are limited in resource.
- High voltage battery and motors are much preferred over low voltage because this reduces current value and it results in easy operation and easy control.
- Fast charging requires cooling as it produces lot of heat during charging.
- Separate metered connection would be much preferred for EV charging as EV could be charged at a much faster rate.

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