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Creating Green Charging Infrastructure for Electric Vehicles –A Review

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Abstract— *In order to achieve sustainable development and to protect our environment most of the countries are shifting their transport system based on electric vehicles. Battery operated electric vehicles are slowly getting popular and the main factors behind this trend are the need to reduce noise and air pollution, and over dependence on fossil fuels. The Charging infrastructure is one of the main factor which will play important role in helping for transition from fossil fuel based vehicles to electric vehicles (EV). The major limitation of electric vehicle is availability of power only for limited distances, and the long charging time duration to charge the electric batteries. In last few years' lot of work has been done to reduce the time needed to recharge the vehicle batteries using pulse charging instead of supplying current and/or voltage continuously. This paper is about the potential need for electric vehicles (EV) charging station (CS) infrastructure and its challenges for the Indian scenario. This paper presents the scenario about charging power station. The concern is about fast charging of electric vehicle batteries by using advance technologies like pulse charging method. Pulse-based charging method might be efficient way to overcome the shortcoming of slow charging time. If the amount of remaining battery capacity can be displayed for the driver then it is possible to make decision on the time of recharging the battery. The battery behavior depends on many conditions hence if we know this than we can estimate the battery performance as well. In this paper we will try to explain how the battery of an EV works and how it is charged. Moreover we will explain how we can create charging station using solar power system.*

Keywords: *Electric Vehicle, Battery management Pulse charging, Fast charging, Slow charging etc.*

1. INTRODUCTION

In large cities air pollution is becoming matter of concern due to CO_2 emission from vehicles operating on fossil fuels hence demand for vehicles which are based on green energy are growing rapidly. Hence demand for Electric Vehicles will be higher in the next few years. In electric vehicle its battery which play a very crucial role on the performance of that vehicle. The running capacity of the Electric vehicle depends on the capacity of battery. Hence the success of EVs is very much depends on the availability of economical and easily available charging infrastructure.

2. CONSTRUCTION AND WORKING OF A BATTERY

A "Battery" is basically a device that converts chemical energy into electricity energy. A battery commonly contains two or more cells connected in parallel or series. Further each cell consists of a cathode (a positive electrode), an anode (a negative electrode) and a paste or ionic conductor also known as an electrolyte. Fig.1. shows the main components of an electrochemical cell. When a load is attached to the electrodes, its leads to occurrence of a chemical reaction which causes generation of current due to movement of electrons from one electrode.

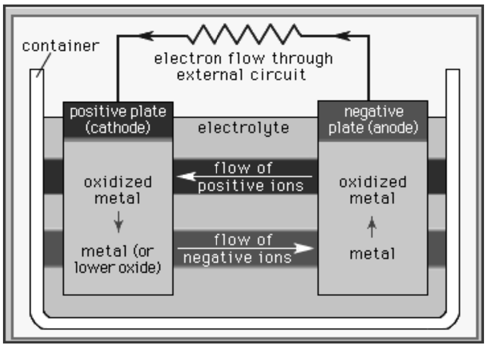

Figure 1: Main Components of an Electro-Chemical Cell

2.1 CLASSIFICATION OF BATTERIES

The batteries can be classified as primary and secondary cells. Primary cells are also called as "Voltaic cells", are the kind of electrochemical cells in which the electrochemical reaction cannot be reversed. Hence once they complete their normal cell operation and their chemical energy has been converted into electricity they become dead and cannot be used further. An example of primary cell is the disposable battery. Whereas Secondary cells are also known as rechargeable cells, storage cells or accumulators, can reconstituted itself into their original chemical form by passing an electric current through them in the opposite direction of the normal cell operation.

Table 1: Details of Energy Density with Operating Temperatures Range for Different Types of Batteries.

Battery System	Gravimetric Energy Density	Volumetric Energy Density	Operating Temperature (°C)	
	W.h/Kg	W.h/dm3	From	To
Mercury-cadmium	22	73	-40	70
Carbon-zinc	55-77	120-152	-7	54
Alkaline manganese	66-99	122-268	-30	54
Mercury- cadmium-bismuth	77	201	-20	90
Zinc chloride	88	183	-18	71
Mercury -zinc	99-123	300-500	-20	54
Magnesium-organic electrolyte	133-330	430-610	-54	74
Lithium-sulphur dioxide	260-330	420	-40	60
Lithium-vanadium pentoxide	264	660	-54	60

Secondary cells batteries are used in electric vehicles. The common rechargeable types of batteries are lead-acid, lithium-ion (Li-Ion), nickel-cadmium (Ni-Cd), nickel-metal-hydride (Ni-MH), lithium-ion polymer and reusable alkaline. Among these lead-acid battery was the pioneer in the secondary cell battery market. French physicist Gaston Planté invented this battery in 1859. The lead-acid battery remains the most widely used in industry and automotive applications. From above given table No. 1 we can see that for their given size and weight, lithium-ion batteries can hold a charge for much longer than conventional rechargeable lead-acid batteries and can pack very high energy density. Lithium is chemically reactive metallic element and lightweight having ability to store large amount of energy in its atomic bonds.

2.2 BATTERY CHARGING TECHNIQUES

Constant voltage (CV) and Constant current (CC) are the two conventional methods commonly used for a battery charging. Out of these two CV offers longer charging time with low temperature rise whereas CC provides shorter time for charging a battery with higher temperature rise which is harmful for battery life. Also due to the limit of voltage per cell (V I*cell*) and maximum charging current (Imax) from battery providers, CV and CC method cannot meet the 30 minutes charging time and requirements of low temperature rise from Electric Vehicle users. Therefore an alternative technique called pulse charging method which was invented later-on can be used for a quick charging at high current. A pulse charge method can inject higher peak voltage and current with the same V I*cell* and I*max* rated battery; therefore, the charging time is shorter comparing to CV and CC method. In pulse charging method periodically interrupting charge is injected for a short period which facilitates the ions in the battery system to get diffuse and distribute uniformly in the battery. It helps to control the negative effects of high temperature rise during CC method. The pulse charging technique works on supplying a current charging pulse for about a full second and then followed by a resting period in of about milliseconds. This process of charging and resting period is carried out repeatedly till the battery is fully charged. The pulse charging technique may be used to charge batteries of EVs at charging station for fast charging.

3. DESIGNING SELF SUSTAINABLE GREEN CHARGING STATION FOR EVS

The limited capacity of battery is the main constraint in using an electric vehicle for long distances travels. At present an average EVs can run for 100 km after that the battery of that EV must be recharged to run the vehicle further. Therefore in place of gas station charging station is required to recharge the batteries of EVs. The three important issued related with charging station which are of immediate attention are: standardization (all vehicle makes EVs can use the same charging set up), quick charge (less than 30 minutes for full recharge of batteries), long battery lifetime (minimum rise of temperature during charging). Further it also important to use renewable energy at charging stations for recharging of batteries. So there is no pollution from the charging station otherwise the aim of whole exercise will be defeated. Hence by using renewable energy sources i.e. wind energy, solar energy etc. at charging station we can create a complete pollution free transportation system. In this paper we will try to explain and explore the idea of creating green infrastructure for EVs charging.

3.1 CONSTRUCTION AND LAYOUT OF A SOLAR POWER EVs CHARGING STATION

The layout of a Solar Power (SP) also known as photovoltaic energy charging station is shown in Fig.2. The main components of this self-sustainable green energy charging station are shown in this fig.

Fig. 2: A Quick Charging Green Energy EVs Charging Station layout

The construction details and function of main components of solar Power charging station is explained below:-

Solar Panel: Solar energy (SE) or Photovoltaic energy (PE) generation is non-polluting, freely available & is highly reliable. All these unique characteristics make the solar energy resources very attractive for applications such as EVs battery charging stations. We can use the solar power system for purpose of charging stations of electric vehicles. The design of the solar panels depends upon the battery rating of the EVs. So solar panel has to be designed for batteries of same ratings.

DC Control unit: - The main function of DC control unit is to connect and disconnect the charger to the battery and it will take care of starting charging and stop charging when battery is fully charged, it also ensure that correct voltage is maintained during charging process. It also regulates the power going from solar panel to battery and will save the battery from any damage due to overcharging. The battery level will be checked by the Microcontroller in the circuit, it will disconnect the solar power connection to the battery when the desired level (fully charged) of battery is reached. This will save batteries from overheated and damage to the internal component of battery.

Backup battery: - Battery backup system is to store the surplus solar power produced by the solar panels and it feed the power back to the system when no power is being generated by solar panels. Lead– acid batteries are very much suitable where surge current are not so important.

3.2 CAPACITY CALCULATION OF SOLAR

POWER CHARGING PLANT

The capacity of solar power plant is calculated by using the total power consumption of all the loads to which power is to be supplied from solar plant. The method of calculation is as detailed below:-

A. Calculation of No. of Photovoltaic panel Modules required:-

- For each appliance calculate total Watt-hours per day. Calculate Watt-hours needed for all appliances together to get the total Watt- hours per day to be needed for all the appliances.
- Calculate the total solar power needed per day from the solar plant i.e. Photovoltaic modules. The total Watt-hours per day which must be provided by the solar panel can be calculated by multiplying the total appliances Watt-hours per day by 1.3 (the energy lost in the system) to get Size of the PV modules.
- The maximum power produced (peak watt) (Wp) depends on two major factors i.e. Climate of the site and photovoltaic module size. Therefore we have to take in to account the panel generation factor (PGF) which depends on the location of site. For example PGF is 2.93 for EU countries whereas PGF is 3.43 for Thailand. The calculation can be done as explained below to find out size of photovoltaic module using PGF as 3.43 (Thailand):-
- In order to calculate the total Watt-peak (Wp) power for PV modules divide the total Watt-hours (Wp) per day needed from the Photovoltaic modules by PGF i.e. 3.43. It will provide us the Watt-peak (Wp) rating needed from the photovoltaic panels to operate the appliances.
- From the above we can find out minimum number of photovoltaic panels.
- If we install more than minimum number of photovoltaic modules the performance of solar power generation system will be better which will also improve the battery life. Reciprocally if less power is produced during cloudy situation by the solar panels due to installation of minimum photovoltaic modules the life of battery will be shortened.

B. Battery capacity/Size Calculations:-

- It is generally recommended that charging stations should make use of deep cycle batteries. Because these batteries have feature of rapid recharge to full charge level and can get discharged to very low energy levels and cab be used for years .The battery size should be large enough so that it can store enough amount of energy and can operate appliances without shortage of energy during cloudy weather conditions and night. The calculation to find out battery size are given below :-
- Calculate the total Watt-hours per day required by the appliances (Wh). Now to calculate the total Watt-hour $(Wh)_b$ needed from battery divide it by 0.85 (BLF) to take in account battery losses.
- Now divide the watt hour needed from battery $(Wh)_b$ by 0.6 (BDF) to take in account depth of discharge. Let it be call $(Wh)_{b2}$. Now divide the Divide the $(Wh)_{b2}$ by the battery nominal voltage (V)n. Let the answer be called $(Wh)_{b3.}$ Now multiply the $(Wh)_{b3}$ with autonomy days (AD) (the days during which there is no power produced by photovoltaic panels and system will be in operation mode) it will give the required capacity of deep-cycle battery in terms of Ampere-hour (Ah).

Battery capacity (Ah) =Total watt hours per day used by load (Wh) x days of autonomy (AD) / 0.85(BLF) x 0.6 (BDF) x nominal battery voltage (V)n.

C. Solar charge controller rating calculations :-

The solar charge controller has to control load, current and voltage of the power generation system and is a very important part of overall charging system. Therefore selection of the solar charge controller must be done according to its application in the charging system, it's current carrying capacity must be more than the current carrying capacity of

Photovoltaic array and batteries and It's operating voltage must match the operating voltage of Photovoltaic array and batteries. The rating of solar charge controller is calculated while taking in to account the photovoltaic array short circuit current (Isc) and then multiplying it by factor of 1.3 (factor of safety).

Solar charge controller rating = Total Photovoltaic array short circuit current (Isc) x 1.3.

4. CONCLUSION

Most of the countries on our earth are trying to reduce the environmental pollution caused by exhaust gases emitted from fossil fuel based transportation systems and are in process of shifting their transportation systems from the fossil fuels based vehicles to electric vehicles. The same trend is being followed in our county as well. In our country the problem of environmental pollution is further increased due to our over-dependence on fossil fuels (coal and petroleum products) based power generation system. Thus, this model which combines solar power generation and charging stations for EVs can reduce emission of pollutants from the power generation and transportation systems. It can help us to control the carbon emissions from these two sectors and to successfully achieve our carbon emission control objectives. In future this type of Eco-friendly Solar EVs Charging stations has potential of playing a major role in creating non-polluting Charging infrastructure for our Electric vehicles in our country.

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