A TECHNOLOGICAL REVIEW OF CHARGING STATIONS FOR ELECTRIC VEHICLES BASED ON PHOTOVOLTAIC ENERGY

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ABSTRACT

Electric vehicles (EVs) can be charged using renewable energy sources like solar photovoltaic (PV), which has a number of technological and financial advantages. Combining emission-free EVs with low-carbon PV power generation can help solve the problems posed by greenhouse emissions from internal combustion engines. Grid-powered EV charging has been the focus of numerous articles, including reviews, throughout the years. However, it doesn't seem like there is a review article on EV charging that uses PV as one of the energy sources. In light of the growing interest in PV-EV charging, this study analyses and updates some of the key components. For the benefit of a reader, it contains details on the fundamentals of EVs, batteries, and a brief introduction to PV systems.

Keyword : **Electric *Vehicle, Batteries, Charging Station, Fast Charging, Photovoltaic.***

1. INTRODUCTION

The environmental, scientific, and financial potential of EVs have inspired previously unimaginable levels of integration between the transportation and electrical power sectors. The primary connection between the two areas is the battery charge, which supplies the traction, control, lighting, and air conditioning systems for electric vehicles. However, using the electrical grid to charge the EV puts additional strain on the utility, particularly during periods of high demand. One practical way to lessen the harmful effects of the grid is to encourage charging from renewable sources. The use of this clean energy is anticipated to benefit the environment while also increasing the overall effectiveness of the charging system.

Solar power is getting more affordable as photovoltaic (PV) module costs continue to decline. The reference number should be shown in square bracket. However the authors name can be used along with the reference number in the running text. The order of reference in the running text should match with the list of references at the end of the paper.

PVEV charging has become more popular as a result of improvements in power conversion technologies, battery management systems, installation techniques, and design guidelines. Especially during the day, the EV is regularly left idle in the parking lot in full sunshine. This creates the opportunity to immediately charge the EV using the "charging-while-parking" method in addition to the more popular "charging-by-stopping" method. By adding a PV roof to the parking lot, for instance, the EV may be easily charged while the owner is engaged in other activities The authors of list a number of benefits of the PV-powered charging station. The savings are substantial since charging occurs throughout the day, when load demand and electricity rate are at their peak. Additionally, it emits the least CO2 and consumes the least amount of gasoline. From a structural aspect, covered parking spaces provide free protection from the sun and rain, which is a desirable quality in countries with high temperatures.

Photovoltaic-charging stations are those that use solar modules as a source of electric energy for battery recharging (PVCS), which are required for all electrically assisted vehicles. PVCS are divided into two groups: PV freestanding charging systems and PV charging systems for the grid. By contrasting the two designs' characteristics and outlining the charging system's current technological status, we shall investigate this topic in this essay. In order to give engineers and researchers the most recent information, we disclose every component of the PV charging system.

2. PHOTOVOLTAIC SYSTEM

The most important part of a photovoltaic (PV) system is the solar panels, which directly convert the energy of the sun into electricity. Silicon (Si), the most prevalent semiconductor material, is used to construct the bulk of solar panels. Recently, materials with better conversion properties—like gallium (Ga) and aluminum (Al)—have become more popular. The components of the PV system comprise the electrical equipment that connect the PV output to the AC or DC loads.

Maximizing the utilization of solar cells for electricity generation involves overcoming two significant challenges: increasing cell efficiency and enhancing energy extraction. Maximum power from the solar cell can be produced at a particular operating point, which varies depending on the ambient air quality. This changing output hinders utilities' ability to predict output power at a given time for a certain location, creating a scheduling challenge. The ideal operating point of the cell for generating the most power can be calculated using the I-V (current-to-voltage) characteristic.

In the solar cell, a p-n junction is made using a thin layer of semiconductor. The quantity of solar energy (photons) absorbed by the semi-conductor material determines the output power of the solar cell. The I-V characteristic of the semiconductor material governs the solar cell's output power, as shown in Fig. 1. The maximum power point (MPP), at which the solar cell generates the most output power, can also be found using the I-V curve. The maximum power point can be found by multiplying the voltage by the output current. The solar cell is often operated at or very close to its maximum power point in order to receive the most power. This location is close to the "knee" or "bend" of the voltage-current characteristic, which may be seen in Fig. 1 at point A.

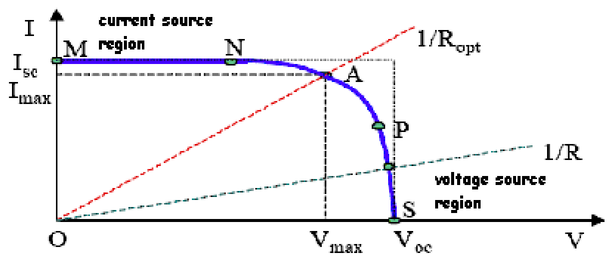

Fig 1. Typical I-V characteristic of a solar cell

The voltage-current characteristic of a solar cell is composed of two parts:

A)The location of the current source, in area

B) The vicinity of the source of the voltage.

The output current is constant as the voltage rises because the solar cell has a high internal impedance in the first region of the I-V characteristics, but the terminal voltage is constant over a large range of output current and the internal impedance is low in the later.

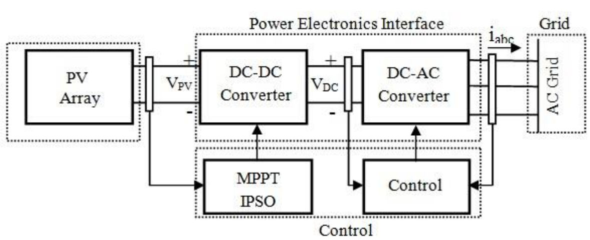

Fig. 2 Solar PV System Connected to Grid

According to the maximum power transfer theory, the load receives the most power when the source's internal impedance and the load's impedance are exactly equal. The output impedance of the solar cell must be made equal to the input impedance of the load in order to operate the solar cell at or close to its maximum power point. Since the terminal voltage and output current control the internal impedance of the solar cell, it is possible to maintain the maximum power working point by adjusting either the voltage or output current, or both.

External factors like temperature and irradiance have an impact on the maximum operating point, making it uncertain to maintain it at the optimal point (MPP) and causing output power fluctuation. A maximum power point tracker (MPPT) is utilized to finish the assignment. The majority of MPPT controllers use the buck converter (step-down), boost converter (step-up), or buck-boost converter configuration.

3. ELECTRIC VEHICLE CHARGING STANDARDS

Three significant groups work to standardize the electrical features of EV charging stations around the globe: the International Electro-technical Commission (IEC), the CHAdeMO organization, and the Society of Automotive Engineering (SAE). In addition to these associations, Tesla Motors, the main producer of electric vehicles worldwide, develops its own standards for its Model S, Model X, and Roadster models.

Each of the businesses above has a selection of charger standards that work with both AC and DC power. For instance, the SAE has been developing standard J1772, which categorizes electric car chargers into Level 1, Level 2, and Level 3.

i) Level 1: The charger is built-in and delivers DC voltage with a maximum current of 80 A and a power output of 40 kW.
ii) Level 2: The charger gives a DC voltage of up to 200 A with a maximum output of 90 kW.
iii) Level 3: The charger is disconnected from the board. With a maximum capacity of 240 kW, the charging station delivers DC electricity straight to the battery through a DC connection.

All Level 3 chargers fall within the category of fast chargers. Different power and current specifications for DC quick charging were suggested by CHAdeMO and the International Electrotechnical Commission (IEC). Table 1 provides more details by providing a brief summary of the power and current level evaluation for DC charging standards for electric cars.

Standard	Level	Max Current Rating (A)	Max Power Rating (kW)
SAE	DC Level 1	80	40
	DC Level 2	200	90
	DC Level 3	400	240
CHAdeMO	DC Fast Charging	125	62.5
IEC	DC Fast Charging	400	100-200
Tesla	DC Super Charger	340	136

Table 1: EV Charger categories

4. PHOTOVOLTAIC CHARGING STATION TECHNOLOGIES

There are two ways to use solar energy to charge an electric vehicle: PV-grid and PV-standalone. When there is insufficient solar irradiation, PV-grid charging offers the benefit of allowing for grid-based charging. In the absence of the EV (to be charged), PV electricity may be pushed into the grid, making it more versatile. On the other hand, PV-standalone is more beneficial in remote locations where utility supply is either nonexistent or excessively expensive. It has a simpler setup because there are fewer power conversion processes.

4.1 PV-Grid Charging System:

Two conversion phases created by AC/DC and DC/DC converters are depicted in Figure 3's charging architecture, which has been studied from a variety of angles in a number of published papers. Additionally, the dc bus is essential since it will link the PV array, ESU, and EV battery pack in addition to other dc-powered devices. In this configuration, batteries or an energy storage unit (ESU) may not be required because the station is directly connected to the grid. Even yet, it would be really helpful if individuals were willing to reduce their reliance on the grid. According to the authors of , efficient topologies for integrated PV-grid chargers are preferred.

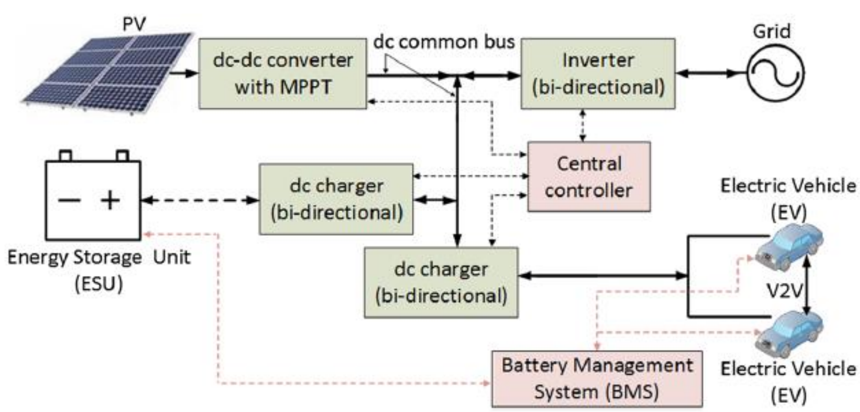

Fig 3. Block Diagram of a General PV-Grid CS

The SOC of an EV when it is first plugged in is usually less than 100 percent. The charging priority in the most generic PV-grid system (without the ESU, V2G, and V2V activities) are as follows [21]:

• Case 1: If the PV generates more electricity than the EV requires, the PV will be utilised to charge the EV entirely. The power from the grid is not used for charging. If there is any residual extra electricity, it will be put into the grid.

• Case 2: If PV power is unavailable due to inclement weather or at night, the charging will be carried out only by the grid. In addition, if the PV system develops a problem, the same procedure will be followed.

• Case 3: If the available PV power is insufficient to charge the EV due to low irradiance, the EV will be charged using whatever power is available from the PV. The rest (balancing) will be provided by the grid.

• Case 4: If the charging station does not have a commitment to charge (i.e. there is no EV to be charged), the PV energy will be immediately sent into the utility grid, usually with a monetary advantage to the owner.

The entire charging process will be handled by the PV if there is sufficient PV energy to charge the EV. Using a dc-dc converter and a dc charger is illustrated in Figure 4. In this case, the PV will charge independently, and the system will be electrically decoupled from the grid. To match the charging profile of a particular EV, the dc charger modifies the dc voltage.

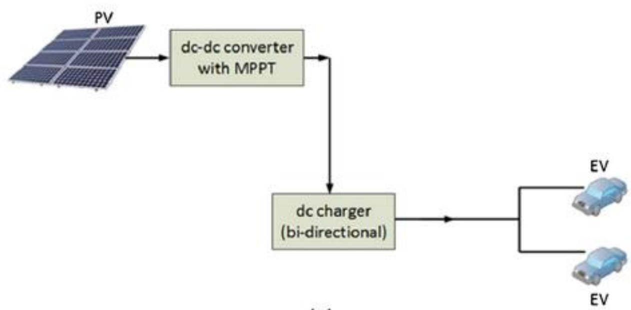

Figure 4: PV Charging Mode

second mode (rectification mode coupled to the grid

On the other side, the EV will be charged directly from the grid if the PV system is absolutely unable to supply any power (due to zero or extremely low irradiation). Initially, a bidirectional inverter in rectification mode is used to convert grid ac power to dc. The dc charger then adjusts the dc voltage further. Figure 5 [24] shows how this situation is.

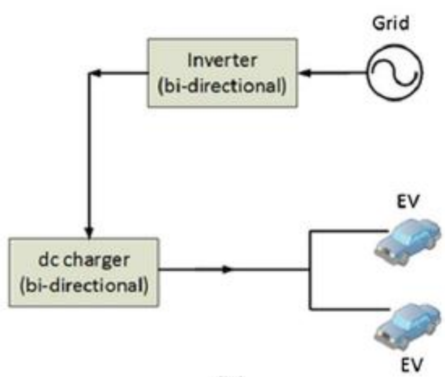

Figure 5: Grid Charging Mode

Grid-connected rectification and PV charging is the third mode.

As shown in Figure 6, both the PV and the grid assist in charging the battery when the PV can provide some energy (but not enough for fully independent charging). How much energy the PV can supply frequently determines how much energy is drawn from the grid. The grid will cover the shortfall. The controller must constantly monitor the electricity generated by the PV and adjust the grid intake in accordance with changing irradiance conditions to ensure that the EV continues to receive the necessary power.

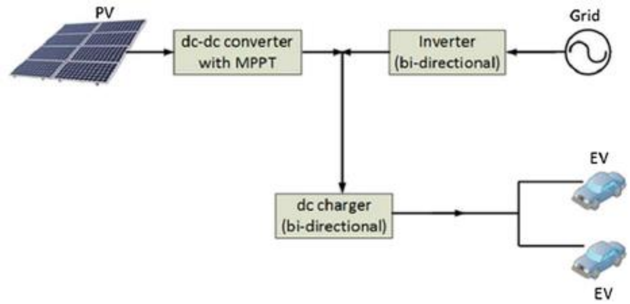

Figure 6: Hybrid Charging Mode

4th Mode (Grid inversion mode)

When no EVs are available for charging and the PV system is producing electricity, all of the energy is sold to the grid using two-step conversion operations, namely the dc–dc converter and the bidirectional inverter. Figure7 depicts this operation. Even though the EV is charging, it may be more cost-effective to run in this mode in some circumstances. When the feed-in-tariff rate is significantly higher, such a concept becomes practical.

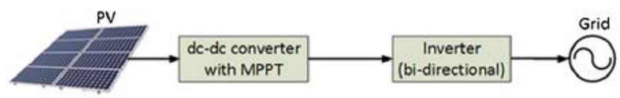

Figure 7: Grid Inversion Mode

4.2 Standalone PV Charging System

PV-standalone charging, as shown in Figure 8, is the process of recharging an electric vehicle (EV) entirely from solar power, independent of the utility (grid). It is more effective since there are fewer steps involved in power conversion . On the other hand, the PV array must be sufficiently large to accommodate the number of cars that are need to be charged. Figures 8(b) or 8(c) demonstrate a charging goal attained with an intermediary ESU, while Figure 8(a) depicts a straight PV to EV connection. In addition, there are numerous approaches that make use of hybrid solutions.

The PV power is insufficient and erratic to charge the EV continuously, which is the main issue with the direct charging method. On the other side, when PV power is not available, the ESU enables surplus energy to be stored and used later. This is better, but the ESU's initial investment cost might be too high. In both cases, the charge controller is a crucial element. It functions fundamentally as a dc-dc converter with MPPT capabilities and the additional feature of controlling PV voltage to ensure the charging current is at its best.

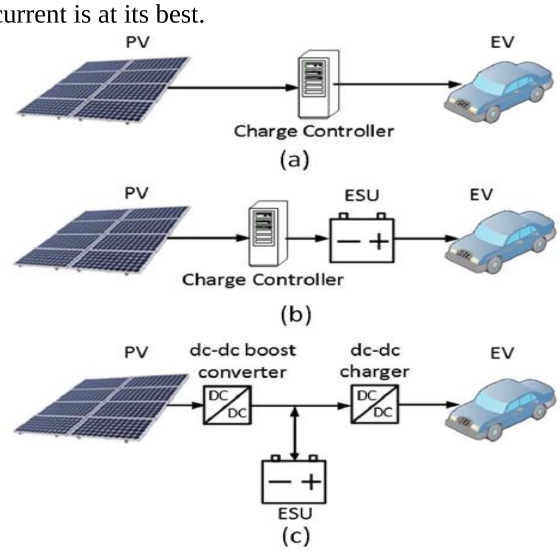

Figure 8: PV standalone CS

5. CONCLUSION

The current developments in the area of photovoltaic DC charging stations for electric vehicles are briefly discussed in this study. All of the charging stations' various parts are compared and explained. In conclusion, grid operators and automakers will pay more attention to and spend more in the benefits of PV-EV chargers that utilize V2G technology in the future. The photovoltaic charging structure is becoming more complex as new functions are added to the system, needing sophisticated controls in each block as well as real-time station administration, to sum up.

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