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Maximum Power Point Tracking for Electric Car Solar Charging Stations

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Abstract

Over the years, there has been a greater level of development within the premises of electric vehicle production and utilisation. As humanity slowly seeps into global warming, the development of solar powered electric vehicles characterises zero pollution along with high efficiency and low maintenance. It is to be noted that the charging stations required to charge the electric vehicle batteries. These vehicles however impose high energy demand on the utility grid. On the other hand, the electrical design of these potential systems has different techniques and are sometimes considered complex. It cannot be denied that the economic development of any nation essentially depends on fossil fuels, which are particularly used for transportation and generation of electricity. It can be understood that hybrid electric vehicles can play a crucial role in reducing greenhouse gas emission from the transport sector. Based on this understanding, the current research study tends to talk about the maximum power point tracking of the electric car solar charging stations. The research emphasises the introduction of the vehicle-to grid technology and the associated control for both PV-grid and PV standalone DC charging systems.

Introduction

The notion of MPPT controller is considered to be a major element in the association of electric car solar charging stations. The MPPT tends to represent the potential bias towards which the solar cell essentially outputs the maximum net power. This MPP voltage is found to effectively drift the wide range of variables that includes the aspects of irradiance intensity and that of device temperature and device degradation. MPPT is essentially electronic tracking and digital features. The potential inspiration behind the association of solar-powered automobiles derives from a potentially social phenomenon. The decrease in the fuel resources and traffic congestion have further contributed to the advent and need of electric vehicles. It cannot be denied that solar energy is convenient and is considered to be inexhaustible ("www.solar-electric.com", 2021). The consequent contribution can be established through effective utilisation of solar power that is highly important in practical situations. The charge controller figures out the best power that the panel can put out towards charging the battery. Solar powered EV charging station essentially comprises photovoltaic array (PV) along with a DC-to-DC converter. It is potentially dedicated to the PV array, which is further attached to the maximum power point tracking controller (MPPT). Apart from this, solar powered EV charging stations are characterised to have over 15 bidirectional DC/DC converters for 15 charging stations that are provided for charging EVs. There are certain definite conditions in which the MPPTs are found to be the most effective. The first condition is that of cold weather, where the solar panel works better. This is because during winters the sun hours are low and need to be recharged the most to heat them up. Furthermore, another major condition, which requires the most use of MPPT is that of long wire runs. If an EV is being charged with a 2-volt battery, and the panels are found to be 100 feet away, voltage is likely to drop. However, it is predicted that if the car has 12-volt panels and series wires of 48 bolts the power loss is considered to be much less. In addition to this, it is important to note that the maximum power point of a definite solar panel is found to change in accordance with the changes prevalent in the solar irradiance and panel temperature. However, the most common way that is found to be prevalent towards the development of solar car charging stations is towards the implementation of the MPPT algorithm that is potentially used in the single-ended primary inductance converter. In accordance with the notions of the research study, it is likely that the high penetration of EVs tends to possess distribution networks along with quality issues. This in particular includes the aspects of network congestion and maintenance of reliability and security of the grid. Based on this definite assumption, it has been found that the initiation of the electric car solar power charging stations can be designed with the help of PV grid implementation along with an alternative namely Vehicle grid implementation.

Literature review

In the present society, fossil fuel is used as the main resource for the energy production in industrial or domestic use. About 74% of the global consumption of energy is dependent on fossil fuel which includes the use of petroleum, coal and other fossil fuels. However, in the present days several countries have started putting focus on the renewable source of energy as the present generation is more concerned about the contamination and pollution created by the fossil fuels and their low efficiency level. Solar energy is one of the greatest sources of renewable energy drawing the attention of researchers. But till date the development of various solar energy systems has been restrained by factors like large cost of the establishment of solar energy conversion system, low efficiency of the conservation of light and many others. Yang et al., (2014) discusses the utilisation and invention of energy saving cars that use solar energy. With the implementation of optical angle modelling design silicon photocells, maximum power point tracking and drag coefficient, the automobiles can be highly efficient with the use of solar energy. With the decreasing fuel resources and increasing traffic congestion, the solar energy is inexhaustible as well as convenient source of energy for automobile vehicle. Khoucha *et al.*, (2013) discussed the development of an interleaved boost of dc/ dc converter that featured much smaller input/ output filters, with low device stress comparative to the conventional design, much faster dynamic response for the application of solar electric vehicles. In a typical case there is a need for a current control loop for interleaved converters in order to reduce the ripples of input current, the output voltage ripples and the size of the passive components that are of high efficiency. In this case the converter was placed in such a way that it connected the DC bus and photo voltage power generation in the multi-source energy storage system for the SEVs. with the maximum power point tracking controller with the photo voltage solar system helped in the association of battery backup source that guaranteed the uninterrupted power supply. It also assisted in the proportion of the vehicle in case of recovering energy at the time of the regenerative braking as well as transients. The authors discussed the details of the construction, design and preliminary testing of the experimental hardware prototype in their article. Their study provided the idea of a power supply system with the utilisation of solar photovoltaic power and mains from the utility power supply that fed the DC output and helped in backup battery charging. During the daylight with the appreciable intensity of radiation or even in any situation when there is a possible supply of a utility power source the battery is charged. With the simulation of the whole system the result of their study provided proper functioning and energy assessment for different flows in presence of variation of load parameters and the changes of illumination in photo voltage panels. Mohammad et al. (2020) discussed a review on the integration of various electric vehicles in the distribution network with the special emphasis on the PV based electrical vehicle modelling. According to them, the electrical vehicles are the efficient solution for different sustainability issues like depletion of fossil fuel resources, greenhouse emissions and global warming. In such cases electric vehicles have been shown to emit higher emission while measured from the source to the tailpipe for the countries that are fossil fuel based. This makes renewable energy sources more important for maximizing the benefits of electrical vehicles. as the electrical vehicles acts as the storage system and helps in mitigating various challenges concerned with the renewable energy sources and helps in providing the grade with different ancillary services like frequency regulation, voltage regulation, spinning reserves and many others. The authors focus on the review of the state of art literature on the particular model of grid-connected photovoltaic EV-PV system. For extraction of the maximum benefit from the electrical vehicle as well as minimization of the associated impact on the network of distribution, the optical modelling of integration of the electrical vehicle in the network is necessary. The renewable energy source based electrical vehicle charging is desirable for the overall reduction of various emissions and therefore obtains the best of all technologies. The authors provided a general framework of design that describes the EV-PV grid connected system with smart charging algorithm. Obeidi et al. (2018) studied the maximum power point tracking system for the purpose of high efficiency photo will take array application in a vehicle that is solar powered. Though photo energy can be a very promising energy alternatives, its high initial cost makes it essential for improving the efficiency of energy conversion. The particular incident of temperature and solar insolation, a specific voltage harvest the maximum power which is defined as the maximum power point. This is achieved at a particular voltage which is dependent on the temperature and insulation. and therefore, the correct maximum power point tracking system is necessary for any e vehicles that are solar powered as it relates to the Rapid changing insulation which can lead to the dynamic motion of that particular vehicle. With the maximum power extraction, the total cost of the PV system can be reduced and that can enable much better paybacks in the PV projects. A rapidly adapting maximum power point algorithm can harness the maximum power to make the application more cost-effective and technologically efficient. The Fuzzy Logic method proposed by the author helped them achieve even more stable and faster power output from the PV module. The following paper focuses on the DC-DC converters for the effective interfacing of the PV with the SEV powertrain. The requirements in a high power boost converters are essential to include boost inductors and an associated capacitor for the output. Small inductor inclusion can help in reducing the size and weight of the inductor installed in the model. PV and the characteristics of the ESS also can significantly improve the performance output of the DC-DC converter. The MATLAB Simulink model built by the group of scientists helped in emphasising the performance of these controllers that help in simulation running of various operational scenarios. The simulated results proved the higher efficiency of the Fuzzy Logic controller in maximum power point tracking as well as the significant differences of performance achieved through various parameters influencing the power outputs like irradiation and temperature. The authors established a robust performance and better stability from their Fuzzy Logic based controller with the offering of several advantages in the power fluctuation mitigation. Improvement of the power conversion mode of the Fuzzy logic based MPPT algorithm would require the PV array to have an optimum operational output depending on the temperature and the level of insolation incident on the surface of the PV panel. The recent usage of Fuzzy controller in the PV models of the solar energy driven electric vehicles would have the comparison in performance with the Perturb and Observe (P&O) controller simulated through MATLAB. Use of Buck in place of Boost along with the replacement of the Triangle forms of the functional members with the Gaussian form can implicate changes in the novelty functions of the desired output. It is also understood that the algorithms have different technical approaches of the MPPT methods as discussed in the following report literature. The variation is based on the convergence speed, the complexity during implementation, level of accuracy in the functional output and the associated costs of the entire set-up of the design module. The MPPT model based on the Incremental Conductance can be utilised in the design model of a gas-solar cell, with high performance output for the locomotion of hybrid EV application purposes.

Materials and methods

Research approach

The solar-powered car design model in the conducted research has been considered to have 4 major segments:

- Energy acquisition system
- Central control system
- Dynamic feedback system
- Optimised body design

The optimized body design takes the factors of solar radiation absorption for the full hull cells and the coefficient of the vehicle drag. The synergistic system of the considered segments has the potential to achieve a high transformation rate of solar energy and provide stability to the driving procedure. The hull cells are considered because of their lightweight design and portability along with the added flexibility. Even though the cost of these hull cells is higher than the conventional silicon batteries they generally provide more cost-effectiveness especially in the design of the solar-powered vehicle.

Research design

The lithium battery stores the solar power energy collected through the solar panels and utilizes the energy to rotate the motor of the electric vehicle design. This essentially provides safety due to the collection of energy through solar sources and renewable methods.

The following can be considered as the operational flow chart of the design model.

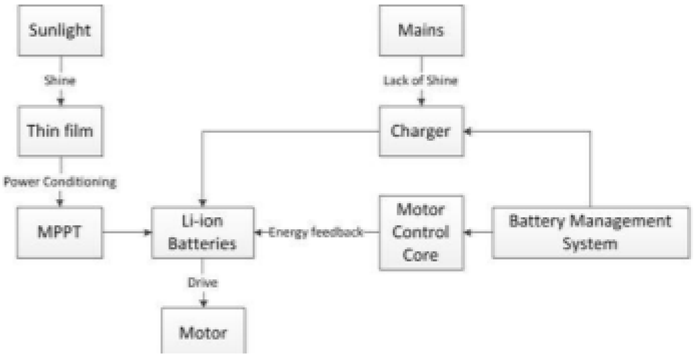

Figure: operational Flowchart of the model

Taking solar power conservation efficiency into consideration the automobile design is covered with a thin film on its surface in order to dynamically increase the illumination area. The inclination is calculated from the body angle and the baseboard to enhance the effective illumination area of the battery. The pressure and forces acting on the outer surface act as the aerodynamic force walking on the center of pressure within the symmetrical plane of the electric vehicle the aerodynamic forces (F) are dependent on the shape factor (Cf) and can be calculated as:

$$F = P_q S C_F = \frac{1}{2}\rho\vartheta^2 S C_F$$

Where S is the frontal projected area of the vehicle.

Data collection and analysis

For generating a high solar energy conversion efficiency, the MPPT solar charge controller technique is implemented in the proposed design. It works by setting the charging parameter of the traditional PWM controller before reaching the intended destination. Additionally, MPPT is a process that requires sticking to the guidelines of the MPP of a solar panel, which means it can work efficiently and store faster electricity in the batteries. It can also improve the charging efficiency of the panels. When the voltage and current are equal, the output power of the solar cells will increase. It does so by measuring its voltage and current before and after a disturbance.

Ethical considerations

The components in the PV array should follow MPPT in order to maximize the system's power efficiency. This design method allows the various components to use the available solar resources and enhance the output. In this field, the micro-DC/DC power converter can be used as a PV power optimizer. Through simulation, a distributed PV power generation system is proposed. Currents and voltage fluctuations happen as a result of a disturbance. The output power and voltage of solar panels would then be measured before and after a disturbance. A set of directions would then be set for the next cycle. The following parameters are considered for a single thin-film cell:

- Open circuit voltage: 26.5V
- Operating Voltage: 23V
- Short-circuit current: 0.8A

The application is based to charge the 48-volt lithium battery pack

Results

According to the study conducted by Atawi, Hendawi & Zaid, (2021), it has been found that, the authors tend to talk about a proposed charging station development. This system is considered to be an off-grid panel, which is to be powered with the help of solar energy. This is further carried with the help of a PV array that is found to generally generate electrical energy to the EVCS. This PV panel essentially represents the major source of energy for the charging station. However, the authors have found out that the configuration of this system is found to be unsteady. Hence the output terminals of the PV are to be connected with a boost converter. The proposed charging station description is illustrated below:

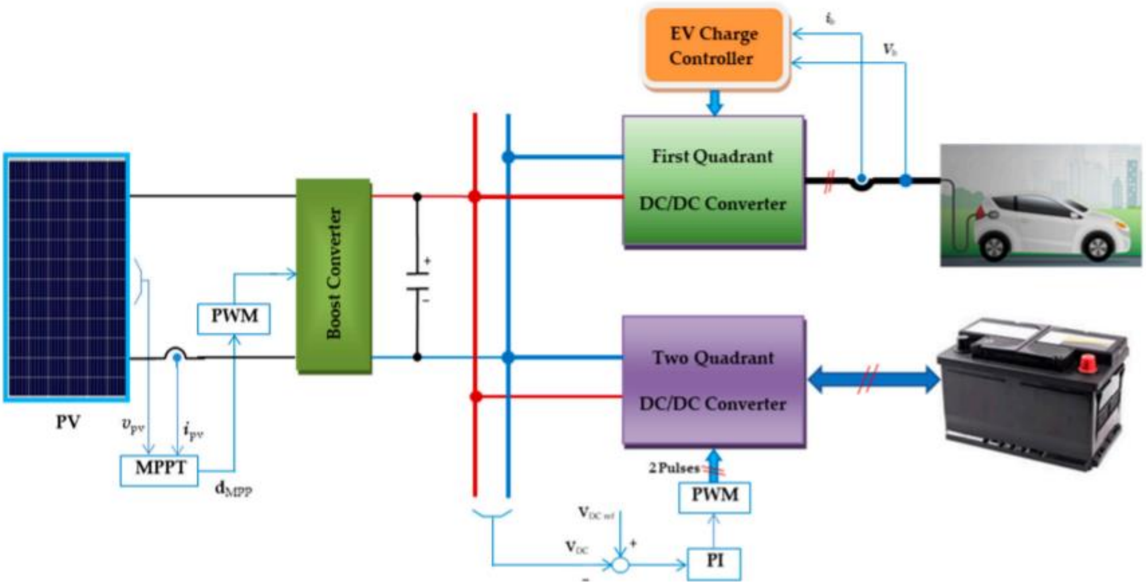

Fig: PV-powered EVCS with battery storage system

(Source: Atawi, Hendawi & Zaid, 2021)

The above illustrated image tends to show the potential architecture of the proposed electronic vehicle charging station system (EVCS). The converters that are being preferred by the authors are that of DC/DC converters. It is further used to potentially control the charge as well as the discharge process of the storage battery. The following characteristic analyses are derived from the design and are as follows:

- The electrical design of the EVSC is referred to as the designing of he all possible electrical parts of the station, which includes the PV array along with DC bus voltage level.
- The station power is essentially related to the number of the EVs that are to be charged in a simultaneous manner. It is to be noted that the initial energy of the storage battery is that of E_i in Wh
- The output power of the EV station is P_{EV} and is constant
- The solar power of the PV panel changes in accordance with time and is-

$Ppv = \frac{p_{max}}{36}(36 - t^2)$

- The above indicative s referred to the relation that is sketched below, and the rime axis origin is set at noon. This is because of acquiring the highest levels of insolation in every possible manner. The estimated period decided for the solar energy is that of 12 hours.

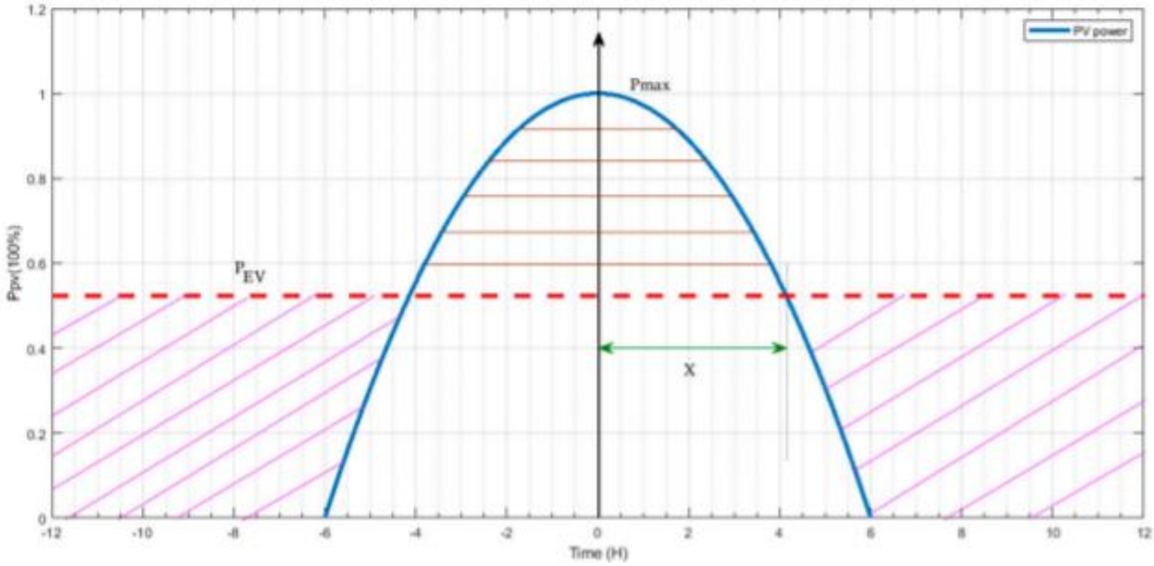

Fig: PV array power distribution for a day

(Source: Atawi, Hendawi & Zaid, 2021)

Apart from this, according to Youssef, Fatima & Chakib (2018) developed a definite block diagram for the initiation of a PV-grid charging system for solar powered electric vehicles. This involves the association of a greater depth of understanding about the use of photovoltaic energy for EV charging. This is known to perceive an advanced and exponential development. The basic architecture of the proposed system is developed as follows:

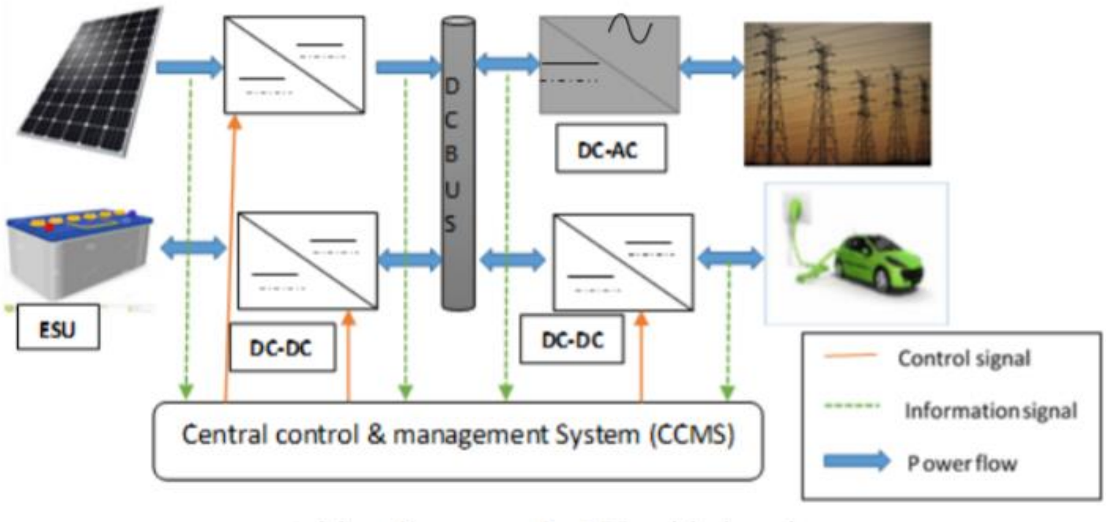

Fig: Block diagram of PV-grid charging system

(Source: Youssef, Fatima & Chakib, 2018)

The above proposed architecture for solar powered electric vehicles as shown above tends to talk about the different points of view that are characterised by two conversion stages. These stages are essentially obtained with the help of AC/DC along with DC/DC converters. The batteries or the potential energy storage units of this definite proposed system architecture is considered to be optional. This is because the station is directly connected to the grid. However, this acts as a substantial part involved with reducing the dependence to the grid. On the other hand, it is to be noted that the authors have also stated the hardware infrastructure of the PV-grid charging station, which would also comprise a MPPT control. This would include harvesting electric energy from the sunlight and the PV modules are required for making the conversion.

While generating potential experiments regarding the development of EV charging stations with maximum power point tracking, a lot of authors have emphasised on the use of PV grid connected configuration. One such instance is prevalent in the work of Locment, Sechelariu & Forgez (2010). The authors have stated that the EV charging system would require the facilitation of local power generation, which would also be characterised by integrated energy management systems (Atawi *et al*,2021). It further operates on the assumption related to the sources of electric energy. The following image shows the proposed system architecture designed for the development of EVCS and is as follows:

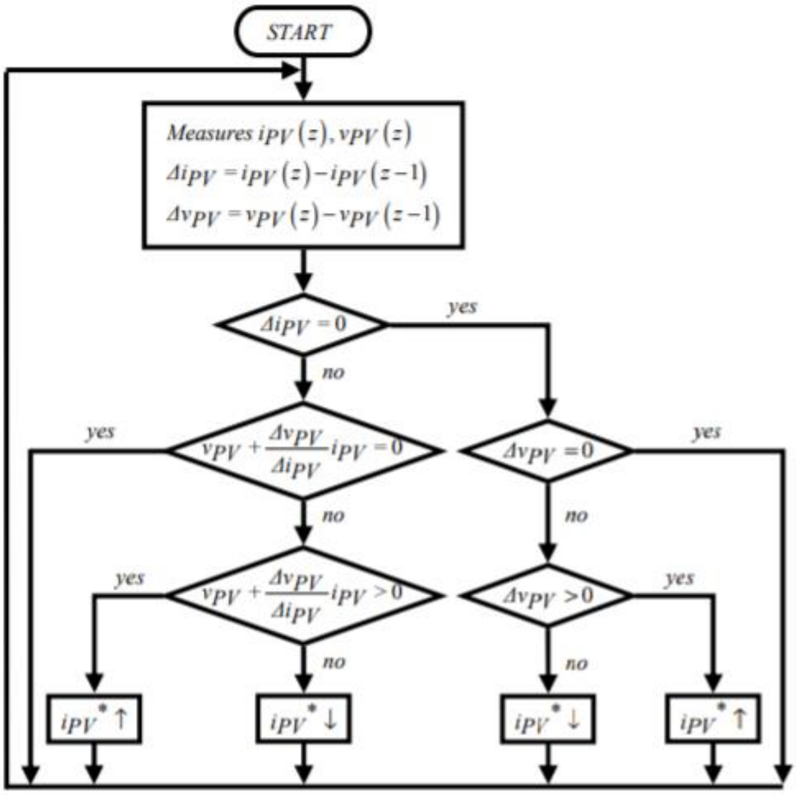

Fig: Flowchart of the INC diagram

(Source: Locment, Sechilariu & Forgez, 2010)

The above illustrated image shows the configuration and the identification of the identified derivatives that needs to be taken into account. The utility grid of the system architecture would be used as a backup and will potentially eliminate energy consumption and sale the excess power under the allowance of the public grid. The PV array here is encompassed by 16 PV panels Solar Fabrik SF-130/2-125. The electrical coupling is essentially given on the series of four parallel branches that are formed by PV panels. The diode 'D' is essentially placed for the sole purpose of protecting the PV panel for the run-back current, which might be a possibility in the local areas to a great extent. Therefore, the equation of the PVA and the adapter system for the configuration stands out:

$$\frac{di_{PV}}{dt} = \frac{1}{L_{PV}}\left(v_{PV} - v'_{PV}\right)$$

$$\begin{bmatrix} i'_{PV} \\ v'_{PV} \end{bmatrix} = a_{PV} \begin{bmatrix} i_{PV} \\ v \end{bmatrix}$$

$$a_{PV} = \frac{1}{T}\int_0^T f_{B1}\,dt\,,\ a_{PV} \in [0;1]$$

The configurational architecture of Hassoune, Khafallah, Mesbahi & Bouragba (2018) comprises of grid that is tied PV with BSB. This PV array is further tied to the DC link with the help of a MPPT algorithm. This boost converter aims to extract the most possible power from the association of social irradiance. The transferring of electricity within high power scale is considered to be one of the charging modes that would require DC voltage. This modelled strategy is essentially based on the charging of the DC link power that is based on the development of a power forecasting model. This would further help in the decreasing of the consumption of grid power to a great extent.

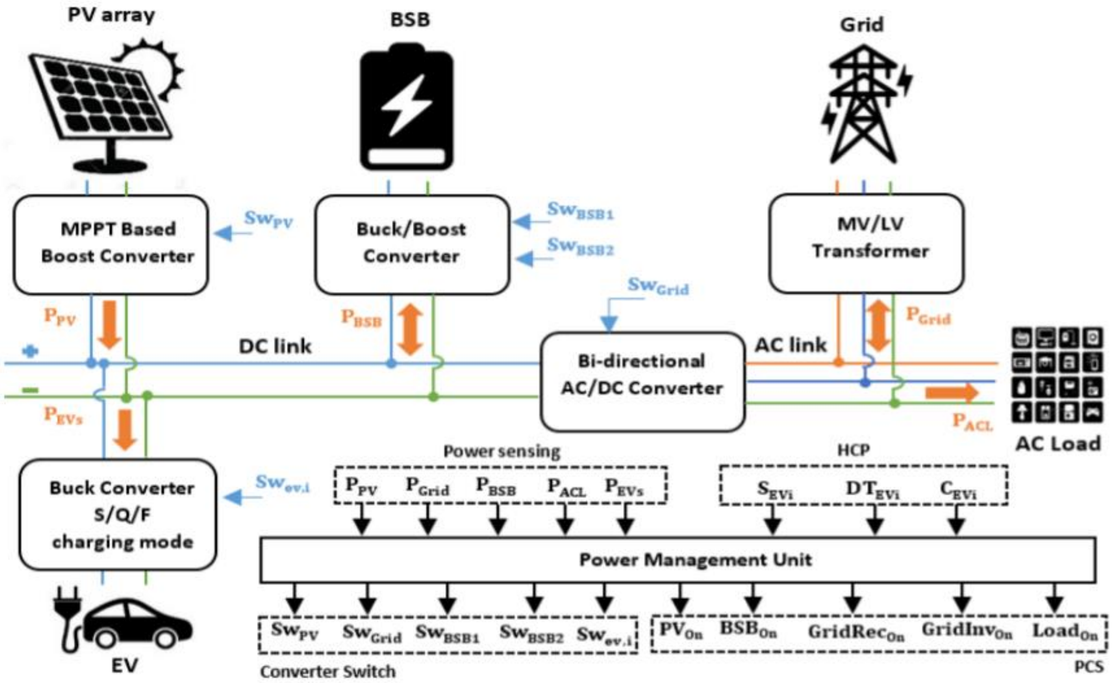

Fig: EV charging station-based Grid tied PV-battery system

(Source: Hassoune, Khafallah, Mesbahi & Bouragba, 2018)

In accordance with the given propositions, it has been found that Ul-Haq, Cecati & Al-Ammar (2017) have emphasised on the association of smart charging station architecture. This is primarily supplied with the help of PV power generation. However, if the system requires any excess power, the DC/DC boost converter and that of the bidirectional power converter would be of effective use. The charging station architecture is supplied by a common DC bus that is energised with the help of PV and the utility grid. However, this aspect potentially depends on the availability of the operating conditions. The use of the MPPT would help in delivering the PV power generation to the variable DC bus and the EV battery charger with a bidirectional DC/DC boost converter. It has further been found that the direction of power flow is essentially monitored and controlled under three different modes. These aspects involve the notions of voltage magnitude and the current loading of the grid.

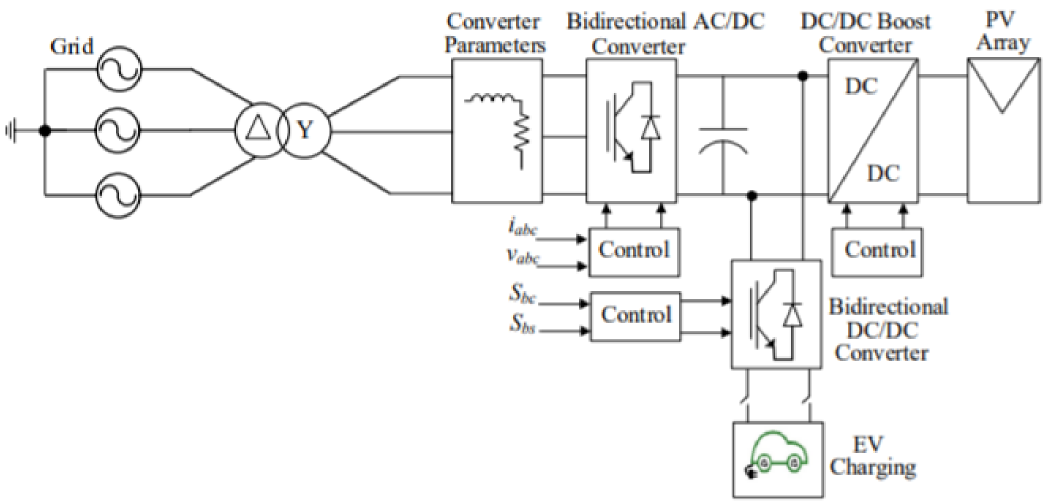

Fig: Charging station architecture for electric vehicle

(Source: Ul-Haq, Cecati & Al-Ammar, 2017)

On the other hand, Xu, Kang, Zhong & Cao (2014) have stated how the extent of the energy crisis and pollution problems have led to long-term disasters. However, for the sole purpose of resolving the negative problems caused by automobiles, this involved the use of application of alternative energy within the field of automobiles. The systems architecture propagated by these authors tend to state the use of photovoltaic power, which effectively provides important opportunities for the association of energy efficiency. Hence, the use of photovoltaic pulse chargers would be a popular choice for the development of this definite system. It would further help the system to be able to identify the charging behaviour of the MPPT and would further help in effectively delaying the crystallization of sulfating electrode pores of the battery.

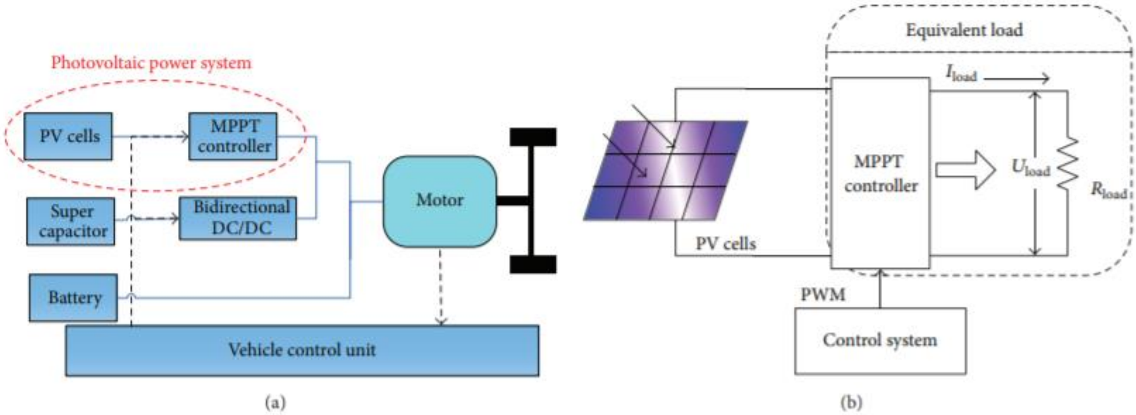

Fig: (a) Structure of hybrid power system and (b) Structure of photovoltaic power system

(Source: Xu, Kang, Zhong & Cao, 2014)

The authors also tend to further emphasize on the use of a control algorithm for the operational activities of the PV cells at the MPPT that is prevalent under definite environmental conditions. The overall structure of the hybrid power system is parallel with each other and is further switched with the DC bus.

Discussion

From the conducted research and analysis of various research journals by esteemed researchers, those understood that the PV based EV system of charging can provide better penetration into the generated power of the model scope and hence prove useful in the Maximum Power Point Tracking (MPPT) conversion. A PV module is used for the conversion of solar energy into electrical energy from the incident radiation on the surface of the model. In this context it is also necessary to understand that there are variable intensity of radiation depending on the geographical and meteorological factors. The major uncertainty considerations during the development of the model of photovoltaic module in the conducted research were the type of the sky, solar irradiance, temperature, and level of humidity. For a bigger PV module, the latest uncertainty modelling methods of machine learning and functioning is essential to be utilised in the approach.

The validation of the proposed algorithm of the irradiance profile was utilised for smart charging of the PV grid. From the reference of multiple authors, the application of PV energy with the help of EV as a storage system for energy can help up in reducing the peak loading that was generated in the grids. The multiple algorithms that can be e applied for different economic technical or social prospects of the charging models for the proposed design of the solar-powered vehicles and for generating maximum power point tracking. The stochastic behaviour of PV generation can prove to be highly disadvantageous in the case of charging and hence it requires smart charging algorithm application in order to account for the uncertainties associated with the generation of PV. There are other concerns regarding the uncertainties of the electric vehicle charging demands in the context of the behaviour of the users, infrastructure of the charging points, and operational parameters. The computational cost and issues regarding the accuracy associated with the Probability Distribution based modelling method proposed by Monte Carlo give rise to consideration for more advanced methods and models. Markov Chain and information gap decision theory can be utilised in this context of improvement in the charging demands of electrical vehicles. It is also advised to take a more hybrid approach of methods combination in order to lower the chances of hindrance and drawbacks in the associated model.

The maximum power point tracking algorithm of the proposed model can be effectively compared to the conventional model of the hill climbing P&O method (Debnath *et al,* 2020). From the simulated results of the maximum power point voltage and the iteration models under the fast-changing condition, it can be understood that the duty cycle of the energy generation will be influenced by the weather conditions which can be analyzed and compared with the P&O method. As a result of the subsequent development of a more effective and validated algorithm was developed according to the CENELEC EN50530 standards which can provide proper stimulation for measurement of the efficiency in the maximum power point tracking algorithm. Technical specification of the PV module is not necessary as an input in the newly generated model of the algorithm. This algorithm can be implemented through the utilization of a microcontroller and other associated hardware which can connect to the photovoltaic battery microgrid system and hence generate a stable voltage supply under varying load conditions. There can be other control algorithms such as the fuzzy logic and AI implemented models which will help in the load control of the proposed design of the electric vehicle.

From the research and argument provided by Saravanan *et al,* 2020, it can be understood that the most utilised and common method of mitigating the uncertainties associated with PV and generated energy in the electric vehicle can be done by adding an external battery storage system in the vehicle. The excess generation of solar energy from the panels especially during the afternoon can be stored in this external battery storage and can be utilised when there is inadequate irradiance. Using a sigmoid function-based discharging algorithm can be e the best approach to store the excess generated PV energy in the electric vehicle.

Conclusion

The concept of solar-powered automobile devices from the social point of view of the present-day scarcity of natural food resources and increasing traffic conditions can prove to be helpful. The inexhaustible nature of solar energy can be conveniently used for providing energy to the automobile model as far as the requirements are concerned. The practical and effective approach of exploring and utilization of solar energy is one of the main features why many scholars have considered this application as a point of interest for conducting in-depth research. the real opportunity of communication with individuals working across the globe on the similar topic of solar energy utilization for electrical appliances on a regular day-to-day basis (Atawi *et al*,2021). From the conducted research and study of the modeling techniques associated with the grid EV-PV connection, there still lies uncertainties regarding the electrical load, PV generation, and demand for EV. There is scope for future research directions on various aspects of the following:

- The implementation of the smart charging algorithms of the model in a comprehensive nature.
- P2p v2g power transfer modes for transactive charging systems can aggregate the energy trade in the design model of vehicles.

The various uncertainties associated with the effectiveness and practical implementation of the solar-powered vehicle model can put the manufacturing companies under concern. The optimal rebalanced simplicity of the proposed design of the vehicle model and the analysis of challenging variables like the human behaviour and mode of utilization can raise multiple questions regarding the feasibility e of the functional benefits of the proposed model. The forecasting of the PV accuracy is being highly researched on the topic at the moment which puts the entire design utility under scrutiny and uncertainty. Also, it is necessary to consider that the effectiveness of the easy implementation strategy of the generated design of the vehicle and the associated management of the charging load in peak times, the generated schedule of the varying prices can be an attractive aspect to the aggregators. The charging models, as well as the price elasticity, are factors that would require further consideration of research and development.

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