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Solar EV Charging

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***Abstract*— Electric Vehicle charging has been so far considered unreliable and unpopular due to several reasons such as the unavailability of sufficient charging stations and the long charging time. Therefore, renewable energy resources such as solar energy can be very effective in providing faster and cost effective electric vehicle charging. This paper presents the different battery charging technologies and discusses the recent solar electric vehicle charging approaches and the technical challenges in this domain.**

Keywords—Electric Vehicles, EV Charging, Solar Charging.

I. INTRODUCTION

Although Electric Vehicles (EV) have become more popular in the recent few years, there are several challenges in this field such as the lack of efficient charging stations, and most often electrical vehicles are charged with unclean electricity from conventional thermal power plants. Possible charging options include power points using electricity from the grid. However, electricity from the grid is not green, expensive, provides slow charging and the ordinary house plugs are not capable of charging the car effectively. Second option is the recharging in public stations which is also considers expensive and impractical (high demand and low supply; because of time period of charging). Thirdly and most convenient option charging at home with a solar power system. Such a method provides a renewable energy charging source, independency of utility companies, and relatively less expensive [1].

Renewable energy is energy obtained from an unused natural source, such as wind and solar power. Renewable energy has become increasingly popular, as it does not harm the environment [2]. The renewable energy market is booming around the world and is expected to surpass consumption of fossil fuels due to factors like falling demand and the Paris Climate on Climate Change [3]. Solar energy is a clean source of sun-based renewable energy that can be used to produce electricity and heat. The generation of electricity is via photovoltaic panels or solar thermal panels which normally contain a liquid capture sun heat [2, 4]. With the use of wind turbines installed onshore or offshore, wind energy is harnessed. Wind spins the turbine's blades, which then act as a generator to produce electricity. A large turbine can power around 3000 homes [5]. Geothermal energy is extracted from shallow ground or hot water and hot rock is located a few miles below the surface of the Earth, and even deeper down from high temperatures of molten rock or magma. The heat can also be used directly or for electricity generation [2, 6]. Biomass energy is when plant and animal matter are burned to generate heat or to drive a turbine for electricity generation. Hydropower is energy harnessed from moveable water like rivers, tides and waves. Alternatively, water is captured in dams, and released to produce electricity through a turbine [2].

Nowadays electrical vehicles are available, but they are not popular as gasoline cars and are expensive, however there are hybrid cars which work on electricity and gasoline but not fully dependent on electricity and suffer from the unavailability of sufficient charging stations. In this research we discuss the issues by looking at the main points of this problem. One of proposed methods is to install solar PV panels at the top of buildings and the shading of parking area to generate energy to charge the EVs. Charging stations can be more efficient by integrating them with energy storage systems so EVs are charged directly from PV panels during sunny days and the remaining generated power is stored in batteries in order to be used during night and rainy days.

II. BATTERY CHARGING TECHNOLOGY

Batteries performance and life time are highly effected by the charging procedure. Charge efficiency is the percentage ratio between the energy removed during discharge from a battery when compared to the energy used during charging to restore the original capacity. If there is a chance of overloading the battery for any reason, either due to errors in calculating the cut-off point or due to misuse this will usually be followed by an increase in temperature. Inside the battery, internal fault conditions or high ambient temperatures can also drive a battery beyond its safe operating temperature limits. High temperatures hasten battery death and track cell temperature is a safe way to detect signs of trouble from a variety of causes. The temperature warning, or a resettable fuse, can be used to shut off or disconnect the charger when danger signs occur to prevent battery damage. This simple additional safety precaution is especially important for high-powered batteries where the effects of failure can be both serious and costly [7].

Electrical energy can be injected into the battery quicker during fast charging than can be responded to by the chemical process, with damaging effects. The chemical process cannot take place immediately, and there will be a gradient of reaction between the electrodes in the bulk of the electrolyte with the electrolyte closest to the electrodes being transformed or "charged" before the electrolyte further away. This is especially evident in high-capacity cells which contain a large volume of electrolyte.

When charging the chemical reaction lags behind the charge voltage application, and similarly when a charge is applied to the battery to discharge it, there is a delay before the full current can be delivered through the charge. As with

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hysteresis by magnet, Due to the chemical hysteresis effect, energy is lost during the charge-discharge cycle. Once a battery has been fully charged, the charging current must somehow be dissipated. The effect is heat generation and gasses both bad for batteries. The essence of good charging is to be able to detect when the active chemicals are reconstituted and to stop the charging process before any damage always occurs whilst maintaining the cell temperature within its safe limits. Detecting this cut-off point and stopping the charging is crucial to sustaining battery life. This is in the simplest of chargers when a fixed upper voltage cap has been hit, also called termination voltage. This is especially important with fast chargers where there is a greater risk of overcharging [7].

Charging methods are basically categorized as constant voltage (CV), constant current (CC), Constant voltage-constant current (CVCC), taper current, pulsed charging. Constant voltage charger is simply a DC power supply which can consist of a step-down transformer from the mains with a rectifier to provide the DC voltage for charging the battery. These basic designs are often used in low cost battery chargers for cars. Usually, the lead-acid cells used on cars and backup power systems use continuous voltage chargers. Additionally, lithium-ion cells often use constant voltage systems, although these are typically more complicated with additional circuitry to protect both the batteries and the health of the users.

Constant current chargers adjust the voltage applied to the battery to keep a constant current flow, shutting off when the voltage exceeds the full charge point. This method is usually applied to cells or batteries of nickel-cadmium and nickel-metal hydride. Constant voltage / constant current (CVCC) is a mixture of the two methods above. The charger limits the amount of current to a pre-set level until a pre-set voltage level is reached. The current then reduces as the battery is charged to the maximum. This system allows fast charging without the possibility of overloading and is ideal for Li-ion and other types of batteries.

Taper current charger is charge from a source of crude unregulated constant voltage. This is not a controlled charge. The current decreases with the buildup of the cell voltage (back emf). There is a serious danger that the cells will be damaged by overload. To prevent this the rate and length of charging should be limited. Suitable only for batteries made from SLA. Pulsed current charging Pulsed chargers feed the charging current in pulses into the tank. The charge rate (based on the average current) can be controlled precisely by varying the width of the pulses, typically about one second. Short rest periods of 20 to 30 milliseconds, during the charging process, the chemical actions in the battery can be stabilized between pulses by equalizing the reaction throughout the majority of the electrode before restarting the charge. This allows for the chemical reaction to keep pace with the rate of electrical energy input. It is also claimed that this approach can minimize unwanted the growth of crystals and their passivation. The open circuit voltage of the battery can also be sampled during the rest period, if required. Chemical reactions such as gas formation on the electrode surface.

EVs are powered by the electric power that is collected from their batteries. Although EVs are presented as zero emission cars, due to several factors, mainly the long charge period, the public has yet to accept them. Apparently most EVs are able to charge three charging systems:

Method 1: A cord-set made by monophasic alternating current (AC) connecting to a regular household outlet with a charge time of 7 to 30 hours depending on the size of the battery.

Method 2: AC charging mode for charging a medium sized EV within 4 to 5 hours. Typically, this allows use of three-phase outlets that can be found in public places.

Method 3: DC Fast Charger. It is distinguished by the use of direct current (DC) providing up to 120kW in around 30 minutes to fill a Li-ion battery up to 80% charging capacity.

III. EV Charging Approaches

Solar panels systems can be installed easily on the roof of the garage and be used to generate clean power for the whole household. Or electrical vehicles can be charged directly from a wall box. Wall box is an intelligent charging device where it communicates with the solar system and the electrical vehicle to make sure that the car is only being charged by the solar panels. Even though it is theoretically achievable and appealing yet there are some challenging associated with such a technique. One of these challenges is the long charging period, unlike the conventional cars charging an electrical vehicle can take up to 8 hours to charge. Thus, recently intensive research was devoted to enhance the charging process of electrical vehicles [1]. These researches include optimization studies, developed strategies for implementation and development of hybrid systems. One of these studies was done by [8], where they proposed an intelligent solar powered EV charging station with energy storage (i.e. battery). The proposed system has three main components, first the charging system design which is shown in Figure 1. Second is the photovoltaic (PV) electrical energy forecasting. Third is EV charging demand projection. Such approach provides an optimal energy management. The authors stated that using the forecasting of the PV electricity & EV projected charge load, the battery Sate of Charge (SOC) was optimized; and optimization simulation was obtained by LabVIEW.

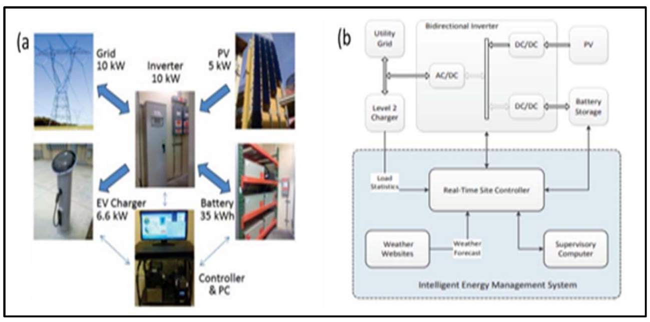

Fig. 1. (a) charging station system (b) charging system block diagram proposed by [8].

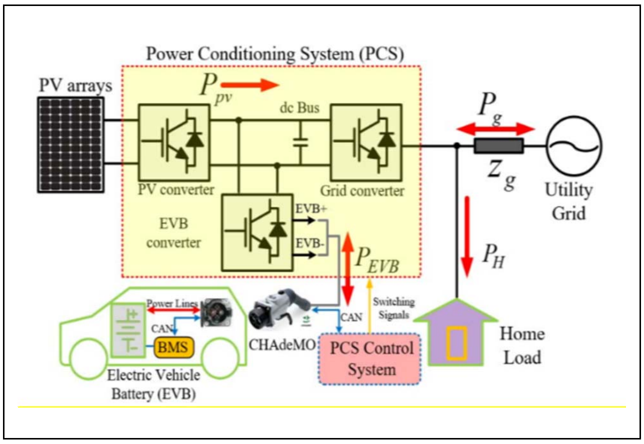

Fig. 2. Integrated electric vehicle battery grid for residential solar PV system [12].

Another interesting study was done by [9] where their work was based on hybrid optimization of EV charging stations algorithm for energy storage management. Their objective was to minimize the EV charging cost with the help of energy storage system (ESS) at PV integrated EV charging station using time of use (TOU) wholesale electricity pricing. The algorithm is based on the wholesale electricity is first categorized into upper and lower price bands every half hour. The algorithm comprises of three parts: categorization of real-time electricity price in different price bands, real-time calculation of PV power from solar irradiation data and optimization for minimizing the operating cost of EV charging station integrated with PV and ESS. A simulation of the algorithm is done by uncoordinated and statistical EV charging model in the context of their homeland (Singapore) to validate the algorithm. To give a platform gaudiness to make the adoption of PV integrated EV charging stations easier since it is expected that in few years, they will replace traditional gas stations. The study proposed a self-adaptive hybrid optimization algorithm which is a combination of deterministic and rule-based approaches for implementing energy storage management in PV integrated EV charging station. They stated that the proposed algorithm can effectively perform energy storage management between the ESS and the distribution grid, while continuously feeding statistical as well as uncoordinated EV charging loads [10].

A relatively study done by [11] proposed the implementation of solar PV- battery and diesel generator based electric vehicle charging station. In their work they design the charging station in a way that the implemented storage battery is being charged by PV array to charge the EV when needed. However, in case of exhaust of storage battery and unavailable solar PV generation, the charging station intelligently takes power from the grid and DG (Diesel Generator) set. In their design the power from DG is set to always operate at optimum loading (in their case 80-85% loading) to achieve maximum fuel efficiency. In addition, the charging station regulates the generator voltage and frequency without a mechanical speed governor. This was used to ensure that the power drawn from the grid or the DG set is at unity power factor (UPF) even at nonlinear loading. They proposed a design with a single voltage sources converter is used to interface the solar PV array, a storage battery, the grid and a DG set. The control algorithm of the charging station prioritizes the use of energy sources. Where it first utilizes the solar PV array and storage battery energy, but when PV is unavailable, it takes power from the grid and at last the DG set is utilized to support the charging of the EV. In off-grid operating mode the charging station operates as a standalone generator using solar PV and storage battery power to feed the load and to charge the EV connected at the PCC. While taking power from the DG set, it is ensured that the DG set is optimally loaded under all operating conditions [11].

The authors of [12] discuss the technological problems that could arise when EV chargers are integrated into the distribution grid. They highlighted the potential problem of severe voltage deviations and overloaded distribution transformers which can be caused by the uncontrolled charging pattern in high EVs penetration. In addition, the grid incorporation of the distributed renewable energy has been done in recent years, as shown in Figure 2.

A mixed integer linear model is developed by [13] to formulate the problem, based on the energy management assignment rules for each charging station. Applying the model to five charging station candidates in Mashhad, the results show that using this model as well as the simultaneous presence of EVs and renewable energy sources in the network, results in cost reductions while increasing profits. Investing in charging stations for electric vehicles that are supplied through a mix of the main energy grid and renewable energies, such as solar energy, is considered to be sustainable both economically and environmentally.

In addition, a considerable amount of electricity generation in the country will remain unused in winter, which can be used effectively to charge electric vehicles, especially at off-peak times. The number of electric vehicles will meet the target of 70 per cent of the total available vehicles by 2050 according to the government's plan. In order to determine the optimum level of EV penetration, location, scale, and year of establishment of renewable distribution generation systems, a multi-objective model is provided that minimizes both emissions and device costs throughout the lifetime project. The arrival time and charging status of electric vehicles are used in the charging process model which considers optimizing the installation and operation of the EVCS, showing that the best cost-efficient solution is achieved through the collaboration of renewable energies and storage systems. In a Multipurpose model is designed to obtain renewable energy resource position and capability and EVCS taking into account both economic and technological constraints [14].

As reported by [15], the most eco-friendly solution to charging an electric vehicle is to use the solar power to charge a battery. The Lithium-Ion battery on board an electric vehicle must be charged while maintaining Tension level as indicated. The output pulse from the feedback loops is used to drive the buck converter's MOSFET to control the electric vehicle battery's output voltage.

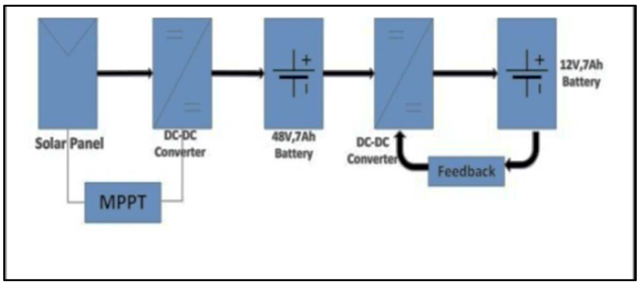

Fig. 3. Block diagram proposed by [15].

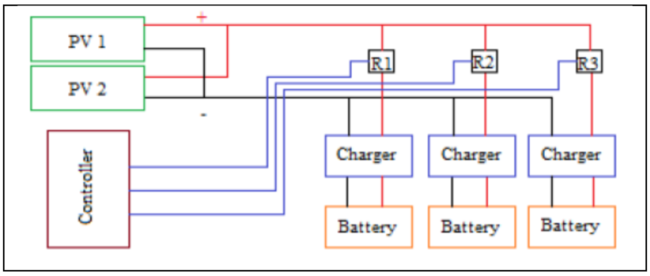

Fig. 4. System layout proposed by [16].

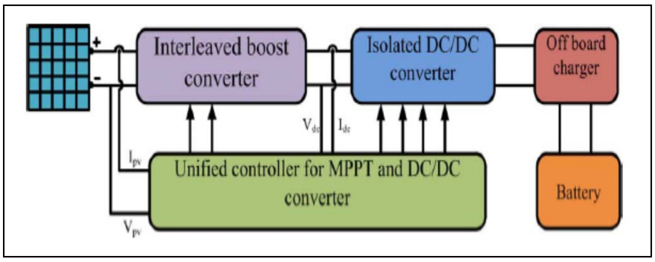

Fig. 5. Solar PV based isolated unidirectional charger circuit proposed by [18].

The system proposed by [16] is made up of three principal sections. The first is the Pulse-Width-Modulation (PWM) chargers connected directly after the PV panels to minimize the voltage to a battery level that is constant and appropriate. The second part is the relay, which is responsible for interrupting each charger's power flow and behaving like switches. The Controller is the last part that regulates the changeover of the relays in a specific way.

In the work done by [17], the authors used an experimental setup consisting of two solar panels were used and connected in parallel. Giving an optimal voltage of 18.9 V and 10.6 A under STC conditions, and typically a total output of 200 W, although the actual data were not supplied by the PV OEM. PV panel voltage and current will vary according to temperature. The expected values listed above will vary to some extent due to the different operating conditions during the actual implementation [17].

According to [18], because of the low cost and high efficiency, the high voltage direct power grid connected solar PV system became more common than traditional low voltage alternating current (LVAC) gird PV system. The problems in LVAC systems are addressed by direct conversion of solar dc power into the HVDC grid, i.e., stability, reactive power compensation, and transmission losses. The DC / DC converters play an important role in solar PV-based HVDC grid system such as converting low voltage PV input into high voltage output and converting high voltage DC into low voltage applications. These compact and reliable DC / DC converters enhance system efficiency with improved dynamic and steady state performance. A dc-dc converter is used to increase solar photovoltaic system performance efficiency. By applying the MPPT algorithms, a dc-dc boost converter increases the performance efficiency of the Solar PV array. The current stress in conventional boost converters increases for high power solar photovoltaic systems and requires more power rating components. Use of the interleaved boost converter to solve this problem. In IBC the input current shared between the interleaved legs decreases the loss of the switching and increases the converter's power rating. The converter's interleaving operation improves the quality of input power that allows for accurate MPPT and higher output power. The IBC is the most useful with reduced current stress and high consistent efficiency in the large-scale solar PV array network. Maximum power point tracking (MPPT) is an algorithm used in photovoltaic (PV) inverters to continuously change the impedance measured by the solar array to keep the PV device running at or close to the PV panel's peak power point under varying conditions; like solar irradiance, temperature, and load change. There are various types of charging methods available for charging a battery such as constant voltage, constant current, and pulse charging. The pulse charging is popular among all these methods because of its multiple advantages. In this process pulse the battery in the form of current charges. There are certain chemical reaction issues in the batteries such as passivation and gas formation due to the off-period in the pulses. The proposed HVDC link is fed from a 50-kW solar photovoltaic system via an interleaved boost converter (IBC) operated at MPPT. An isolated dual bridge unidirectional dc-dc converter (IUDC) is used for fast, unidirectional charging of vehicle batteries. The proposed HVDC link is fed from a 50-kW solar photovoltaic system via an interleaved boost converter (IBC) operated at MPPT. An isolated dual bridge unidirectional dc-dc converter (IUDC) is used for fast, unidirectional charging of vehicle batteries. [18].

When time passed, priority 1 of the battery charged up to the highest battery voltage, i.e., the highest SOC. The battery with priority 2 came next and the battery with priority 3 was last as planned. It is worth noting that the code in the controller (Arduino) followed one-minute cycles where it uses a one-hour cycle as the one used in the software simulation.

The authors of [19] investigates and performs the implementation of PV-powered fast charger to produce different output power levels from the source to the load. To achieve the aforementioned task, the topology of the DC-DC boost converter is chosen. The proposed rapid charger were installed near the available PV power in the designated areas so that consumers can charge their EVs for a short period. With the implementation of Internet of Things (IoT), consumers are able to track their EV's charging status using mobile devices.

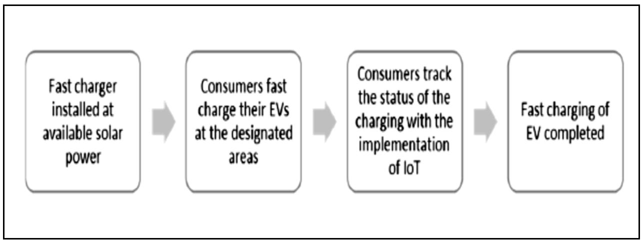

Fig. 6. Pipeline of fast charging the EVs proposed by [19].

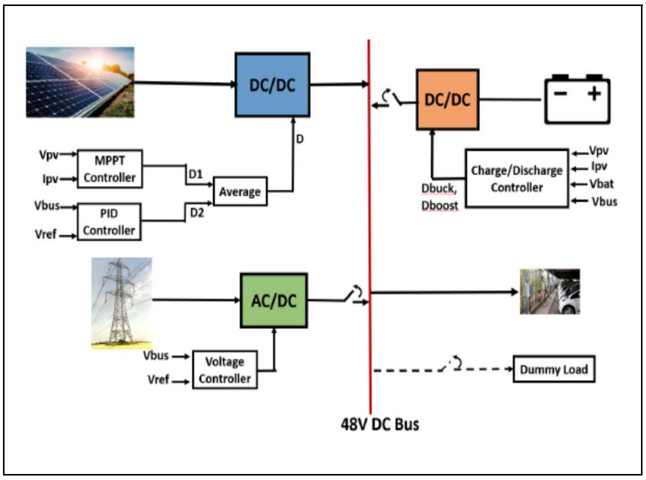

Fig. 7. EV charging station model with controllers proposed by [20].

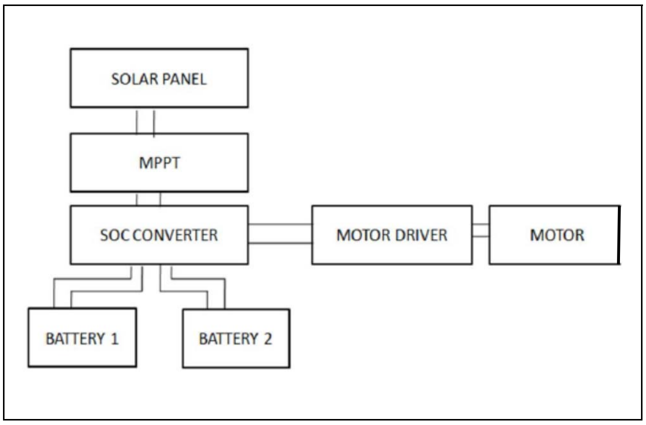

Fig. 8. Block diagram of charging module proposed by [21]

The approach introduced in [20] predicted PV system and EV pattern projection according to the data collected. PV and Grid charging schedules for EVs are given by reducing the total parking lot cost. Model Predictive Control is implemented in the coming time slots with the real-time information about EVs for present time slot and predicted information. Prioritizing the charging of the EVs from limited solar energy available. Feasibility for commercial charging of various types of PV and BESS. The solar powered e-bike charging station which provides electric bikes with AC, DC and contactless charging. The charging station has built-in battery storage which provides both grid and off-grid functionality. This displays the concept of a grid-connected rapid charging station for electric vehicles maintaining the power quality with reduced harmonics. Control of each vehicle charging is centralized, and control is provided individually to transfer energy from AC grid to the DC bus. So, for a well-grounded EV charging station, In the current scenario the idea of using both renewable energy and an energy storage network with additional grid support is becoming very popular. This describes an ideal solution for designing and operating electric vehicle charging station powered by solar photovoltaic and a Battery Energy Storage System (BESS) with AC grid. For the power flow strategy, the unreliability of the solar and dynamic charging requirements of EVs is considered. Solar PV serves as the primary source for charging all the connected EVs at the charging location. Since the power from PV at night is not there, a battery as an energy storage device is provided to charge the EVs connected in the charging station. Whenever there is a deficiency in the power output of solar or BESS to charge the EVs, The appropriate amount of power will be taken from the AC grid ensuring that the charging station works continuously throughout the day. The proposed system is designed, formulated and validated using MATLAB / Simulink. [20].

Global transport technology moved partly to hybrid fuels and battery electric vehicles. Such technological advances are not attractive to the global customer because of their expense and reliability. The research in [21] is to develop a low-cost Solar Powered Electric Vehicle that would meet global customer needs. The system is composed of solar PV panels, MPPT, SOC, battery and DC motor. Solar Panel Polycrystalline solar panels are used because they are simpler and cost-effective to make polycrystalline solar panels. Compared to mono crystalline solar panels, the heat tolerance of polycrystalline solar panels is lower. Maximum Power Point Tracking (MPPT) which is an electronic converter designed to determine the best power the solar panel can put out to charge its battery. Thus the charging controller looks at the panel output and compares it to the voltage of the battery. State of Charge (SOC) is an important parameter which has been taken into account in electric vehicles. Since battery charging and discharge is dependent on SOC status. 24 Volt battery 25Ah Lead acid batteries are used because of their lower cost. The engine has to run for 6 hours and it will have a total power of 600 Watt hours. Brushless DC Motor (BLDC) is chosen because of higher efficiency (more than 75 percent) and longer service life compared to Brushed DC motors.

IV. CONCLUSION

Electric vehicles are the future of transport since they reduce to a greater extent the use of fossil fuels. Because of its efficiency and supposed green technology, developed and developing countries are encouraging electric vehicle usage. This work presents the battery charging technologies and recent EV charging approaches and discusses the technical challenges in this field. The paper illustrates the importance of integrating renewable energy resources, particularly solar energy in the UAE and the Arab World, to provide clean and cost-effective public and private EV charging stations.

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