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Modeling and Control of Renewable Energy based EV Charging Systems

Om Shankar Prasad*

Abstract: **In order to provide adequate charging rates for the growing number of electric cars (EVs) and plug-in hybrid electric vehicles, charging stations must be well-designed. The pressure on the traditional grid would increase the cost of charging. Therefore, using local renewable energy sources in addition to the traditional grid, such as solar (PV) electricity, may improve the performance of charging stations. In this study, the grid and PV sources work together to sustain the EV load. The PV is renowned for being irregular and very reliant on local and climatic factors. For continuous operation of a hybrid PV-based charging station in a system that is linked to the grid and to make up for the intermittent nature of PV, a battery storage system (BSS) is coupled with the PV. In order to fulfil the various demands of EVs load in a range of conditions, hybrid sources-based charging stations should normally be available, effective, and reliable. In order to maximize on-site PV energy, meet the variable demand of EVs while taking into account the quick reaction of BSS, and reduce grid stress, this study proposes and executes an effective hierarchical energy management method. This approach enhances dependability, affordability, and overall performance. To ensure the safe functioning of BSS and reduce losses during the conversion stage, an effective bidirectional power conversion stage for BSS is presented in the form of an interleaved buck-boost converter. It is possible to improve power quality by reducing current ripples by employing this approach. With the use of MPPT and an interleaved boost converter, PV systems can produce the most electricity possible despite erratic weather. To address the dynamic power needs of EVs while maintaining the balance between the available generating quantities, interleave converter is recommended in combination with sub-management technology for car charging phases. When there is a significant demand on the grid side, the suggested conversion stage and management cope with the restricted dependency on grid sources for charging reasons. As a result, the suggested pricing structure significantly reduces grid stress, particularly during peak hours. A rule-based management method may be used to run the system under desired settings (REMS). This interactive method with time constraints makes the most of the PV source initially, adds power via the BSS, and then switches to the grid when the PVs have intermittent issues. The management plan guarantees consistent system performance while increasing PV consumption, satisfying EV demand, and extending the life of the BSS. It is advised to employ a hybrid charging system in this study that draws power from the normal grid, BSS, and solar energy. Interleaved buck-boost converters are recommended as a beneficial energy conversion step to enhance power quality. It is suggested to determine the lithium-ion battery's state of charge (SoC) using an extended Kalman filter (EKF). To enhance BSS utilization, relieve grid stress, and increase the use of renewable energy sources, an online management plan is created.**

Keywords: **electric vehicle charging station, power conversion stages, battery modelling energy management system.**

1. Introduction

The continuing need for petroleum demonstrates how cars have become integral to modern life, both for getting about and transporting products. Concerns about rising fuel prices and the environmental threats posed by air pollution and climate change have been raised in tandem with this demand. As a result, numerous governments have put pressure on businesses to provide transportation options that are both ecologically responsible and low in emissions [1]. To mitigate this reliance on nonrenewable resources and reduce emissions of greenhouse gases and other pollutants, electric vehicles (EVs) have been created and are in widespread usage [2]. The environmental effect of traditional automobiles has been reduced thanks in part to the implementation of vehicle emission laws [3]. Countries including the US, UK, Japan, and Europe have all instituted transportation network limits to cut down on automotive emissions. Euro 5 emission standards have resulted in a 99 percent reduction in the total quantity of "atmospheric aerosol particles" released into the atmosphere from vehicle exhaust. In addition, the introduction of the Euro 1 emission standard has resulted in a dramatic decrease in carbon dioxide and nitrogen dioxide emissions. However, a decrease of 35 mg/km of nitrogen dioxide and 95 g/km of carbon dioxide from vehicles is planned for Europe by 2020 [4].

This study plans and builds a high-performance charging system for electric vehicles (EVs) at the workplace by integrating solar energy, a grid connection, and a storage system to improve the charging station's accessibility and dependability. This dissertation seeks to develop a hybrid energy-based charging platform capable of rapidly charging EVs, increasing the utilisation of integrated renewable energy sources like PV while charging EVs, and demonstrating how the use of energy storage devices impacts the charging station's performance.

This study employs a four-pronged strategy to achieve its objectives:

Creation of both one-way and two-way power conversion topologies for use with various power supplies.

In modelling a hybrid power source for charging electric vehicles, the interconnections between the grid, local energy storage capacity, photovoltaic output, and EV load

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*Corresponding author: thesisworks2022@gmail.com

requirements.

The grid load curve, BSS energy level, and solar projection serve as the foundation on which EV charging management approaches are built. Considered in this analysis are the following aspects of public charging of electric cars (EVs) from hybrid power sources, such as those found in office buildings and workplaces. In a sizable public area suitable for the installation of PV panels and ancillary equipment such as energy storage systems and electric vehicle chargers; (ii) the working day, which roughly coincides with the hours of daylight during which the solar energy is available for longer time to charge the EVs' batteries; and (iii) the cha Integrating photovoltaics (PVs), electric vehicles (EVs), and energy storage (ES) into the grid requires careful load planning and coordinated management. If not, reliability of the electrical grid might be jeopardised. The most crucial component of PV energy generation is its time unpredictability. It's possible that EVs' burden on the grid's demand side may cause genuine problems.

A. Charging Structure Design

In order to fulfil the rising power demand of EVs at the chosen site, as well as to feed power back into the electrical grid or consume it by conventional load at the same site, it is necessary to research and analyse the design of the EV charging system. However, it's crucial to keep in mind that RES energy output is subject to factors like installation location, seasonality, daily weather changes, power grid stability concerns (such power quality and voltage fluctuation), and storage capacity. Therefore, a hybrid PV/grid/storage system is created in this research to charge EVs.

The gap between energy demand and supply and how it affects the layout of the charging infrastructure is taken into account. Additionally, an examination of daily EV users' travel behaviours and a detailed modelling of climatic variables like sun irradiation and temperature are required. The nominal power of the PV/grid/BSS should be taken into account when constructing the EV charging system's necessary power conversion processes. Solar energy output or the power grid fluctuations may be regulated by the ESS, which can also store energy during times of overproduction to feed the charging system during times of low production. In today's charging infrastructure, intelligent charging techniques are used to adapt the EV charging procedure to the fluctuating output of power generators [15], [16].

This research takes hierarchical control into account while creating the charging station. To maximise PV power utilisation, improve charging system capacities, lessen the cost of electricity purchased from the grid, and minimise the grid stress resulting from the simultaneous recharging of the large number of EVs, this example demonstrates the first level of control and on-line energy management. Positive changes to the EV charging process may be implemented by integrating PV and ESS into the grid and putting in place the necessary control and energy management system (EMS).

2. Literature Review

Adoption of PV power sources is hindered in large part because of intermittent electrical power generation. Variations in solar isolation and environmental temperature contribute to the intermittent and stochastic character of PV power sources. The day-night cycle also has a significant effect on the viability of employing PV sources in isolation. As a result, PV systems are not counted as dispatchable resources. As a result, PV systems need to implement a variety of solutions to ensure the grid's stability and the continued operation of all associated loads.

Several publications have examined the storage system as part of the hybrid source design of EV charging stations. Topologies of power converters, charging processes, control and optimization of on-grid, off-grid, and hybrid systems, and everything else related to PV-EV charging.

The authors of [6], identify the reciprocal advantage of charging electric vehicles from solar energy for delivering a high level of penetration of both technologies, and they do so by studying the whole design and multi-mode combinations of the EV solar charger and its performance.

Designing a charging system with several RES that can somewhat offset the local grid oscillations is one viable option. However, the capacity must be properly sized and the right RES and storage devices must be chosen. PV+wind hybrids have been the subject of discussion. The continual supply of the load, however, has necessitated either a storage system or a link to the grid.

For a presentation on PV with FCs for residential load. Since the FCs provides a sluggish dynamic response, it was necessary to keep some PV capacity idle in order to feed the demand. This causes an imbalance between the PV MPP and the system's actual power consumption. To address these issues, a hybrid power source consisting of photovoltaics, fuel cells, and ultracapacitors has been investigated. Due to their quick dynamic response, ultra-capacitors have been utilised in the research to help mitigate the effects of.

PV power variations when following the MPP. This setup, however, may fall short of meeting load requirements during times of low irradiation.

The role of storage devices in SER integration may be crucial. In order to provide a steady supply of electricity to loads, researchers have examined a number of different energy storage systems.

A WT coupled with FCs and super-capacitors is used to create a hybrid system. The established control system has regulated the flow of energy between the several generators in the research. The increasing prevalence of renewable energy sources (RES) in today's electrical grid system has piqued interest in the wind turbine's ability to provide auxiliary services to the grid. Solutions for storing energy generated by wind turbines have included batteries, ultra-capacitors, and hydrogen cells. Combining PV sources with storage devices may provide the required resources for the tasks. A larger degree of demand-side deregulation is possible with the precise selection of the energy storage technology and the deliberate design of its scale, leading to reduced operating costs.

The distributed battery storage in grid connection and PV system has been utilised to enhance power quality. The purpose of ESS was to guarantee constant power output from PV systems. To regulate PV systems in tandem with storage to provide steady electricity, presented an energy management technique. The system may get into the electrical market since it generates power continuously. While utility limits on PV power supply to the grid were still in place, profits were maximised by connecting battery storage to the grid to smooth out power swings. The size of the batteries has been examined, where the goal was to minimise the cost of grid electricity. The battery size achieves the same goal by taking into consideration the cost of battery deterioration in an effort to increase the lifespan of the system.

A. Architecture 1: AC micro-grid structure and EVs charging system

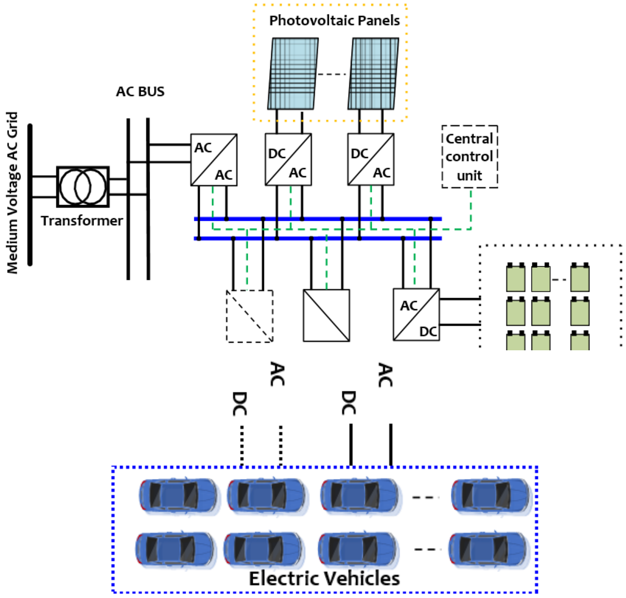

Fig. 1. AC micro-grid structure with EVs chargers

Fig. 1 depicts the layout of an AC based charging station, complete with three distinct converters for the photovoltaic panels, the battery storage system, and the electric vehicle charge and discharge. Maximum power point tracking (MPPT) is a feature of PV inverters, which are DC/AC inverters, whereas EV chargers are AC/DC converters. In addition, most areas where electricity is distributed employ a 50Hz alternating current system. The DC electricity needed to charge the EV is not always readily accessible from the PV system. With contrast, in an AC micro-grid, both the PV inverter and the EV charger do the DC/AC conversion. The AC charging method for EVs involves connecting RES to an inverter, which then supplies electricity to the AC bus. Due to the AC bus connecting the AC power source to the grid, an inverter is not necessary to provide AC power to the other loads. The base load system can be integrated into the conventional electrical grid and can support AC equipment such as asynchronous motors. However, some problems make it difficult to control and operate the AC charging system with many stages of power conversion.

Connecting the charging system and switching to island mode is accomplished using the AC bus's common connection point (PCC) switch. Using the AC charging infrastructure, EVs may be juiced up, and at specific periods, they can even discharge that juice back into the distribution grid, achieving V2G capabilities. In light of the present state of the AC charging system's features, this system continues to be the primary form of integration for many RES installations and the charge/discharge of EVs. Power production units, WT, PV, intelligent charging/discharging, and controllable/ uncontrollable loads are only some of the aspects of the AC micro-grid that have been explored. Use with photovoltaic, wind, and diesel-powered micrograds. The effects of many sources on the voltage and frequency profile of a microgrid have been analysed.

From what we can see, integrating EVs into micro-grids has the potential to boost system efficiency and make the most of renewable energy sources. A semi-Markov decision process (SMDP) based on actual EV charging data has been developed. which takes into account the stochastic nature of EVs in renewable energy and AC micro grids. The simulation findings demonstrate that the technique may increase RES usage and better fulfil charging demand.

B. Architecture 2: DC micro-grid structure and EVs charging system

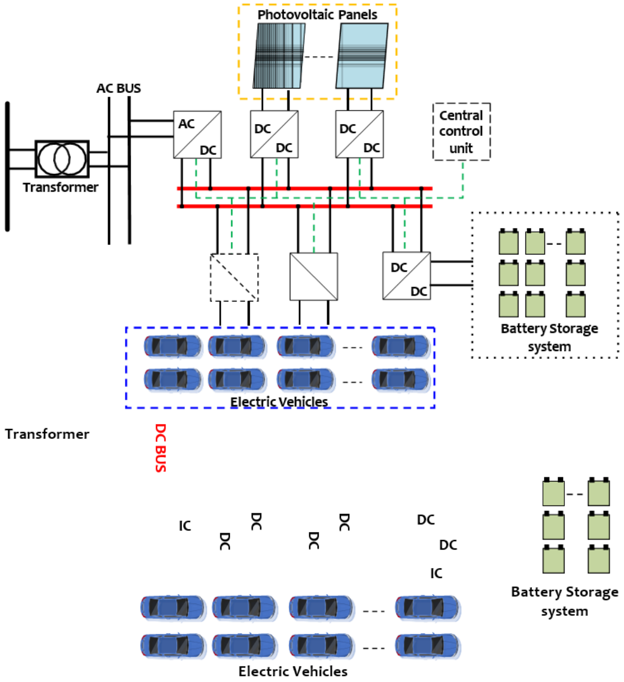

Fig. 2. EV charging station module based on DC micro-grid

In Fig. 2, we can see the key components of the DC based EV charging system facility, which are PV with MPPT, BSS, EVs chargers, power converters, and a central controller. Using the DC power of the PV directly for the DC charge of the EV through the common DC bus reduces power losses, allowing for high efficiency. Power (drawing/supplying) in the charging system is provided by a central inverter/rectifier, which is necessary for the deployment of V2G owing to the disparity between PV power generation and EVs' demand. The system's expenses and losses will shrink as a result. In addition, the DC bus control is based on the DC bus voltage, while the power flow control is based on the current, making the control of a DC-based charging station simpler to construct than the management of an AC-based charging system. In this way, a coordinated control between the different energy sources can be efficiently carried out.

In the envisioned charging infrastructure for EVs shown in Fig. 2, AC/DC converters construct a 750V DC bus. Additional power conversion units provide EV charging and BSS charging/discharging during off-and on-peak hours of operation. To provide more uniform operation, we describe a coordinated control for charging that takes DC bus voltage and AC grid stability issues into consideration. Here, we have a look at the EV charging assessment, power converter design, and hybrid power source implementation. The proposed charging architecture also has a well-thought-out way of control, allowing it to function as intended in a wide range of scenarios. This section will thus concentrate on the DC bus, which connects the EV chargers, AC/DC interlinking converter, local PV system, and BSS.

C. PV System Modelling and MPPT Control

Power electronics architectures for PV systems may be classified into many classes using a wide variety of criteria. The converter chain is characterised first by the fact that the PV modules are galvanically isolated from the grid. Another distinguishing element of the conversion chains is the number of power conversion stages. A DC/DC converter may be used to increase the voltage before switching from DC to AC, or the process can be done in a single step. The last distinguishing characteristic is the number of intermediate steps in the conversion process. In Fig. 3, we see the analogous circuit for a PV cell, which consists of a reverse parallel diode, a capacitor, and an ideal current source.

Resistor (R_s) in series and another (R_{sh}) in parallel. The PV system's current is directly related to solar irradiation and temperature. A description of the PV cell's current-voltage curve goes as follows:

$$I = I_{sc} - I_s\left(\exp^{(q(IR_s+V)/c_d B\theta)} - 1\right) - \frac{IR_s + V}{R_{sh}} \quad (1)$$

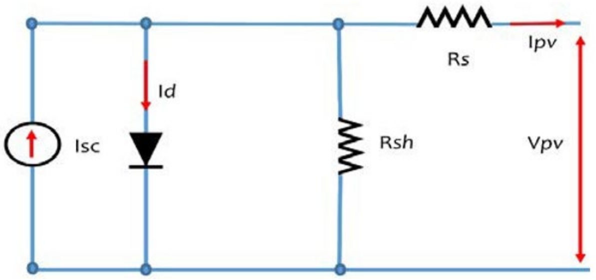

Fig. 3. Equivalent circuit model PV panel

In equation (2), V is the output voltage of the PV cell; I is the output current of the PV cell; I_{sc} is the short current of PV cell; Is is the saturation current of the diode; Cd is the coefficient of diode; B is the Boltzmann constant $1.38*10^{-23}$ j/k, q is the charge of electron $1.6*10^{-19}$ c, and θ is the inner temperature of the PV cell. Due to difficulty to estimate the accurate values of these parameters, a generalized approximated model is given in (2)-(4).

$$I = I_{sc}[1 - C_1(\exp^{(\frac{V}{VoC\,C_2})-1}] \quad (2)$$

$$C_1 = [\exp^{(-V_o/(VoC\,C_2))} \times 1 - \frac{I_o}{I_{sc}}] \quad (3)$$

$$C_2 = [\ln^{(1-\frac{I_o}{I_{sc}})-1} \times \frac{V_o}{VoC - 1}] \quad (4)$$

Here, I_{sc} is the short circuit current, VoC is the open circuit voltage, V_o and I_o are the output voltage and output current at MPP respectively. The performance of this model is dependent on both the temperature and irradiance.

To obtain the I-V and P-V characteristics based on the PV model, Sim Power Systems package from Simulation is used. The P-V and I-V characteristics of the PV model are similar to a PV system with proportionality ratios. These ratios depend on the number of cells connected in series and the number of branches of associated cells in parallel. This characteristic is non-linear, it has a MPPT characterized by a current (Imax) and a voltage (V_{max}).

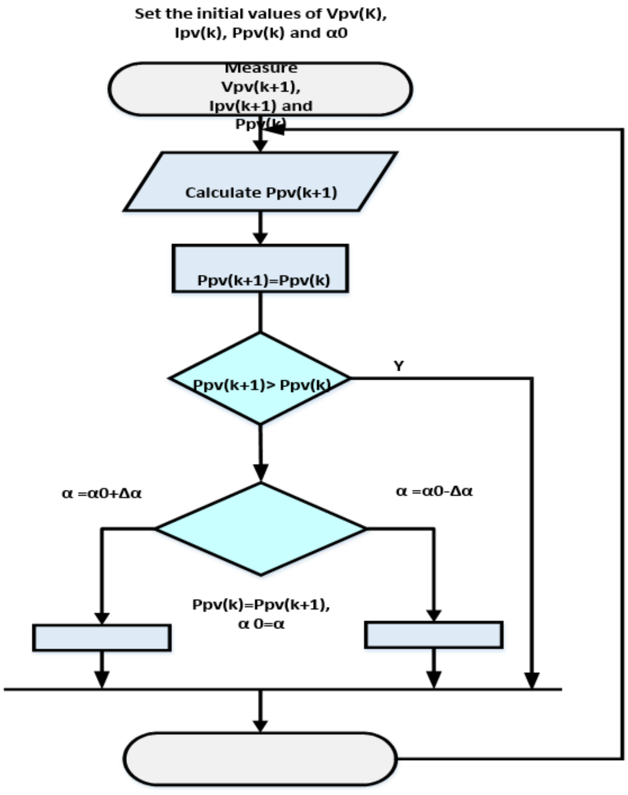

Fig. 4. Flow chart for the MPPT control

To maximize the utilization of PV generation, the MPPT technique is applied to the PV-Interleaved system. The MPPT is achieved by regulating the PV output voltage through controlling the IBC. The classical perturbation and observation method is adopted to harvest the maximum solar power. Fig. 4 illustrates the principle of the MPPT technique. This technique consists of imposing an initial duty cycle "α0" and an initial power P_0.

3. Results and Discussions

In the charging of EVs, the DC/DC converter is the conversion interface between the DC bus and the EV battery as shown Fig. 5, realizing flow of energy between the charging station and the EV battery. The buck converter has the advantages of simple structure, easy control, few components, small size, and high conversion efficiency [9], and can be applied to high-power applications. Therefore, in this work a selection and design of the topological structure of buck converter. The proposed buck model for EV charging uses a two-stage charge control strategy of constant current first and then constant voltage for the charging of the battery pack of EV.

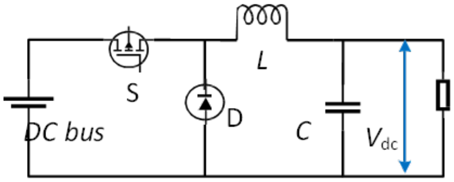

Fig. 5. Buck DC/DC converter

Since EVs battery starts charging, a constant current is used for charging process. As time increases, the state of charge SoC of the battery gradually increases, the acceptable charging capacity gradually decreases, and the temperature of the battery continues to rise. When the battery terminal voltage reaches the maximum allowable or the temperature reaches the upper limit, it needs to stop immediately the constant current charging, switch to constant voltage charging. After that, the charging current will gradually decrease until the battery is fully charged and automatically stop charging. Therefore, to prolong the life of the battery and shorten the charging time as much as possible, the proposed DC/DC converter adopts a charging control strategy of constant current first and constant voltage. The control block diagram of constant current charging, constant voltage charging is shown in Fig. 6. Among them, the constant voltage stage charging adopts the dual-loop control of the voltage outer loop and the current inner loop. The outer loop compares the measured battery terminal voltage V_{bat} with the given voltage V*bat and sends it to the PI regulator for adjustment to generate current Set the value of the loop and compare it with the charging current i_{cha}. After the PI regulator adjusts and limits the amplitude, it is compared with the triangular wave to generate the control pulse of the bidirectional DC/DC converter and control the turn-on and turn-off of VD1, it can realize the constant voltage charging of the battery pack.

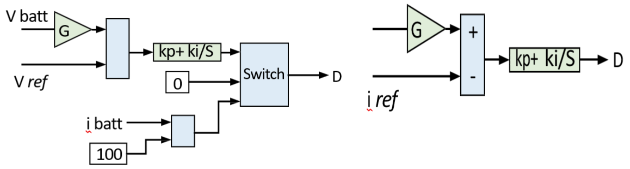

Fig. 6. PI controller scheme of EV charger

Constant current charging stage proportional coefficient KP, integral coefficient KI; and the proportional coefficient of the voltage outer loop of constant voltage charging stage KP, integral coefficient KI in table 1.

Table 1
Parameter of PI controller for the EV charger

	k_p	k_i
Constant current charging	0.75	50
Constant voltage charging	5.65	0.150

The initial state of the battery is set to SOC=60%, the given value of charging current i_{cha}*=100A, and the simulation results of the terminal voltage and charging current of the battery pack are shown in Fig. 7.

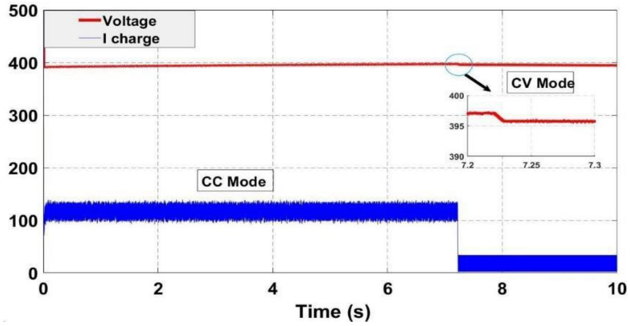

Fig. 7. Voltage and current waveforms of the charging battery

The EVs charging system modeling is simulated in MATLAB. The aim of the simulation is to test the capabilities of the REMS algorithm to deliver an uninterrupted charging process with a constant or lower price at different operating conditions. Typically, these tests are performed for an uninterrupted charging at a constant charging price:

1. Under different weather conditions (normal and abnormal days).
2. With different levels of BSS SoC.

The variable price of electricity at grid as shown in Fig. 7.

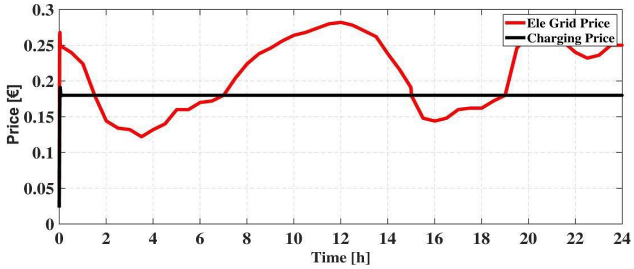

Fig. 8. Electricity grid price and EV charging price

The charging price (Chrg_Pr) is set to a constant value of 0.18 euro/kWh according to [187]. This value is lower than the average grid electricity price at parity and below the parity conditions. As the grid electricity prices are directly proportional to its load, the off-peak conditions are defined on the basis of the grid electricity price.

In Fig. 8, the grid electricity price is lower than the charging price at periods (1.30 a.m.) to (7:00 a.m.) and in the period (15:00 p.m.) to (19:00 p.m.) these periods represent the off peak of the grid side.

A. Charging EVs load Clear Day Profile

Fig. 8 shows the EV load profile under the condition that the PV power is high, the increase in PV power is regular, indicating that the irradiation is not affected by a sudden change in the weather. During the morning (before 9:00 a.m.) and evening (after 18:00 p.m.), the irradiation is low, and the PV power is insufficient to charge all EVs. In this situation, the charging of EVs is fulfilled by activating additional modes, namely BSS2EVs and G2EVs. Prioritization of energy sources with the comparison of the GE price and the charging price is done by the proposed EMS according to the following order: PV2EVs, BSS2EVs, and G2EVs. Priority is given to the use of PV energy first.

The battery is used if the PV power is insufficient to fulfill EV charging. If the joint contribution of the two sources is still insufficient, grid power is used to maintain the continuous load. This sequence can be clearly seen in Fig. 8, from 8:00 a.m. to 18:00 p.m. under "Uninterruptible load using PV, BSS, and grid at high and low grid electricity prices. The transition from thePV2EVs BSS2EVs to the G2EV and PV2EV operating mode is determined by grid electricity price and started at 15:00p.m. to 19:00 p.m. Hence, the BSS and EV load is charged outside of the grid peak hours, with the load is supplied by the grid under low price of electricity to ensure uninterrupted charging. In the mode of EVs load more than the PV power the charging system was tested under different BSS SoC levels, if the SoC levels is on the middle level or high level the charging system will be operated under the charging price and grid price completely as shown in figure. If the SoC at low level the charging system will use the grid power beside the PV power to fill full the EVs load.

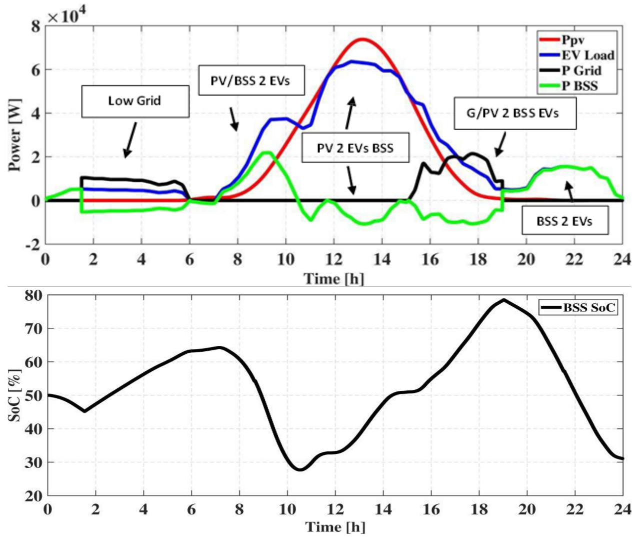

Fig. 8. Power flow of charging system components and BSS SoC at 50 %

With the same PV profile, simulation of REMS based PV charging system with same of EVs load profile and different BSS SoC is establish. In this context, Fig. 8 explains the power profiles of the overall system components to meet the EVs load requirement. Since BSS SoC is 85%, thus the demand gap is provided by BSS besides PV and grid in case low electricity price. In this case, extra energy is absorbed by BSS or grid in case of SoC high to keep the power balance. Not only it decreases the operational cost of electricity production by grid side but also reduce the charging cost. In general, the proposed REMS provide power balance between connected sources and EVs load.

With considering (Gd2EV and Gd2 BSS) which represent the amount of energy purchased from the grid at time t to charge the EV and the BSS. Similarly, the selling price is the sum of the energy sold to grid from PV under the grid electricity price. The energy price under REMS and grid only can calculated from Matlab directly under the proposed prices. From the results in Table 2, the REMS is clearly shown to be about 12.1-12.5 % less than the grid-based charge only for the 24-hour scenario.

Table 2
Price comparison of REMS-based PV BSS grid charging and the grid charging

Profile	**Average charging price (€)**		**Reduction in charging price using REMS (%)**
	REMS charging	**Grid charging**	
A	55.3	67.4	12.1
B	56.2	68.6	12.4
C	53.6	66.1	12.5
D	55.5	67.8	12.3

4. Conclusion and Discussion

General economic value considerations, Recommendations and Future research directions:

Although the impacts of a large number of EVs and their charging facilities on the safety of electricity grids have been investigated by several studies reported in literature, relatively few have assessed the economic value of electricity grid operation and EV load schedule. In this context, the studies many literature have proposed and implemented a real-time advanced EMS to optimize the micro-grid performance including the EV load; their objectives were to minimize energy costs and carbon dioxide and pollutant emissions while maximizing the capacity of the available RES. It is concluded that charging stations can also perform a function in peak-load shaving and valley-filling. The economic value of the foregoing is mainly reflected in the following aspects.

i. A reasonable EV charge planning achieves valley-filling and peak-clipping. That is, by smoothing the load curve, it becomes possible to reduce the cost of electric generation and delay the investment on a new charging facility set that depends on the grid as power source to reduce the peak load.
ii. The electrical energy stored in a large number of EV batteries may be used for frequency and voltage regulation by investing on discharge facilities and improving the reliability of the power system.
iii. The efficient management of charging and discharging of a large number of EVs and the coordination of intermittent renewable energy sources can improve the capacity of the electrical system to accommodate these power supplies and thereby improve the cost-

effectiveness of system operation. In other words, although the electricity grid has a limited capacity to accept intermittent renewable energy sources, the widespread use of EVs contributes to increase the power system capacity.

Some studies published in literature have considered the first two aforementioned aspects; however, no systematic research has ever been conducted on the third, although a few studies have this problem. So far, there is no rigorous analytical tool to assess the economic value of different EV distributions and grid penetration rates for different combinations of intermittent renewable energy sources. The economic value is mainly the potential savings on the operating and investment costs of the electricity grid. A comprehensive mathematical model is required to assess the economic value and study the appropriate load and management strategies to maximize the economic value of EVs and their facilities in power system planning and operation. Moreover, in the analysis of the impact of EVs on the economics of power system operation and planning, it is important to take into consideration the specific characteristics of the electricity distribution system being studied, i.e., the associated electricity market model and regulatory policies. In the context of the electricity market, the impact of EVs on the economics of the electricity grid is particularly remarkable. In addition, the value of EVs in terms of greenhouse gas emission reduction is also an important aspect that has to be examined; to a large extent, this depends on the combination of the types of electricity production for EV charging. This combination generally exhibits a typical variation pattern throughout the day. Research can be conducted on the following three levels.

- Integration of EVs based on home charging and commercial facility charging; emphasis is placed on the economic value of charging and discharging EVs in a typical home at several commercial CPs or at specialized battery recharge/replacement stations.
- Widespread penetration of EVs at specific locations in the distribution grid; tools have been developed to assess the economic impact of power systems on a large number of EVs at specific locations in the distribution system when they are connected at the substation level. The research should consider two cases, private use and commercial use, because these two situations are considerably different.
- System-level search; the focus should be on the impact of numerous EVs on the electricity sales market as a whole and on the retail distribution market after extensive access to the electricity grid. Three scenarios can be studied for each level: (i) absence of EV charging and discharging management; (ii) optimized EV charging and discharging management; (iii) optimized EV charging and discharging management in a smart grid framework and use of renewable energies.

5. Future Research Directions

Concerning EV charging models, it is necessary to introduce more diversity in order to introduce further variability into the model assumptions. For instance, if several magnitudes of charging power, charging locations, and battery capacities are modelled by the same work, then such will provide a more accurate model that reflects the different requirements of various EVs. Moreover, few articles report on the modelling of the charging and integration of EVs in urban areas. Future research on V2G and management of charging and discharging can aid in identifying a compromise between the requisites of vehicle owners and power grid stability.

The high penetration of PV and EVs in the electricity market requires more research. Further studies on the response of vehicle owners to the requirements of grid operators should be implemented; benchmarking research, which evaluates both the produced power costs and charging costs, must be explored.

The PV energy and electric vehicles are essential elements in minimizing both CO2 emissions and fossil fuels consumption. Even though electric vehicles are more economical and environmentally friendly than gasoline cars, the increased penetration of electric vehicles is restricted mainly due to several reasons. Out of these reasons, the charging scheduling of electric vehicles and efficient design of dedicated charging facility are the most noticeable ones. If the charging facility solely relies on central grid to meet the electric vehicles load, there will be unwanted overloading of the distribution system due to this new load. This would result in extensive stress on main grid, which may occur during peak load hours increasing the operational cost and incremental the greenhouse gasses. In this context, designing a dedicated charging station can enable lesser dependency on the main grid together with efficient scheduling of electric vehicles load.

In this research work, a dedicated renewable assisted charging station is proposed, simulated and validated under different weather and load profiles. The PV, BSS and EVs load are connected through a common DC bus. Furthermore, the main grid is connected to the common DC bus via a rectifier/inverter stage. The benefits of using common DC bus is the overall reduction in power conversion steps. In the context of power conversion, to enhance the efficiency of conversion, while providing a reliable and consistent power supply, interleave converters are utilized individually for PV, BSS and EVs load. In case of PV system, interleave boost converter with maximum power point tracking is utilized. For BSS a bidirectional interleave converter is suggested and analyzed. Hence, the interleave converter provides several benefits, such as low ripples output, less stress on converter components and lesser losses in passive elements resulting in higher conversion efficiency. It also provides intrinsic redundancy, which is the capability to tolerate a faulty condition.

The overall performance of the hybrid charging system together with interleave conversion stage under various intermittent conditions depends on efficient design of coordinated control mechanism and the respective energy management strategy. The overall control mechanism consists of various decentralized controllers. There is an interlinking converter for rectifier/inverter of the main grid. For the interleave converters of battery storage and electric vehicles charger, a traditional PI controller is used. For the PV system, a PO algorithm-based controller is used for interleave boost converter to extract maximum power from the PV. A centralized energy management strategy is developed to generate the reference signals for individual controllers, so that maximum preference is given to maximization of local PV utilization. The energy management strategy also ensures lesser dependency on the grid to reduce the operational cost along with greenhouse effect. The BSS plays a vital role in energy management as it behaves s like a rapid buffer either to absorb surplus power from PV or to meet the deficiency at EVs load side.

The performance of the proposed centralized energy management strategy together with interleave conversion stages is studied and validated with different real-time scenarios. These scenarios consist of different weather profiles covering the 24h horizon and various intermittent EVs loading conditions. The modeling of the whole system and the corresponding simulations are performed in Matlab/Simulink environment. In order to examine the performance of proposed strategy, different real-time PV profiles covering sunny, partially sunny and cloudy conditions are considered and simulated with different levels of SoC of BSS. During all the scenarios, it is recorded, analyzed and concluded that energy balance between sources and the EVs load retains. Moreover, the system retains a consistent regulated voltage at DC bus due to the proposed energy management and control architecture.

The energy management strategy provides adequate generation-load balance and the suggested controllers provide a rapid and stable response under variable operating conditions.

The future perspectives relevant to this research work are highlighted as:

1. Location and V2G Technology: The selection of the charging station site is critical in distribution grid planning. The partial load demand can be offset to some extent by considering the V2G technology, taking advantage of the discharge characteristics of EVs, and adopting the marginal access mode; consequently, the foregoing can change the direct supply load space prediction of the charging station. The location of the substation should also be considered in relation to future developments in the city.
2. Optimal Sizing and Capacity: The capacity of EV charging facilities should be fully considered in the design of the EV charging station. The total capacity of the charging station should be able to satisfy the EV load; accordingly, overloading is avoided.
3. Reliability and power density: To increase the reliability of the power supplied to areas where the density of EV charging facilities is relatively large, the reserve of spare capacity can be appropriately increased. This improves the overall system reliability apart from unifying the layout of charging facilities and achieving a reasonable load distribution.
4. Mass integration of EVs: If a large number of EVs are connected to the grid, the power supply behavior will vary; consequently, this may change the power flow in the distribution grid. The uncertainty in the EV load density will introduce considerable problems to the location, capacity, and planning of EV charging stations.

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