

# TWO-WAY ENERGY MANAGEMENT OF ELECTRIC VEHICLE CHARGING STATION

Tripti Kunj,\* Anand Mohan,\* and Kirti Pal\*

## Abstract

This article presents a system comprising a solar photovoltaic (PV) array, a battery energy storage (BES), a diesel generator (DG) set, and a grid-based electric vehicle (EV) charging station (CS) for continuous charging in islanded, grid-connected, and DG set connected modes. The CS is primarily designed to utilise the solar PV array and BES for charging the EV battery. However, if the storage battery is depleted or the solar PV array generation is unavailable, the CS intelligently switches to drawing power from either the grid or the DG set. Notably, the power from the DG set is carefully managed to maintain an operating level of 80%–85% loading, ensuring maximum fuel efficiency across all loading conditions. Additionally, in collaboration with the storage battery, the CS regulates the generator voltage and frequency without the need for a mechanical speed governor. It also ensures that power drawn from the grid or DG set maintains a unity power factor even under nonlinear loading conditions. Moreover, the point of common coupling voltage is synchronised with the grid/generator voltage to enable uninterrupted charging.

## Key Words

Electric vehicle charging station, diesel generator, solar PV array, controller, energy management

## 1. Introduction

After the advantages of electric vehicles (EVs), 3 million vehicles have been placed on the road, with the number forecast to reach 100 million by 2030 [1]. However, the suggested plan's implementation will necessitate massive charging infrastructure and massive amounts of electricity. However, using fossil fuels does not reduce emissions; as the same amount of emission which was previously produced by EVs is now produced by thermal power plants. The PV, wind, hydro, and fuel cell-based energy are among the numerous renewable energy sources accessible [2].

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The development of a renewable energy-based charging station has taken a lot of time and work. The necessity of renewable energy for the long-term viability of an EV charging station was explored by [3]. Mouli *et al.* [4] utilised solar power to charge EV using a high-power bidirectional EV charger. The intended charger is incapable of mainly AC charging base. Monteiro *et al.* [5] suggested a three-port converter for merging a PV system with an EV charge point. The planned charger, on the other hand, does not account for the current of charger distortions in the grid current. To design a photovoltaic (PV) array/grid-connected EV charger, [6] developed an improved Z-source converter here. The charger, however, is not meant for use in the islanded mode of process. As a result, it is unable to enable EV charging in the non-appearance of a grid. An amalgam optimisation prototypical for controlling battery storing in order to decrease charging station operating costs while maximizing the use of solar PV array output suggested by [7]. Kineavy and Duffy [8] have suggested to utilise the onsite PV-generated power in coordination with the EV charging station for maximum usage of solar PV array with less effect on the grid. Zhang *et al.* [9] investigated the best time to set up an EVCS in the office with double charging point manners. The PV-powered CS is also appropriate for onsite placement to provide the top class of service at the deepest rate while dropping the charging grid effect [10], [11]. Due to its convenience together during the day and at night, wind energy-powered CS is also advantageous for EVs, and many research has been done [12]–[14].

Due to the large quantity of energy kept in EV strings, EVs are currently being exploited as a distributed live lines reserve for offering numerous ancillary facilities. Singh *et al.* [15] proposed a PV-based charging station for charging, V2G with active and reactive power sifting. A grid-connected PV scheme for EV and household use was developed by [16]. Razmi and Doagou-Mojarrad [17] have suggested a grid-connected and islanded power management technique using a multi-residential PV-storage battery system. Many authors [18]–[21] concluded EV charging can be used to provide the benefits to both consumer and utility.

Furthermore, the performance of CS in real-world situations is rarely discussed. Furthermore, most of the researcher only discusses the performance of CS in either

grid-connected or islanded mode. The PV, develops impracticable if the grid is unavailable, even if solar irradiance is accessible, due to the solitary approach of the process in grid-connected method. Likewise, in islanded manner, the PV control is disrupted by irradiance's inconstancy of the solar. As a result, a storing series is essential to counteract the effects of changing solar irradiation. To avoid overcharging, the MPPT must be disabled in the case of a fully charged storage battery. Both islanded and grid-linked approaches have been considered in several articles. These dual methods, however, are regulated distinctly, and there is no automatic mode swapping between them. As a result, deprived of involuntary method switching capacity, PV power would be stopped, and EV charging will be interrupted. As a result, an involuntary approach switching logic is provided in this study, which allows the controller to transition between multiple operating modes based on the power generated by the PV array and the changing needs of the EV. As the PV arrays are intermittent in nature and unavailability at night, a storing series with a PV array is utilised to keep the CS running continuously and reliably. However, due to the storage battery's low storage capacity, it is difficult to deliver continuous hold-up. As a result, the CS requires grid support in the event that PV array electricity is not available.

However, in rural regions, the DG set may be needed to continue the charging. The working of the DG set, however, is influenced by the type of loading, and it is not utilised to its highest potential. DG sets are often meant for a small degree of harmonics in the burden current [22].

A hybrid approach called the SGO-RERNN technique is presented to efficiently manage energy in EVCS and the distribution system. This approach combines shell game optimisation (SGO) with recalling-enhanced recurrent neural network (RERNN). The primary objective is to provide the maximum amount of energy to the EVCSs and generate optimal charging plans. The SGO-RERNN system ensures a balanced solution, aiming to maximise the planned charging capacity for the EVCSs within the distribution system [23]. Here presents a method that enhances the CS's power capabilities in two ways, promoting sustainable development. Additionally, any surplus power is converted to AC supply, which can be utilised by people. This prototype model operates using a microcontroller board [24].

The development of EV is rapidly increasing in today's scenario, leading to a rising demand for charging stations. It is crucial to ensure the proper maintenance and health of these CS to enhance their utility. Simultaneously, there is a need to adopt an energy usage approach that supports sustainable development, a dual-powered CS is proposed, which not only caters to the charging needs of EVs but also generates surplus power converted into AC supply for public use. This prototype model operates efficiently using a microcontroller board [25].

EVs suffer from limited range due to their inadequate energy storage space, resulting in longer recharge times. Additionally, charging stations are not as abundant as fuelling stations for diesel or gasoline vehicles.

Consequently, the main goal of an optimal driving-based energy management system (DAEM) is to efficiently utilise the stored energy to complete the entire trip. Furthermore, various factors like road quality, speed limits, and safety considerations lead to restricted speed limits both in downtown areas and highways, causing increased trip complexity. This complexity affects the ability to maintain a consistent driving strategy throughout the journey. In this study, the impact of trip complexity on DAEM results was investigated, focusing on two driving cycles (neighbourhood and highway) to create different trip complexities [26]. This paper focuses on the classification of the charging regime for EVs at the fast charging station (FCS) based on their status upon arrival. The two scenarios considered are when the EVs are charged immediately upon arrival or have to wait in a queue. This classification involves specific parameters, such as arrival time, charging time, and waiting time [27].

EV charger normally employs a rectifier trailed by a power factor modification circuit and a DC-DC converter for step down, the DG set recital is badly impacted by EV charging owing to the occurrence of harmonics in the EV current.

The following are the worthwhile contributions made in this study.

- In this article, a solar PV array, a battery energy storage (BES), a diesel generator (DG) set, and a grid-based EV charging station (CS) are utilised to provide the incessant charging in islanded, grid-connected, and DG set connected modes.
- Development of a united supervision system that permits the CS to function in islanded, grid-connected mode, and DG set-connected with only a single VSC and no hardware changes.
- Scheme of a method swapping rationality that permits the CS to smoothly shift modes to deliver incessant charging. The CS is primarily designed to use the solar PV array and a BES to charge the EV battery. However, in case of exhausted storage battery and unavailable solar PV array generation, the CS intelligently takes power from the grid or DG set. However, the power from DG set is drawn in a manner that it always operates at 80%–85% loading to achieve maximum fuel efficiency under all loading conditions. Moreover, in coordination with the storage battery, the CS regulates the generator voltage and frequency without a mechanical speed governor. It also ensures that the power drawn from the grid or the DG set is at unity power factor even at nonlinear loading. Moreover, the point of common coupling voltage is synchronised to the grid/generator voltage to obtain ceaseless charging.
- Strategy of a control policy for V2V and V2G power transfer for EV charging and grid support is proposed.

## 2. System Description of Charging Station

The proposed CS is based on a solar energy, a battery storing series, and a D-G set, and AC power grid to supply or charge the EV as shown in Fig. 1. The supply

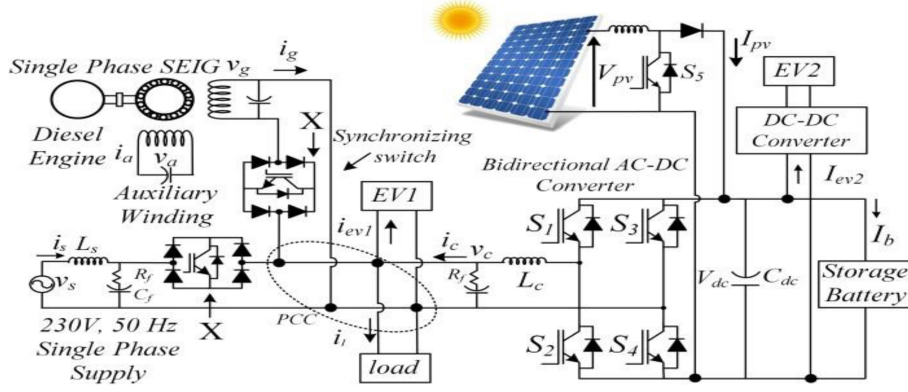


Figure 1. Block diagram of CS [15].

is also used to provide power to load connected at CS. A boost converter is used with PV solar energy to increase the generated power with voltage source converter (VSC) connected at common DC link. On AC side of VSC a 1 $\Phi$  Self Excited Induction Generator, an EV1 (consider as charging station 1) and a nonlinear load are connected with coupling inductor. To make the supply ripple and harmonics free filters are connected at point of common coupling. Another charging station represented as EV2 is connected with DC link through DC-DC converter.

### 3. Control Strategies

#### 3.1 VSC Control in Islanded Approach

In an island mode, it is assumed that it is disconnected from the grid. The supply to charge the EVs is used only by solar energy-based PV array. In this case, charging station EV2 can be used only. When the generated power is more than charging station requirement batteries are charged by solar energy. This is the example of stand-alone power supply. In this case, D-G set is also disconnected. As the power grid is not present here reference voltage input to controller is not present. In this case controller generate reference voltage 230 V and reference frequency 50 Hz. The generated references are then compared with converter terminal voltage and frequency. These are the representation of error minimisation and production of reference current.

$$i_c^*(s1) = i_c^*(s1-1) + z_{pv} \{v_{pv}(s1) - v_{ce}(s1-1)\} + z_{iv} v_{ce}(s1) \quad (1)$$

Here gate signal by converter is generated by comparing the reference current generated by the controller with measured terminal converter current and then sending it to another controller.

#### 3.2 VSC Control for D-G and Power Grid

When solar energy is not available in that case EVs are charged by grid. The amount of energy flowing from grid to EVs is controlled by controller. In this case charging

station EV1 is used as shown in Fig. 1. In case grid power is not available D-G set can be used which provides run at constant power mode. The role of controller in both cases are to control ripples, harmonics, and reactive current required by EVs. In power grid mode only real current is taken as reference current for comparator. In case of D-G set both real and reactive currents are taken as the reference current. To extract the fundamental frequency current of an EV an adaptive notch cancellation (ANC) [28] is used. In the grid-connected mode, real and reactive currents are given as:

$$\begin{aligned} I_{sp} &= I_p - I_{ef2} - I_{pf} \\ I_{sq} &= 0 \end{aligned} \quad (2)$$

As stated above in case of D-G set both real and reactive currents of EVs are used. The currents are represented as:

$$\begin{aligned} I_{sp} &= I_p - I_{ef2} - I_{fp} - I_{pf} \\ I_{sq} &= I_{vq} - I_q \end{aligned} \quad (3)$$

here,  $I_p$  and  $I_q$  are the real and reactive currents of EVs when connected in D-G mode.

The  $I_{ef2}$  and  $I_{pf}$  are the feed-forward current of the charging station EV2 where it is connected with DC link and the PV array.

The  $I_{fp}$  and  $I_{vq}$  are the regulated frequency and voltage in the D-G set connected mode.

The  $I_{ef2}$  controls the vehicle-to-grid power transfer from the EV.  $I_{pf}$  is the solar PV array feed-forward current in grid mode. It also controls the charging of the storage battery so that it cannot be overcharged. The energy storage batteries are directly connected to the DC link. These storage batteries are charged by solar energy PV arrays in case EVs are not available in charging station or if more energy generated required for EVs charging. In case batteries are fully charged solar generated energy is directly fed to the grid.

The reference current of power grid or D-G set is given as:

$$i_s^* \text{ or } i_g^* = I_{tp} \times u_p + I_{tq} \times u_q \quad (4)$$

$u_p$  and  $u_q$  are synchronising signals of the D-G set or power grid voltage ( $v_g$  or  $v_s$ ). By comparing reference and

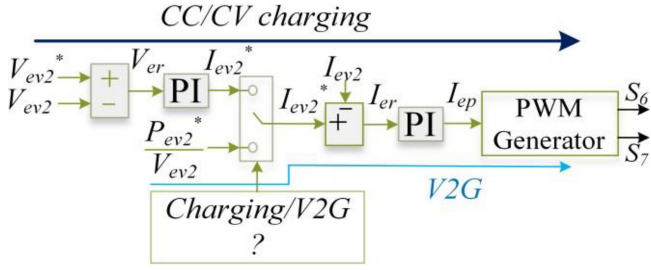


Figure 2. Charging mode allocation [15].

actual current of power grid and D-G set a synchronising signal is sent to the controller to generate switching signal.

### 3.3 Voltage and Frequency Control

To operate the DG set usual at a solitary opinion, the occurrence and voltage of the DG sets are controlled by decoupled governor of the VSC. The occurrence is governed by real power, while the voltage is adjusted by reactive power in decoupled control. To regulate voltage and frequency, two PI controllers are introduced. The PI control is as follows, for voltage regulation:

$$I_{va}(s1) = I_{va}(s1 - 1) + Z_{Vp1} \{V_{me1}(s1) - V_{me1}(s1 - 1)\} + Z_{vi1} V_{me1}(s1) \quad (5)$$

Where  $V_{me1} = V_{m1}^* - V_{m1}$  and the  $Z_{vi1}$  and  $Z_{Vp1}$  are the gains of the PI regulator.

The separate appearance of the occurrence PI controller is as,

$$I_{fp}(s1) = I_{va}(s1 - 1) + Z_{fp} \{f_e(s1) - f_e(s1 - 1)\} + Z_{fi} f_e(s1) \quad (6)$$

Where  $f_e$  is the fault frequency and  $Z_{kfp}$ ,  $Z_{fi}$  are gains of PI.

The productivities of the occurrence and voltage supervisors are merged in grid linked regulator. In the grid-tied method, however, the grid voltage and occurrence remain controlled so that the yields of these supervisors develop nothing.

### 3.4 Control of EV Charging

In charging station DC-DC converter is used to convert DC voltage in range of EV charging capability. The EVs are then connected to suitable DC link. The EVs are charged in two modes constant current (CC) and constant voltage (CV). When EVs are in charging mode and level of voltage is less than full charging condition EVs are charged in CC mode. As soon as EVs are near to full charge condition close to desirable voltage the charging mode is shifted from CC to CV mode. The charging modes shifting are controlled by two PI controllers with a PWM generator as shown in Fig. 2. In this method, represented in Fig. 2, both an initial constant current and a final constant voltage are used. The charging process starts with a constant

current until a certain voltage value, known as cut-off voltage, is reached. For Li-ion with the traditional cathode materials of cobalt, nickel, manganese, and aluminum typically the cut-off voltage value is around 4.20 V/cell. The tolerance is  $\pm 50$  mV/cell. Battery charging continues with a constant voltage just equal to the cut-off value. Full charge is reached when the current decreases to between 3% and 5% of the rated current. Trickle or float charge at full charge is not suitable for a Li-ion battery; since it would cause plating of metallic lithium and compromise safety. Instead of trickle charge, a topping charge can be applied when the voltage drops below a set value.

### 3.5 Transition Switching Control

The CS functions in different manners liable on the cohort and charging request, a mode switching policy must be created so that the transition from one mode to additional level is possible and the incriminating continues uninterrupted power supply. The mode switching logic is created for such scenarios as an island to power grid and island to generator set usual linked styles. Transition switching control refers to the process of smoothly switching or transitioning between different controls modes in a dynamic system. In certain systems, it becomes necessary to switch between different control strategies or modes to adapt to changing conditions, achieve specific objectives, or handle varying operational requirements. These control modes can be different sets of control parameters or strategies that are suitable for different operating conditions. The mode-switching policy is a crucial component of transition-switching control. It is a set of rules or algorithms that determine when and how to switch between different control modes. The policy considers various factors, such as system state, external disturbances, performance criteria, and safety constraints, to make decisions about which mode to activate at any given time. The mode-switching policy aims to ensure a smooth and efficient transition between control modes to avoid abrupt changes that might lead to instability, performance degradation, or safety issues. Overall, the mode-switching policy is an essential element of transition-switching control, enabling the system to effectively adapt to changing conditions and achieve its intended objectives.

## 4. Results and Discussion

The uninterrupted operation of the CS is demonstrated in computer-generated results as shown in Fig. 5. The CS is initially in an islanded method, with the PV collection command being utilised to control the EVs associated with the point of common coupling (PCC). The excess generation is stored in the energy storing because the PV array peer surpass the EV charging needs. The sun irradiation drops from  $1000 \text{ W/m}^2$  to  $300 \text{ W/m}^2$  in 0.32 s. As a result, the PV array's power diminishes, and the packing battery jumps to discharge in order to maintain uninterrupted charging. The storage battery empties at

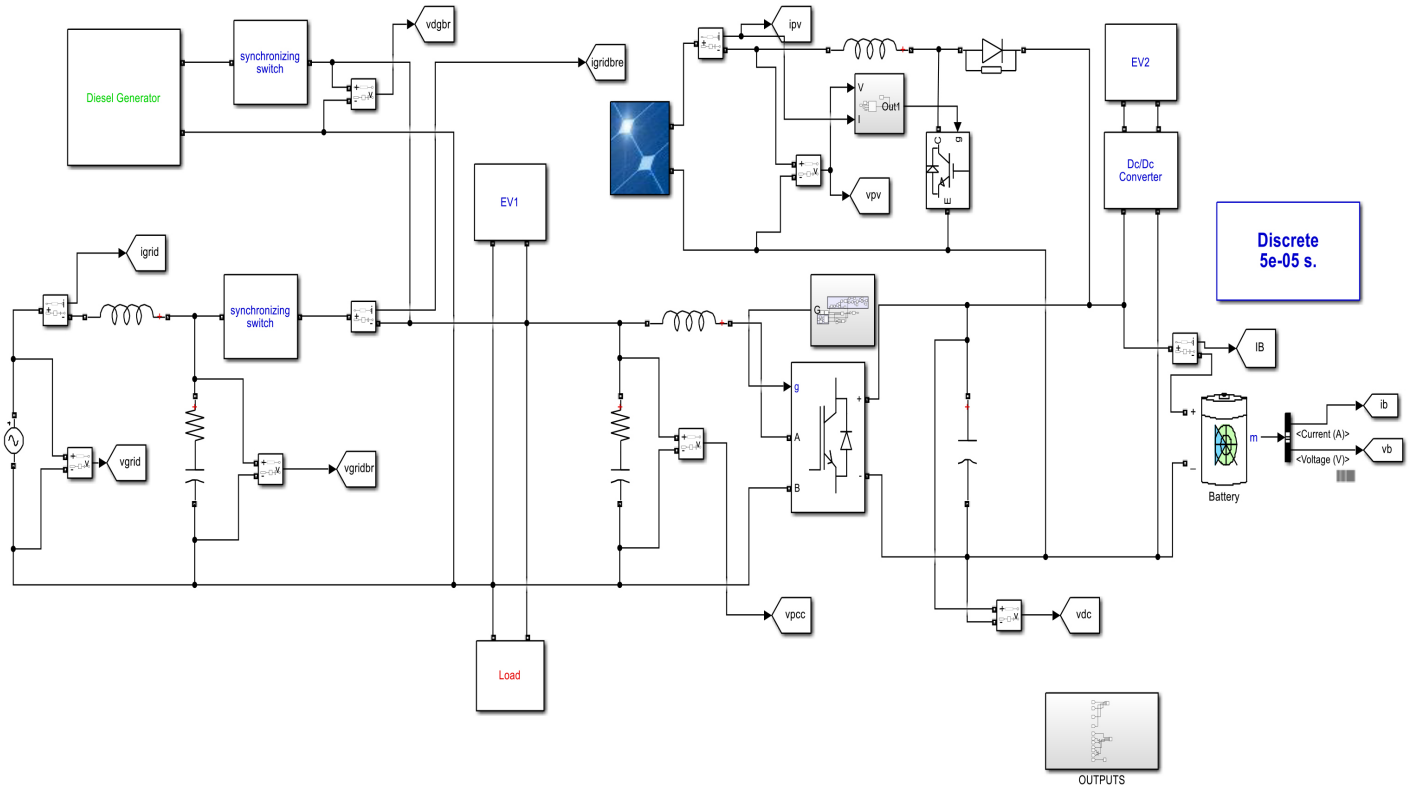


Figure 3. Simulation model of charging station.

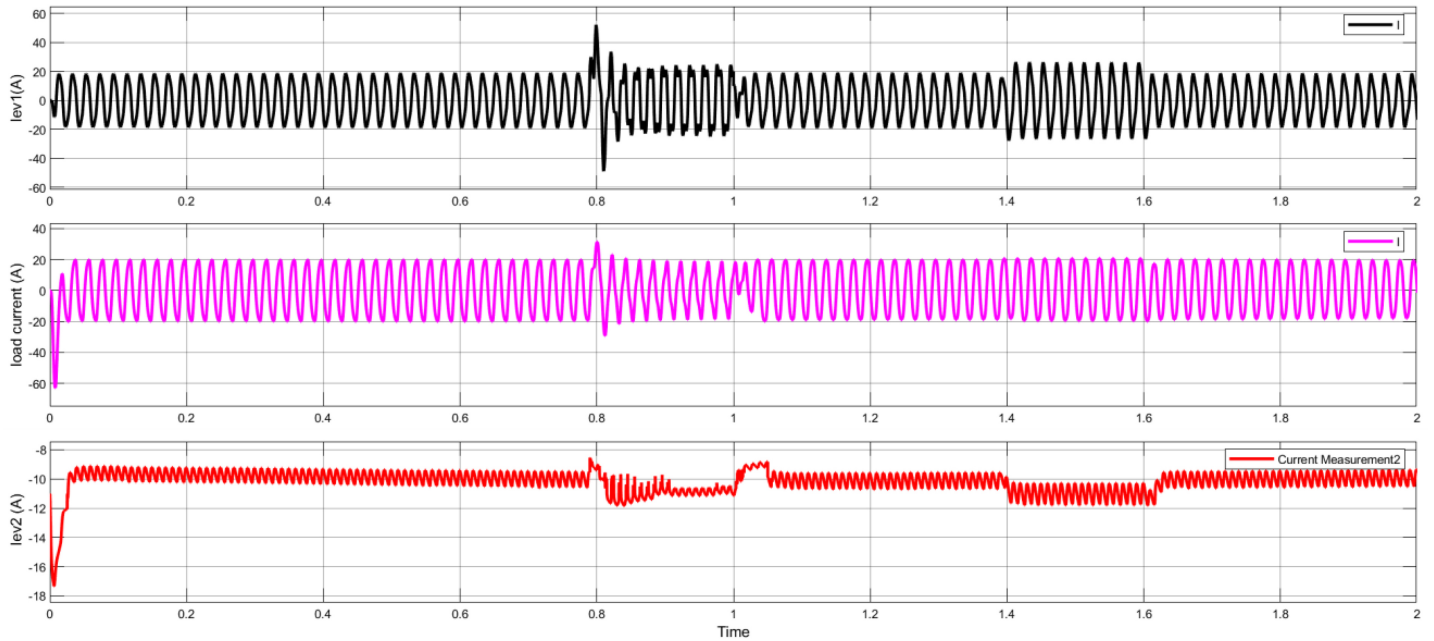


Figure 4. EV1 current, load current, EV2 current.

0.48 s, as the PV array control drops to zero. After that, as long as the SOC > SOCmin, the storage battery fully enables charging. After the battery has been fully discharged, the controller synchronizes the CS and connects it to the grid.

The CS is in taking power out of the grid at 0.59 s. Because grid and storage battery power are unavailable at this point, charging station is provided by the DG set, as

shown in Fig. 6, it can be seen that the CS changes modes automatically based on the generation and demand.

## 5. Conclusion

For EV charging, a PV array, storing set, grid, and DG set-based CS have been designed. In this way, results show that the CS can operate in multiple modes (islanded

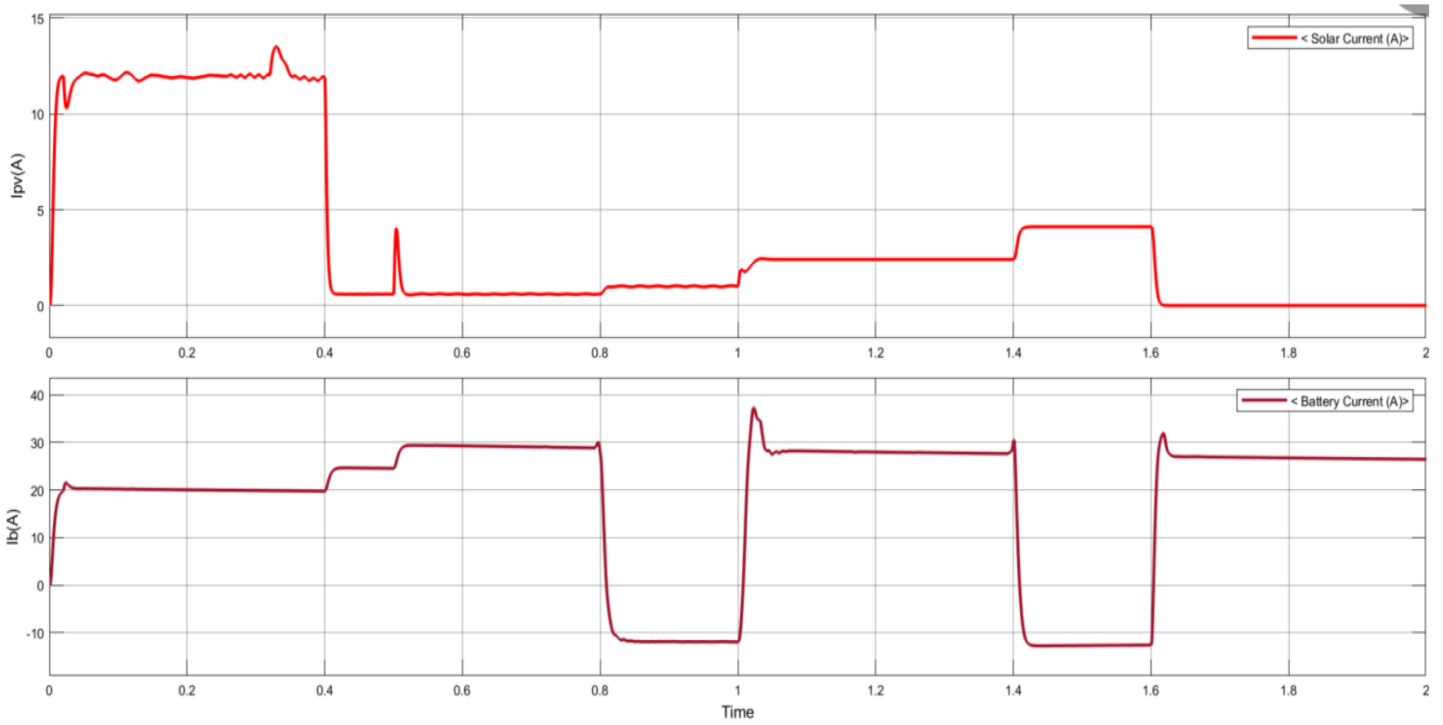


Figure 5. Solar current, battery current.

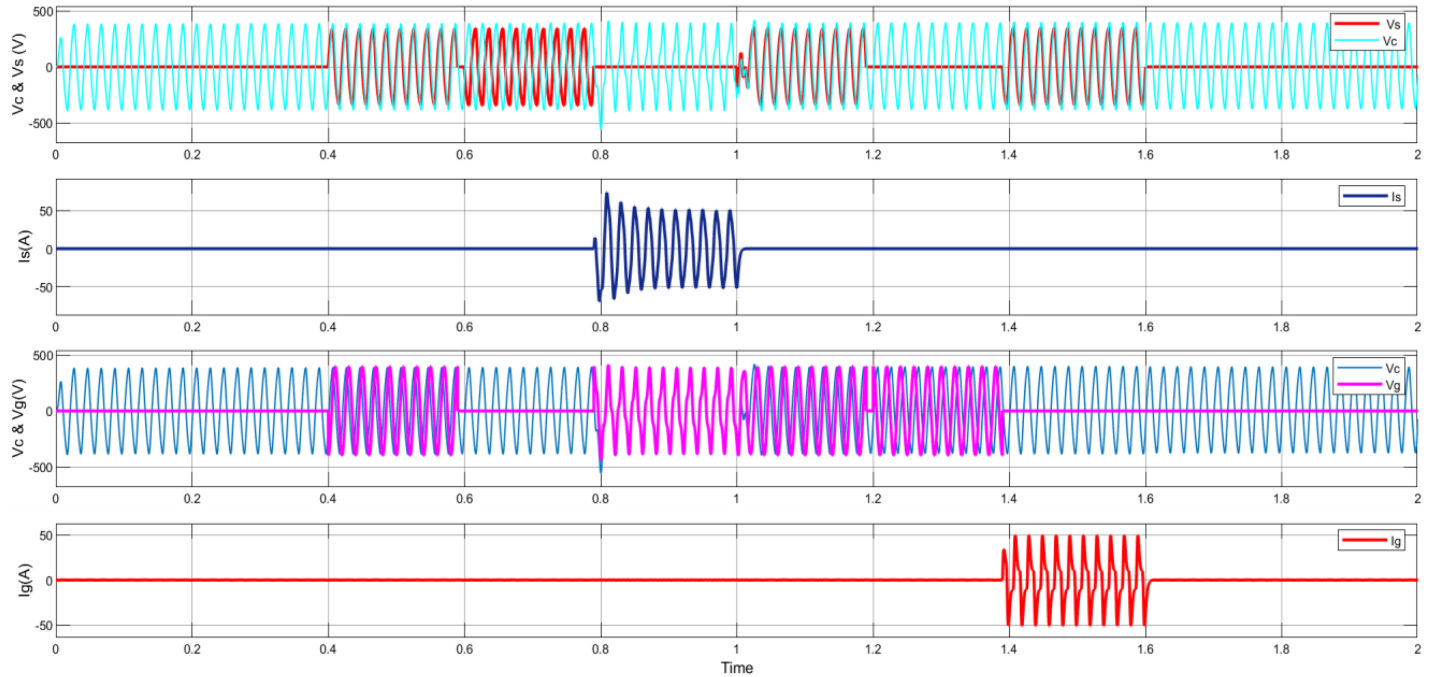


Figure 6. Diesel voltage, diesel current, grid voltage, grid current.

procedure, grid linked, and DG set linked) through only one VSC. The provided findings have confirmed the charging station's performance as an independent generator with good voltage quality. Furthermore, islanded procedure, grid-tied and DG conventional associated procedures, and automatic mode switching have boosted the likelihood of

PV array maximum power point (MPP) operation and DG set optimum loading and charging dependability. From the foregoing, it can be inferred that this CS, through the offered controller, has the potential to efficiently use multiple energy bases while providing consistent and profitable charging to EVs.

## References

- [1] IEA (2018), Global EV Outlook 2018, IEA, Paris <https://www.iea.org/reports/global-ev-outlook-2018>.
- [2] IEA (2018), Renewables 2018, IEA, Paris <https://www.iea.org/reports/renewables-2018>.
- [3] J. Ugirumurera and J. Z. Haas, Optimal capacity sizing for completely green charging systems for electric vehicles, *IEEE Transactions on Transportation Electrification*, 3(3), 2017, 565–577.
- [4] G.R.C. Mouli, J. Schijffelen, M. van den Heuvel, M. Kardolus, and P. Bauer, A 10 kW solar-powered bidirectional EV charger compatible with chademo and COMBO, *IEEE Transactions on Power Electronics*, 34(2), 2018, 1082–1098.
- [5] V. Monteiro, J. Gabriel Pinto, and J.L. Afonso, Experimental validation of a three-port integrated topology to interface electric vehicles and renewables with the electrical grid, *IEEE Transactions on Industrial Informatics*, 14(6), 2018, 2364–2374.
- [6] A.S. Singh, C. Giampaolo, N.A. Azeez, and S.S. Williamson, Modeling, design, control, and implementation of a modified Z-source integrated PV/grid/EV DC charger/inverter, *IEEE Transactions on Industrial Electronics*, 65(6), 2017, 5213–5220.
- [7] K. Chaudhari, A. Ukil, K. Nandha Kumar, U. Manandhar, and S.K. Kollimalla, Hybrid optimization for economic deployment of ESS in PV-integrated EV charging stations, *IEEE Transactions on Industrial Informatics*, 14(1), 2017, 106–116.
- [8] F. Kineavy and M. Duffy, Modelling and design of electric vehicle charging systems that include on-site renewable energy sources, In *Proc. IEEE 5th International Symposium on Power Electronics for Distributed Generation Systems (PEDG)*, pp. 1–8. 2014.
- [9] Y. Zhang, P. You, and L. Cai, Optimal charging scheduling by pricing for EV charging station with dual charging modes, *IEEE Transactions on Intelligent Transportation Systems*, 20(9), (2018), 3386–3396.
- [10] Y. Yang, Q.-S. Jia, G. Deconinck, X. Guan, Z. Qiu, and Z. Hu, Distributed coordination of EV charging with renewable energy in a microgrid of buildings, *IEEE Transactions on Smart Grid* 9(6), 2017, 6253–6264.
- [11] Kandasamy, N. Kumar, K. Kandasamy, and K.J. Tseng, Loss-of-life investigation of EV batteries used as smart energy storage for commercial building-based solar photovoltaic systems, *IET Electrical Systems in Transportation* 7(3), 2017, 223–229.
- [12] A. Tavakoli, M. Negnevitsky, D.T. Nguyen, and M.M. Kashem, Energy exchange between electric vehicle load and wind generating utilities, *IEEE Transactions on Power Systems* 31(2), 2015, 1248–1258.
- [13] Y. Shan, J. Hu, K.W. Chan, Q. Fu, and M.G. Josep, Model predictive control of bidirectional DC–DC converters and AC/DC interlinking converters—A new control method for PV-wind-battery microgrids, *IEEE Transactions on Sustainable Energy*, 10(4), 2018, 1823–1833.
- [14] P. Liu, J. Yu, and E. Mohammed, Decentralised PEV charging coordination to absorb surplus wind energy via stochastically staggered dual-tariff schemes considering feeder-level regulations,” *IET Generation, Transmission & Distribution*, 12(15), 2018, 3655–3665.
- [15] B. Singh, A. Verma, A. Chandra, and K. Al-Haddad, Implementation of solar PV-battery and diesel generator based electric vehicle charging station, *IEEE Transactions on Industry Applications*, 56(4), 2020, 4007–4016.
- [16] N. Saxena, B. Singh, and A.L. Vyas, Integration of solar photovoltaic with battery to single-phase grid, *IET Generation, Transmission & Distribution*, 11(8), 2017, 2003–2012.
- [17] H. Razmi, and H. Doagou-Mojarrad, Comparative assessment of two different modes multi-objective optimal power management of micro-grid: grid-connected and stand-alone, *IET Renewable Power Generation*, 13(6), 2019, 802–815.
- [18] O. Erdinc, G.P. Nikolaos, T.D.P. Mendes, G.B. Anastasios, and J.P.S. Catalão, Smart household operation considering bi-directional EV and ESS utilization by real-time pricing-based DR, *IEEE Transactions on Smart Grid*, 6(3), 2014, 1281–1291.
- [19] H. Kikusato, K. Mori, S. Yoshizawa, Y. Fujimoto, H. Asano, Y. Hayashi, A. Kawashima, S. Inagaki, and T. Suzuki, Electric vehicle charge-discharge management for utilization of photovoltaic by coordination between home and grid energy management systems, *IEEE Transactions on Smart Grid*, 10(3), 2018, 3186–3197.
- [20] F. Hafiz, A.R. de Queiroz, and I. Husain, Coordinated control of PEV and PV-based storages in residential systems under generation and load uncertainties, *IEEE Transactions on Industry Applications*, 55(6), 2019, 5524–5532.
- [21] K. Tripti and K. Pal, EVs Owner benefit evaluation through energy exchange in the smart radial distribution network,” *Electric Power Components and Systems*, Aug. 2023. DOI: 10.1080/15325008.2023.224078
- [22] Wies, W. Richard, R.A. Johnson, A. N. Agrawal, and T.J. Chubb, Simulink model for economic analysis and environmental impacts of a PV with diesel-battery system for remote villages, *IEEE Transactions on Power Systems*, 20(2), 2005, 692–700.
- [23] U. Dharmalingam and V. Arumugam, Optimal energy management in EVCS and distribution system considering QoS using hybrid technique, *Artificial Intelligence Review*, 2023, 1–30.
- [24] T. Kokilavani, D. Gunapriya, V. Govindaraj, N. Pusphalatha, N. Hemalatha, V. Sharma, and A. Alkhayyat, Electric vehicle charging station with effective energy management, integrating renewable and grid power, In *Proc. 2023 3rd International Conference on Innovative Practices in Technology and Management (ICIPTM)*, pp. 1–5. 2023.
- [25] D.R. Priya, R.K. Srithika, V.T.S. Narayani, R. Thelagavathy, and T. Malini, Solar powered energy management system for electric vehicle and grid based home automation, In *Proc. IEEE 2023 9th International Conference on Electrical Energy Systems (ICEES)*, pp. 476–480. 2023.
- [26] M. Khanra and A.Kr Nandi, Influence of trip complexity on optimal driving based energy management system of electric vehicle, In *Proc. IEEE 2019 International Conference on Communication and Electronics Systems (ICCES)*, pp. 334–339. 2019.
- [27] S. Tripathi, P.K. Gurjar, C.P. Barala, P. Mathuria, and R. Bhakar, The future of transportation: a review of electric vehicle charging management and navigation, In *Proc. IEEE 2023 International Conference for Advancement in Technology (ICONAT)*, pp. 1–6., 2023.
- [28] R.R. Chilipi, N.Al Sayari, A.R. Beig, and K. Al Hosani, A multitasking control algorithm for grid-connected inverters in distributed generation applications using adaptive noise cancellation filters, *IEEE Transactions on Energy Conversion*, 31(2), 2016, 714–727.

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