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Implementation of Electric Vehicle Charging Station Based on Solar PV-Battery and Diesel Generator

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Abstract—In this study, a grid-based EV charging station (CS), a solar PV (Photovoltaic) array, a battery energy storage system, a diesel generator set, and a battery are used to enable continuous charging in islanded, grid-connected, and DG set connected modes. The main purpose of the charging station is to charge the electric vehicle (EV) battery using a BES and a solar photovoltaic PV array. However, the charging station intelligently uses electricity from the grid or a DG (Diesel Generator) set if the storage battery is empty and the solar PV array generation is not available. However, the power from DG sets is drawn in such a way that, in order to achieve optimal fuel economy under all loading conditions, it always operates at 80–85% loading. Additionally, the charging station controls the generator's voltage and frequency in conjunction with the storage battery without the use of a mechanical speed governor. Additionally, it makes sure that even under nonlinear loads, the power drawn from the grid or DG set is at unity power factor (UPF). In order to achieve continuous charging, the PCC (Point of Common Coupling) voltage is also synced to the grid/generator voltage. To improve the charging station's operational efficiency, the charging station also performs active/reactive power transfers from vehicles to the grid, homes, and other vehicles. Using the lab-developed prototype, the charging station's functionality is experimentally tested.

Index Terms— Solar PV generation, EV charging station, power quality, and DG set.

I. INTRODUCTION

Electric vehicles (EVs) are currently regarded as one of the most effective forms of transportation due to their absence of tailpipe emissions. Because of their advantages, 3 million EVs have already been put on the road, and by 2030, that number is predicted to reach 100 million [1]. However, the suggested plan's execution calls for a substantial amount of electrical energy and charging infrastructure. Additionally, the only way EVs can be sustainable is if the electrical energy needed for charging is produced from sustainable and renewable energy sources. However, using fossil fuels to generate electricity does not lower emissions; rather, it only transfers them from automobiles to the power plant. As a result, using renewable energy sources to generate power can eliminate emissions while also benefiting the environment. Solar PV based generation is the most practical option for EV charging among the different renewable energy sources that are now available because it is virtually always accessible, regardless of whether one lives in a rural or urban area (solar PV array, wind energy, hydro energy, and fuel cell-based energy are other examples) [2]. In terms of the Indian region, it is accessible virtually all year long. The wind and hydro energy, as opposed to the solar PV array, are location-specific. The coastline region benefits the most from wind energy, while highland areas benefit from hydropower.

Even though renewable energy-based charging stations are the most practical option for EV charging, integrating them into the current charging system adds a new power conversion stage, which increases the system's complexity and power loss. Additionally, each conversion stage has its own controller, which must relate to the current control. Therefore, it is important to create an integrated system with the ability to operate in several modes and functions, which requires unified control and coordination between the numerous sources.

The development of a charging station powered by renewable energy has received a lot of attention. The significance of renewable energy for the sustainability of the EV charging station has been covered by Grimier et al. [3]. Using a high-power bidirectional EV charger, Mouli et al. [4] have used solar energy to charge EVs. The designed charger, however, does not offer AC charging. For combining a PV array with an EV charger, Monterio et al. [5] have introduced a three-port converter. The planned charger does not, however, consider the current distortions the charger causes in the grid current. A modified z-source converter has been suggested by Singh et al. [6] for developing a PV array/grid connected EV charger. The charger, however, is not intended for the island method of operation. As a result, in the absence of a grid, it is unable to enable EV charging. A hybrid has been discussed by Chaudhari et al. An optimisation model is used to manage the battery storage so that the solar PV array's output is fully exploited and the charging station's operating costs are kept to a minimum. For maximal solar PV array utilisation (under uncertainty) with little grid impact, Keavy et al. [8] suggested using the on-site PV generated power (deployed on the commercial building) in cooperation with the EV charging station. The best scheduling of an EV charging station with dual charging modes at a workplace has been researched by Zhang et al. [9]. The onsite deployment of the PV array-powered charging station (CS) is also appropriate for providing the highest level of service at the lowest possible cost while minimising the impact of charging on the grid [10]. Kandasamy and others [11] have investigated the death of a storage battery used with the solar PV array technology installed on commercial buildings. Due to its availability both during the day and at night, the wind energy powered CS is also advantageous for EVs. Numerous papers have been made in this area [12]–[14].

Due to the enormous quantity of energy stored in EV batteries, EVs are now employed as a distributed energy resource for offering numerous ancillary services. A PV array-based CS for providing charging capabilities coupled with vehicle-to-grid reactive/active power, active power filtering, and vehicle-to-home has been presented by Singh et al. [15]. A grid-tied PV array system has been put in place by Saxena et al. [16] for use in residential and EV applications. A home integrated PV-storage battery system with multi-mode control has been presented by Razmi et al. [17] for both grid-connected and islanded operation. Kusto et al. [18] and Erdinc et al. In order to provide the vehicle-to-home and vehicle-to-grid operation for the advantage of both the utility and the consumer, [19], Hafiz et al. [20] have provided the smart household operation where EV can be employed as a store.

According to a thorough analysis of the reviewed literature, research on renewable energy-based charging stations has largely focused on optimising various aspects of charging, including the size of the renewable energy sources, the size of the storage unit, driving patterns of the vehicles, the time it takes to charge, the cost of charging, the scheduling of charging, etc. However, yet, only a small number of publications have actually put the charging station using renewable energy into practise. Furthermore, there is less discussion of how well charging stations operate in actual use.

Additionally, most of the literature only discusses the performance of CS in either grid connected mode or islanded mode. The solar PV panel, even if the sun (solar irradiance) is present, is rendered useless if the grid is unavailable due to the single mode of operation in grid linked mode. Like this, intermittent solar irradiation causes problems for PV electricity in island mode. As a result, a storage battery is necessary to reduce the impact of fluctuating solar irradiation. To prevent the storage battery from being overcharged, the maximum power point tracking (MPPT) must be turned off after the storage battery is fully charged.

In order to make the most of the PV array energy under all operating conditions, a grid, energy storage, and DG set supported CS is provided in this work. This CS can run in islanded, grid-connected, and DG set-connected modes.

There has been discussion of both islanded and grid connected models in several papers [15]. These two modes are handled separately, though, and there is no automatic mode switching available. Therefore, the PV array power must be disconnected and the EV cannot continue to charge without the ability for automatic mode switching. In order to make the controller automatically transition between various operating modes depending on the PV array's power generation and the demand for EV charging, an automatic mode switching logic is provided in this work.

Storage battery with PV array is utilised for continuous and dependable functioning of CS due to the PV array's intermittent nature and lack of availability at night. However, it is not feasible to offer backup constantly due to the storage battery's constrained capacity. As a result, if PV array electricity is unavailable and energy storage is also drained, the CS need grid support.

However, because to the restricted grid availability, particularly in the DG set might be necessary in isolated places to preserve the charging's consistency. The DG set performance, though, It is not used to its maximum potential and is impacted by the sort of loading. DG sets are often built to handle very little harmonic current in the load [21]. As a result, the performance of DG sets is significantly impacted by EV charging because harmonic currents are present in EV current, which is caused by the fact that EV chargers often utilise rectifiers, followed by power factor correction circuits and DC-DC converters for step-down. However, in this study, the DG set is always loaded to at least 80% of its rated value since the voltage source converter (VSC) supplies the harmonics and reactive current needed by the EV charger.

The following are the paper's main contributions.

- Grid-integrated CS, which continuously supports both DC and AC charging of EVs, was supported by the design and experimental validation of the PV array, energy storage, and DG set.
- The creation of a unified controller that allows the charging station to function in islanded, grid-connected, and DG set-connected modes with only a single VSC and no hardware modifications.
- Design of a mode switching algorithm that allows the charging station to seamlessly shift modes in order to provide continuous charging.
- Control strategy design for vehicle-to-vehicle (V2V) power transfer for EV charging and vehicle-to-grid (V2G) power transfer for grid support.
- The charging station operates with an active power filter to reduce harmonic grid currents and ensure that the power exchange occurs at unity power factor. This is necessary for the charging station to adhere to the IEEE-519 standard.
- DG set frequency and voltage regulation method without a mechanical automated voltage regulator.
- To prevent the storage battery from being overcharged, a plan is in place to feed any extra power generated by the PV array into the grid.

II. SYSTEM DESCRIPTION

The proposed charging station, as depicted in Fig. 1, uses a solar PV array, a storage battery, a DG set, and grid energy to power the load linked to the charging station as well as to charge the electric vehicle. Through a boost converter, the solar PV array is connected to the DC link of the voltage source converter (VSC), and the storage battery is connected directly to the DC link. On the AC side of the VSC, a coupling inductor connects the grid, a single-phase SEIG (Self Excited Induction Generator), an EV, and a nonlinear load. At PCC, a ripple filter is utilised to transform the grid and generator currents from switching harmonics to sinusoidal currents. The auxiliary winding of the SEIG is coupled to an excitation capacitor. Additionally, a tiny capacitor is linked across the SEIG's main winding. For controlled connection and separation of the charging station from the grid and DG set, a synchronising switch is employed between the grid/DG set and PCC.

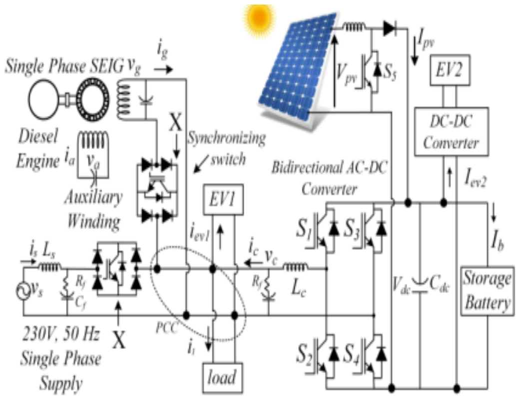

Fig. 1 Topology of charging station

III. CONTROL STRATEGIES

Here, various control techniques utilised in the CS are covered.

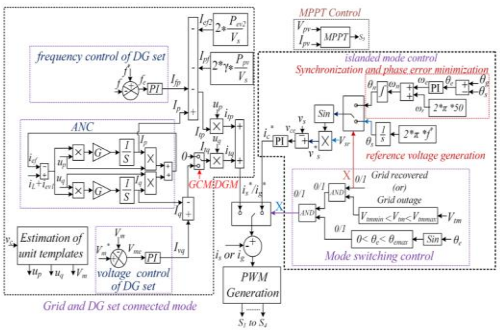

Fig.2 Unified control of VSC for standalone and grid and DG set connected mode

A. Control of VSC in Islanded Mode (Absence of DG Set and Grid)

The CS's islanded control guarantees its steady functioning in the absence of the grid, preserving both the AC and DC charging of EVs as well as the uninterrupted production of solar electricity. The storage battery can control the DC charging and solar PV generating with little change to the control. However, as there is no voltage reference accessible without the grid, the AC charging requires a separate controller for VSC that generates the local voltage reference. Because of this, the islanded controller produces an internal voltage reference of 230 V and 50 Hz in accordance with the logic shown in Fig. 2, which incorporates frequency and passes through sin to produce the reference voltage. After minimising voltage error with a proportional integral (PI) controller, the generated reference is compared to the converter's terminal voltage to determine the reference converter current. It is possible to express the error minimization and reference current generation as,

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

The gate signals of the converter are produced by the reference current after it has been compared to the measured converter current and after going through the hysteresis controller.

B. Control of VSC in DG Set or Grid Connected Mode

In grid connected mode, it is up to the controller to choose how much electricity will be traded with the grid. In linked mode, the DG set runs in constant power mode to maximise fuel efficiency. But in both situations, the controller must make up for the harmonic and reactive current demands of the EVs. To do this, it estimates the reference current of the grid or DG set using the EV current. When an EV is connected to the grid, the reference current is calculated only using its active current. However, in DG set connected mode, both the reactive and active currents of the EV are used to determine the reference DG set current. The fundamental frequency current of the EV is extracted in this study using an adaptive notch cancellation (ANC) [22]. The fundamental current at each zero crossing of the quadrature and in-phase unit templates further with the sample and hold logic yields the active and reactive current, respectively.

Currently, the total active and reactive currents when linked to the grid are as follows:

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

To achieve unity power factor functioning in grid connected mode, only the active current of an EV is considered, and the reactive current is taken into account as zero. However, both the active and reactive current components of the EV are used when the DG set is attached.

Currently, the total active and reactive current for the connected DG set is as follows:

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

Where Ief2 and Ipf are the feed-forward terms of the EV2 and the PV array, and Ip and Iq are the active and reactive currents of the EV, respectively. The names for the voltage and frequency regulators used in the DG set connected mode are Ifp and Ivq. The EV's power transfer from the car to the grid is controlled by Ief2. The grid-connected PV array feed-forward term, or Ipf, regulates the storage battery's overcharging. The storage battery cannot be charged in CC/CV mode since the energy storage is directly interfaced to the DC link. But it is possible to guarantee that the storage battery will never be overcharged. In a grid-connected setting, overcharging of the storage battery is prevented by supplying the grid with solar PV electricity. As illustrated in Fig. 2, this is accomplished by including the solar PV array feed-forward term in the grid linked mode control. The feed-forward term is multiplied by a variable gain, "," which determines the proportion of PV array electricity fed into the grid. Constant "" has a range of 0 to 1, which is determined by the storage battery's SOC data. Therefore, the " takes the value of '1' if the storage battery is fully charged. The " becomes '0' if the storage battery is completely discharged.

Finally, the grid or DG set's estimated reference current is as follows:

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

where the synchronising signals for the grid voltage (vg or vs) or the DG set are up and qp. The switching signals are produced using a hysteresis controller employing the detected and reference currents of the grid/DG set, as shown in Fig. 2.

C. DG Set Control for Voltage and Frequency

The frequency and voltage of the DG set are controlled via decoupled control of VSC to operate at a single point. Reactive power controls the voltage in a decoupled control system whereas active power controls the frequency. Therefore, voltage and frequency regulation are handled by two PI controllers. The voltage regulation PI control is given as,

$$I_{vq}(s) = I_{vq}(s-1) + z_{vp}\{V_{me}(s) - V_{me}(s-1)\} + z_{vi}V_{me}(s) \quad (5)$$

Where zvi and zvp are the PI controller gains and Vme=Vm * -Vm.

Similarly, the frequency PI controller's differentiated expression is as follows:

$$I_{fp}(s) = I_{fp}(s-1) + z_{fp}\{f_e(s) - f_e(s-1)\} + z_{fi}f_e(s) \quad (6)$$

Where zkfp and zfi are PI gains and fe is the frequency error.

In grid-connected control, the outputs of the frequency and voltage controllers are combined as depicted in Fig. 2. However, because the grid's voltage and frequency are still regulated when it is linked to the grid, these controllers' outputs become zero in this mode.

D. Control of EV2

The constant current/constant voltage (CC/CV) control method is used to regulate an electric vehicle (EV) connected via a DC-DC converter. The EV charges in CC mode up to the terminal voltage of the battery reaches the voltage corresponding to the full charge condition. However, the charging of the EVs is switched to CV mode once it has approximately reached the appropriate terminal voltage in a nearly full charge condition. Here, two PI controllers are used to regulate the CC/CV manner of charging, as seen in Fig. 3. For the current control step, the outside voltage loop provides a reference current.

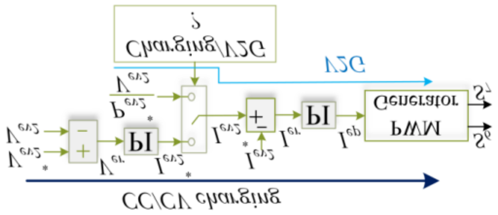

Fig. 3 EV2 control for CC/CV charging and V2G power transfer

The expected reference charging current is,

$$I^*_{ev2}(s) = I^*_{ev2}(s-1) + z_{evp}\{V_{er}(s) - V_{er}(s-1)\} + z_{evi}V_{er}(s) \qquad (7)$$

Where Zevp and Zevi are the controller gains and Ver is the EV battery voltage error. The PI controller and PWM generator are used to derive the switching signals for the converter using the reference and detected battery currents. The PI controller for calculating duty cycle is written as,

$$d_{ev}(s) = d_{ev}(s-1) + z_{ep}\{I_{er}(s) - I_{er}(s-1)\} + z_{ei}I_{er}(s) \qquad (8)$$

where zep and zei are the controller gains and Ier is the battery current error.

The EV2 battery is depleted for the V2G power transfer based on the reference power, and the controller follows the deviated path as depicted in Fig. 3. In Fig. 3, the reference power regulates the EV2 feed-forward term.

E. Synchronization and Switching Control

The design of a mode-changing strategy is required because the charging station operates in a variety of modes depending on the generation and charging demand, ensuring a smooth transition from one mode to the next and uninterrupted charging. These situations include islanded to grid connected and islanded to DG set connected modes, for which the mode switching logic is created. In this method, the controller first determines the phase difference between the two voltages before bringing them into phase for synchronisation. The logic depicted in Fig. 2 is used by the PI controller to do this by altering the frequency of the VSC produced voltage in an islanded condition. The phase minimization PI controller is stated as,

$$\Delta\omega(s) = \Delta\omega(s-1) + z_{pa}\{\Delta\theta(s) - \Delta\theta(s-1)\} + z_{ia}\Delta\theta(s)$$

where is the phase difference and zpa and zia are the tuning settings for the controller. The conditions under which the CS functions in islanded mode and under which a mode shift must be made are also shown in Fig. 2. The control logic generates the enabling signal X='1' for the synchronising switch after all synchronisation requirements are met.

IV. RESULTSAND DISCUSSION

Simulated and actual results are used to discuss the CS's performance.

A. Simulation Results

Figure 4's simulation results demonstrate the CS's uninterrupted operation. The CS is initially running in islanded mode, and power from the PV array is provided to charge the EVs connected to the PCC. The excess generation is kept in the energy storage since the PV array's generation is more than the demand for charging EVs. The sun irradiation decreases from 1000 W/m2 to 300 W/m2 in 0.32 seconds. As a result, the PV array's output drops, and the storage battery begins to discharge in order to maintain uninterrupted charging. The storage battery empties at 0.48 seconds as the PV array's power is reduced to zero. After that, if SOC > SOCmin, the storage battery fully enables charging. The controller synchronises the CS with the grid after the battery has been completely discharged.

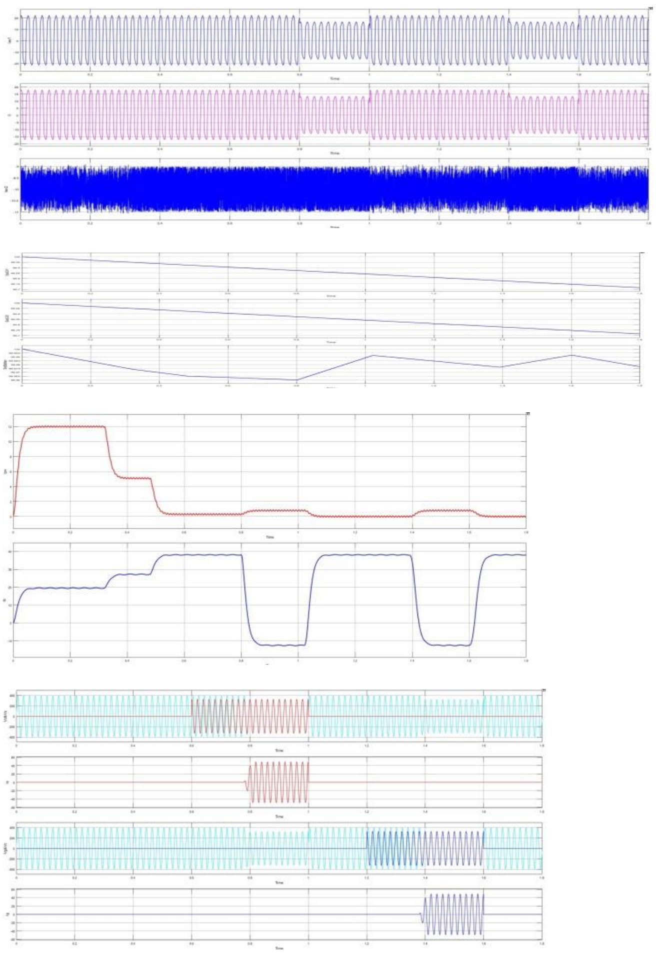

Fig. 4 Simulation results showing the different modes of operation

The CS began utilising grid electricity at 0.79s. Due to the lack of grid and storage battery power after this, CS is supported by the DG set as indicated in Fig. 4. According to Fig. 4, the charging station changes its modes automatically based on the generation and demand.

V. CONCLUSION

For EV charging, a charging station built on a grid, DG set, storage battery, and PV array has been realised. It has been given demonstrate that the CS can operate in multiple modes while utilising just one VSC, including island operation, grid connectivity, and DG set connectivity. Test findings have also confirmed the charging station's successful performance under a variety of steady-state settings and dynamic situations brought on by variations in solar irradiation level, EV charging current, and loading. The data shown below have confirmed that the charging station operates as a stand-alone generator with good voltage quality. The ability of the ANC-based control algorithm to maintain the power exchange with the grid at UPF or the optimal loading of the DG set has been demonstrated by test results in DG set or grid linked mode. Additionally, the probability of MPP functioning of the PV array and optimal loading of the DG set as well as boosting the charging dependability have been made possible by islanded operation, grid connected and DG set connected operations, coupled with the automatic mode switching. The charging station's performance in accordance with IEEE standards, with voltage and current THD always less than 5%, attests to the efficiency of the control. From the statement, it can be inferred that this charging station, with the control that is now being used, has the capacity to utilise multiple energy sources very well while providing the EVs with steady and affordable charging.

REFERENCES

[1] International Energy Agency-Global EV Outlook 2018- Towards cross modal electrification. [Online] Available: https://webstore.iea.org /download/direct/1045?fileName=Global_EV_Outlook_2018.pdf

[2] International Energy Agency- Renewables 2O18 - Analysis and Forecasts to 2O23 [Online]. Available: https://webstore.iea.org/ download/summary/2312?fileName=English-Renewables-2018ES.pdf.

[3] J. Grimier and Z. J. Haas, "Optimal Capacity Sizing for Completely Green Charging Systems for Electric Vehicles," IEEE Trans. Transportation. Electrificat.vol. 3, no. 3, pp. 565-577, Sept. 2017.

[4] G. R. Chandra Mouli, J. Schieffelin, M. van den Heuvel, M. Karolos and P. Bauer, "A 10 kW Solar-Powered Bidirectional EV Charger Compatible with CHAdeMO and COMBO," IEEE Trans, Power Electron., vol. 34, no. 2, pp. 1082-1098, Feb. 2019.

[5] V. Monteiro, J. G. Pinto, and J. L. Afonso, "Experimental Validation of a Three-Port Integrated Topology to Interface Electric Vehicles and Renewables with the Electrical Grid," IEEE Trans. Ind. Informant., vol. 14, no. 6, pp. 2364-2374, June 2018.

[6] S. A. Singh, G. Carli, N. A. Azeez and S. S. Williamson, "Modelling, Design, Control, and Implementation of a Modified Z-Source Integrated PV/Grid/EV DC Charger/Inverter," IEEE Trans. Ind. Electron., vol. 65, no. 6, pp. 5213-5220, June 2018.

[7] K. Chaudhari, A. Ukil, K. N. Kumar, U. Manandhar, and S. K. Columella, "Hybrid Optimization for Economic Deployment of ESS in PV-Integrated EV Charging Stations," IEEE Trans. Ind. Informant., vol. 14, no. 1, pp. 106-116, Jan. 2018.

[8] F. Keavy and M. Duffy, "Modelling and design of electric vehicle charging systems that include on-site renewable energy sources," in IEEE 5 the Int. Symp. Power Electron. For Distributed Gene. Syst. (PEDG), Galway, 2014, pp. 1-8.

[9] Y. Zhang, P. You and L. Cai, "Optimal Charging Scheduling by Pricing for EV Charging Station with Dual Charging Modes," IEEE Trans. Intelligent Transportation. Syst., vol. 20, no. 9, pp. 3386-3396, Sept. 2019.

[10] Y. Yang, Q. Jia, G. Deconinck, X. Guan, Z. Qiu and Z. Hu, "Distributed Coordination of EV Charging with Renewable Energy in a Microgrid of Buildings," IEEE Trans. Smart Grid, vol. 9, no. 6, pp. 6253-6264, Nov. 2018.

[11] N. K. Kandasamy, 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, vol. 7, no. 3, pp. 223-229, 9 2017.

[12] A. Tavakoli, M. Magnitsky, D. T. Nguyen and K. M. Muttaqi, "Energy Exchange Between Electric Vehicle Load and Wind Generating Utilities," IEEE Trans. Power Sys., vol. 31, no. 2, pp. 1248-1258, 2016.

[13] Y. Shan, J. Hu, K. W. Chan, Q. Fu and J. M. Guerrero, "Model Predictive Control of Bidirectional DC-DC Converters and AC/DC Interlinking Converters - A New Control Method for PV-Wind-Battery Microgrids," IEEE Trans. Sustain. Energy, Early Access.

[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 Gene., Trans. & District., vol. 12, no. 15, pp. 3655-3665, 28 8 2018.

[15] B. Singh, A. Verma, A. Chandra, and K. Al-Haddad, "Implementation of Solar PV-Battery and Diesel Generator Based Electric Vehicle Charging

Station," in IEEE Int. Conf. Power Electronics, Drives and Energy Systems (PEDES), Chennai, India, 2018, pp. 1-6.

[16] N. Saxena, B. Singh and A. L. Vyas, "Integration of solar photovoltaic with battery to single-phase grid," IET Generation, Transmission & Distribution, vol. 11, no. 8, pp. 2003-2012, 1 6 2017.

[17] H. Razmi and H. Doagou-Mojarrad, "Comparative assessment of two different mode's multi-objective optimal power management of micro grid: grid-connected and stand-alone," IET Renewable Power Generation, vol. 13, no. 6, pp. 802-815, 2019.

[18] O. Erdinc, N. G. Paterakis, T. D. P. Mendes, A. G. Bakirtzis and J. P. S. Catalo, "Smart Household Operation Considering Bi-Directional EV and ESS Utilization by Real-Time Pricing-Based DR," IEEE Trans. Smart Grid, vol. 6, no. 3, pp. 1281-1291, May 2015.

[19] H. Kusto, K. Mori, S. Yoshizawa, Yu Fujimoto, H. Asano, Y. Hayashi, A. Kawashima, S. Inagaki, T. Suzuki, "Electric Vehicle Charge-Discharge Management for Utilization of Photovoltaic by Coordination between Home and Grid Energy Management Systems," IEEE Trans. Smart Grid, Early Access.

[20] F. Hafiz, A. R. de Queiroz and I. Husain, "Coordinated Control of PEV and PV-based Storages in Residential System under Generation and Load Uncertainties," IEEE Trans. Ind. Applica., Early Access.

[21] R. W. Wies, 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 Trans. Power Systems, vol. 20, no. 2, pp. 692-700, May 2005.

[22] R. R. Chipili, N. Al Sayari, A. R. Beig, and K. Al Hossain, "A Multitasking Control Algorithm for Grid-Connected Inverters in Distributed Generation Applications Using Adaptive Noise Cancellation Filters," IEEE Trans. Energy Conversion, vol. 31, no. 2, pp. 714-727, June 2016.