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

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Abstract- A solar PV (Photovoltaic) array, a battery energy storage (BES), a diesel generator (DG) set, and grid-based energy storage are all discussed in this study.The EV charging station (CS) is used to offer the constant supply of electricity.Charging modes include islanded, grid connected, and DG set connected.The charging station is primarily intended for solar power.To charge the electric vehicle, a solar PV array and a BES are used.(Electric vehicle) battery However, if the storage battery is depleted and charging station, solar PV array generation not available smartly utilises grid or DG power (Diesel Generator) set. However, the DG set's power is extracted in such a way that to ensure maximum fuel efficiency, always operate at 80-85% loading efficiency in any loading situation. Furthermore, without using a mechanical speed regulator, the charging station manages the generator voltage and frequency in conjunction with the storage battery. Even during nonlinear loads, it assures that the power drawn from the grid or the DG set is at unity power factor (UPF). Furthermore, to provide continuous charging, the PCC (Point of Common Coupling) voltage is synchronised to the grid/generator voltage. For increased charging station operational efficiency, the charging station also performs vehicle to grid active/reactive power transfer, vehicle to house, and vehicle to vehicle power transfer. The charging station's operation is experimentally tested using a prototype created in the lab.
EV Charging Station, Solar PV Generation, Power Quality, DG Set are all index terms.

I.INTTORDUCTION:

Electric vehicles (EVs) are now considered one of the most efficient ways of transportation due to their zero tailpipe emissions. Given the benefits of electric vehicles, 3 million vehicles have been placed on the road, with the number predicted to reach 100 million by 2030 [1]. However, the suggested plan's implementation will necessitate massive charging infrastructure and massive amounts of electricity. Furthermore, electric vehicles can only be sustainable if the electrical energy used to charge them comes from renewable and sustainable sources. However, using fossil fuels to generate electricity does not lower emissions; it only shifts them from vehicles to power plants. As a result, using renewable energy sources to generate power can entirely eliminate emissions while also benefiting the environment. Solar PV arrays, wind energy, hydro energy, and fuel cell based energy are among the numerous renewable energy sources accessible. Solar PV based generation is the most feasible alternative for EV charging because it is available almost everywhere, regardless of whether the place is rural or urban [2]. In terms of the Indian subcontinent, it is available virtually all year. The wind and hydro energy, unlike the solar PV array, are place specific. Wind energy is most effective in coastal areas, while hydro energy is most useful in highland areas. Though renewable energy-based charging stations are the most cost-effective alternative for EV charging, their integration into an existing charging system adds a power conversion stage, increasing the system's complexity and power loss. Furthermore, each conversion stage has its own controller, which must be linked with the present system. As a result, designing an integrated system with multifunctional and multimode operating capacity is critical, requiring unified control and coordination across the many sources.

Many efforts have been made to design a charging station that uses renewable energy. The necessity of renewable energy for the long-term viability of an EV charging station was explored by Ugirumurera et al. [3]. Mouli and colleagues[4] have used solar power to charge electric vehicles using a high-power bidirectional EV charger. The designed charger, however, does not support AC charging. Monterio et al. [5] proposed a three-port converter for merging a PV array with an electric vehicle charger. The designed charger, on the other hand, does not account for the charger's current distortions in the grid current. For the construction of a PV array/grid connected EV charger, Singh et al. [6] developed a modified z-source converter. The charger, on the other hand, is not intended for use in the islanded mode. Zhang et al. [9] investigated the best time to set up an EV charging station in the office with dual charging modes. The PV array-powered charging station (CS) is also appropriate for onsite placement for the best quality of service at the lowest cost while minimising charging grid effect [10]. The loss of life of a storage battery utilised with a commercial building-based solar PV array system was explored by Kandasamy et al. [11]. Due to its availability both during the day and at night, wind energy-powered CS is also advantageous for EV, and many papers are available in this area [12]-[14]. Due to the large quantity of energy stored in EV batteries, they are currently employed as a distributed energy resource for offering numerous ancillary services. Singh et al. [15] proposed a PV array-based CS for charging, as well as vehicle-to-grid reactive/active power, active power filtering, and vehicle-to-home. Saxena et al. [16] developed a grid-connected PV array system for EV and household use. Razmi et al. [17] proposed a grid-connected and islanded power management technique for an integrated residential PV-storage battery system with multi-mode control. Kikusato et al. [18] and Erdinc et al. 19], Hafiz et al. [20] have described a smart household operation in which an electric vehicle (EV) can be employed as a storage device to provide vehicle-to-home and vehicle-to-grid services for the benefit of both the utility and the consumer.

According to a thorough review of the literature, work in the field of renewable energy based charging stations is primarily focused on optimising various aspects of charging, such as the size of renewable energy sources, storage unit size, vehicle driving pattern, charging time, charging cost, charging scheduling, and so on. However, few publications have really constructed the charging station using renewable energy sources in the current scenario. Furthermore, the performance of charging stations in real-world situations is rarely discussed.

Furthermore, most of the research only discusses the performance of CS in either grid connected or islanded mode. The solar PV panel, however, becomes unusable if the grid is unavailable, even if the sun (solar irradiance) is accessible, due to the single mode of operation in grid linked mode. Similarly, the intermittency of solar irradiance disrupts PV power in islanded mode. As a result, a storage battery is required to counteract the effects of changing solar irradiation. To avoid overcharging the storage battery, the maximum power point tracking (MPPT) must be disabled when the storage battery is fully charged.

As a result, a PV array, grid, energy storage, and DG set supported CS is provided in this work, which runs in islanded, grid connected, and DG set connected modes to maximise PV array energy utilisation in all operational scenarios. Both islanded and grid linked models have been considered in several papers [15]. These two modes, however, are regulated separately, and there is no automatic mode switching between them. As a result, without automatic mode switching capability, PV array electricity would be halted, and EV charging will be interrupted. As a result, an automatic mode 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 charging needs of the EV. Storage battery with PV array is utilised for continuous and dependable operation of CS due to unavailability at night and the intermittent nature of the PV array. However, due to the storage battery's low storage capacity, it is difficult to provide continuous backup. As a result, the CS need grid backup in the event that PV array electricity is unavailable, and energy storage is also depleted.

However, because to restricted grid availability, particularly in remote places, the DG set may be required to provide charging continuity. However, the type of loading affects the DG set's performance, and it is not used to its maximum potential. DG sets are often built for a small degree of harmonics in the load current [21]. Because the EV charger normally employs a rectifier followed by a power factor correction circuit and a DC-DC converter for step down, the DG set performance is adversely impacted by EV charging due to the presence of harmonics in the EV current. The DG set is always loaded to at least 80% of its rated value in this study since the voltage source converter provides the harmonics and reactive current required by the EV charger (VSC).

The following are the significant contributions made in this study.

• Grid-integrated CS, which enables both DC and AC charging of EVs, was designed and experimentally validated using a PV array, energy storage, and DG set.

• Development of a unified controller that allows the charging station to function in islanded, grid-connected, and

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DG set-connected modes with only one VSC and no hardware changes.

• Design of a mode switching logic that allows the charging station to seamlessly transition modes to provide continuous charging.

• Development of a control strategy for vehicle-to-vehicle (V2V) and vehicle-to-grid (V2G) power transfer for EV charging and grid support.

• The charging station's active power filter operation mitigates grid current harmonics, allowing for power exchange at unity power factor. This is required for the charging station to comply with the IEEE-519 standard.

• Without a mechanical automatic voltage regulator, a strategy for regulating the frequency and voltage of a DG set.

• Strategy to avoid overcharging the storage battery by feeding excess PV array generated power onto the grid.

II.SYSTEM DESCRIPTION

As shown in Fig. 1, the charging station uses a solar PV array, a storage battery, a DG set, and grid electricity .charge the electric vehicle and feed the charging load station. The solar PV array is connected to a DC power link. through a boost converter and a storage converter (VSC).The battery is directly connected to the DC link. The grid is a single-phase system. An EV, an SEIG (Self Excited Induction Generator), and On the AC side of VSC, a nonlinear load is coupled through a Inductor for coupling At PCC, a ripple filter is employed to reduce the grid switching harmonics and the generator current and to sinusoidalize these currents A capacitor for excitation is linked to an auxiliary of the SEIG. A tiny capacitor is also attached to the SEIG's primary winding. For regulated connection/disconnection of charging station to grid/DG set, a synchronising switch is employed between grid/DG set and PCC.

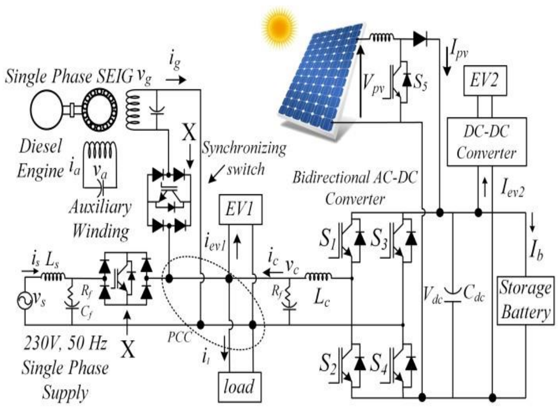

Fig-1:Topology of Charging Station

III.CONTROL STRATEGIES:

Various control strategies are discussed here

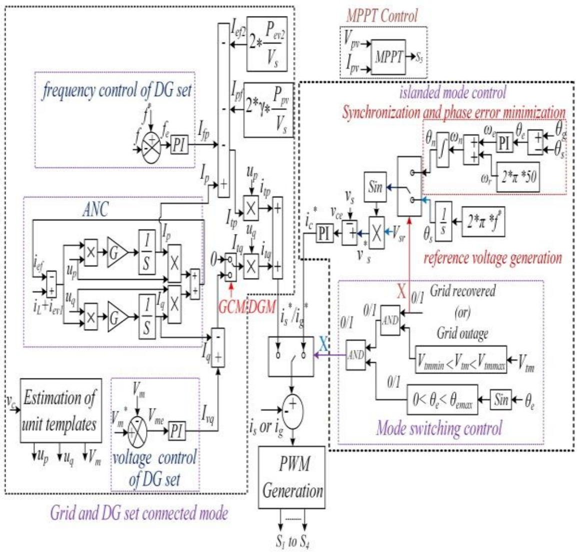

Fig. 2 :Unified control of VSC for standalone and grid and DG set connected mode

A. VSC Control in Islanded Mode (Without DG Set and Grid):

The islanded control of the CS provides reliable functioning of the CS in the absence of the grid, which means that EV charging (both AC and DC) and solar power generation remain uninterrupted. The storage battery can manage DC charging and solar PV generating without requiring significant management changes. However, because there is no voltage reference in the absence of the grid, AC charging requires a separate controller for VSC, which generates the local voltage reference. As a result, the islanded controller provides a 230V and 50 Hz internal voltage reference using the circuitry shown in Fig. 2, which integrates the frequency and passes it through the sin to generate the reference voltage. After minimising voltage error with a proportional integral (PI) controller, the resulting reference is compared to the converter's terminal voltage, yielding the reference converter current. The error minimization and creation of reference current are represented as

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

The gate signals of the converter are generated by comparing the reference current to the measured converter current and then sending it through the hysteresis controller.

B. DG Set or Grid Connected Mode VSC Control:

The controller's job in grid linked mode is to decide how much power to send to the grid. The DG set operates in constant power mode in connected mode to achieve maximum fuel efficiency. In all scenarios, however, the controller must correct for the EVs' harmonic and reactive current demands, which is done by estimating the grid's reference current or the DG set from the EV current. Only the active current of the EV current is used to estimate the reference current under grid connected conditions.

In DG set connected mode, however, the reference DG set current is calculated using both the EV's reactive and active currents. An adaptive notch cancellation (ANC) [22] is used to extract the EV's fundamental frequency current in this study. The active and reactive currents are determined by the fundamental current at every zero crossing of quadrature and in-phase unit template, respectively, using the sample and hold logic. In grid connected mode, the total active and reactive currents are now as follows:

$I_{SP=}I_p$-I_{ef2}-I_{PF}--------------------(2)

I_{sq}=0

Only the active current of the EV is evaluated in grid connected mode, and the reactive current is set to zero to achieve unity power factor functioning. Both active and reactive current components of EV are utilised in DG set connected mode. In the DG set connected mode, the total active and reactive current is now as follows:

$I_{sp}=I_P-I_{ef2}-I_{fp}-I_{PF}$-----------------(3)

$I_{sq=}$Ivq-Iq.

Ief2 and Ipf are the feed-forward terms of the EV2 and the PV array, respectively, and Ip and Iq are the active and reactive currents of EV. In the DG set connected mode, the terms Ifp and Ivq refer to frequency and voltage regulators. Ief2 manages the EV's power transfer from the car to the grid. In grid-connected mode, Ipf is the PV array feed-forward term that prevents the storage battery from overcharging. The storage battery cannot be charged in CC/CV mode since the energy storage is connected directly to the DC link. However, the storage battery should never be overcharged. In grid Overcharging of the storage battery is prevented in the connected state by feeding solar PV generated power into the grid.

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 additionally multiplied by a variable gain, which determines the percentage of PV array electricity sent into the grid.

The SOC information of the storage battery determines the constant '', which ranges from 0-1. As a result, if the storage battery is fully charged, the value of is '1'.

on the other hand, becomes '0' when the storage battery is completely depleted.

Finally, the predicted grid or DG set reference current is as follows:

$I_g^*=I_{tp}*U_{P+}\ I_{tp*}U_q$--------------------------------(4)

The synchronisation signals of the DG set or grid voltage are up and qp (vg or vs). The switching signals are created utilising a hysteresis controller and the sensed and reference currents of the grid/DG set, as shown in Fig. 2.

C. DG Set Voltage and Frequency Control

The frequency and voltage of the DG set are regulated utilising decoupled VSC control for single-point operation. The frequency is controlled by active power, whereas the voltage is controlled by reactive power in decoupled control. For voltage and frequency regulation, two PI controllers are employed. The voltage regulation PI control is given as

$I_{vq}(s)= I_{vq}(s--1)+Z_{VP}\{V_{me}(s)-V_{me}(s-1)\}+Z_{vi}V_{me}(s)$--------------(5)

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

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

Where fe stands for frequency error and zkfp and zfi stand for PI gains.

In grid connected control, the outputs of the frequency and voltage controllers are combined as indicated in Fig. 2. In grid connected mode, however, the outputs of these controllers become zero because the grid voltage and frequency remain regulated is given as,

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

D. Constant current/constant voltage (CC/CV) control of EV2:

EV connected at DC link through a DC-DC converter. The EV charges in CC mode until the terminal voltage of the EV battery reaches the voltage corresponding to the full charge condition. The charging of the EVs is transferred to CV mode after achieving near the necessary terminal voltage in almost full charge condition. As illustrated in Fig. 3, the CC/CV charging mode is controlled by two PI controllers. The reference current for the current control stage comes from the outside voltage loop.

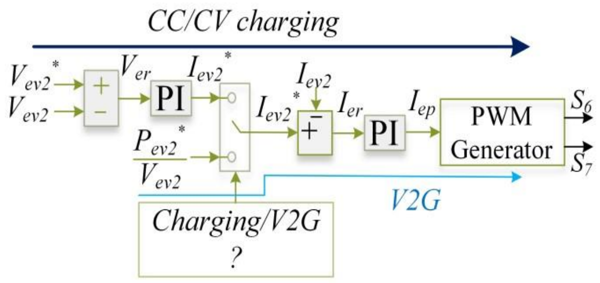

Fig. 3: EV2 control for CC/CV charging and V2G power transfer

The expected reference charging current is

$I_{ev2}^{*}(s)=I_{ev2}^{*}(s-1)+Z_{evp}\{V_{er}(s)-V_{er}(s-1)+Z_{evi}\,V_{er}(s)$--------------(7)

The EV battery voltage error is Ver, and the controller gains are zevp and zevi.

Using the PI controller and PWM generator, the switching signals of the converter are calculated using the reference and detected battery currents. For duty cycle calculation, the PI controller is written as

$D_{ev}(s)=D_{ev}(s-1)+Z_{ep}\{I_{er}(s)-I_{er}(s-1)+Z_{ei}I_{er}(s)$---------------------(8)

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

The EV2 battery is depleted on the basis of the reference power for the V2G power transfer, and the controller chooses the alternate path depicted in Fig. 3. The EV2 feed-forward term in Fig. 3 is controlled by the reference power.

E. Controlling Synchronization and Switching:

Because the charging station operates in multiple modes depending on the generation and charging demand, a mode switching strategy must be designed so that the transition from one mode to another is smooth and the charging continues uninterrupted. The mode switching logic is designed for such scenarios as islanded to grid connected and islanded to DG set connected modes. In this technique, the phase difference between the two voltages is first determined, and then the controller brings the two voltages into phase for synchronisation. Using the logic depicted in Fig. 2, the PI controller modulates the frequency of the VSC generated voltage in islanded situation. The phase minimization PI controller is given as

$W(S)=W(S-1)+Z_{pa}\{\alpha(s)-\alpha(s-1)\}+Z_{ia}\alpha(s)$----------------------(9)

Where zpa and zia are controller tuning parameters, and is phase difference.

Figure 2 also depicts the situations under which the CS functions in islanded mode and when the mode switch is required. The control logic creates the enabling signal X='1' for the synchronising switch after all of the synchronisation requirements are met.

IV.RESULTS AND DISCUSSSION:

Both simulation and experimental results are used to discuss the CS's performance.

A. Simulation Outcomes:

The uninterruptible operation of the CS is demonstrated by simulation results in Figure 4. The CS is initially in islanded mode, with the PV array power being used to charge the EVs connected to the PCC. The surplus generation is stored in the energy storage because the PV array generation exceeds the EV charging needs. The sun irradiation drops from 1000 W/m2 to 300 W/m2 in 0.32s. As a result, the PV array output decreases, and the storage battery begins to discharge in order to maintain uninterrupted charging. The storage battery empties at 0.48s, and the PV array power 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 synchronises the CS and connects it to the grid. The CS began taking power from the grid at 0.79s. Because grid and storage battery power are unavailable at this point, CS is provided by the DG set, as shown in Fig. 4. Figure 4 shows how the charging station changes modes automatically based on generation and demand.

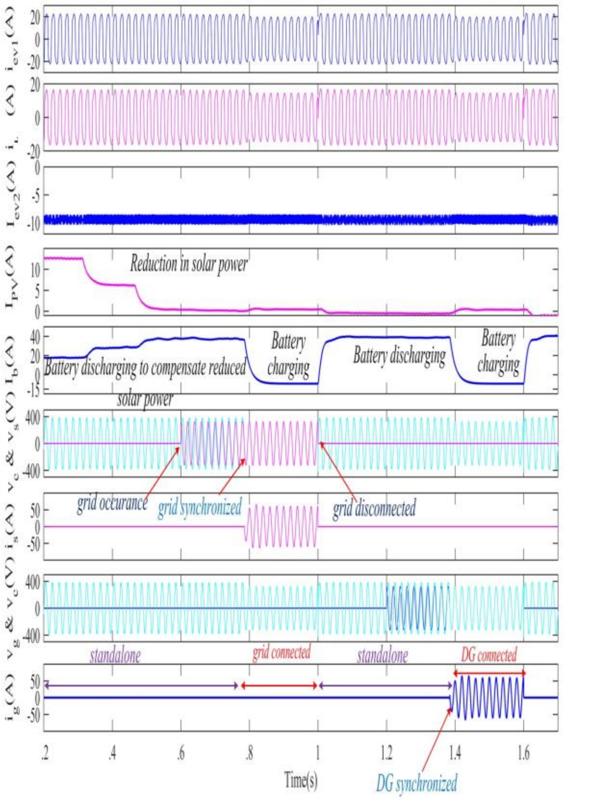

Fig. 4 :Simulation results showing the different modes of operation

B. Experimentation Findings:

Figure 5 shows an image of the laboratory's produced experimental setup. Figs. 6-12 show the charging station's test results. A solar PV simulator (TerraSAS) is employed as a solar PV array in the hardware implementation. . As energy storage, a 360V 14Ah lead-acid battery is employed. A diode bridge rectifier is used to realise a nonlinear load connected at PCC, followed by a resistive and inductive load on the DC side of the rectifier. An EV, on the other hand, is connected to PCC via the charger. As a diesel engine driven generator, a 3.7 kW single phase, two winding SEIG is employed. To create the rated voltage across the main winding at no-load, a 144F excitation capacitor is attached across the auxiliary winding of the SEIG. The DG set's prime mover is a 7.5kW SCIM (Squirrel Cage Induction Motor) powered via variable frequency drive. The digital controller is used to implement the CS station's control algorithm. (dSPACE-1006).

I. Performance in a Stable State Operating Environment:

The CS performance under steady-state conditions certifies the charging's capacity to maintain power balance and power quality. The steady state results are reviewed for three cases: (1) islanded mode: EV charging utilising solar PV array, (2) grid connected charging, and (3) DG set linked charging, because the charging station operates in many modes depending on power supply and charging demand.

1) Grid-Connected Electric Vehicle Charging (Unavailable PV Array Power):

Even if the load connected at PCC is nonlinear, the power drawn from the grid is at UPF in grid connected mode, as shown in Figs. 6 (a), 6 (b) (b). VSC meets the nonlinear load's harmonic current need, as seen in Fig. 6. (e). As demonstrated in Figs. 6 (c) and 6 (d), the THDs of grid voltage (vs) and current (is) are 2.9 and 4.1 percent, respectively (d). Figures 6 (f)-(g) illustrate the load and EV voltage, current, and power (i).

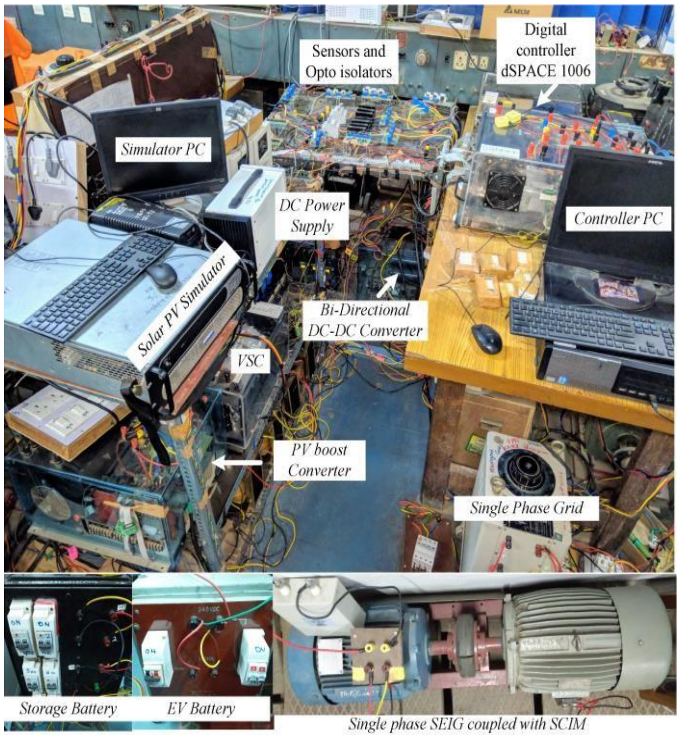

Fig. 5 Experimental setup

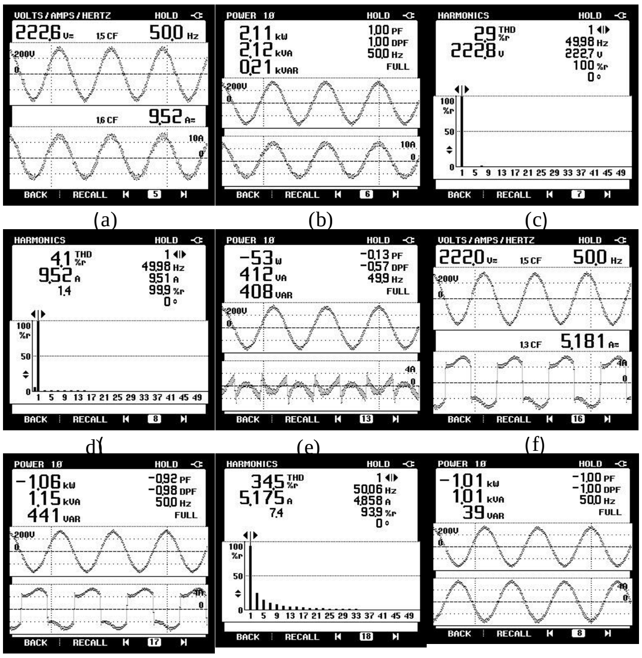

Fig. 6 Performance under grid connected mode, (a) v_s and i_s, (b) grid power, (c)-(d) THDs of v_s and i_s, (e) VSC power, (f) v_c and i_L,(g) load power, (h) THD of i_L ,(i) EV power.

2) Charging an electric vehicle in DG Set Connected Mode (Absence of both Grid and PV Array Generation):

When the solar PV array generation and grid are unavailable, the DG set feeds the load, charges the electric vehicle, and charges the storage battery. The DG set is always operated at 80-85 percent loading in this state, ensuring that the diesel engine's efficiency is maximised. 3.15 kW of electrical energy is generated by a 3.7kW DG system. Figures 7(a)-(d) show the generator voltage (vg), current (ig), and total harmonic distortions (THDs) (d). The nonlinear load consumes 1.13 kW of the 3.15 kW generated electricity, while the EV consumes 1.35 kW. The nonlinear load's voltage (vc), current (iL), and power are presented in Fig. 7. (e). Figures 7(h)-(i) show the voltage (vc), current (iev), and power of the EV (i). The storage battery stores the DG set's remaining power. Figure 7 shows the voltage (Vb), current (Ib), and power of the storage battery (h). As indicated in Fig. 7, the THD of the load current (iL) is 27.8%. (f). Despite the fact that the DG set is serving the nonlinear load, the generator current (ig) has a THD of only 1.7 percent. This is because, as illustrated in Fig. 7, the VSC

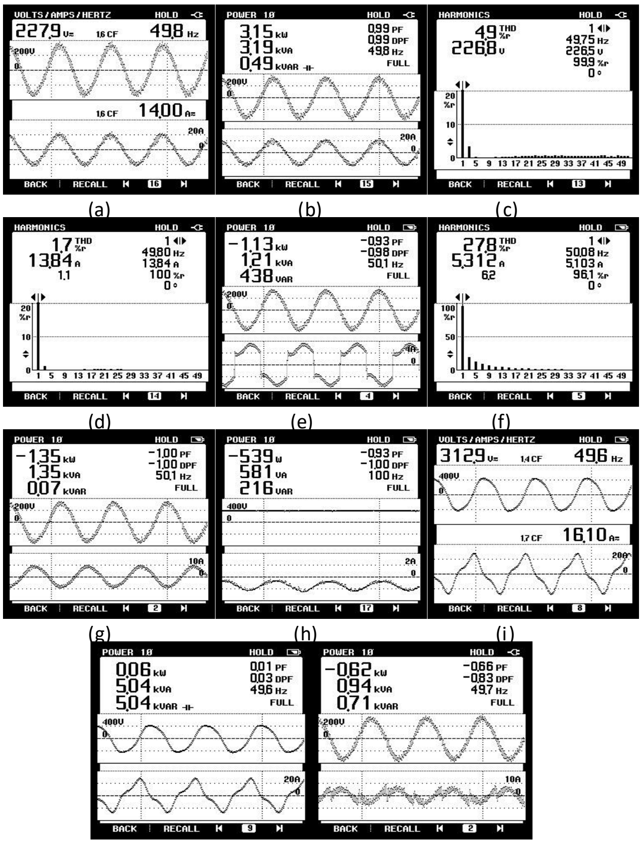

Fig. 7 Performance of the charging station when DG set is feeding load, charging EV and charging storage battery, (a) vg and ig , (b) generator power, (c)-(d) THDs of ig and vg, (e) load power, (f) THD of iL, (g) EV power, (h) battery power, (i) va and

supplies the harmonics current required by the nonlinear load (k). The storage battery in this case ensures that the DG set is always operating at 80-85 percent of capacity. If the combined demand of the EV and load surpasses the DG set's maximum load of 80-85 percent, the storage battery drains its energy to meet the additional demand. By maintaining the active power balance, the storage battery also aids in maintaining the generator frequency at 50Hz. Figures 7 (i)-(ii) illustrate the voltage (va) and current (ia) of the generator's auxiliary winding (j). I from Fig. 7 (j),

The excitation capacitor is pictured supplying reactive power to keep the generator's voltage stable.

II. CS PERFORMANCE UNDER DYNAMIC CONDITIONS:

Under irradiance disturbance and EV charging current variation, the behaviour of the hybrid CS is confirmed in islanded, grid connected, and DG set connected mode.

1.Islanded Mode Performance Operation:

The CS operation is disrupted in islanded mode by changes in solar irradiation and EV current, but the energy storage compensates for all disturbances. Figures 8 (a)-(b) show how changes in irradiance affect PV array generation and how energy storage actively compensates for the drop in

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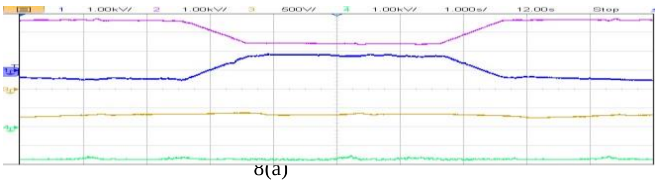
PV generated power, allowing EV charging to continue uninterrupted. The undisturbed EV current shows the same behaviour. The undisturbed EV current shows the same behaviour.

Similarly, when one EV's charging current is disrupted, the charging of another EV is unaffected. Furthermore, PV generation is consistent. Figures 8 (c)-(d) show the performance of the EV2 when the charging current is varied in steps.

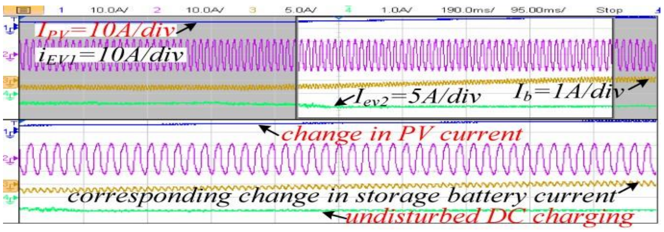
Figures 8(e)-(f) depict the performance of an EV when the AC charging current varies. The storage battery is balancing the power imbalance caused by the disturbance in EV charging current, as seen in Figs. 8 (c)-(f). The EV is connected or removed in response to changes in sun irradiance. As illustrated in Fig. 8, the storage battery takes care of the variation in demand at the charging station in this case as well (g).

2. GCM performance:

Figures 9 (a)-(d) show the performance of GCM when the AC charging requirement of an EV varies (b). Only the grid power is affected by changes in AC charging demand.



8(a)



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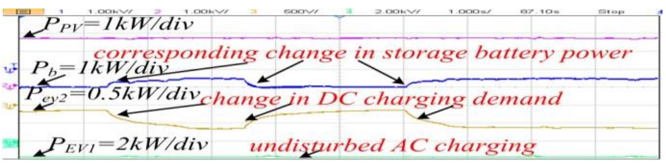

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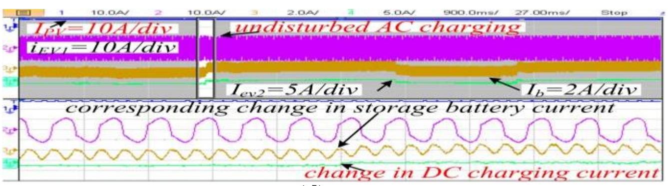

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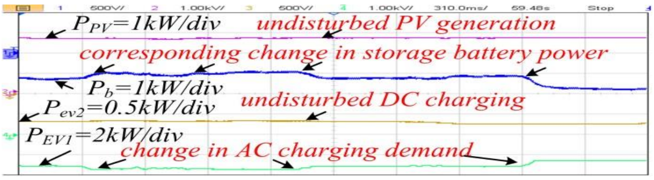
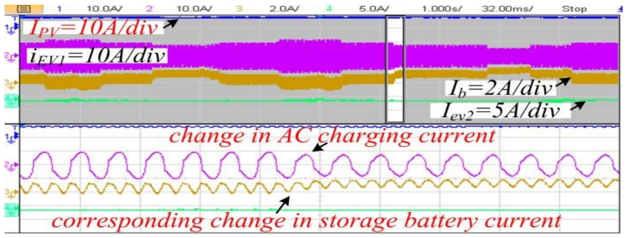


8(e)



8(f)

Fig. 8 Dynamic performance in islanded mode, (a)-(b) under solar irradiance change, (c)-(d) under change in DC charging (EV3) demand, (e)-(f) under change in AC charging (EV1) demand.

However, as seen in Figs. 9 (a)-(c), PV generation stays constant (b). Figures 9 (c)-(e) show the CS behaviour as a function of irradiance change (d). PV array generated power varies with changes in irradiation level. As a result, the amount of power sent into the grid varies in order to keep the active power balanced. However, as shown in Figs. 9 (c)-(d), the charging of the electric vehicle is unaffected by irradiance changes (d). Figure 9 illustrates the CS's vehicle-to-grid (V2G) power transmission capacity (e). The amount of electricity fed into the grid grows when the EV2 battery is discharged. PV array generating and AC charging of the electric vehicle, on the other hand, are unaffected.

3) DG Set Connected Mode Performance:

The load at PCC is varied as shown in Fig. 10 to demonstrate the efficient performance of the DG set under all loading circumstances (a).The DG set current (ig) is not affected by the load adjustment. Furthermore, the DG set's voltage (vg) and frequency are regulated at the reference levels. The storage battery, on the other hand, maintains the power balance when the load changes. The change in battery current (Ib) with the change in load current demonstrates this (iL). The VSC current (ic) fluctuates when the nonlinear load changes, as seen in Fig. 10 (b).The DC link voltage (Vdc) and the EV charging current (iev) do not vary, though.

4) Automatic and Uninterruptible Charging Station Mode Switching Performance:

Figures 11 (a)-(c) illustrate the results of grid voltage (vs) to PCC voltage (vc) synchronisation (b). On the occurrence of the grid, the charging station's control first synchronises the grid voltage to the PCC voltage, as shown in Fig. 11 (a). The grid then begins transmitting demand to PCC and charging the storage battery. The performance of the control loop as

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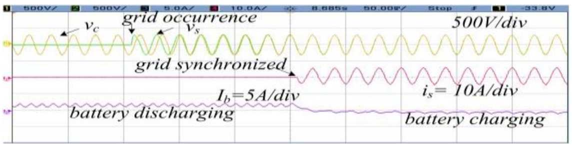
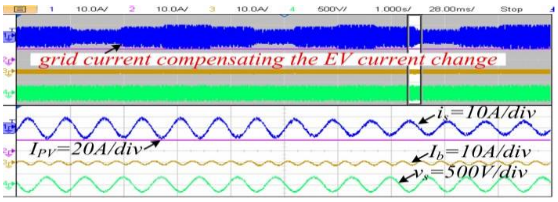
mentioned in Fig. 2 and the creation of the control signal "X" for the bidirectional switch are shown in Fig. 11(b).The load current is unaffected during the synchronization/de-synchronization process, as shown in Fig. 11 (b).

5) V2G Reactive Power Support and Active Filtering Performance:

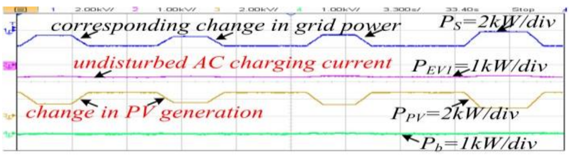
The performance under a step shift in reactive power demand is shown in Figure 12 (a). The grid current (ig) turns trailing from leading due to the step shift in the reference reactive power (Qref) from -1kVAR to 1kVAR. The harmonic correction capacity of CS is shown in Figure 12(b). After the compensation, the grid current becomes sinusoidal, which is the same as the load current without compensation.



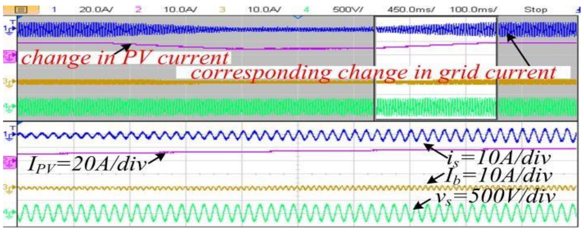
9(a)



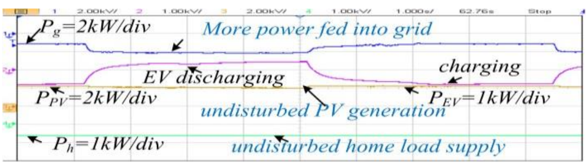
9(b)



9(c)

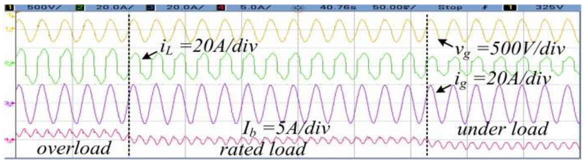


9(d)

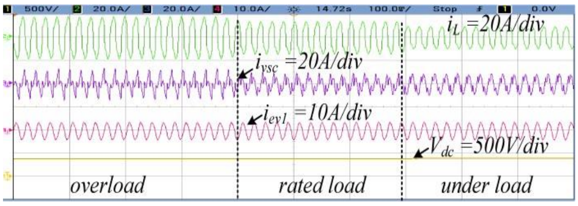


9(e)

Fig. 9 Dynamic performance in grid connected mode, (a)-(b) under change in AC (EV1) charging demand, (c)-(d) under solar irradiance change, (e) under change in DC charging (EV2) demand (V2G)

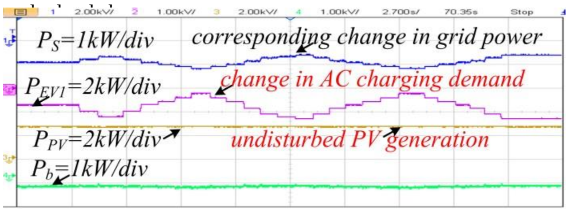


10(a)

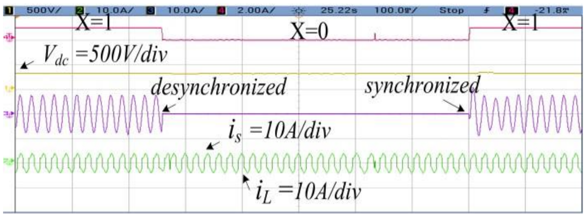


10(b)

Fig. 10 Dynamic performance of the charging station with DG set, (a)-(b)

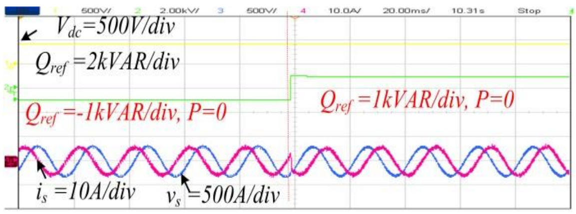


11(a)

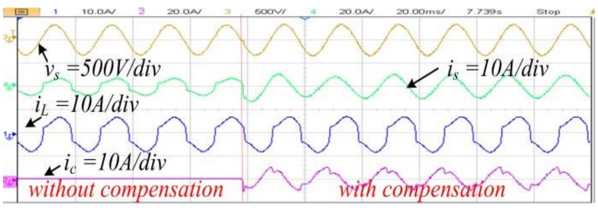


11(b)

Fig. 11 Automatic and uninterruptible mode switching (a) synchronization of grid voltage with PCC voltage, (b) generation of signal X=0/1



12(a)



12(b)

Fig. 12 Performance of charging station (a) under V2G reactive power compensation, (b) under active filtering

V.CONCLUSION:

For EV charging, a PV array, storage battery, grid, and DG set-based charging station has been implemented.

The results show that the CS can operate in many modes (islanded operation, grid connection, and DG set connection) with only one VSC. The charging station's satisfactory operation under various steady state settings and dynamics was further confirmed by the test results. circumstances resulting from changes in sun irradiation, EV charging current, and loads.The results show that the charging station can operate as a stand-alone generator with good voltage quality. The capacity of the ANC-based control algorithm to maintain the power exchange with the grid at UPF or the optimum loading of the DG set has been proven in DG set or grid linked mode. Furthermore, islanded operation, grid linked and DG set connected operations, as well as automatic mode switching, have boosted the likelihood of PV array MPP operation and DG set optimum loading, as well as charging dependability. The charging station's IEEE compliance operation, with voltage and current THD always less than 5%, proves the control's effectiveness. From the foregoing, it can be stated that this charging station, with the offered control, has the potential to efficiently utilise multiple energy sources while providing consistent and cost-effective charging to EVs.