"An Implementation of Multimode Operating Capability for Electric Vehicle Charging Station"

AUDISANKARA

A Project report submitted in partial fulfillment
for the award of the degree of

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IN
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Submitted by

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ABBREVIATIONS

BES	Battery Energy Storage
DG	Diesel Generator
EV	Electric Vehicle
CS	Charging Station
PCC	Point of Common Coupling
MPPT	Maximum Power Point Tracking
VSC	Voltage Source Converter
SEIG	Self Excited Induction Generator
ANC	Adaptive Notch Cancellation

ABSTRACT

A solar PV (Photovoltaic) array, a battery energy storage (BES), a diesel generator (DG) set and grid based EV charging station (CS) is utilized to provide the incessant charging in islanded, grid connected and DG set connected modes. The charging station is primarily designed to use the solar photovoltaic PV array and a BES to charge the electric vehicle (EV) battery. However, in case of exhausted storage battery and unavailable solar PV array generation, the charging station intelligently takes power from the grid or DG (Diesel Generator) 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 charging station 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 (UPF) even at nonlinear loading. Moreover, the PCC (Point of Common Coupling) voltage is synchronized to the grid/ generator voltage to obtain the ceaseless charging. The charging station also performs the vehicle to grid active/reactive power transfer, vehicle to home and vehicle to vehicle power transfer for increasing the operational efficiency of the charging station. The operation of the charging station is modeled in MAALB environment and the simulation results validate the performance of proposed scheme.

Chapter 1

INTRODUCTION

1 INTRODUCTION

1.1 Introduction

Currently, electric vehicles (EVs) are recognized as one of the most efficient modes of transportation with zero trailing emission. Considering the advantage of EVs, 3 million vehicles are already deployed on the road, and it is expected to cross 100 million by 2030 [1]. However, the execution of proposed plan demands for huge charging infrastructure and enormous electrical energy. Moreover, EVs can only be sustainable when the electrical energy required for charging is generated from renewable and sustainable energy sources. However, the use of fossil fuels for electricity generation does not reduce the emission but merely shift it from vehicles to the power plant. Therefore, the use of renewable energy sources for electricity generation can completely eliminate the emission and provides an environmental benefit. Among various available renewable energy sources, solar PV array, wind energy, hydro energy and fuel cell based energy, solar PV based generation is a most feasible solution for EV charging because it is available almost everywhere irrespective of the rural or urban region [2]. As far as the Indian region is concerned, it is available almost throughout the year. On the contrary to the solar PV array, the wind and hydro energies are location specific. The wind energy is mostly useful in the coastal region, and hydro energy is useful for hilly region.

Though, the renewable energy based charging stations are the most feasible solution for the EV charging, however, their integration to the existing charging system introduces the additional power conversion stage, which increases the complexity and power loss in the system. Moreover, each conversion stage needs an individual controller, which needs to be integrated with the existing control. Therefore, it is imperative to design an integrated system with multifunctional and multimode operating capability, for which a unified control and coordination between the various sources are essential.

1.2 Literature Survey:

Many efforts have been made to develop the renewable energy based charging station. Ugirumurera et al. [3] have discussed the importance of renewable energy for the sustainability of the EV charging station. Mouli et al. [4] have utilized the solar power for charging of EVs using the high power bidirectional EV charger. However, the designed charger does not provide the AC charging. Monterio et al. [5] have presented a three port converter for integrating PV array with the EV charger. However, the designed charger does not consider the current distortions in the grid current created by the charger. Singh et al. [6] have proposed a modified z-source converter for designing of PV array/grid connected EV charger. However, the charger is not designed for the islanded mode of operation. Therefore, it cannot provide the EV charging in absence of grid. Chaudhari et al. [7] have discussed a hybrid optimization model for managing the battery storage such that the running cost of charging station can be minimized and the solar PV array power is utilised maximally. Kineavy et al. [8] have proposed to use the on-site PV generated power (deployed on the commercial building) in coordination with the EV charging station for maximum utilisation of solar PV array (under uncertainties) with less impact on the grid. Zhang et al. [9] have studied the optimal scheduling of the EV charging station in workplace with dual charging modes. The PV array powered charging station (CS) is also suitable for the onsite deployment for the best quality of service at a minimum cost while reducing the grid impact of charging [10]. Kandasamy et al. [11] have investigated the loss of life of a storage battery used with the commercial building based solar PV array system. The wind energy powered CS is also beneficial for EV due to its availability in both day and night time, and many publications are available in this area [12]-[14].

EVs nowadays are also used as a distributed energy resource for providing various ancillary services due to the huge amount of energy stored in EV batteries. Singh et al. [15] have presented a PV array based CS for providing charging facility along-with the vehicle-to-grid reactive/active power, active power filtering and vehicle-to-home. Saxena et al. [16] have implemented a grid tied PV array system for EV and residential application. Razmi et al. [17] have proposed the power management strategy with multi-mode control of an integrated residential PV-storage battery system for both grid-connected and islanded operation. Erdinc et al. [18] and Kikusato et al. [19], Hafiz et al. [20] have presented the smart household operation such that EV can be used as a storage for providing the vehicle-to-home and vehicle-to-grid operation for the benefits of both utility and the consumer.

The detailed analysis of reviewed literature, advocates that the work presented in the area of renewable energy based charging station, are mostly focusing on the optimization of different aspects of charging such as the size of the renewable energy sources, size of the storage unit, vehicle driving pattern, charging time, charging cost, charging scheduling etc. However, in present scenario only few publications have actually implemented the charging station using renewable energy sources. Moreover, the performance of charging station under real circumstances, is also less discussed. Moreover, in most of the literature, the performance of CS, is discussed only in either grid connected mode or islanded mode. However, due to the single mode of operation in grid connected mode, the solar PV panel becomes unusable if the grid is not available even if the sun (solar irradiance) is available. Similarly, in islanded mode, the PV power is disturbed by the intermittency of solar irradiance. Therefore, a storage battery is required for mitigating the effect of variable solar irradiance. However, in case of the fully charge storage battery, the maximum power point tracking (MPPT) has to be disabled to avoid the overcharging of the storage battery.

Therefore, in this paper, a PV array, grid, energy storage and DG set supported CS is presented, which operates in islanded, grid connected and DG set connected modes, so that the PV array energy is utilized for all operating conditions.

Some publications [15] have discussed both islanded and grid connected modes. However, these two modes are controlled separately and the automatic mode switching between two modes are not presented. Therefore, without automatic mode switching capability, the PV array power is to be interrupted and the charging of the EV is not to be continuous. Therefore, in this paper, an automatic mode switching logic is presented, so that the controller automatically switches between different operating modes depending on the power generation of PV array and the charging demand of EV.

Due to the unavailability in the night and the intermittent nature of the PV array, storage battery with PV array is used for continuous and reliable operation of CS. However, due to the limited storage capacity of the storage battery, it is hardly possible to provide backup all the time. Therefore, the CS needs support of the grid in case of PV array energy is unavailable, and energy storage is also discharged.

However, due to the limited availability of grid, especially in remote areas, the DG set may be required for maintaining the continuity of the charging. However, the DG set performance is affected by the type of loading, and it is not utilized to its full capacity. Generally, the DG sets are designed for very limited amount of harmonics in the load current [21]. Therefore, the DG set performance is severely affected by the EV charging, due to presence of harmonics in the EV current because the charger of the EV generally uses rectifier followed by a power factor correction circuit and a DC-DC converter for step down. However, in this paper, the DG set is always loaded to at least 80% of the rated value because the harmonics and reactive current requirement of the EV charger are provided by the voltage source converter (VSC).

The major contributions in this project, are as follows.

- Design of PV array, energy storage and DG set supported grid integrated CS, which uninterruptedly supports both DC and AC charging of EVs.
- Design of a unified controller, which enables the charging station to operate in islanded, grid connected and DG set connected modes without changing the hardware and using only a single VSC.
- Design of a mode switching logic using which, the charging station changes the mode seamlessly to provide the continuous charging.
- Design of control strategy for vehicle-to-vehicle (V2V) power transfer for charging the EV and vehicle-to-grid (V2G) power transfer for supporting the grid.
- Active power filter operation of the charging station for mitigating the grid current harmonics, so that the power exchange takes place at unity power factor. This is required for the compliance of the charging station with the IEEE-519 standard.
- Strategy for regulating the frequency and voltage of DG set without mechanical automatic voltage regulator.
- Strategy to feed the surplus PV array generated power into the grid for avoiding the overcharging of the storage battery.

Verification of a new energy control strategy for dynamic voltage restorer by simulation

M. R. Banaei and S. H. HosseiniTo restore the load voltage, dynamic voltage restorer (DVR), which installed between the supply and a sensitive load, should inject voltage and active power from DVR to the distribution system during voltage sag. Due to the limit of energy storage capacity of DC link, it is necessary the minimize energy injection from DVR. In this paper the techniques of the supply voltage sag compensation in a distribution feeder are presented. In addition, a new concept of restoration technique is suggested to inject minimum energy for a given apparent power of DVR.

Summary: Due to the limit of energy storage capacity of DC link, it is necessary the minimize energy injection from DVR.

Intermittent and stochastic character of renewable energy sources

G. Notton Solar and wind energy are inherently time-varying sources of energy on scales from minutes to seasons. Thus, the incorporation of such intermittent and stochastic renewable energy systems (ISRES) into an electricity grid provides some new challenges in managing a stable and safe energy supply, in using energy storage and/or 'back-up' energy from other sources. In such cases, the ability to accurately forecast the output of "unpredictable" energy facilities is essential for ensuring an optimal management of the energy production means. This review synthesis the reasons to predict solar or wind fluctuations, it shows that variability and stochastic variation of renewable sources have a cost, sometimes high. It provides useful information on the intermittence cost and on the decreasing of this cost due to an efficient forecasting of the source fluctuation; this paper is for engineers and researchers who are not necessarily familiar with the issue of the notions of cost and economy and justify future investments in the ISRES production forecasting.

Summary: The utilization of RESs are the bright future to shift from non-renewable energy sources, there should be optimal solutions to reduce end users' power fluctuation problems which arise from its intermittent nature.

Design and analysis of dynamic voltage restorer for deep voltage sag and harmonic compensation

F. A. L. Jowder A dynamic voltage restorer (DVR) to compensate deep voltage sags and harmonics is proposed. The DVR consists of shunt and series converters connected back-to-back through a dc-to-dc step up converter. The presence of the dc-to-dc step converter permits the DVR to compensate deep voltage sags for long duration. The series converter is connected to the supply side whereas the shunt converter is connected to the load side. With this configuration, there is no need for large dc capacitors. A design procedure for the components of the DVR is presented under a voltage sag condition. The control system of the proposed DVR is based on hysteresis voltage control. Besides voltage sag compensation, the capability of compensating load voltage harmonics has been added to the DVR to increase the power quality benefits to the load with almost negligible effect on the sag compensation capability. The proposed DVR is modeled and simulated using SIMULINK/MATLAB environment. Time domain simulations are used to verify the operation of the DVR with linear and non-linear loads.

Summary: The control system of the proposed DVR is based on hysteresis voltage control. Besides voltage sag compensation, the capability of compensating load voltage harmonics has been added to the DVR to increase the power quality benefits to the load with almost negligible effect on the sag compensation capability.

Power quality improvement using STS and DVR in wind energy system

S. Agalar and Y. A. Kaplan Recently, renewable energy has attracted special interest because it seems to be a positive alternative to fossil fuels. European countries, in particular, and many other developed countries in the world have been in search of utilizing wind energy in order to meet the need for energy. The purpose of this study is the utilization of the wind energy in a safer and more quality way. Two systems were suggested for increasing the quality of the wind energy. In the first system, the wind energy and the grid were connected in parallel with the help of static transfer switch (STS), and if the wind energy is cut, the load will be supported by the alternative feeder. In the second system, dynamic voltage restorer (DVR) was connected to wind energy system (WES). The intention is, with the help of DVR system, preventing the fluctuations that might happen in the energy that is produced, due to the variations of wind speed.

Summary: In the first system, the wind energy and the grid were connected in parallel with the help of static transfer switch (STS), and if the wind energy is cut, the load will be supported by the alternative feeder. In the second system, dynamic voltage restorer (DVR) was connected to wind energy system (WES). The intention is, with the help of DVR system, preventing the fluctuations that might happen in the energy that is produced, due to the variations of wind speed.

SRF Theory Revisited to Control Self-Supported Dynamic Voltage Restorer (DVR) for Unbalanced and Nonlinear Loads.

P. Kanjiya, B. Singh, A. Chandra The protection of the sensitive unbalanced non-linear loads from sag/swell, distortion and unbalance in supply voltage is achieved economically using the dynamic voltage restorer (DVR). A simple generalized algorithm based on basic synchronous reference frame (SRF) theory has been developed for the generation of instantaneous reference compensating voltages for controlling a DVR. This novel algorithm makes use of the fundamental positive sequence phase voltages extracted by sensing only two unbalanced and/or distorted line voltages. The algorithm is general enough to handle linear as well as nonlinear loads. The compensating voltages when injected in series with a distribution feeder by 3-single phase H-bridge voltage source converters (VSCs) with constant switching frequency hysteresis band voltage controller, tightly regulates the voltage at the load terminals against any power quality problems on the source side. A capacitor supported DVR does not need any active power during steady state operation because the injected voltage is in quadrature with the feeder current. The proposed control strategy is validated through extensive simulation and real-time experimental studies.

Summary: The compensating voltages when injected in series with a distribution feeder by 3-single phase H-bridge voltage source converters (VSCs) with constant switching frequency hysteresis band voltage controller, tightly regulates the voltage at the load terminals against any power quality problems on the source side.

Performance Evaluation of a MW-Class SMES-BES DVR System for Mitigation of Voltage

Z. Zheng, X. Xiao Performance evaluations of a MW-class dynamic voltage restorer (DVR) system are presented for mitigation of voltage quality disturbances. A pre sag compensation strategy is introduced to lock the instantaneous magnitudes and phase angles of real-time line voltages, and thus to compensate the improper voltage components exactly after symmetrical or asymmetrical voltage disturbances. A 0.3-H/1.76-kA superconducting magnetic energy storage (SMES) magnet is used to cooperate with conventional battery energy storage (BES) device for developing a high-performance hybrid energy storage (HES) system. In the SMES-BES HES-based DVR system, the SMES can compensate the worst voltage sag for five cycles (1 MW, 100 ms, and absorb the highest voltage swell for six cycles (1 MW, 120 ms). The accessorial high-capacity BES device is subsequently discharged or charged for lasting long-time mitigation operations. Various simulation cases with regard to combined voltage sag, swell, and harmonic disturbances are carried out. The simulations and comparisons among the SMES-based, BES-based, and HES-based DVR schemes have demonstrated that the HES-based DVR scheme integrates the merits of fast response speed and high-power density from the SMES-based scheme, and the merits of low capital cost and high-energy density from the BES-based scheme.

Summary: In the SMES-BES HES-based DVR system, the SMES can compensate the worst voltage sag for five cycles (1 MW, 100 ms, and absorb the highest voltage swell for six cycles (1 MW, 120 ms). The accessorial high-capacity BES device is subsequently discharged or charged for lasting long-time mitigation operations.

1.3 The aim and objective of the Project

The main objective of this project is to regulate the frequency and voltage of DG set without a mechanical automatic voltage regulator.

Chapter 2

MAXIMUM POWER POINT TRACKING

2. MAXIMUM POWER POINT TRACKING

2.1 Solar Cell

The name solar cell means that it is a cell or a plate which converts solar energy into the useful electrical energy. The energy which we get from sun is enormous and it is a great source of energy. Its energy will never finish so this is also known as the main source of renewable energy. With the scarcity of non-renewable energy it is of utmost importance to find a way out to solve the energy problem by some means within a very short period of time. So there is a way out which is now developing. That is we are now able to convert the sun energy to electrical by some means and that is why the importance of solar cell comes into play. Though it is developing but if it is developed completely, then every household may produce the energy of its own. The solar cell is a device which is made of p-n junction diode which effect photovoltaic effect to convert light energy into electrical energy.

Construction of Solar Cell

The junction diode is made of SI or GaAs . A thin layer of p-type is grown on the n-type semiconductor. Top of the p-layer is provided with a few finer electrodes which leaves open space for the light to reach the thin p-layer and it under lays p-n junction. Bottom of the n-layer is provided with a current collecting electrode.

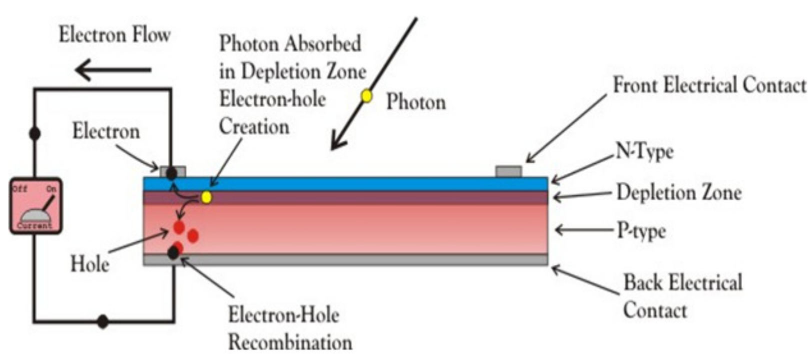


Fig 2.1 Working Principle of Solar Cell

When light reaches the p-n junction, electron is excited to the valance band under the condition that light energy is higher than the band gap energy; it generates the electron and holes which are equal in number in the valance and conduction band respectively. These electron hole pairs move in opposite directions to the barrier field. Electrons move towards the n-side and the hole is moved towards the p-side. So a voltage is set up which is known as photo voltage and when a load is connected, the current flows.

2.2 V-I Characteristics of a Photovoltaic Cell

Solar cell is the basic unit of solar energy generation system where electrical energy is extracted directly from light energy without any intermediate process. The working of a solar cell solely depends upon its photovoltaic effect hence a solar cell also known as photovoltaic cell. A solar cell is basically a semiconductor device. The solar cell produce electricity while light strikes on it and the voltage or potential difference established across the terminals of the cell is fixed to 0.5 volt and it is nearly independent of intensity of incident light whereas the current capacity of cell is nearly proportional to the intensity of incident light as well as the area that exposed to the light. Each of the solar cells has one positive and one negative terminal like all other type of battery cells. Typically a solar or photovoltaic cell has negative front contact and positive back contact.

A semiconductor p-n junction is in the middle of these two contacts. While sunlight falling on the cell the some photons of the light are absorbed by solar cell. Some of the absorbed photons will have energy greater than the energy gap between valence band and conduction band in the semiconductor crystal. Hence one valence electron gets energy from one photon and becomes excited and jumps out from the bond and creates one electron – hole pair. These electrons and holes of e-h pairs are called light-generated electrons and holes. The light – generated electrons near the p-n junction are migrated to n-type side of the junction due to electrostatic force of the field across the junction. Similarly the light – generated holes created near the junction are migrated to p – type side of the junction due to same electrostatic force. In this way a potential difference is established between two sides of the cell and if these two sides are connected by an external circuit current will start flowing from positive to negative terminal of the solar cell. This was basic working principle of a solar cell now we will discuss about different parameters of a solar or photovoltaic cell upon which the rating of a solar panel depends. During choosing a particular solar cell for specific project it is essential to know the ratings of a solar panel. These parameters tell us how efficiently a solar cell can convert the light to electricity.

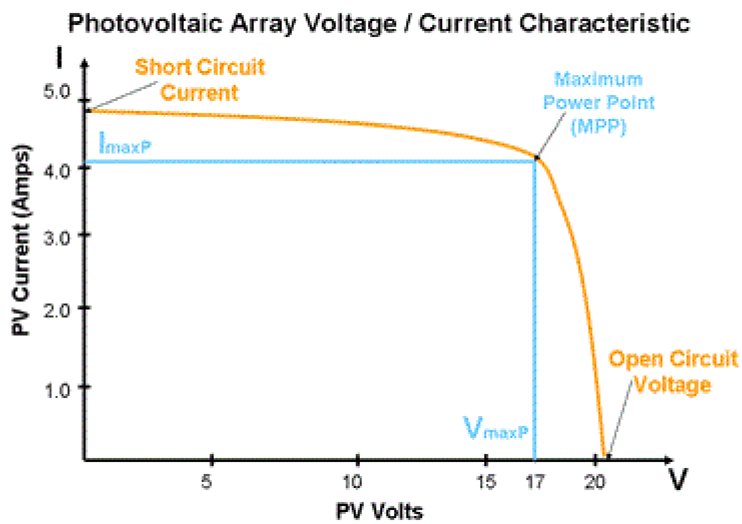


Fig 2.2 V-I Characteristics of a Photovoltaic Cell

Short Circuit Current of Solar Cell

The maximum current that a solar cell can deliver without harming its own constriction. It is measured by short circuiting the terminals of the cell at most optimized condition of the cell for producing maximum output. The term optimized condition I used because for fixed exposed cell surface the rate of production of current in a solar cell also depends upon the intensity of light and the angle at which the light falls on the cell. As the current production also depends upon the surface area of the cell exposed to light, it is better to express maximum current density instead maximum current. Maximum current density or short circuit current density rating is nothing but ration of maximum or short circuit current to exposed surface area of the cell.

$$J_{sc} = \frac{I_{sc}}{A}$$

Where, I_{sc} is short circuit current, J_{sc} maximum current density and A is the area of solar cell.

Open Circuit Voltage of Solar Cell

It is measured by measuring voltage across the terminals of the cell when no load is connected to the cell. This voltage depends upon the techniques of manufacturing and temperature but not fairly on the intensity of light and area of exposed surface. Normally open circuit voltage of solar cell nearly equal to 0.5 to 0.6 volt. It is normally denoted by V_{oc}.

Maximum Power Point of Solar Cell

The maximum electrical power one solar cell can deliver at its standard test condition. If we draw the v-i characteristics of a solar cell maximum power will occur at the bend point of the characteristic curve. It is shown in the v-i characteristics of solar cell by P_m.

Current at Maximum Power Point

The current at which maximum power occurs. Current at Maximum Power Point is shown in the v-i characteristics of solar cell by I_m.

Voltage at Maximum Power Point

The voltage at which maximum power occurs. Voltage at Maximum Power Point is shown in the v-i characteristics of solar cell by V_m.

Fill Factor of Solar Cell

The ratio between product of current and voltage at maximum power point to the product of short circuit current and open circuit voltage of the solar cell.

$$Fill\ Factor = \frac{P_m}{I_{sc} \times V_{oc}}$$

Efficiency of Solar Cell

It is defined as the ratio of maximum electrical power output to the radiation power input to the cell and it is expressed in percentage. It is considered that the radiation power on the earth is about 1000watt/square meter hence if the exposed surface area of the cell is A then total radiation power on the cell will be 1000A watts. Hence the efficiency of a solar cell may be expressed as

$$Efficiency(\eta) = \frac{P_m}{P_{in}} \approx \frac{P_m}{1000A}$$

2.3 Maximum Power Point Tracker (MPPT)

MPPT or Maximum Power Point Tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. Typical PV module produces power with maximum power voltage of around 17 V when measured at a cell temperature of 25°C, it can drop to around 15 V on a very hot day and it can also rise to 18 V on a very cold day

A MPPT or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries. (These are sometimes called "power point trackers" for short - not to be confused with PANEL trackers, which are a solar panel mount that follows, or tracks, the sun).

MPPT charge controller

A MPPT solar charge controller is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module.

MPPT is DC to DC converter which operates by taking DC input from PV module, changing it to AC and converting it back to a different DC voltage and current to exactly match the PV module to the battery.

How Maximum Power Point Tracking works

Here is where the optimization or maximum power point tracking comes in. Assume your battery is low, at 12 volts. A MPPT takes that 17.6 volts at 7.4 amps and converts it down, so that what the battery gets is now 10.8 amps at 12 volts. Now you still have almost 130 watts, and everyone is happy.

Ideally, for 100% power conversion you would get around 11.3 amps at 11.5 volts, but you have to feed the battery a higher voltage to force the amps in. And this is a simplified explanation - in actual fact the output of the MPPT charge controller might vary continually to adjust for getting the maximum amps into the battery.

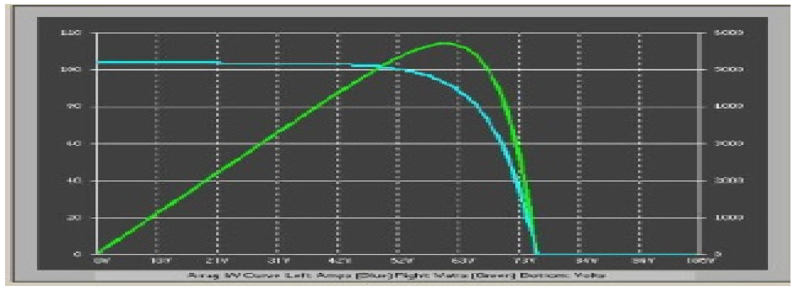


Fig 2.3 P-V and V-I curves of PV cell

On the left is a screen shot from the Maui Solar Software "PV Design Pro" computer program (click on picture for full size image). If you look at the green line, you will see that it has a sharp peak at the upper right - that represents the maximum power point. What an MPPT controller does is "look" for that exact point, and then does the voltage/current conversion to change it to exactly what the battery needs. In real life, that peak moves around continuously with changes in light conditions and weather.

A MPPT tracks the maximum power point, which is going to be different from the STC (Standard Test Conditions) rating under almost all situations. Under very cold conditions a 120 watt panel is actually capable of putting over 130+ watts because the power output goes up as panel temperature goes down - but if you don't have some way of tracking that power point, you are going to lose it. On the other hand under very hot conditions, the power drops - you lose power as the temperature goes up. That is why you get less gain in summer.

MPPT's are most effective under these conditions:

- Winter, and/or cloudy or hazy days - when the extra power is needed the most.
- Cold weather - solar panels work better at cold temperatures, but without a MPPT you are losing most of that. Cold weather is most likely in winter - the time when sun hours are low and you need the power to recharge batteries the most.
- Low battery charge - the lower the state of charge in your battery, the more current a MPPT puts into them - another time when the extra power is needed the most. You can have both of these conditions at the same time.
- Long wire runs - If you are charging a 12 volt battery, and your panels are 100 feet away, the voltage drop and power loss can be considerable unless you use very large wire. That can be very expensive. But if you have four 12 volt panels

wired in series for 48 volts, the power loss is much less, and the controller will convert that high voltage to 12 volts at the battery. That also means that if you have a high voltage panel setup feeding the controller, you can use much smaller wire.

2.3.1 Working principle of MPPT

The Power point tracker is a high frequency DC to DC converter. They take the DC input from the solar panels, change it to high frequency AC, and convert it back down to a different DC voltage and current to exactly match the panels to the batteries. MPPT's operate at very high audio frequencies, usually in the 20-80 kHz range. The advantage of high frequency circuits is that they can be designed with very high efficiency transformers and small components. The design of high frequency circuits can be very tricky because the problems with portions of the circuit "broadcasting" just like a radio transmitter and causing radio and TV interference. Noise isolation and suppression becomes very important.

There are a few non-digital (that is, linear) MPPT's charge controls around. These are much easier and cheaper to build and design than the digital ones. They do improve efficiency somewhat, but overall the efficiency can vary a lot - and we have seen a few lose their "tracking point" and actually get worse. That can happen occasionally if a cloud passed over the panel - the linear circuit searches for the next best point, but then gets too far out on the deep end to find it again when the sun comes out.

The power point tracker (and all DC to DC converters) operates by taking the DC input current, changing it to AC, running through a transformer (usually a torrid, a doughnut looking transformer), and then rectifying it back to DC, followed by the output regulator. In most DC to DC converters, this is strictly an electronic process - no real smarts are involved except for some regulation of the output voltage. Charge controllers for solar panels need a lot more smarts as light and temperature conditions vary continuously all day long, and battery voltage changes.

Photovoltaic (PV) power systems:

A photovoltaic system, also solar PV power system, or PV system, is a power system designed to supply usable power by means of Photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution, as prices for storage devices are expected to decline. Strictly speaking, a solar array only encompasses the ensemble of solar panels, the visible part of the PV system, and does not include all the other hardware, often summarized as balance of system (BOS). Moreover, PV systems convert light directly into electricity and shouldn't be confused with other technologies, such as concentrated solar power or solar thermal, used for heating and cooling.

PV systems range from small, rooftop-mounted or building-integrated systems with capacities from a few to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts. Nowadays, most PV systems are grid-connected, while off-grid or stand-alone systems only account for a small portion of the market.

Operating silently and without any moving parts or environmental emissions, PV systems have developed from being niche market applications into a mature technology used for mainstream electricity generation. A rooftop system recoups the invested energy for its manufacturing and installation within 0.7 to 2 years and produces about 95 percent of net clean renewable energy over a 30-year service lifetime.

Due to the exponential growth of Photovoltaics, prices for PV systems have rapidly declined in recent years. However, they vary by market and the size of the system. In 2014, prices for residential 5-kilowatt systems in the United States were around $3.29 per watt, while in the highly penetrated German market, prices for rooftop systems of up to 100 kW declined to €1.24 per watt. Nowadays, solar PV modules account for less than half of the system's overall cost, leaving the rest to the remaining BOS-components and to soft costs, which include customer acquisition, permitting, inspection and interconnection, installation labor and financing costs.

Modern system:

A photovoltaic system converts the sun's radiation into usable electricity. It comprises the solar array and the balance of system components. PV systems can be categorized by various aspects, such as, grid-connected vs. standalone systems, building-integrated vs. rack-mounted systems, residential vs. utility systems, distributed vs. centralized systems, rooftop vs. ground-mounted systems, tracking vs. fixed-tilt systems, and new constructed vs. retrofitted systems. Other distinctions may include systems with micro inverters vs. Central inverter, systems using crystalline silicon vs. thin-film technology, and systems with modules from Chinese vs. European and U.S.-manufacturers.

About 99 percent of all European and 90 percent of all U.S. solar power systems are connected to the electrical grid, while off-grid systems are somewhat more common in Australia and South Korea. PV systems rarely use battery storage. This may change soon, as government incentives for distributed energy storage are being implemented and investments in storage solutions are gradually becoming economically viable for small systems. A solar array of a typical residential

PV system is rack-mounted on the roof, rather than integrated into the roof or facade of the building, as this is significantly more expensive. Utility-scale solar power stations are ground-mounted, with fixed tilted solar panels rather than using expensive tracking devices. Crystalline silicon is the predominant material used in 90 percent of worldwide produced solar modules, while rival thin-film has lost market-share in recent years. About 70 percent of all solar cells and modules are produced in China and Taiwan, leaving only 5 percent to European and US-manufacturers. The installed capacity for both, small rooftop systems and large solar power stations is growing rapidly and in equal parts, although there is a notable trend towards utility-scale systems, as the focus on new installations is shifting away from Europe to sunnier regions, such as the Sunbelt in the U.S., which are less opposed to ground-mounted solar farms and cost-effectiveness is more emphasized by investors.

Driven by advances in technology and increases in manufacturing scale and sophistication, the cost of Photovoltaic is declining continuously. There are several million PV systems distributed all over the world, mostly in Europe, with 1.4 million systems in Germany alone– as well as North America with 440,000 systems in the United States, The energy conversion efficiency of a conventional solar module increased from 15 to 20 percent over the last 10 years and a PV system recoups the energy needed for its manufacture in about 2 years. In exceptionally irradiated locations, or when thin-film technology is used, the so-called energy payback time decreases to one year or less. Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity; have also greatly supported installations of PV systems in many countries. The liveliest from large-scale PV systems has become competitive with conventional electricity sources in an expanding list of geographic regions, and grid parity has been achieved in about 30 different countries.

As of 2015, the fast-growing global PV market is rapidly approaching the 200 GW mark – about 40 times the installed capacity of 2006. Photovoltaic systems currently contribute about 1 percent to worldwide electricity generation. Top installers of PV systems in terms of capacity are currently China, Japan and the United States, while half of the world's capacity is installed in Europe, with Germany and Italy supplying 7% to 8% of their respective domestic electricity consumption with solar PV. The International Energy Agency expects solar power to become the world's largest source of electricity by 2050, with solar photovoltaic and concentrated solar thermal contributing 16% and 11% to the global demand, respectively.

2.4 MPPT Implementation

When a load is directly connected to the solar panel, the operating point of the panel will rarely be at peak power. The impedance seen by the panel derives the operating point of the solar panel. Thus by varying the impedance seen by the panel, the operating point can be moved towards peak power point. Since panels are DC devices, DC-DC converters must be utilized to transform the impedance of one circuit (source) to the other circuit (load). Changing the duty ratio of the DC-DC converter results in an impedance change as seen by the panel. At a particular impedance (or duty ratio) the operating point will be at the peak power transfer point. The I-V curve of the panel can vary considerably with variation in atmospheric conditions such as radiance and temperature. Therefore it is not feasible to fix the duty ratio with such dynamically changing operating conditions.

MPPT implementations utilize algorithms that frequently sample panel voltages and currents, then adjust the duty ratio as needed. Microcontrollers are employed to implement the algorithms. Modern implementations often utilize larger computers for analytics and load forecasting.

2.4.1 Classification

Controllers can follow several strategies to optimize the power output of an array. Maximum power point trackers may implement different algorithms and switch between them based on the operating conditions of the array.

a) Perturb and observe

In this method the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common, although this method can result in oscillations of power output. It is referred to as a *hill climbing* method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

b) Incremental conductance

In the incremental conductance method, the controller measures incremental changes in PV array current and voltage to predict the effect of a voltage change. This method requires more computation in the controller, but can track changing conditions more rapidly than the perturb and observe method (P&O). Like the P&O algorithm, it can produce oscillations in power output.[18] This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV).

The incremental conductance method computes the maximum power point by comparison of the incremental conductance (I_Δ / V_Δ) to the array conductance (I / V). When these two are the same ($I / V = I_\Delta / V_\Delta$), the output voltage is the MPP voltage. The controller maintains this voltage until the irradiation changes and the process is repeated.

The incremental conductance method is based on the observation that at the maximum power point $dP/dV = 0$, and that $P = IV$. The current from the array can be expressed is a function of the voltage: $P = I(V)V$. Therefore $dP/dV = VdI/dV + I(V)$.

Setting this equal to zero yields: $dI/dV = -I(V)/V$. Therefore, the maximum power point is achieved when the incremental conductance is equal to the negative of the instantaneous conductance.

c) Current sweep

The current sweep method uses a sweep waveform for the PV array current such that the I-V characteristic of the PV array is obtained and updated at fixed time intervals. The maximum power point voltage can then be computed from the characteristic curve at the same intervals.

d) Constant voltage

The term "constant voltage" in MPP tracking is used to describe different techniques by different authors, one in which the output voltage is regulated to a constant value under all conditions and one in which the output voltage is regulated based on a constant ratio to the measured open circuit voltage (V_{OC}). The latter technique is referred to in contrast as the "open voltage" method by some authors. If the output voltage is held constant, there is no attempt to track the maximum power point, so it is not a maximum power point tracking technique in a strict sense, though it does have some advantages in cases when the MPP tracking tends to fail, and thus it is sometimes used to supplement an MPPT method in those cases.

In the "constant voltage" MPPT method (also known as the "open voltage method"), the power delivered to the load is momentarily interrupted and the open-circuit voltage with zero current is measured. The controller then resumes operation with the voltage controlled at a fixed ratio, such as 0.76, of the open-circuit voltage V_{OC}. This is usually a value which has been determined to be the maximum power point, either empirically or based on modelling, for expected operating conditions. The operating point of the PV array is thus kept near the MPP by regulating the array voltage and matching it to the fixed reference voltage $V_{ref}=kV_{OC}$. The value of V_{ref} may be also chosen to give optimal performance relative to other factors as well as the MPP, but the central idea in this technique is that V_{ref} is determined as a ratio to V_{OC}.

One of the inherent approximations to the "constant voltage" ratio method is that the ratio of the MPP voltage to V_{OC} is only approximately constant, so it leaves room for further possible optimization.

2.4.2 Comparison of methods

Both perturb and observe, and incremental conductance, are examples of "hill climbing" methods that can find the local maximum of the power curve for the operating condition of the PV array, and so provide a true maximum power point.

The perturb and observe method requires oscillating power output around the maximum power point even under steady state irradiance.

The incremental conductance method has the advantage over the perturb and observe (P&O) method that it can determine the maximum power point without oscillating around this value. It can perform maximum power point tracking under rapidly varying irradiation conditions with higher accuracy than the perturb and observe method. However, the incremental conductance method can produce oscillations (unintentionally) and can perform erratically under rapidly changing atmospheric conditions. The sampling frequency is decreased due to the higher complexity of the algorithm compared to the P&O method.

In the constant voltage ratio (or "open voltage") method, the current from the photovoltaic array must be set to zero momentarily to measure the open circuit voltage and then afterwards set to a predetermined percentage of the measured voltage, usually around 76%. Energy may be wasted during the time the current is set to zero. The approximation of 76% as the MPP/V_{OC} ratio is not necessarily accurate though. Although simple and low-cost to implement, the interruptions reduce array efficiency and do not ensure finding the actual maximum power point. However, efficiencies of some systems may reach above 95%.

2.5 MPPT placement

Traditional solar inverters perform MPPT for the entire PV array (module association) as a whole. In such systems the same current, dictated by the inverter, flows through all modules in the string (series). Because different modules have different I-V curves and different MPPs (due to manufacturing tolerance, partial shading, etc.) this architecture means some modules will be performing below their MPP, resulting in lower efficiency.

Some companies (see power optimizer) are now placing maximum power point tracker into individual modules, allowing each to operate at peak efficiency despite uneven shading, soiling or electrical mismatch.

Data suggests having one inverter with one MPPT for a project that has east and west-facing modules presents no disadvantages when compared to having two inverters or one inverter with more than one MPPT.

Chapter 3

CHARGING STATION DESCRIPTION

3. CHARGING STATION DESCRIPTION

3.1 Operation with batteries

At night, an off-grid PV system may use batteries to supply loads. Although the fully charged battery pack voltage may be close to the PV panel's maximum power point voltage, this is unlikely to be true at sunrise when the battery has been partially discharged. Charging may begin at a voltage considerably below the PV panel maximum power point voltage, and an MPPT can resolve this mismatch.

When the batteries in an off-grid system are fully charged and PV production exceeds local loads, an MPPT can no longer operate the panel at its maximum power point as the excess power has no load to absorb it. The MPPT must then shift the PV panel operating point away from the peak power point until production exactly matches demand. (An alternative approach commonly used in spacecraft is to divert surplus PV power into a resistive load, allowing the panel to operate continuously at its peak power point.)

In a grid connected photovoltaic system, all delivered power from solar modules will be sent to the grid. Therefore, the MPPT in a grid connected PV system will always attempt to operate the PV modules at its maximum power point.

The presented charging station, as shown in Fig. 2.1, uses a solar PV array, a storage battery, a DG set and grid energy to charge the EV and to feed the load connected to charging station. The solar PV array is connected at DC link of voltage source converter (VSC) through a boost converter and a storage battery is connected directly to DC link. The grid, a single phase SEIG (Self Excited Induction Generator), an EV and a nonlinear load, are connected on the AC side of VSC through a coupling inductor. A ripple filter at PCC, is used to eliminate the switching harmonics from the grid and the generator current and to make these currents sinusoidal. An excitation capacitor is connected to the auxiliary winding of the SEIG. A small capacitor is also connected across the main winding of the SEIG. A synchronizing switch is used between grid/DG set and PCC for controlled connection/ disconnection of charging station to grid/DG set.

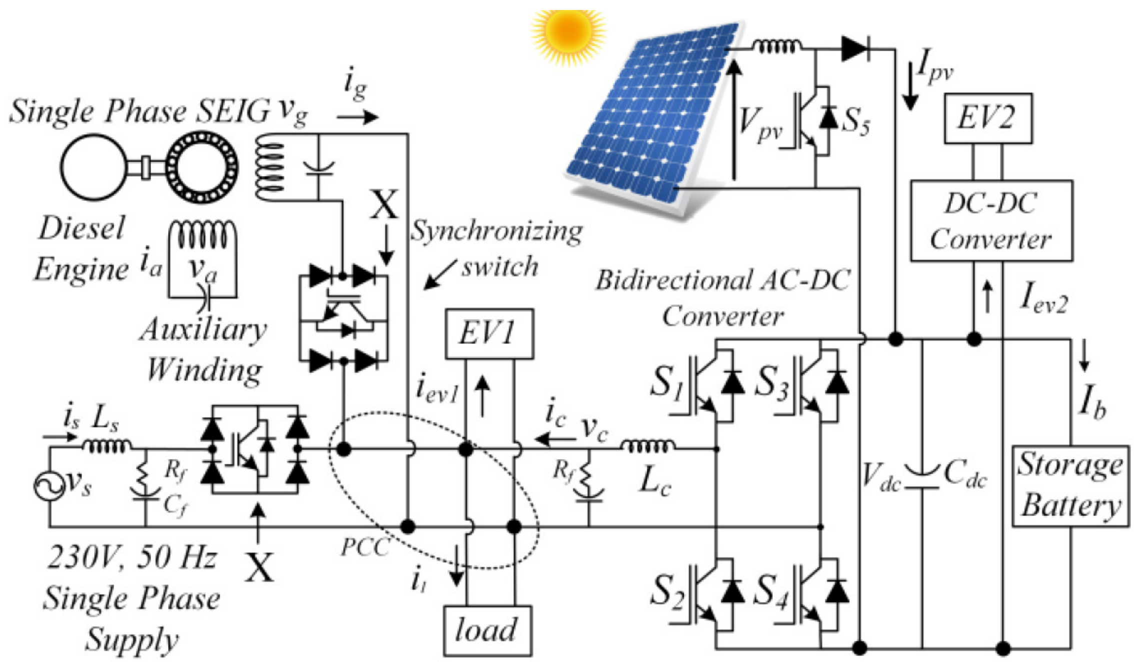


Fig. 3.1 Topology of charging station.

3.2 DG set

A diesel generator is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy. This is a specific case of engine-generator. A diesel compression-ignition engine often is designed to run on fuel oil, but some types are adapted for other liquid fuels or natural gas.

Diesel generating sets are used in places without connection to a power grid, or as emergency power-supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid.

Proper sizing of diesel generators is critical to avoid low-load or a shortage of power. Sizing is complicated by the characteristics of modern electronics, specifically non-linear loads. In size ranges around 50 MW and above, an open cycle gas turbine is more efficient at full load than an array of diesel engines, and far more compact, with comparable capital costs; but for regular part-loading, even at these power levels, diesel arrays are sometimes preferred to open cycle gas turbines, due to their superior efficiencies.

The packaged combination of a diesel engine, a generator and various ancillary devices (such as base, canopy, sound attenuation, control systems, circuit breakers, jacket water heaters and starting system) is referred to as a "generating set" or a "genset" for short.

Set sizes range from 8 to 30 kW (also 8 to 30 kVA single phase) for homes, small shops and offices with the larger industrial generators from 8 kW (11 kVA) up to 2,000 kW (2,500 kVA three phase) used for large office complexes, factories. A 2,000 kW set can be housed in a 40 ft (12 m) ISO container with fuel tank, controls, power distribution equipment and all other equipment needed to operate as a standalone power station or as a standby backup to grid power. These units, referred to as power modules are gensets on large triple axel trailers weighing 85,000 pounds (38,555 kg) or more. A combination of these modules are used for small power stations and these may use from one to 20 units per power section and these sections can be combined to involve hundreds of power modules. In these larger sizes the power module (engine and generator) are brought to site on trailers separately and are connected together with large cables and a control cable to form a complete synchronized power plant. A number of options also exist to tailor specific needs, including control panels for autostart and mains paralleling, acoustic canopies for fixed or mobile applications, ventilation equipment, fuel supply systems, exhaust systems, etc. Diesel generators, sometimes as small as 200 kW (250 kVA) are widely used not only for emergency power, but also many have a secondary function of feeding power to utility grids either during peak periods, or periods when there is a shortage of large power generators.

Ships often also employ diesel generators, sometimes not only to provide auxiliary power for lights, fans, winches etc., but also indirectly for main propulsion. With electric propulsion the generators can be placed in a convenient position, to allow more cargo to be carried. Electric drives for ships were developed prior to World War I. Electric drives were specified in many warships built during World War II because manufacturing capacity for large reduction gears was in short supply, compared to capacity for manufacture of electrical equipment. Such a diesel-electric arrangement is also used in some very large land vehicles such as railroad locomotives.

Grid support:

Emergency standby diesel generators, for example such as those used in hospitals, water plant, are, as a secondary function, widely used in the US and, in the recent past, in Great Britain to support the respective national grids at times for a variety of reasons. In the UK the tenders known as the Short Term Operating Reserve have exhibited quite variable prices, and from 2012 the volume of demand-side participation, which mainly entails the use of on-site diesels, has dropped as the tendered prices fell. Some 0.5 GWe of diesels have at times been used to support the National Grid, whose peak load is about 60 GW. These are sets in the size range 200 kW to 2 MW. This usually occurs during, for example, the sudden loss of a large conventional 660 MW plant, or a sudden unexpected rise in power demand eroding the normal spinning reserve available.

This is beneficial for both parties - the diesels have already been purchased for other reasons; but to be reliable need to be fully load tested. Grid paralleling is a convenient way of doing this. This method of operation is normally undertaken by a third party aggregator who manages the operation of the generators and the interaction with the system operator.

These diesels can in some cases be up and running in parallel as quickly as two minutes, with no impact on the site (the office or factory need not shut down). This is far quicker than a base load power station which can take 12 hours from cold, and faster than a gas turbine, which can take several minutes. Whilst diesels are very expensive in fuel terms, they are only used a few hundred hours per year in this duty, and their availability can prevent the need for base load station running inefficiently at part load continuously. The diesel fuel used is fuel that would have been used in testing anyway.

In Great Britain, National Grid can generally rely upon about 2 GW of customer demand reduction via back-up diesels being self-dispatched for about 10 to 40 hours a year at times of expected peak national demand. National Grid does not control these diesels - they are run by the customer to avoid "triad" transmission network use of system (TNUoS) charges which are levied only on consumption of each site, at the three half-hours of peak national demand. It is not known in advance when the three half-hours of peak national demand (the "triad" periods) will be, so the customer must run his diesels for a good deal more half-hours a year than just three.

The total capacity of reliably operable standby generation in Britain is estimated to be around 20 GW, nearly all of which is driven by diesel engines. This is equivalent to nearly 29% of the British system peak, although only a very small fraction will ever be generating at the same time. Most plant is for large offices blocks, hospitals, supermarkets, and various installations where continuous power is important such as airports. Therefore, most is in urban areas, particularly city and commercial centers. It is estimated that around 10% of plant exceeds 1 MW, about 50% is in the 200 kW-1 MW range, and the remaining 40% is sub-200 kW. Although it is growing, only a very small proportion is believed to be used regularly for peak lopping, the vast majority just being only for standby generation. The information in this paragraph is sourced from section 6.9 of the government report: "Overcoming Barriers to Scheduling Embedded Generation to Support Distribution Networks"

A similar system to Great Britain's Short Term Operating Reserve operates in France. It is known as EJP; at times of grid stress, special tariffs can mobilize at least 5 GW of diesel generating sets to become available. In this case, the diesels prime function is to feed power into the grid.

During normal operation in synchronization with the electricity net, power plants are governed with a five percent droop speed control. This means the full load speed is 100% and the no load speed is 105%. This is required for the stable operation of the net without hunting and dropouts of power plants. Normally the changes in speed are minor. Adjustments in power output are made by slowly raising the droop curve by increasing the spring pressure on a centrifugal governor. Generally this is a basic system requirement for all power plants because the older and newer plants have to be compatible in response to the instantaneous changes in frequency without depending on outside communication.

3.3 Photovoltaic (PV) power systems

When sunlight strikes on photovoltaic solar panels solar electricity is produced. That is why this is also referred to as photovoltaic solar, or PV solar.

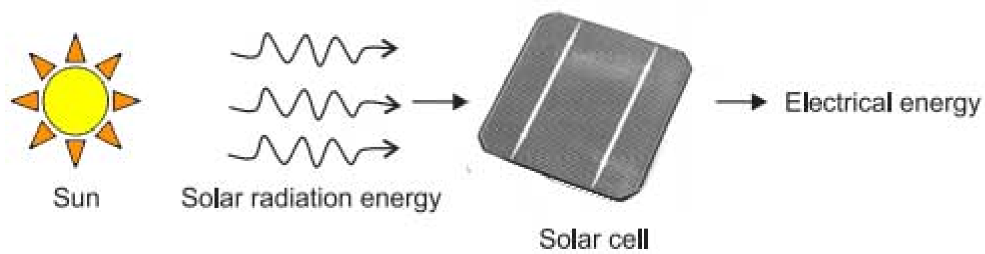


Fig 3.2 Principles of Solar Electricity

Generation of electricity by using solar energy depends upon the photovoltaic effect in some specific materials. There are certain materials that produce electric current when these are exposed to direct sun light. This effect is seen in combination of two thin layers of semiconductor materials. One layer of this combination will have a depleted number of electrons. When sunlight strikes on this layer it absorbs the photons of sunlight ray and consequently the electrons are excited and jump to the other layer. This phenomenon creates a charge difference between the layers and resulting to a tiny potential difference between them. The unit of such combination of two layers of semiconductor materials for producing electric potential difference in sunlight is called solar cell.

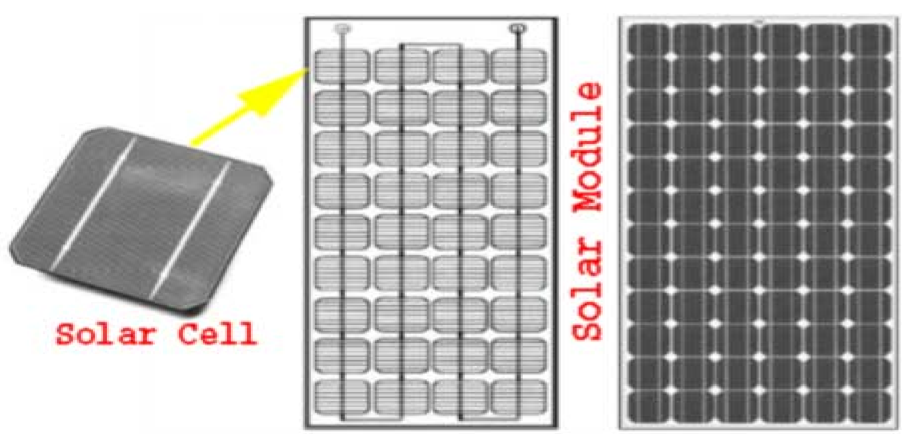


Fig 3.3 Solar Cell and Solar Module

Silicon is normally used as the semiconductor material for producing such solar cell. For building cell silicon material is cut into very thin wafers. Some of these wafers are doped with impurities. Then the un-doped and doped wafers are then sandwiched together to build solar cell. Metallic strip is then attached to two extreme layers to collect current. Conductive metal strips attached to the cells take the electrical current. One solar cell or photovoltaic cell is not capable of producing desired electricity instead it produces very tiny amount of electricity hence for extracting desired level of electricity desired number of such cells are connected together in both parallel and series to form a solar module or photovoltaic module.

Solar electric power generation system is useful for producing moderate amount of power. The system works as long as there is a good intensity of natural sunlight. The place where solar modules are installed should be free from obstacles such as trees and buildings otherwise there will be shade on the solar panel which affects the performance of the system. It is a general view that solar electricity is an impractical alternative of conventional source of electricity and should be used when there is no traditional alternative of conventional source of electricity available. But this is not the actual case. Often it is seem that solar electricity is more money saving alternative than other traditional alternatives of conventional electricity.

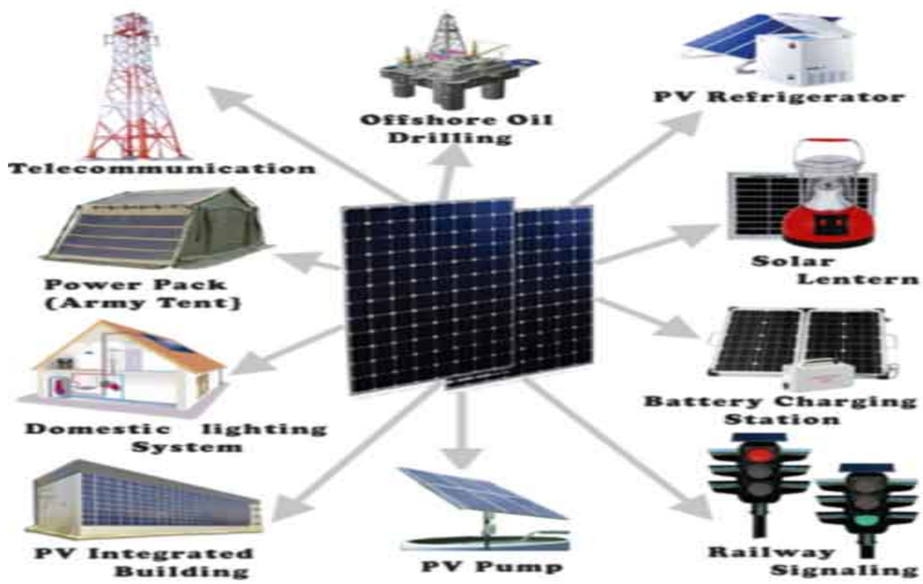


Fig 3.4 Application of Solar Electricity

It is always economical to install a solar light or a solar power source where it is difficult and costly to get point from local electric supply authority such as in remote garden, shed or garage where standard electric supply point is not available. Solar electricity system is more reliable and uninterrupted as it does not suffer from unwanted power cut from electric supply company. For constructing a mobile electric power source, for moderate power requirements solar module is good choice. It can be useful whilst camping, working on outdoor sites. It is most effective means for creating green energy for our own purpose and may be for selling surplus energy to customers but for producing electricity in commercial scale the investment and volume of the system becomes large enough. In that case area of the project will be much larger than conventional one. Although for running few lights and low-power electrical gadgets such as laptop computer, portable sized television, mini fridge etc solar electricity system is quite suitable provided there is sufficient free space on ground or on roof top for installing solar panels. But it is not at all economical to run high-power consuming electric equipments like high speed fans, heaters, washing machines, air conditioners and power tools with the help of solar electricity as the cost of production such high energy is quite higher that it is expected. Moreover there may be lack of space availability in your premises for installation of large solar panel. Ideal uses of low-cost solar panels are charging batteries in caravans and recreational vehicles or on boats when these are not in movement provided there should be tickle charging facility from dynamo during movement of these vehicles.

3.4 Types of Solar Power Station

There are mainly four types of solar power stations**.**

- Stand Alone or Off Grid type Solar Power Plant
- Grid Tie type Solar Power Plant
- Grid Tie with Power Backup or Grid Interactive type Solar Power Plant
- Grid Fallback type Solar Power Plant.

Let us discuss a brief introduction of each type of solar power plant

3.4.1 Stand Alone or Off Grid Solar Power Station

This is most commonly used photovoltaic installation used to provide localized electricity in absence of conventional source of electric power at certain location. As the name prefers this system does not keep any direct or indirect connection with any grid type network. In standalone system the solar modules produce electric energy which is utilized to charge a storage battery and this battery delivers electricity to the connected load. Standalone systems are normally small system with less than 1 kilo watt generation capacity.

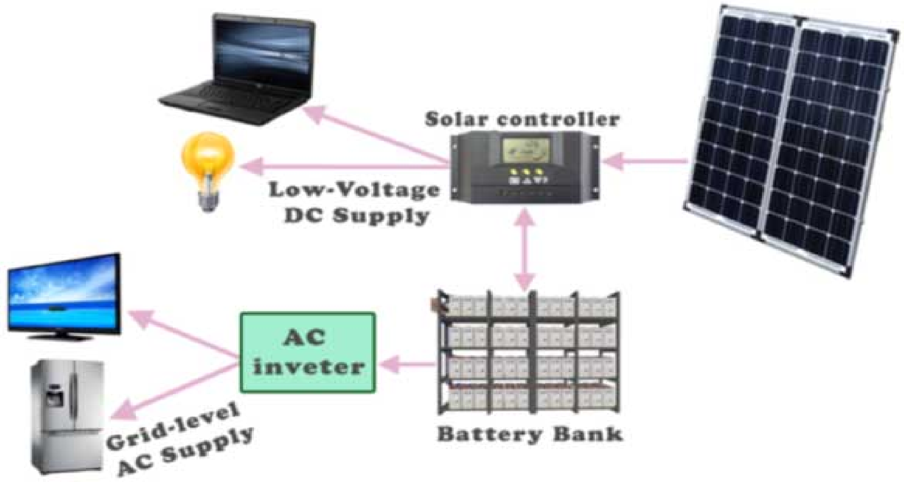


Fig 3.5 Stand Alone or Off Grid Solar Power Station

3.4.2 Grid Tie Solar Power Station

Grid tie solar systems are of two types one with single macro central inverter and other with multiple micro inverters. In the former type of solar system, the solar panels as well as grid supply are connected to a common central inverter called grid tie inverter as shown below. The inverter here converts the DC of the solar panel to grid level AC and then feeds to the grid as well as the consumer's distribution panel depending upon the instant demand of the systems. Here grid-tie inverter also monitors the power being supplied from the grid. If it finds any power cut in the grid, it actuates switching system of the solar system to disconnect it from the grid to ensure no solar electricity can be fed back to the grid during power cut. There is on energy meter connected in the main grid supply line to record the energy export to the grid and energy import from the grid.

As we already told there is another type of grid-tie system where multiple micro-inverters are used. Here one micro inverter is connected for each individual solar module. The basic block diagram of this system is very similar to previous one except the micro inverters are connected together to produce desired high AC voltage. In previous case the low direct voltage of solar panels is first converted to alternating voltage then it is transformed to high alternating voltage by transformation action in the inverter itself but in this case the individual alternating output voltage of micro inverters are added together to produce high alternating voltage.

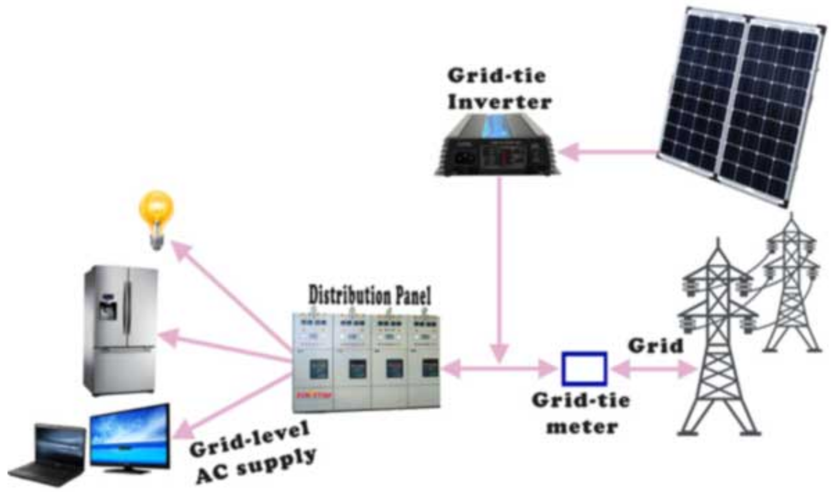


Fig 3.6 Grid Tie Solar Power Station

3.4.3 Grid Tie with Power Backup or Grid Interactive type Solar Power Plant

It is also called grid interactive system. This is a combination of a grid-tie solar power generation unit and storage battery bank. As we said, the main drawback of grid tie system is that when there is any power cut in the grid the solar module is disconnected from the system. For avoiding discontinuity of supply during power cut period one battery bank of sufficient capacity can be connected with the system as power backup.

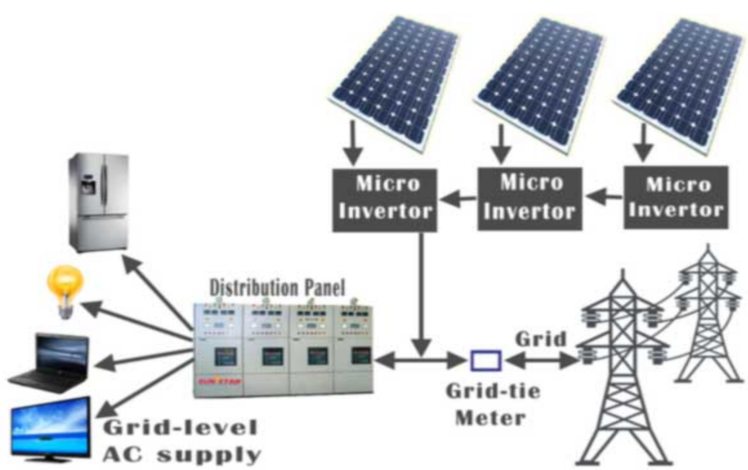


Fig 3.7 Grid Tie with Power Backup Solar Power Generation

3.4.4 Grid Fallback Solar Power Generation

Grid fallback is most reliable and stable system mainly used for electrifying smaller households. Here solar modules charge a battery bank which in turn supplies distribution boards through an inverter. When the batteries are discharged to a pre-specified level, the system automatically switches back to the grid power supply. The solar modules then recharge the batteries and after the batteries are being charged up to a pre – specified level again the system switches back to solar power. We do not sell electricity back to the electricity utility companies through this system. All the power that we produce is utilized for ourselves only.

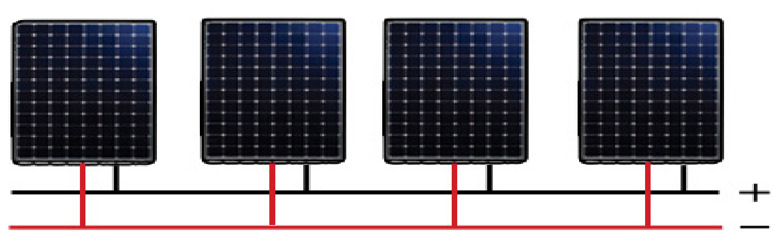
Although we do not have any direct earning benefit from this system but the system has its own big advantages. This system is most popular where there is no facility of selling power to the grid.

Grid fallback system has all advantages of grid interactive system except power selling, but it adds benefit of using own power whenever it is required irrespective of position and condition of sun in the sky.

3.5 Components of a Solar Electric Generating System

Solar Panels

The main part of a solar electric system is the solar panel. There are various types of solar panel available in the market. Solar panels are also known as photovoltaic solar panels**.** Solar panel or solar module is basically an array of series and parallel connected solar cells. The potential difference developed across a solar cell is about 0.5 volt and hence desired number of such cells to be connected in series to achieve 14 to 18 volts to charge a standard battery of 12 volts. Solar panels are connected together to create a solar array. Multiple panels are connected together both in parallel and series to achieve higher current and higher voltage respectively.



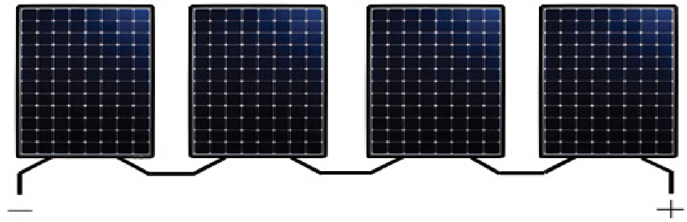


Fig 3.8 Series and Parallel connection of PV panels

Batteries

In grid-tie solar generation system, the solar modules are directly connected to inverter not with load. The power collected from solar panel not in constant rate rather it varies with intensity of sunlight. This is the reason why solar modules or panels do not feed any electrical equipment directly instead they feed an inverter whose output is synchronized with external grid supply. Inverter takes care of the voltage level and frequency of the output power from the solar system it always maintains it with that of grid power level. As we get power from both solar panels and external grid power supply system, the voltage level and quality of power remain constant. As the stand-alone or grid fallback system is not connected with grid any variation of power level in the system can directly affects the performance of the electrical equipment fed from it. So there must be some means to maintain the voltage level and power supply rate of the system. A battery bank connected parallel to this system takes care of that. Here the battery is charged by solar electricity and this battery then feeds a load directly or through an inverter. In this way variation of power quality due to variation of sunlight intensity can be avoided in solar power system instead an uninterrupted uniform power supply is maintained. Normally Deep cycle lead acid batteries are used for this purpose. These batteries are typically designed to make capable of several charging and discharging during service. The battery sets available in the market are generally of either 6 volt or 12 volts. Hence number of such batteries can be connected in both series as well as parallel to get higher voltage and current rating of the battery system.

Controller

This is not desirable to overcharge and under discharge a lead acid battery. Both overcharging and under discharging can badly damage the battery system. To avoid these both situations a controller is required to attach with the system to maintain flow of current to and fro the batteries.

Inverter

It is obvious that the electricity produced in a solar panel is DC. Electricity we get from the grid supply is AC. So for running common equipment from grid as well as solar system, it is required to install an inverter to convert DC of solar system to AC of same level as grid supply. In off grid system the inverter is directly connected across the battery terminals so that DC coming from the batteries is first converted to AC then fed to the equipment. In grid tie system the solar panel is directly connected to inverter and this inverter then feeds the grid with same voltage and frequency power.

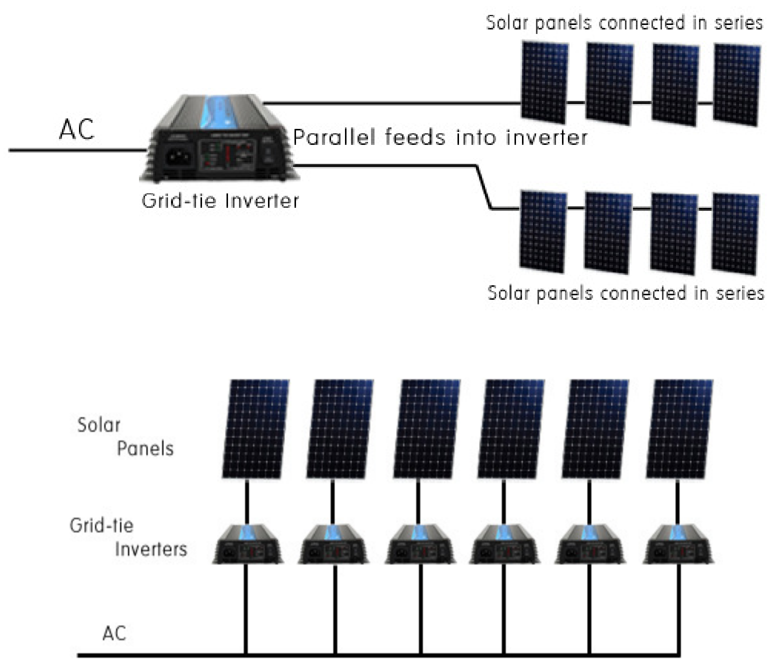


Fig 3.9 Grid tie Inverter

Chapter 4

CHARGING STATION CONTROL STRATEGIES

4 CHARGING STATION CONTROL STRATEGIES

4.1 Basic Controller Types

PID controllers use a 3 basic behavior types or modes: P - proportional, I - integrative and D - derivative. While proportional and integrative modes are also used as single control modes, a derivative mode is rarely used on it' s own in control systems.
Combinations such as PI and PD control are very often in practical systems.

4.1.1 P Controller:

In general it can be said that P controller cannot stabilize higher order processes.
For the 1st order processes, meaning the processes with one energy storage, a large increase in gain can be tolerated. Proportional controller can stabilize only 1st order unstable process. Changing controller gain K can change closed loop dynamics. A large controller gain will result in control system with:

a) Smaller steady state error, i.e. better reference following

b) Faster dynamics, i.e. broader signal frequency band of the closed loopsystem and larger sensitivity with respect to measuring noise

c) Smaller amplitude and phase margin

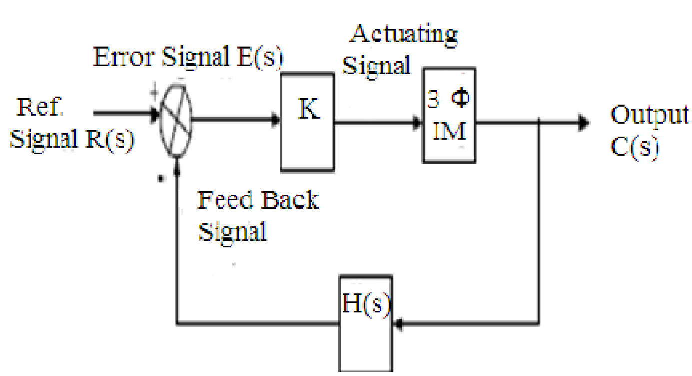


Fig 4.1 Block diagram of P controller

The error of signal given as follows:

$$e(t) = k[r(t) - h(t)] \quad Eq(4.1)$$

When P controller is used, large gain is needed to improve steady state error. Stable systems do not have problems when large gain is used. Such systems are systems with one energy storage (1st order capacitive systems). If constant steady state error can be accepted with such processes, than P controller can be used. Small steady state errors can be accepted if sensor will give measured value with error or if importance of measured value is not too great anyway.

4.1.2 PD Controller:

D mode is used when prediction of the error can improve control or when it necessary to stabilize the system. From the frequency characteristic of D element it can be seen that it has phase lead of 90°.Often derivative is not taken from the error signal but from the system output variable. This is done to avoid effects of the sudden change of the reference input that will cause sudden change in the value of error signal. Sudden change in error signal will cause sudden change in control output. To avoid that it is suitable to design D mode to be proportional to the change of the output variable.

PD controller is often used in control of moving objects such are flying and underwater vehicles, ships, rockets etc. One of the reason is in stabilizing effect of PD controller on sudden changes in heading variable y(t). Often a "rate gyro" for velocity measurement is used as sensor of heading change of moving object.

4.1.3 PI Controller:

PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system.

The controller output in this case is :

$$u(t) = K_p \cdot e(t) + K_i \int e(t)\, dt \quad Eq(4.2)$$

Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller.

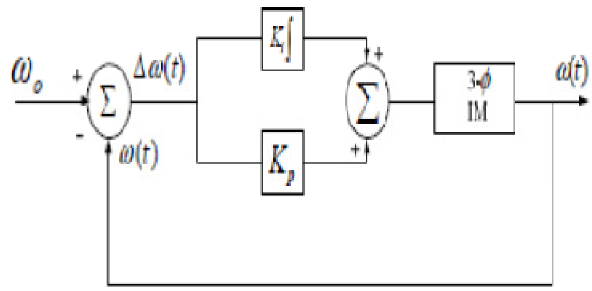


Fig 4.2 Block diagram of PI controller

PI controllers are very often used in industry, especially when speed of the response is not an issue. A control without D mode is used when:

a) Fast response of the system is not required

b) Large disturbances and noise are present during operation of the process

c) There is only one energy storage in process (capacitive or inductive)

d) There are large transport delays in the system

4.1.4 PID Controller:

PID controller has all the necessary dynamics: fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode).

Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response.

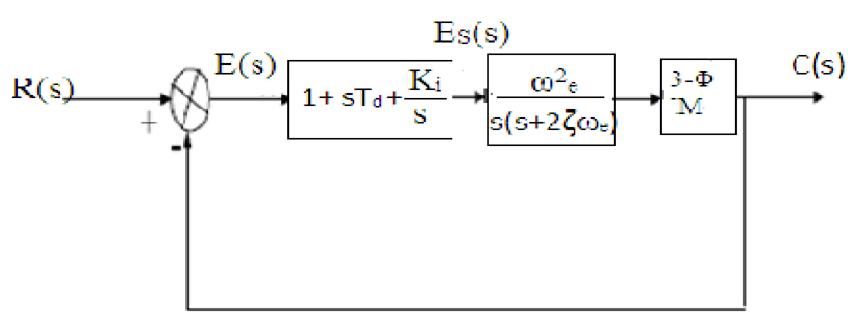


Fig 4.3 Block diagram of PID controller

Controller output is

$$u(t) = K_p.e(t) + K_i \int e(t).dt + K_d \frac{de(t)}{dt}$$

PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes). PID controller is often used in industry, but also in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. Conventional autopilot is for the most part PID type controllers.

Effects of Coefficients

Parameter	Speed of response	Stability	Accuracy
increasing K	increases	deteriorate	improves
increasing K_i	decreases	deteriorate	improves
increasing K_d	increases	improves	no impact

Table 4.1 Effects of changing control parameters.

Parameter	Rise Time	Overshoot	Settling Time	S.S Error	Stability
Kp	Decrease	Increase	Small Change	Decrease	Worse
Ki	Decrease	Increase	Increase	Significant Decrease	Worse
Kd	Minor Dec.	Minor Dec.	Minor Dec.	No change	If Kd small, Better.

4.2 Charging Station (CS) Control Strategies

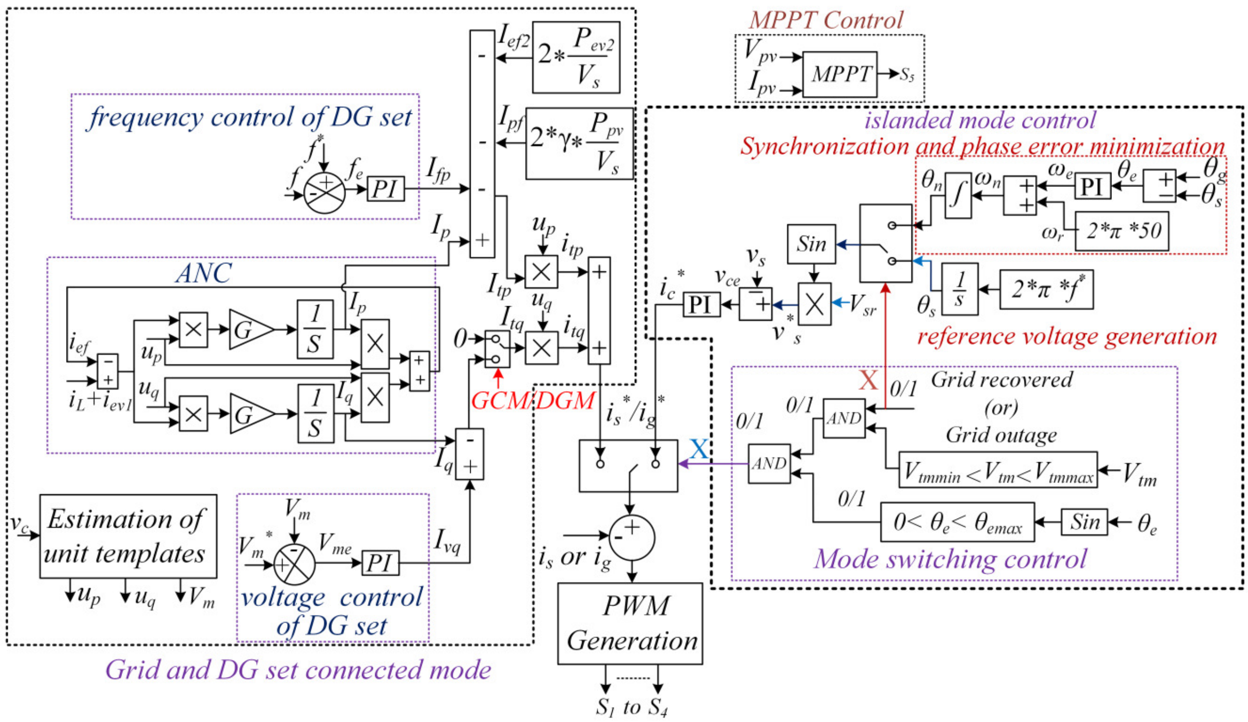


Fig 4.4 Unified control of VSC for standalone and grid and DG set connected mode

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

The islanded control of the CS ensures the stable operation of the CS in absence of the grid, which means the AC as well as the DC charging of the EV remains intact along with the undisturbed solar power generation. The DC charging and the solar PV generation can be managed by the storage battery without much modification in the control. However, the AC charging needs a separate controller for VSC using which the local voltage reference is generated, because in absence of the grid no voltage reference is available. Therefore, the islanded controller generates the internal voltage reference of 230V and 50 Hz as per the logic presented in Fig. 2, which integrates the frequency and pass through the sin for generating the reference voltage. The generated reference is compared with the terminal voltage of the converter, which ultimately gives the reference converter current after minimization of voltage error using proportional integral (PI) controller. The error minimization and reference current generation is expressed as,

$$i_c^*(s) = i_c^*(s-1) + z_{pv}\{v_{ce}(s) - v_{ce}(s-1)\} + z_{iv}v_{ce}(s) \quad \text{Eq (4.3)}$$

The reference current after comparison with sensed converter current and after passing through hysteresis controller generates the gate signals of the converter.

4.2.2 Control of VSC in DG Set or Grid Connected Mode

In grid connected mode, the controller task is to decide the amount of power to be exchanged with the grid. In DG set connected mode, DG set operates in constant power mode for achieving maximum fuel efficiency. However, in both cases, the controller has to compensate the harmonic and reactive current demand of the EVs, which is achieved by estimating the reference current of the grid or the DG set from the EV current. In grid connected condition, the reference current is estimated by considering only the active current of the EV current. However, in DG set connected mode, the reference DG set current is estimated using both reactive and active currents of the EV. In this work, an adaptive notch cancellation (ANC) [22] extracts the fundamental frequency current of the EV. Further with the sample and hold logic, the fundamental current at every zero crossing of quadrature and in-phase unit template, gives the active and reactive current, respectively. Now, the total active and reactive currents in grid connected mode are,

$$\begin{aligned} I_{sp} &= I_p - I_{ef2} - I_{pf} \\ I_{sq} &= 0 \end{aligned} \quad \text{Eq(4.4)}$$

In grid connected mode, only active current of EV is considered and the reactive current is considered zero for achieving unity power factor operation. However, in DG set connected mode, both active and reactive current components of EV are used. Now, total active and reactive current in DG set connected mode is

$$\begin{aligned} I_{sp} &= I_p - I_{ef2} - I_{fp} - I_{pf} \\ I_{sq} &= I_{vq} - I_q \end{aligned} \quad \text{Eq(4.5)}$$

Where, Ip and Iq are the active and reactive currents of EV, and Ief2 and Ipf are the feed-forward term of the EV2 and the PV array. Ifp and Ivq are the frequency and voltage regulators terms used in the DG set connected mode. Ief2 controls the vehicle to grid power transfer of the EV. Ipf is the PV array feed-forward term in grid-connected mode, which controls the overcharging of the storage battery. Since the energy storage is directly interfaced to DC link, the storage battery cannot be charged in CC/CV mode. However, it can be ensured that the storage battery does not get over charged in any condition.

In grid connected condition, overcharging of storage battery is protected by feeding the solar PV generated power into the grid. This is achieved by adding the solar PV array feed-forward term in the grid connected mode control as shown in Fig. 2. A variable gain 'γ' is also multiplied with the feed-forward term, which decides the percent of PV array power fed into grid. Constant 'γ' is defined between 0-1, which is decided by the SOC information of the storage battery. Therefore, if the storage battery is fully charged, the 'γ' takes the value as '1'. However, in case of fully drained storage battery, the 'γ' becomes '0'.

Finally, the estimated reference current of grid or DG set is as,

$$i_s^* or\ i_g^* = I_{tp} \times u_p + I_{tq} \times u_q \quad \text{Eq. (4.6)}$$

Where up and qp are synchronizing signals of the DG set or grid voltage (vg or vs). Using the sensed and the reference current of grid/DG set, the switching signals are generated using hysteresis controller as shown in Fig. 4.4

4.2.3 DG Set Control for Voltage and Frequency

For operating the DG set at single point, the frequency and voltage of DG set are regulated using decoupled control of VSC. In decoupled control, the frequency is regulated by the active power and the voltage is regulated by reactive power. Therefore, two PI controllers are used for voltage and frequency regulations. The PI control for voltage regulation is given as,

$$I_{vq}(s) = I_{vq}(s-1) + z_{vp}\{V_{me}(s) - V_{me}(s-1)\} + z_{vi}V_{me}(s) \quad \text{Eq. (4.7)}$$

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

Similarly, the discrete expression of the frequency PI controller is as,

$$I_{fp}(s) = I_{fp}(s-1) + z_{fp}\{f_e(s) - f_e(s-1)\} + z_{fi}f_e(s) \quad \text{Eq. (4.8)}$$

Where fe is the error in frequency and Z_{kfp}, Z_{fi} are PI gains. The outputs of the frequency and voltage controllers are added in grid connected control as shown in Fig. 4.4. However, the outputs of these controllers become zero in grid connected mode as the voltage and frequency of the grid remain regulated.

4.2.4 Control of EV2

EV connected at DC link through a DC-DC converter is controlled in constant current/constant voltage (CC/CV). Until the terminal voltage of the EV battery reaches the voltage corresponding to the full charge condition, the EV charges in CC mode. However, after reaching near to the desired terminal voltage in nearly full charge condition, the charging of the EVs is shifted in CV mode. Here, the CC/CV mode of charging is controlled using two PI controllers as shown in Fig. 4.5. The outer voltage loop gives reference current for current control stage.

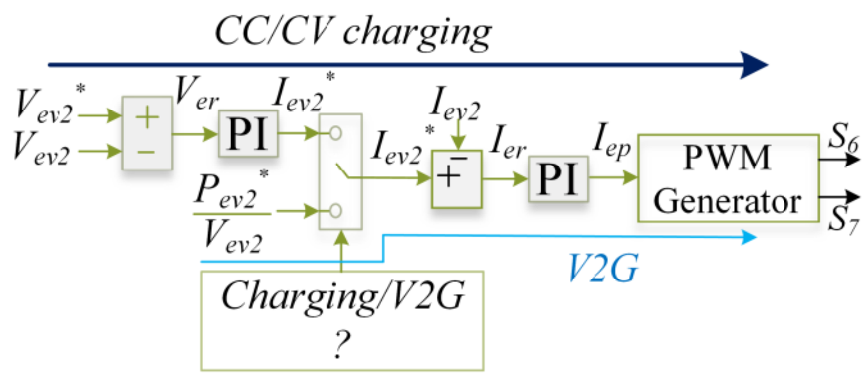


Fig. 4.5 EV2 control for CC/CV charging and V2G power transfer

The reference charging current is estimated as,

$$I_{ev2}^{*}(s) = I_{ev2}^{*}(s-1) + z_{evp}\{V_{er}(s) - V_{er}(s-1)\} + z_{evi}V_{er}(s) \quad \text{Eq. (4.9)}$$

Where, V_{er} is the EV battery voltage error and z_{evp} and z_{evi} are the controller gains.

Using the reference and sensed battery currents, the switching signals of the converter are derived using the PI controller and PWM generator. The PI controller for duty cycle calculation is expressed as,

$$d_{ev}(s) = d_{ev}(s-1) + z_{ep}\{I_{er}(s) - I_{er}(s-1)\} + z_{ei}I_{er}(s) \quad \text{q. (4.10)}$$

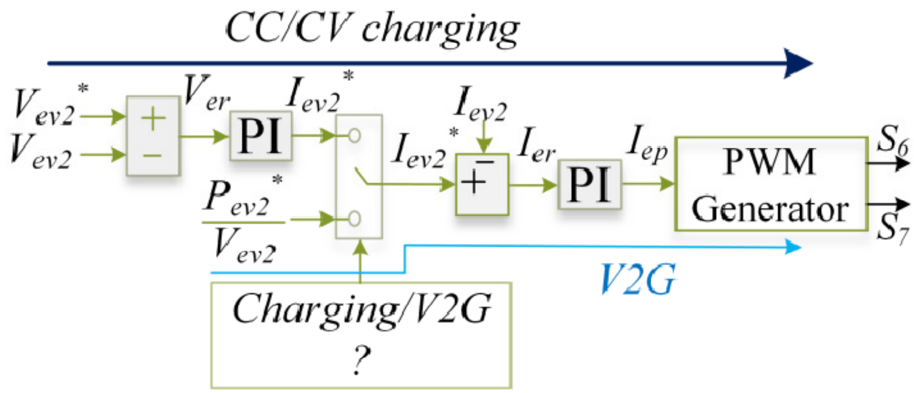


Fig. 4.6 EV2 control for CC/CV charging and V2G power transfer

Where I_{er} is battery current error and Z_{ep} and Z_{ei} are controller gains. For the V_{2G} power transfer, the EV2 battery is discharged on the basis of the reference power and the controller takes the alternate path as shown in Fig. 4.6. The reference power controls the E_{V2} feed-forward term in Fig. 4.6. E. Synchronization and Switching Control Since the charging station operates in many modes, depending upon the generation and the charging demand, the design of mode changing strategy is necessary, so that the switchover from one mode to another mode becomes smooth and the charging remains undisturbed. Islanded to grid connected and islanded to DG set connected modes are such conditions for which the mode switching logic is designed. In this strategy, at first the phase difference between the two voltages are acquired and controller brings two voltages in same phase for the purpose of synchronization. For this the PI controller changes the frequency of the VSC generated voltage in islanded condition using the logic shown in Fig. 4.4. The PI controller for phase minimization is given as,

$$\Delta\omega(s) = \Delta\omega(s-1) + z_{pa}\{\Delta\theta(s) - \Delta\theta(s-1)\} + z_{ia}\Delta\theta(s) \quad \text{Eq(4.11)}$$

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

Fig. 4.4 also shows the conditions for which the CS operates in islanded mode and under which condition; the mode transition has to be done. On fulfilling, all the requirements of synchronization, the control logic generates the enabling signal X='1', for the synchronizing switch.

Chapter 5

SIMULATION RESULTS AND ANALYSIS

5 SIMULATION RESULTS AND ANALYSIS

5.1 Simulink Model

The presented charging station, as shown in Fig. 5.1, uses a solar PV array, a storage battery, a DG set and grid energy to charge the EV and to feed the load connected to charging station. The solar PV array is connected at DC link of voltage source converter (VSC) through a boost converter and a storage battery is connected directly to DC link. The grid, a single phase SEIG (Self Excited Induction Generator), an EV and a nonlinear load, are connected on the AC side of VSC through a coupling inductor. A ripple filter at PCC, is used to eliminate the switching harmonics from the grid and the generator current and to make these currents sinusoidal. An excitation capacitor is connected to the auxiliary winding of the SEIG. A small capacitor is also connected across the main winding of the SEIG. A synchronizing switch is used between grid/DG set and PCC for controlled connection/ disconnection of charging station to grid/DG set.

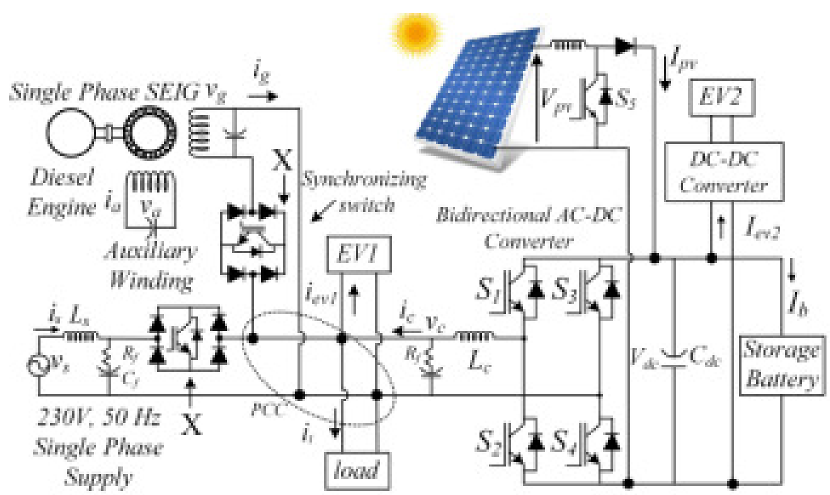


Fig 5.1 Topology of charging station

In Fig 5.2 ,Various control strategies used in the charging station are given below

A. Control of VSC in Islanded Mode (Absence of DG Set and Grid).
B. Control of VSC in DG Set or Grid Connected Mode.
C. DG Set Control for Voltage and Frequency
D. Control of EV2
E. Synchronization and Switching Control

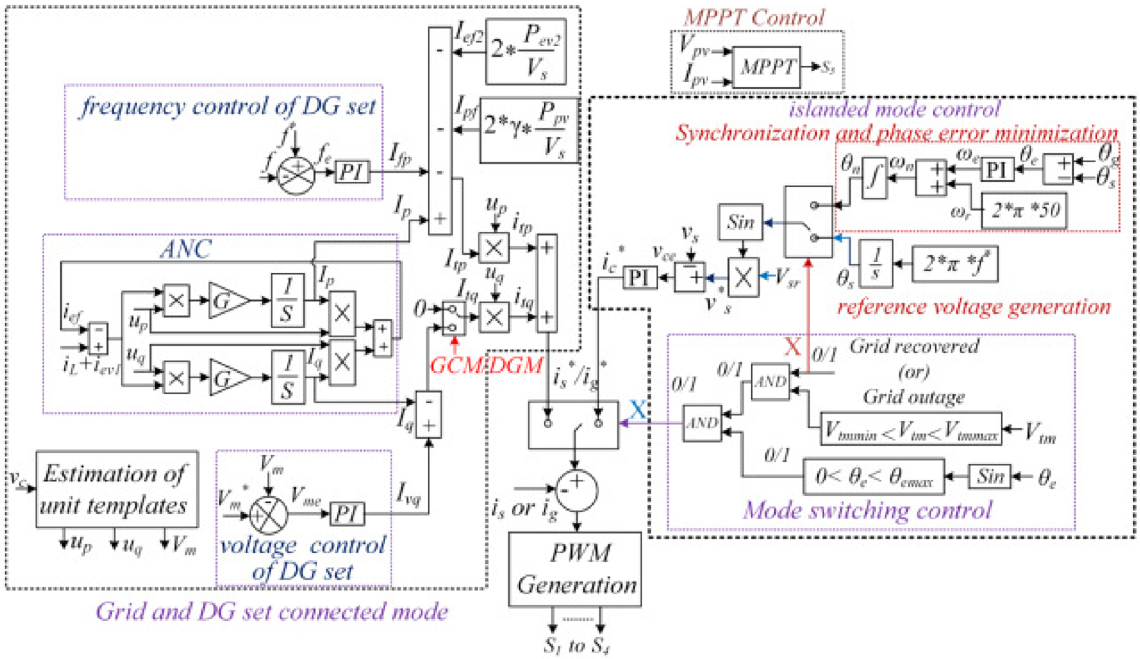


Fig 5.2 Unified control of VSC for standalone and grid and DG set connected mode

The Simulink models of charging station and Unified control of VSC for standalone and grid and DG set connected mode are presented below

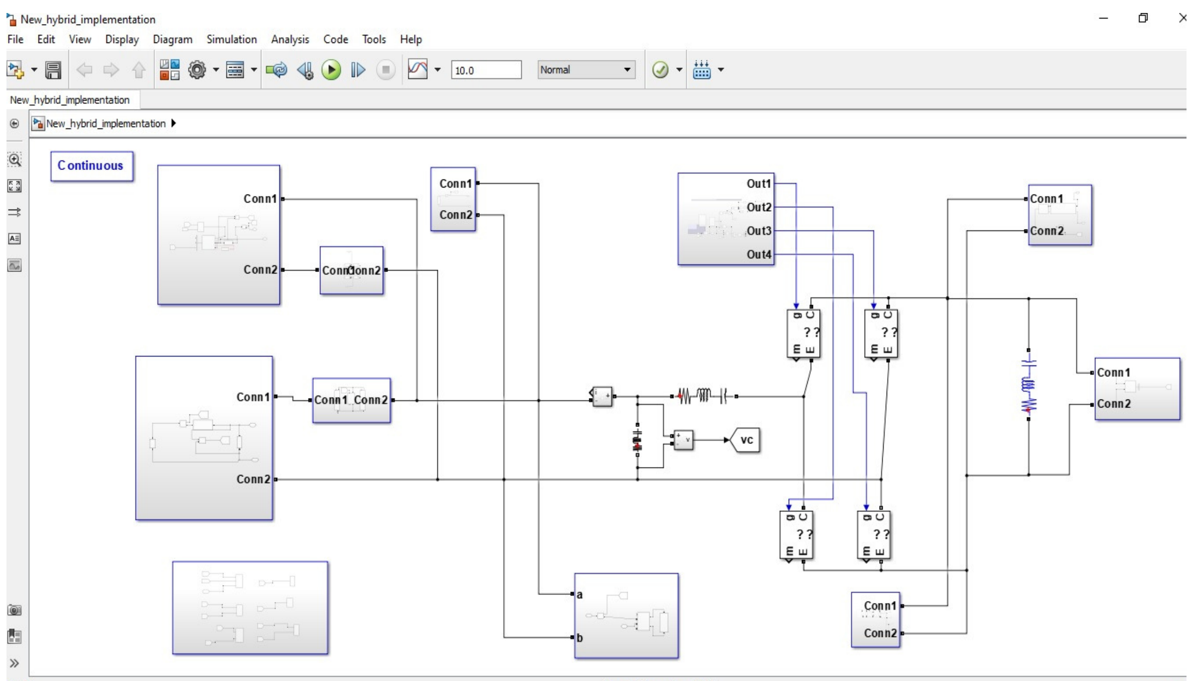


Fig 5.3 Simulink model of charging station topology

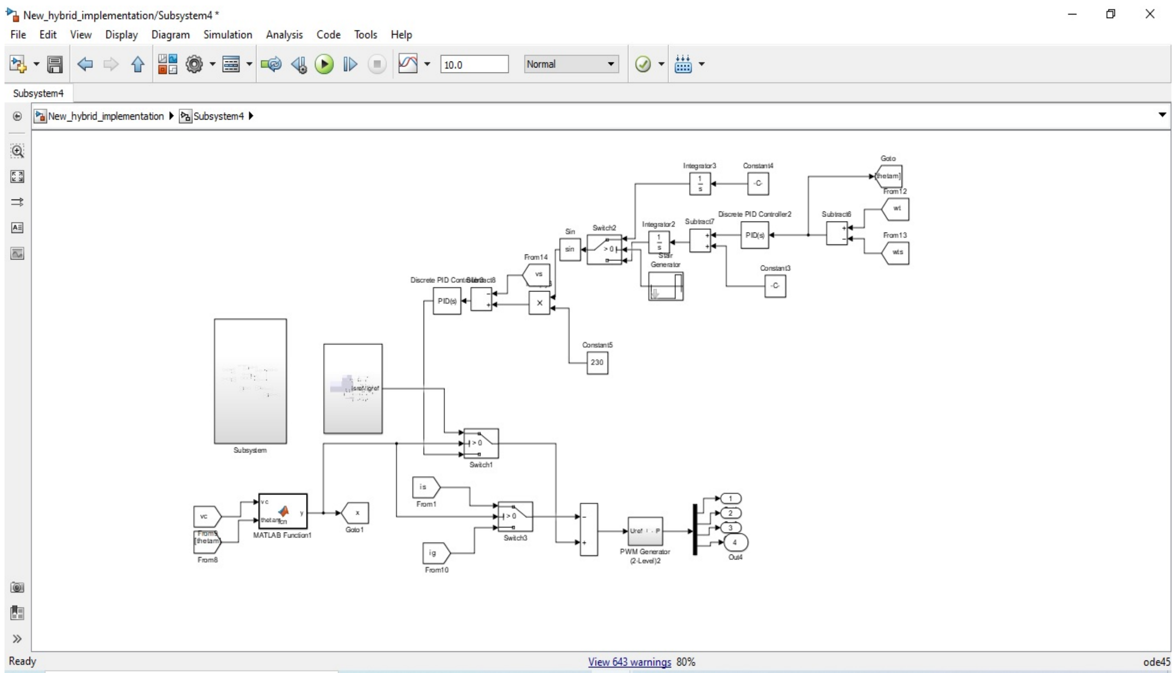


Fig 5.4 (a)

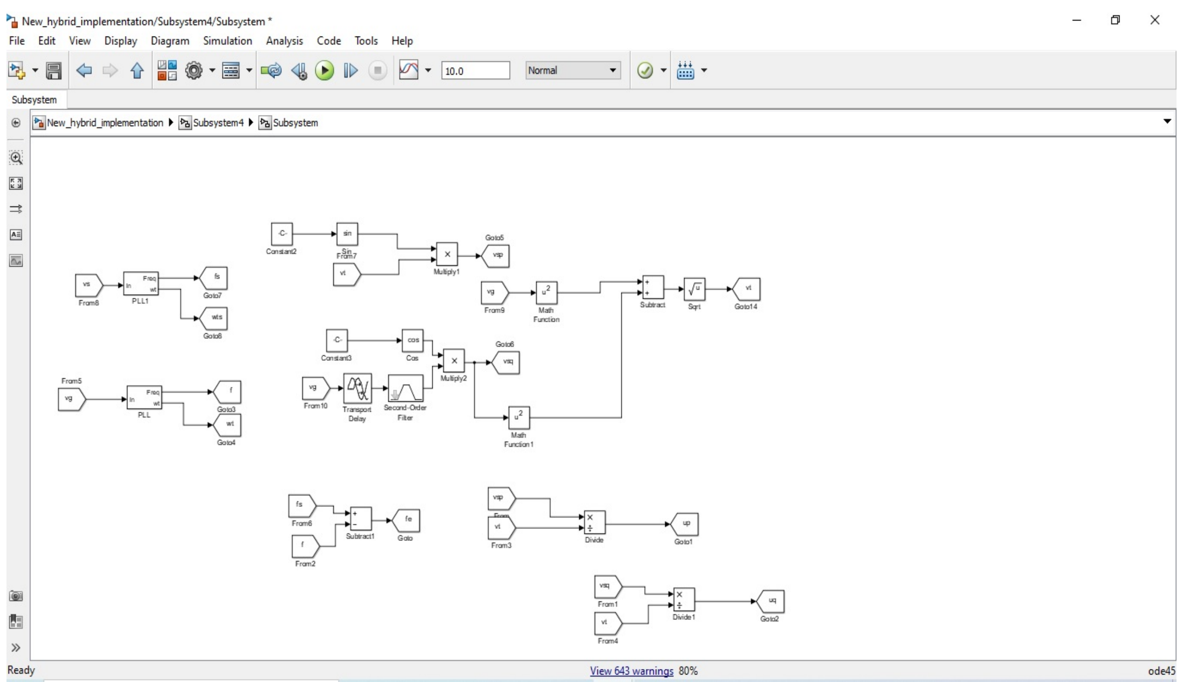


Fig 5.4 (b)

Fig 5.4 (a) & (b) Simulink models of control schemes for unified control of VSC

5.2 Simulink Results and analysis

Simulated results shown in Fig. 5.5 to 5.10, present the uninterruptible operation of the CS. Initially, the CS is operating in the islanded mode, and the PV array power is fed for charging the EVsconnected at PCC. Since the PV array generation is exceeding the EVs charging demand, the surplus generation is stored in the energy storage. At 0.32s, the solar irradiance changes from 1000 W/m2to 300 W/m2. Due to which, the PV array power reduces, and the storage battery starts discharging to keep the charging uninterruptible. At 0.48s, the storage battery discharges, as the PV array power becomes zero. After this, the storage battery completely supports the charging, as long as the SOC >SOC_{min}. After, the complete discharge of the battery, the controller connects the CS to the grid after the synchronization. At 0.79s, the CS has started drawing power from grid. After this point, CS is supported by the DG set due to unavailibility of grid and storage battery power as shown in Fig. 4. From Fig. 4, it is observed that the charging station is automatically changing the modes depending upon the generation and demand

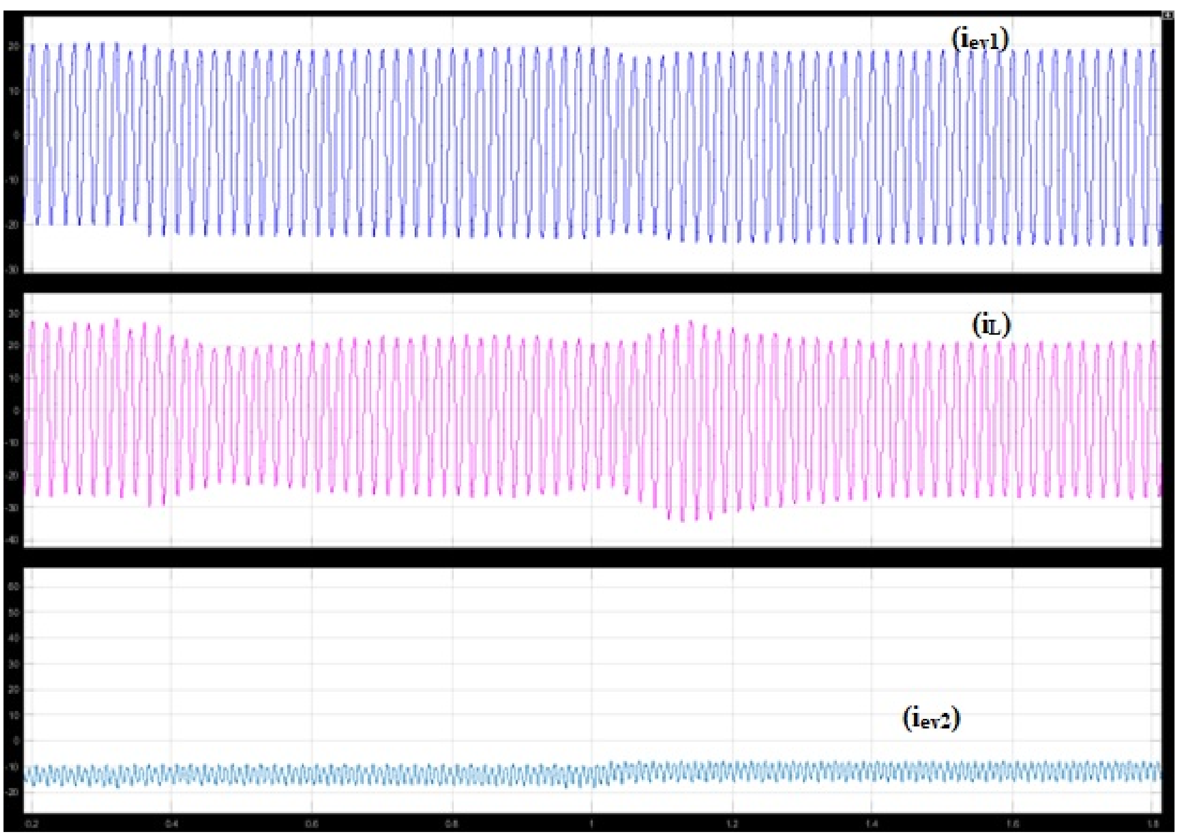


Fig 5.5 Simulated outputs currents of EV1 (i_{ev1}), EV2 (i_{ev2})and load (i_L)

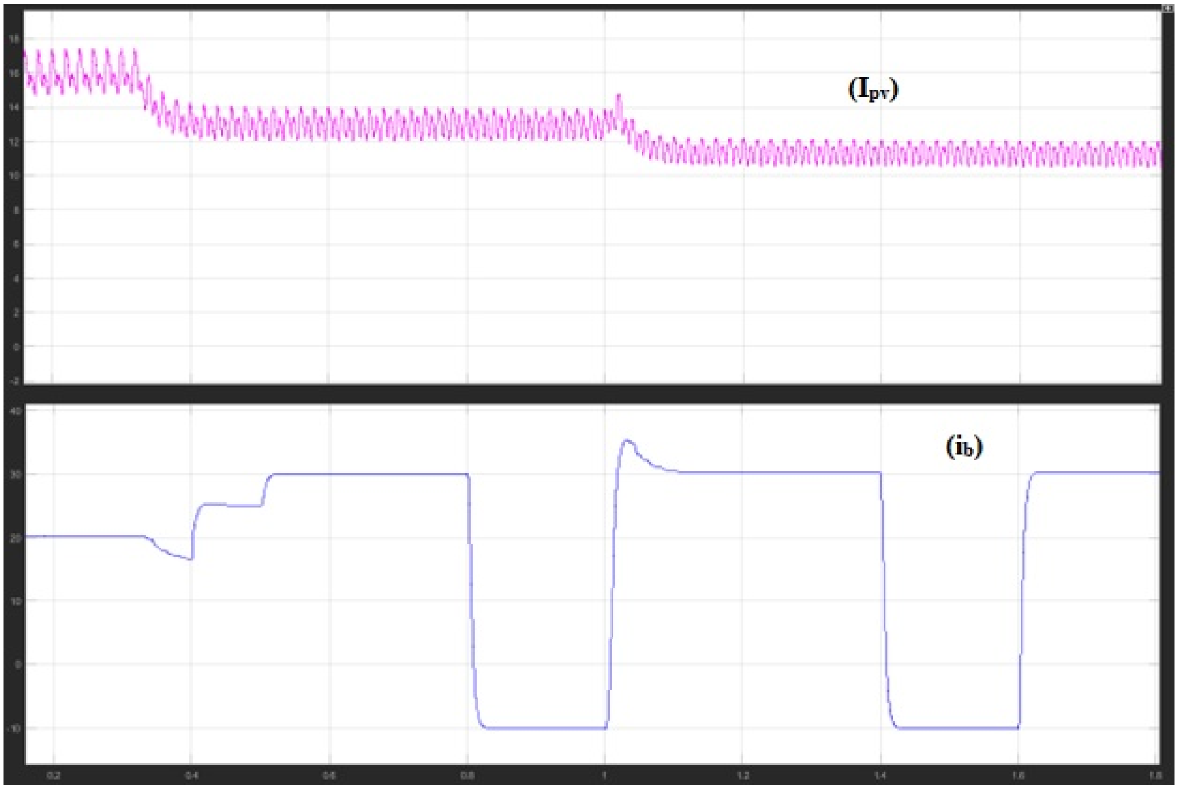


Fig 5.6 Simulated outputs currents of PV current (I_{pv})& battery charging and discharging current (i_b)

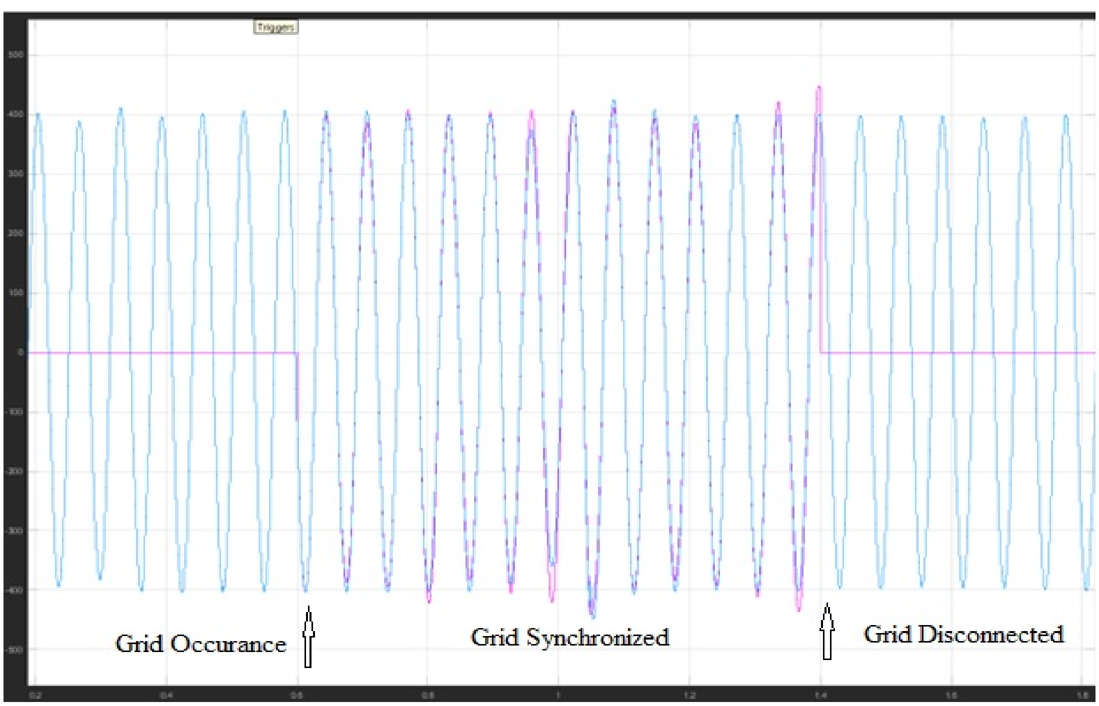


Fig 5.7 Simulated output voltages of supply voltage (V_S) and DC link voltage (V_C)

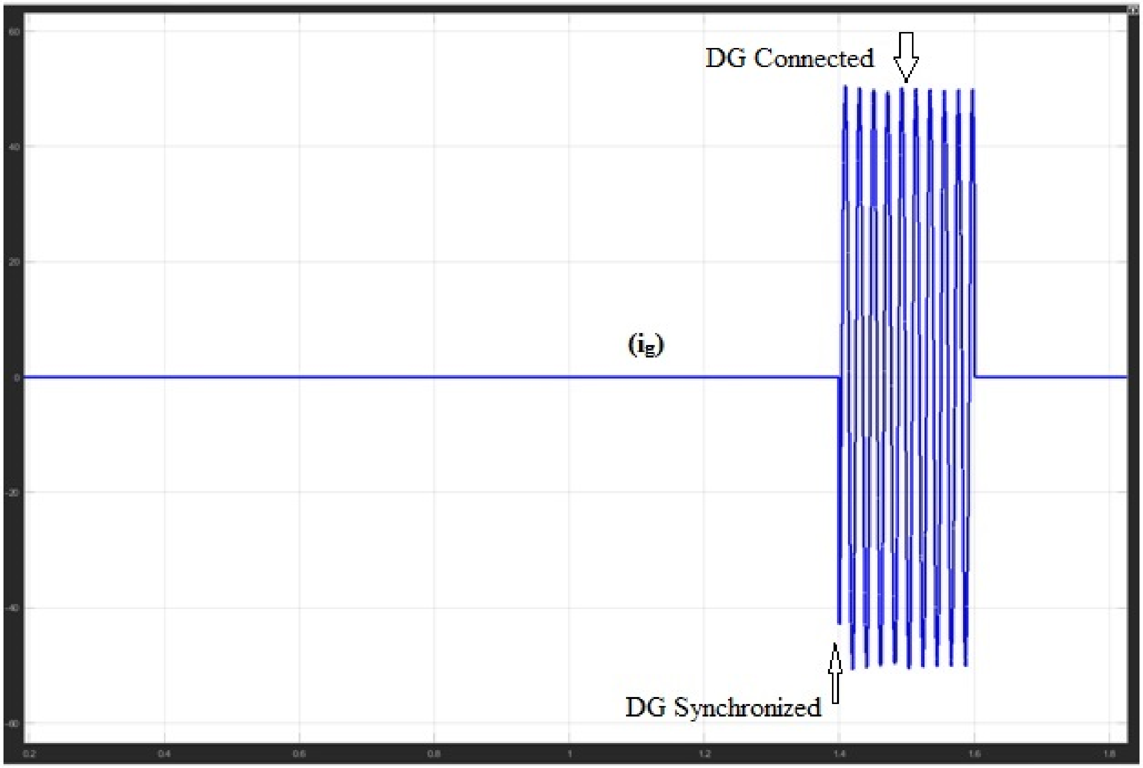


Fig 5.8 Simulated output current of generator (i_g)

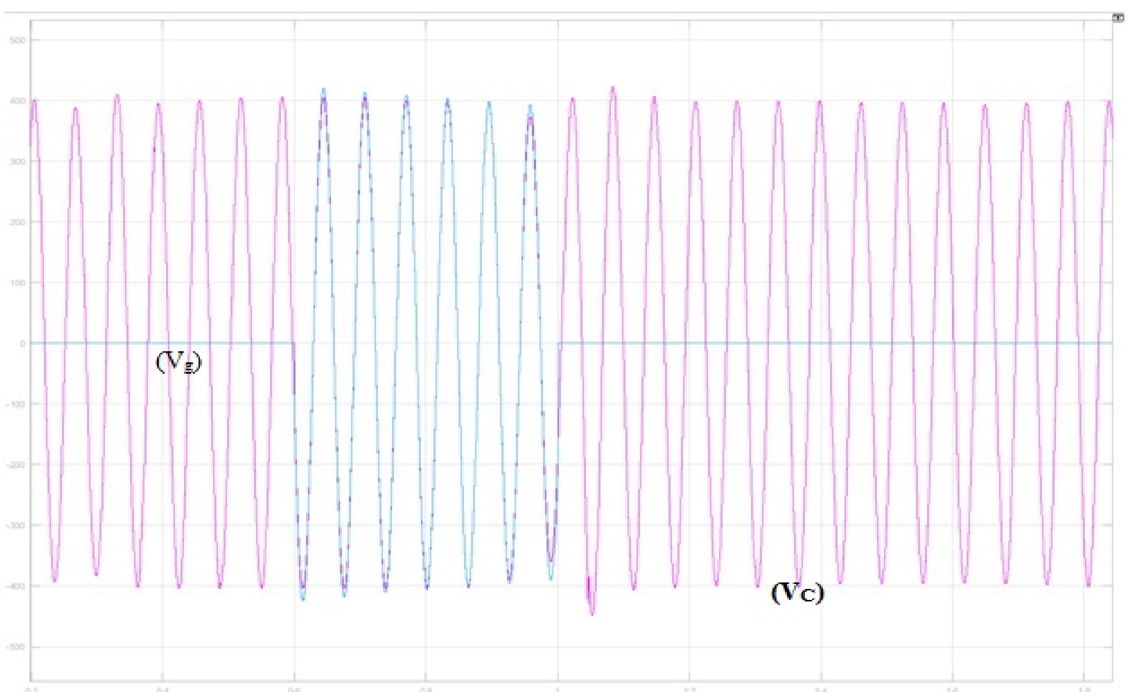


Fig 5.9 Simulated output of generator voltage (V_g) and DC link voltage (V_C)

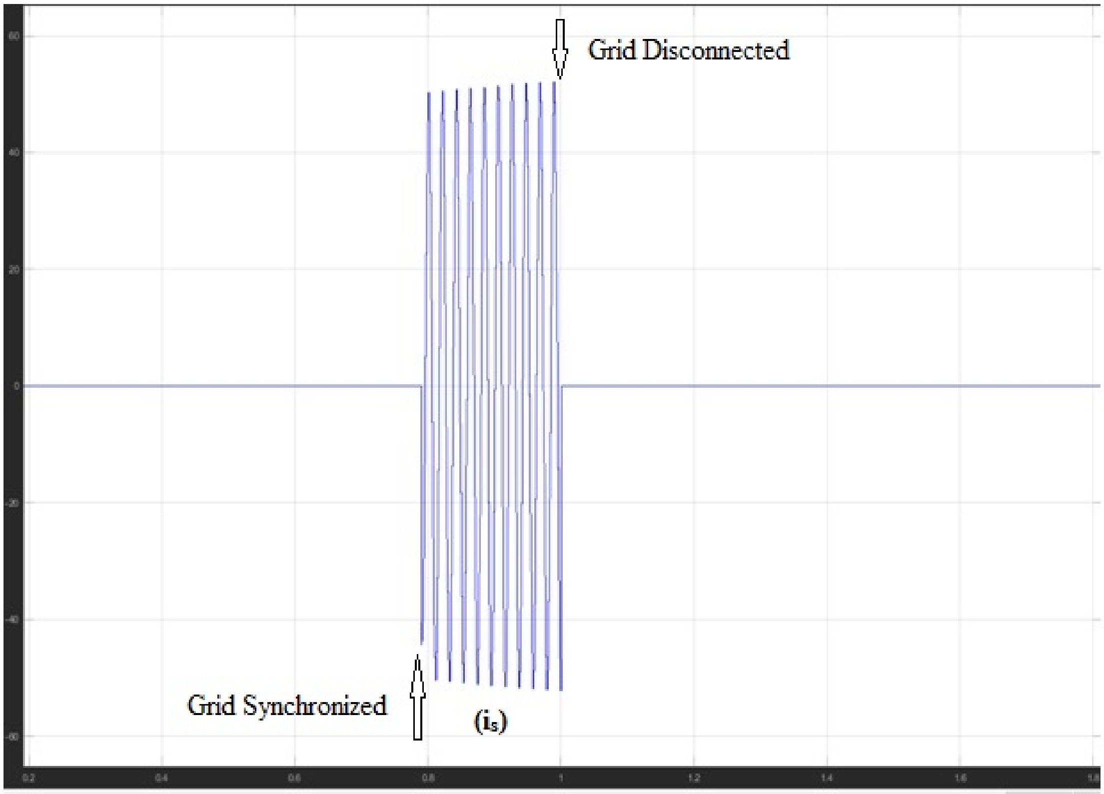


Fig 5.10 Simulated output current of generator (i_s)

Chapter 6

CONCLUSIONS

6 CONCLUSIONS

An implementation of PV array, storage battery, grid and DG set based charging station has been realized for EV charging. The presented results have verified the multimode operating capability (islanded operation, grid connected and DG set connected) of the CS using only one VSC. Test results have also verified the satisfactory operation of charging station under different steady state conditions and various dynamics conditions caused by the change in the solar irradiance level, change in the EV charging current and change in the loading. The operation of charging station as a standalone generator with good quality of the voltage has been verified by the presented results. Whereas, test results in DG set or grid connected mode, have verified the capability of ANC based control algorithm to maintain the power exchange with the grid at UPF or the optimum loading of the DG set. Moreover, the islanded operation, grid connected and DG set connected operations along with the automatic mode switching have increased the probability of MPP operation of the PV array and optimum loading of DG set along with increasing the charging reliability. It can be concluded that this charging station with the presented control have the capability to utilize the various energy sources very efficiently and provides the constant and cost effective charging to the EVs.

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An Implementation of Multimode Operating Capability for Electric Vehicle Charging Station

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Abstract: *In this paper, uses a photovoltaic (photovoltaic) array, battery energy storage (BES), diesel generator set (DG), and grid-based EV charging station (CS) for island and grid connectivity modes. Provides endless charging with and connected DG set. Charging stations are primarily designed to charge electric vehicle (EV) batteries using a solar system and BES. However, when the battery is depleted and the PV system creates a field that is inaccessible, the charging station intelligently absorbs electricity from the grid or DG-Set (diesel generator). However, the power of the DG set is always deducted to operate at 80-85% load to achieve efficient fuel economy under all load conditions. In addition, the charging station regulates the generator voltage and frequency in the same way as a battery, without a mechanical speed controller. Also, ensure that the power drawn from the mains or DG set has a power factor of 1 (UPF) even with an indirect load. In addition, the electrical output of the PCC (Standard Connection Point) is compatible with the mains voltage / generator for continuous charging. Charging stations also enable the transfer of real / active power of the car, return of the car, and transmission of the car's power to the car, increasing the efficiency of the charging station. The operation of the charging station has been experimentally verified using a prototype developed in the laboratory*.

Keywords: **EV Charging Station, Solar PV Generation, Power Quality, DG Set**.

1. INTRODUCTION

Electric vehicles (EVs) are now considered one of the most efficient means of transportation with zero towing emissions. Considering the benefits of electric vehicles, there are already 3 million vehicles on the road and are expected to exceed 100 million by 2030 [1]. However, the implementation of the proposed system requires rechargeable infrastructure and high energy capacity. In addition, electric vehicles are sustainable only when electricity from renewable and sustainable sources is needed for charging.

However, generating electricity using fossil fuels does not reduce pollution and removes fossil fuels from vehicles to power plants. Therefore, by using renewable energy sources to generate electricity, we can completely eliminate emissions and benefit from nature. Among the various renewable energy sources available, PV arrays, wind, hydro, and fuel cell-based energies, PV is available almost everywhere, whether in or out of the country. Therefore, it is the best solution for EV charging. City [2]. The Indian subcontinent is available almost all year round. Unlike solar systems, wind and hydropower are specific. Wind power is very useful in coastal areas, and hydropower is useful in hills. Renewable energy-based charging stations are the most likely solution for EV charging, but when integrated into existing charging systems, they introduce additional power conversion phases that increase system complexity and power consumption. In addition, each change phase requires individual control and integration with existing controls. Therefore, it is important to design an integrated multifunctional and multimodal system with integrated controls. Coordination between different sources is essential..

Much effort has been made to improve charging stations based on renewable energy. Ugil Murella et al. [3] discussed the importance of renewable energy for the sustainability of EV charging stations. Mulietal. [4] Use solar energy to charge the EV with a double-headed high-power EV charger. However, the designed charger does not provide AC charging. Monterio et al. [5] introduced a 3-hole converter to connect the same PV component and EV charger. However, the designed charger ignores the current distortion of the power grid generated by the charger. Shin et al. [6] We propose a modified Z source converter for PV design of the same element / grid connected to the EV charger.

However, the charger is not designed to work on the island. Therefore, EV charging cannot be provided without the grid. Chaudharietal. [7] Described a hybrid model that combines battery storage management to reduce operating costs for charging stations and maximize PV output. Kineavy et al. [8] uses the energy generated at the PV site (installed in a commercial building) in combination with an EV charging station to minimize the impact on the power grid (in uncertain circumstances) on a variety of solar powers. We are proposing to use a photovoltaic system. Zhang. [9] Studied full charging of EV charging stations in a dual charging mode operating environment.

Powerful charging stations for PV arrays (CS) are also suitable for deployments that provide the highest quality service at minimal cost while minimizing the impact of the charging network [10]. Kandasa myetal. [11] Investigate the loss of battery life in commercial buildings based on the PV array system. Wind power CS is also beneficial for EVs as it can be used day and night, and many publications are available in this area [12]-[14].

Due to the large amount of energy stored in EV batteries, EVs are also widely used as a power source to provide a variety of compatible services. Shin et al. [15] introduced PV array-based CS to provide active grids, active power filters, and homes with a place to charge and run vehicle capacity. Saxena et al. [16] Use grids connected to EV and residential PV array systems. Razmi et al. [17] proposed a power management strategy to control a variety of integrated PV live battery systems for grid and standalone applications. Erdincetal. [18] and Kikuzato et al. [19], Hafizetal. [20] Introduced the following smart home functions B. EV. It can be used as storage to power both consumers and consumers from home to home and from grid to grid.

A detailed analysis of the revised manual suggests that the work presented in the renewable energy charging station area focuses on improving various aspects of charging, including: B. Renewable energy source, final device size, driving pattern, charging time, charging cost, charging plan, etc. However, in the current scenario, only a handful of books use renewable energy charging stations.

In addition, there is not much discussion about the performance of charging stations under real-world conditions. In addition, most books only discuss CS performance in grid tie mode or island mode. However, since it is an operation mode only in grid tie mode, even if the sun (solar radiation) is available, if the grid is not available, the PV panel cannot be used. Similarly, in standalone operation, PV power is cut off by the remaining solar radiation.

Therefore, a backup power supply is required to minimize the effects of fluctuating solar radiation. However, once the battery is fully charged, maximum power point tracking (MPPT) should be turned off to prevent overcharging of the stored battery. Therefore, this document introduces PV arrays, grids, power storage, CS-based DG sets, DG connection grids and connection mode DG sets operating on the island to ensure that PV power is used in all operating conditions. increase. Other publications [15] describe both ways to connect to islands and grids. However, the two modes are controlled separately and automatic mode switching between the two modes is introduced.

Therefore, without a power supply in automatic switching mode, the same PV power supply will be interrupted and EV charging cannot continue. Therefore, this document introduces the logic of automatic mode switching. This allows the controller to automatically switch between different operating modes depending on the output power of the PV member and the need to charge the EV. Due to nighttime availability and the temporary nature of the PV system, accumulators with the same PV components are used for continuous and reliable CS performance.

However, due to the limited storage capacity of the battery, it is not always possible to provide a backup copy. Therefore, if the same PV power is not available, CS will need grid support and power storage will be excluded. However, due to the limited availability of the grid, especially in remote areas, a DG set may be required to maintain charge continuity. However, the performance of the DG set is affected by the type of load and is not fully utilized. In general, DG sets are designed for a very limited number of harmonics with a current load [21].

Therefore, EV chargers typically use a converter and then slow down using a power factor adjustment circuit and a DC-DC converter, so EV charging is the performance of the DG set due to the presence of harmonics in the current EV.Will greatly affect.

However, in this document, due to the harmonics of the EV charger provided by the power converter (VSC) and current operating requirements, the DG set will always be charged at least 80% of the estimated value. The main contributions to this paper are:

- PV design and test validation using the same components, power storage and integrated DG grid set supports uninterrupted DC and AC charging of electric vehicles.
- An integrated controller design that allows the charging station to operate in island mode, grid, and connected DG-Set with just one VSC, without hardware switching.
- Switching mode design that allows the charging station to simply switch modes for continuous charging.
- Vehicle-to-Grid (V2V) control system for Car-to-Grid (V2V) charging and Car-to-Grid (V2G) power support design for grid support.
- Operation of active power plant filters to reduce line current so that power exchange occurs at a power factor of 1.

This is required to comply with the charging station and the IEEE-519 standard.

• DG frequency and voltage control strategies different from automatic frequency control.

• A strategy to supply additional PV participants generated from the grid to avoid battery overcharging.

2. SYSTEM DESCRIPTION

As shown in Figure 1, the presented charging station uses solar power, batteries, DG sets, and grid power to charge the EV and power the load connected to the charging station. The PV array is connected to a DC voltage source converter (VSC) port with a boost converter, and the battery is connected directly to the DC port.

The grid, single-phase SEIG (Self Excited Induction Generator), EV, and indirect load are connected to the AC side of the VSC via a link inductor. PCC ripple filters are used to eliminate the exchange of harmonics between the mains and the current generator and make these currents sinusoidal. The excitation capacitor is connected to the SEIG auxiliary window. Small capacitors are also connected to all SEIG major curves. Synchronous switches are used between the main / DG-Set and the PCC to control the connection / disconnection of the main / DG-Set's charging channels.

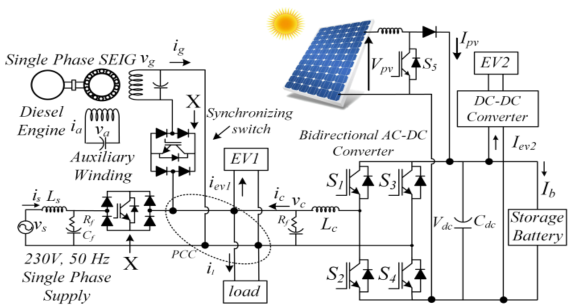

Fig. 1 Topology of charging station

3. CONTROL STRATEGIES

Various control strategies used in the CS, are discussed here

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

CS-on-island control guarantees stable CS performance even in the absence of a grid. In other words, AC and EV-DC charging remains the same, and solar power generation is not interrupted. DC charging and solar power can be controlled by batteries without making many changes to the controller. However, AC charging requires a separate VSC controller that uses voltage readings in the output range, as electrical standards are not available without a grid. Therefore, the island controller produces 230V and 50Hz internal voltage references according to the concept shown in Figure 2. It combines frequency and continuity signs to generate a reference voltage. The generated reference is compared to the terminal voltage of the converter. The converter finally provides a current reference converter after electrical error is reduced using proportional integral (PI) control. The current generation error reductions and references are displayed. Represented as.

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

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

In grid tie mode, the controller is responsible for determining the amount of power being modified by the grid. In DG kit connection mode, the DG kit operates in fixed power mode for maximum fuel efficiency. However, in both cases, the controller must compensate for the current demand for the corresponding active EV.

This is achieved by measuring the current grid indicator or DG set from the current EV in grid connection mode, which is currently limited. Only the active current of the current EV is considered. However, in the DG set connection mode, the current reference DG set is measured using both active EV current and active EV current. In this task, Adaptive Notch Suppression (ANC) outputs the current frequency of the EV. As you proceed with sampling and logic acquisition, all zero power exceeds the quadrature unit template to provide the most active and efficient current power respectively.

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

C. DG Set Control for Voltage and Frequency

By using a single DG set, the frequency and power of the DG set is controlled using the VSC shortcut controller. In another tuning, the frequency is tuned through the active power and the voltage is tuned through the active power. Therefore, two PI controls are used to control voltage and frequency.

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

D. Control of EV2

The EV connected to the DC port via a DC-DC converter is controlled by current / continuous voltage (CC / CV). The EV will be charged in CC mode until the terminal voltage of the EV battery reaches the voltage corresponding to the fully charged state. However, as soon as you get close to the desired terminal, the voltage will almost completely go into charging mode and EV charging will go into CV mode. The CC

/ CV charging mode is controlled by two PI controls, as shown in Figure 3.

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

E. Synchronization and Switching Control

Charging stations operate in different ways depending on power generation and charging requirements, so individual switching strategies can help you make smooth changes from one mode to another and not interrupt the charging process. Is required. Generated in the connected grid and placed on the islands of the DG set in the connected mode is the condition under which the logic switching mode is built. In this technique, the phase difference between the two voltages is detected first and the regulator synchronizes the two voltages in phase.

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

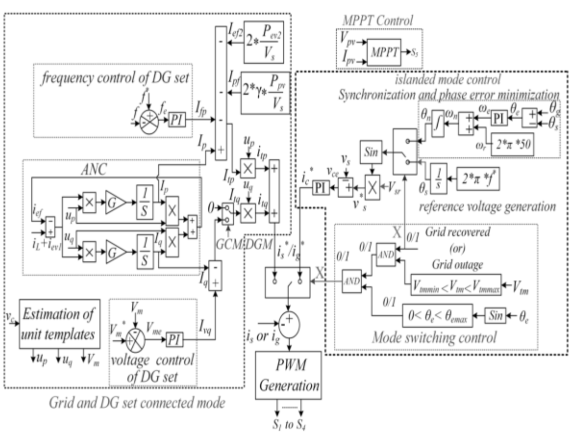

Fig. 2 Unified control of VSC for standalone and grid and DG set connected mode

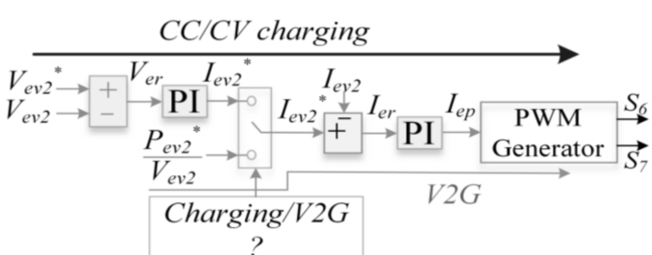

Fig. 3 EV2 control for CC/CV charging and V2G power transfer

4. RESULTS

The simulation results shown in Figures 5.5 to 5.10 show the uninterrupted operation of CS. Initially, the CS operates in island mode and is powered by the same PV to charge the EV connected to the PCC. The production of photovoltaics exceeds the charging demand of electric vehicles, so the rest of the production is stored in electricity storage. In 0.32 seconds, the sunlight changes from 1000 W / m2 to 300 W / m2. As a result, the same PV capacity is reduced and the battery starts charging and keeps charging. At 0.48 seconds, the same PV power will be zero and the battery will run out. The battery fully supports charging as long as SOC> SOCmin. After the battery is completely discharged, the controller will connect the CS to the grid after synchronization. After 0.79 seconds, CS started drawing power from the grid. From this point onwards, CS is supported by the DG-Set due to grid availability and battery storage capacity, as shown in Figure 5.7. From the imitation results, we can see that the charging station automatically changes modes according to the power generation and demand.

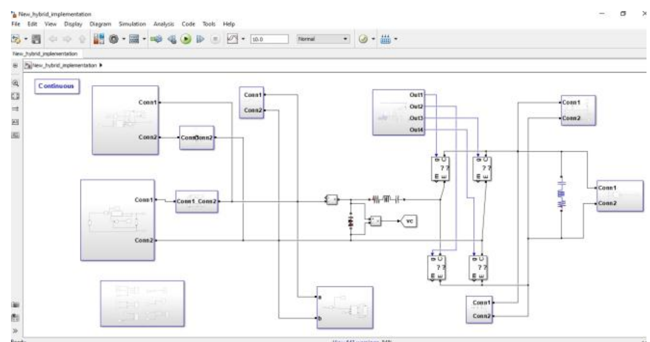

Fig 4 Simulink model of charging station topology

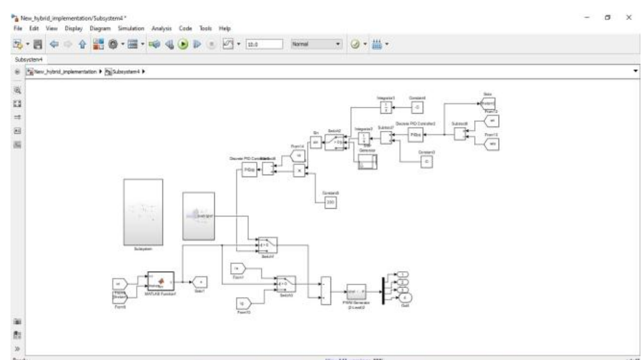

Fig 5. Simulink model of control schemes for unified control of VSC

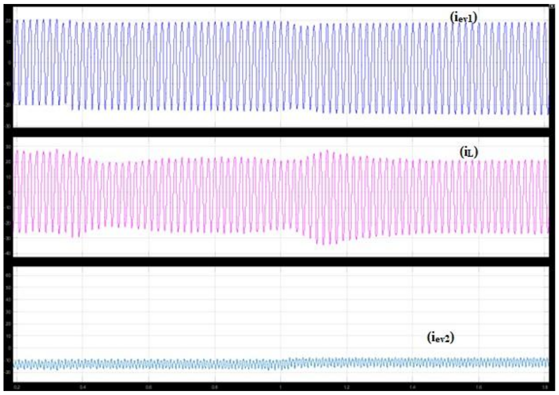

Fig 6. Simulated outputs currents of EV1 (iev1), EV2 (iev2)and load (iL)

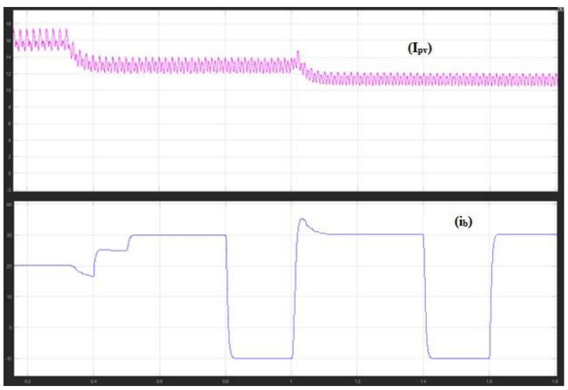

Fig 7 Simulated outputs currents of PV current (Ipv)& battery charging and discharging current (ib)

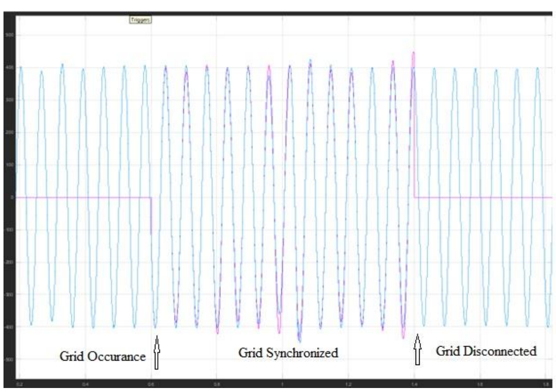

Fig 8 Simulated output voltages of supply voltage (VS) and DC link voltage (VC)

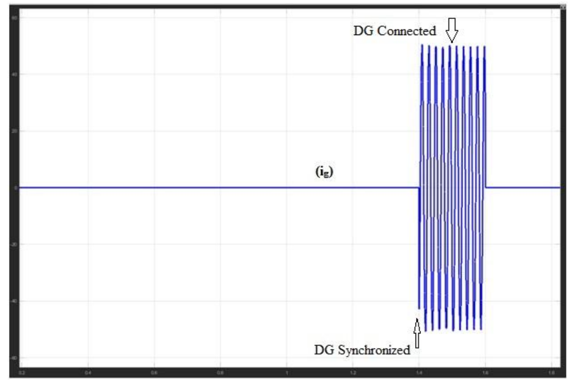

Fig 9 Simulated output current of generator (ig)

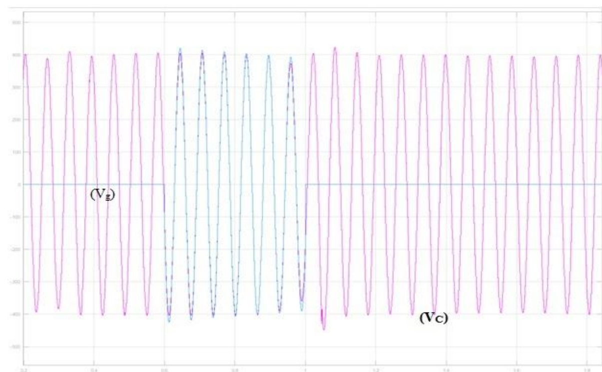

Fig 10 Simulated output of generator voltage (Vg) and DC link voltage (V_C)

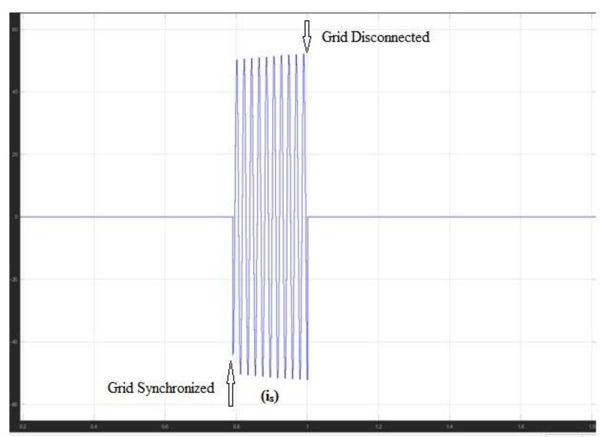

Fig 11 Simulated output current of generator (is)

5. Conclusion

EV charging implements PV configurations, battery storage, grids, and DG-based charging stations. The results presented validate the multimode performance (island power, grid connection, and DG connection set) of a CS with only one VSC. The test results also confirmed the satisfactory performance of the charging station under different stable and dynamic conditions resulting from changes in solar radiation, changes in the current charging EV, and changes in load. The performance of the charging station as an independent voltage generator is guaranteed by the results presented..

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provide AC charging. Monterio et al. [5] introduced a 3-hole converter to connect the same PV component and EV charger. However, the designed charger ignores the current distortion of the power grid generated by the charger. Shin et al. [6] We propose a modified Z source converter for PV design of the same element / grid connected to the EV charger.

However, the charger is not designed to work on the island. Therefore, EV charging cannot be provided without the grid. Chaudharietal. [7] Described a hybrid model that combines battery storage management to reduce operating costs for charging stations and maximize PV output. Kineavy et al. [8] uses the energy generated at the PV site (installed in a commercial building) in combination with an EV charging station to minimize the impact on the power grid (in uncertain circumstances) on a variety of solar powers. We are proposing to use a photovoltaic system. Zhang. [9] Studied full charging of EV charging stations in a dual charging mode operating environment.

Powerful charging stations for PV arrays (CS) are also suitable for deployments that provide the highest quality service at minimal cost while minimizing the impact of the charging network [10]. Kandasa myetal. [11] Investigate the loss of battery life in commercial buildings based on the PV array system. Wind power CS is also beneficial for EVs as it can be used day and night, and many publications are available in this area [12]-[14].

Due to the large amount of energy stored in EV batteries, EVs are also widely used as a power source to provide a variety of compatible services. Shin et al. [15] introduced PV array-based CS to provide active grids, active power filters, and homes with a place to charge and run vehicle capacity. Saxena et al. [16] Use grids connected to EV and residential PV array systems. Razmi et al. [17] proposed a power management strategy to control a variety of integrated PV live battery systems for grid and standalone applications. Erdincetal. [18] and Kikuzato et al. [19], Hafizetal. [20] Introduced the following smart home functions B. EV. It can be used as storage to power both consumers and consumers from home to home and from grid to grid.

A detailed analysis of the revised manual suggests that the work presented in the renewable energy charging station area focuses on improving various aspects of charging, including: B. Renewable energy source, final device size, driving pattern, charging time, charging cost, charging plan, etc. However, in the current scenario, only a handful of books use renewable energy charging stations.

In addition, there is not much discussion about the performance of charging stations under real-world conditions. In addition, most books only discuss CS performance in grid tie mode or island mode. However, since it is an operation mode only in grid tie mode, even if the sun (solar radiation) is available, if the grid is not available, the PV panel cannot be used. Similarly, in standalone operation, PV power is cut off by the remaining solar radiation.

Therefore, a backup power supply is required to minimize the effects of fluctuating solar radiation. However, once the battery is fully charged, maximum power point tracking (MPPT) should be turned off to prevent overcharging of the stored battery. Therefore, this document introduces PV arrays, grids, power storage, CS-based DG sets, DG connection grids and connection mode DG sets operating on the island to ensure that PV power is used in all operating conditions. increase. Other publications [15] describe both ways to connect to islands and grids. However, the two modes are controlled separately and automatic mode switching between the two modes is introduced. Therefore, without a power supply in automatic switching mode, the same PV power supply will be interrupted and EV charging cannot continue. Therefore, this document introduces the logic of automatic mode switching. This allows the controller to automatically switch between different operating modes depending on the output power of the PV member and the need to charge the EV. Due to nighttime availability and the temporary nature of the PV system, accumulators with the same PV components are used for continuous and reliable CS performance.

However, due to the limited storage capacity of the battery, it is not always possible to provide a backup copy. Therefore, if the same PV power is not available, CS will need grid support and power storage will be excluded. However, due to the limited availability of the grid, especially in remote areas, a DG set may be required to maintain charge continuity. However, the performance of the DG set is affected by the type of load and is not fully utilized. In general, DG sets are designed for a very limited number of harmonics with a current load [21].

Therefore, EV chargers typically use a converter and then slow down using a power factor adjustment circuit and a DC-DC converter, so EV charging is the performance of the DG set due to the presence of harmonics in the current EV.Will greatly affect. However, in this document, due to the harmonics of the EV charger provided by the power converter (VSC) and current operating requirements, the DG set will always be charged at least 80% of the estimated value. The main contributions to this paper are:

• PV design and test validation using the same components, power storage and integrated DG grid set supports uninterrupted DC and AC charging of electric vehicles.

• An integrated controller design that allows the charging station to operate in island mode, grid, and connected DG-Set with just one VSC, without hardware switching.

• Switching mode design that allows the charging station to simply switch modes for continuous charging.

• Vehicle-to-Grid (V2V) control system for Car-to-Grid (V2V) charging and Car-to-Grid (V2G) power support design for grid support.

• Operation of active power plant filters to reduce line current so that power exchange occurs at a power factor of 1.

Various control strategies used in the CS, are discussed here

A. Control of VSC in Islanded Mode(Absence of DG Set and Grid)
CS-on-island control guarantees stable CS performance even in the absence of a grid. In other words, AC and EV-DC charging remains the same, and solar power generation is not interrupted. DC charging and solar power can be controlled by batteries without making many changes to the controller. However, AC charging requires a separate VSC controller that uses voltage readings in the output range, as electrical standards are not available without a grid. Therefore, the island controller produces 230V and 50Hz internal voltage references according to the concept shown in Figure 2. It combines frequency and continuity signs to generate a reference voltage. The generated reference is compared to the terminal voltage of the converter. The converter finally provides a current reference converter after electrical error is reduced using proportional integral (PI) control. The current generation error reductions and references are displayed. Represented as.
B. Control of VSC in DG Set or Grid Connected Mode
In grid tie mode, the controller is responsible for determining the amount of power being modified by the grid. In DG kit connection mode, the DG kit operates in fixed power mode for maximum fuel efficiency. However, in both cases, the controller must compensate for the current demand for the corresponding active EV.
This is achieved by measuring the current grid indicator or DG set from the current EV in grid connection mode, which is currently limited. Only the active current of the current EV is considered. However, in the DG set connection mode, the current reference DG set is measured using both active EV current and active EV current. In this task, Adaptive Notch Suppression (ANC) outputs the current frequency of the EV. As you proceed with sampling and logic acquisition, all zero power exceeds the quadrature unit template to provide the most active and efficient current power respectively.
C. DG Set Control for Voltage and Frequency
By using a single DG set, the frequency and power of the DG set is controlled using the VSC shortcut controller. In another tuning, the frequency is tuned through the active power and the voltage is tuned through the active power. Therefore, two PI controls are used to control voltage and frequency.
D. Control of EV2
The EV connected to the DC port via a DC-DC converter is controlled by current / continuous voltage (CC / CV). The EV will be charged in CC mode until the terminal voltage of the EV battery reaches the voltage corresponding to the fully charged state. However, as soon as you get close to the desired terminal, the voltage will almost completely go into charging mode and EV charging will go into CV mode. The CC
E. Synchronization and Switching Control
Charging stations operate in different ways depending on power generation and charging requirements, so individual switching strategies can help you make smooth changes from one mode to another and not interrupt the charging process. Is required.

Generated in the connected grid and placed on the islands of the DG set in the connected mode is the condition under which the logic switching mode is built. In this technique, the phase difference between the two voltages is detected first and the regulator synchronizes the two voltages in phase.

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

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

4.RESULTS The simulation results shown in Figures 5.5 to 5.10 show the uninterrupted operation of CS. Initially, the CS operates in island mode and is powered by the same PV to charge the EV connected to the PCC. The production of photovoltaics exceeds the charging demand of electric vehicles, so the rest of the production is stored in electricity storage. In 0.32 seconds, the sunlight changes from 1000 W / m2 to 300 W / m2. As a result, the same PV capacity is reduced and the battery starts charging and keeps charging. At 0.48 seconds, the same PV power will be zero and the battery will run out. The battery fully supports charging as long as SOC> SOCmin. After the battery is completely discharged, the controller will connect the CS to the grid after synchronization. After 0.79 seconds, CS started drawing power from the grid. From this point onwards, CS is supported by the DG-Set due to grid availability and battery storage capacity, as shown in Figure 5.7. From the imitation results, we can see that the charging station automatically changes modes according to the power generation and demand.

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5. Conclusion

EV charging implements PV configurations, battery storage, grids, and DG-based charging stations. The results presented validate the multimode performance (island power, grid connection, and DG connection set) of a CS with only one VSC. The test results also confirmed the satisfactory performance of the charging station under different stable and dynamic conditions resulting from changes in solar radiation, changes in the current charging EV, and changes in load. The performance of the charging station as an independent voltage generator is guaranteed by the results presented.

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