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Improvement of Power Quality in a PV Based EV Charging Station connected with Three Phase Grid

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Abstract

In this article, we take a look at an electric vehicle (EV) charging station that uses solar photovoltaic (PV) arrays to improve power quality and can work either independently or in conjunction with the grid. When operating independently, the station uses the electricity from the PV panels to immediately charge the electric vehicle's battery. Connected to the utility grid, it may improve the quality of grid electricity via reactive power compensation while also supplying excess energy back to the system. In addition to controlling the charging and discharging of electric vehicle batteries, the suggested charging station can also do the following: (i) compensate for harmonic currents, (ii) charge and discharge electric vehicles at the same time with harmonic compensation, and (iv) discharge electric vehicles at the same time with harmonic compensation. Even when grid voltages are uneven, the management method keeps overall harmonic distortion of grid currents within the 5% level suggested by IEEE-519, ensuring dependable operation. The system is mostly built to work with the grid, but when grid synchronisation is lost, it immediately shifts to independent mode so the PV array can keep charging the electric vehicle battery. When the grid becomes available, the system may be securely connected with the help of a specific synchronisation controller.

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1. INTRODUCTION

Electric motors (EVs) have become greater famous due to the global motion towards renewable electricity and eco-friendly transportation. There is an immediate want for dependable, efficient, and environmentally conscious charging infrastructure due to the growing wide variety of electric motors. The traditional, grid-powered EV charging stations upload to the issues of height call for and the rise in carbon emissions. One capacity manner to lessen these issues is to reduce reliance on fossil fuels and the overall environmental impact with the aid of incorporating renewable strength resources, such photovoltaic (PV) systems, into electric powered automobile charging stations.

But there are some of power fine troubles that arise when PV structures are linked to the energy grid. The electricity machine's stability and efficiency can be compromised through voltage fluctuations, harmonics, and imbalanced hundreds, all of that are because of the intermittent and variable nature of sun power. Electric car charging infrastructure is inherently non-linear, which adds to reactive power call for and harmonics and worsens electricity high-quality issues.

This look at indicates a PV-based totally electric vehicle charging station this is connected to a 3-section grid and has a UPQC to overcome these boundaries. In order to improve strength best, the UPQC is critical for adjusting for reactive energy desires, harmonics, and voltage disturbances. The recommended method improves the grid's stability and strength nice at the same time as simultaneously making sure the green and non-stop charging of electrical cars.

Through the usage of MATLAB/Simulink simulations, we take a look at the incorporated machine's overall performance in several working conditions. The findings show that the UPQC is good at retaining strength best necessities, therefore it may be used in clever grid programs nowadays.

The performance of a PV-based totally electric car charging station this is related to the 3-segment software grid and capabilities a UPQC to improve energy nice is thoroughly tested in this studies. With its capacity to function reliably and step by step irrespective of changes in grid conditions or solar irradiation, the recommended device is well-desirable to cutting-edge metropolitan settings. We use MATLAB/Simulink to version and simulate the device so we can see how nicely it handles voltage fluctuations, harmonic loads, and unbalanced loads, among different energy quality concerns.Building a photovoltaic (PV) electric vehicle charging station that connects to the grid is the main goal of this study.

- To set up a UPQC that can compensate for both voltage and current at the same time.
- To assess how well the system regulates voltage, improves power factor, and measures total harmonic distortion (THD).

The rest of the article is organised like this: Section 2 details the setup and modelling of the system's components; Section 3 delves into the UPQC's control techniques; Section 4 offers the results and analysis of the simulation; and Section 5 wraps up the study with important conclusions and future directions.

2. PHOTOVOLTAIC TECHNOLOGY

A subfield of electrical engineering, photovoltaics deals with gadgets that use semiconductors that show the photovoltaic effect to at once transform sunlight into energy. When a substance is exposed to electromagnetic radiation, it undergoes the photovoltaic effect and generates voltage. In 1839, French scientist Edmund Becquerel discovered that light ought to cause positive materials to generate tiny quantities of electric present day; this discovery changed into the first to be referred to as the photovoltaic impact. Photovoltaic era may additionally hint its roots again to Albert Einstein's 1905 description of mild and the photoelectric effect, for which he could pass on to obtain the Nobel prize in physics.

Bell Laboratories manufactured the primary sun module in 1954. It changed into too highly-priced to gather wide usage, therefore the solar battery, as advertised, remained in general a interest. First tremendous software of the generation to provide strength onboard spacecraft occurred in the Nineteen Sixties, when the gap enterprise began to take use of it critically. Technology advanced, its dependability changed into tested, and costs started to drop way to the gap tasks. Photovoltaic generation became called an opportunity power source for makes use of outdoor of area at some stage in the Nineteen Seventies power crisis.

The photovoltaic generation is predicated on the sun mobile as its essential factor. Silicon and different semiconductors are the constructing blocks of solar cells. Impurities introduced into the crystal lattice of a semiconductor may additionally easily modify its conductivity, which is considered one of its most precious capabilities. For example, with a view to make a photovoltaic sun cellular, the conductivity of silicon—a cloth with 4 valence electrons—is more desirable with the aid of remedy. Impurities, which are n-donor phosphorus atoms with 5 valence electrons, make contributions to the silicon material by way of donating weakly sure valence electrons, main to an extra of bad charge providers on one side of the mobile. While silicon has a decrease electron affinity, boron atoms with three valence electrons (p-donor) produce a more potent one. Electrons diffuse from the n-type side, where the awareness of electrons is excessive, into the p-type facet, wherein the attention of electrons is low, due to the establishment of a p-n junction caused by the close proximity of the p-kind and n-kind silicon. Recombination with holes at the p-type side happens when electrons diffuse over the p-n junction.

The electric area that outcomes from the price imbalance at the junction reasons service diffusion to forestall at a certain point, however. Because of the diode-like effect of this electric subject, modern can simplest travel in one manner. Electrodes are organized to be connected to an outside load after ohmic metal-semiconductor connections had been shaped to each the n-type and p-kind aspects of the solar cell. The rate providers inside the cellular get energy from photons whilst mild hits them. Photographically produced tremendous price providers (holes) and their terrible counterparts (electrons) are separated via the electric subject that spans the junction. When the circuit is closed on an outside load, electrical modern is withdrawn in this manner.

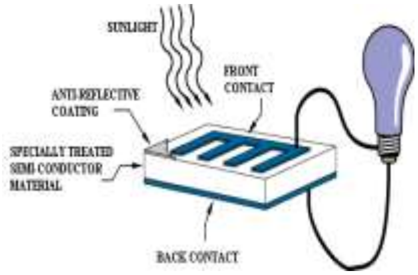


Fig 3.1: Solar cell.

In 1839, Edmund Becquerel made the first report of the photovoltaic impact when he observed that a silver-covered platinum electrode submerged in electrolyte generated an electric cutting-edge in reaction to light. Forty years down the road, researchers searching into selenium's newly discovered photoconductivity constructed the primary stable-country photovoltaic systems. William Adams and Richard Day determined in 1876 that a selenium sample could be made to behavior a photocurrent while two platinum contacts had been delivered into contact with it. In contrast to its photoconductive hobby, selenium's photovoltaic motion causes a contemporary to be generated routinely via light.

An additional strength source changed into no longer required. The semiconductor and metallic contact on this first photovoltaic device had created a rectifying junction. In 1894, Charles Fritts probable created the first large place solar cellular by sandwiching selenium among two metals—gold and some other.

3. POWER QUALITY

3.1Power Quality Problems

As utilized in this article, energy first-class concerns are described as follows: "Any energy trouble that effects in failure or omit operation of purchaser system, manifests itself as an monetary burden to the user, or produces poor influences on the environment." Power issues that lessen strength nice within the container crane enterprise include:Power Factor

- Harmonic Distortion
- Voltage Transients
- Voltage Sags or Dips
- Voltage Swells

Total harmonic present day and voltage distortion are appreciably exacerbated by means of the AC and DC variable pace drives used by box cranes. However, DC SCR drives work at a lower average electricity thing than what's executed with SCR phase manage. Furthermore, line notching occurs whilst SCRs commutate, generating transient top restoration voltages that, relying at the machine impedance and force size, may be 3 to four instances the regular line voltage. As the rate of the pressure will increase, so does the frequency and severity of those strength machine disturbances. When jogging at low speeds, AC and DC drives inject the most harmonic cutting-edge.

When DC drives are walking at low speeds or at the beginning of acceleration and deceleration, the strength thing will be lowest. However, it'll increase to its maximum value whilst the SCRs are became directly to generate rated or base speed. Once you move over your base velocity, the energy element quite lots remains the same. Tragically, as the operator tries to land cargo, box cranes may additionally spend a lot of time at low speeds. The utility's Kva demand is multiplied when the power factor is poor.

4. MODELLING OF CASE STUDY

Reference energetic and reactive energy instructions are used inside the design of the charging station's manage machine. It is as much as the EV proprietor to pick out whether or not to price or drain the EV battery using the reference lively energy command. The inductive and capacitive reactive electricity requirements for the charging station's continuous operation determine the reference reactive power. The charging station is designed so that the electrical car owner may additionally alter whilst their battery is charged or discharged. G2V refers to the gadget action that takes place whilst grid power is wanted to fee the electric automobile's battery (Grid to Vehicle). V2G refers back to the gadget operation in which an electric vehicle's battery is discharged so one can provide electricity to the grid. The charging station might also provide reactive strength adjustment, both trailing or leading, relying at the situation.

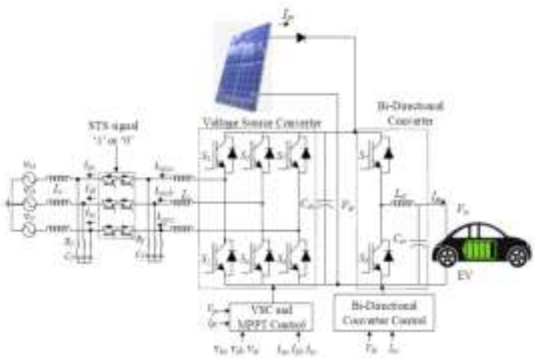


Fig. 1 Three-phase Three wire single-stage grid connected PV system with EV

4.1. SYSTEM CONFIGURATION

Figure 1 shows the schematic of the one-stage PV-based EV charging station. The photovoltaic (PV) charging station's one and only purpose is to feed the DC electricity produced by the PV array into the electric vehicle's battery. To charge and discharge the electric vehicle's battery, a bi-directional converter is used.

A DC-link is directly connected to the PV array. The total cost of the charging station is therefore reduced as a boost converter is not needed. Power conversion from DC to AC is accomplished using an IGBT based VSC so that it may be interfaced with the grid. Static transfer switches (STS) are also IGBT-based and used to link the charging station to the grid.

4.2. CONTROL SCHEME

Utilising the generation from PV arrays for EV charging is the primary goal of the current charging station. The PV array's output might be fed into the grid, and the charging station is grid-synchronized. In addition, electric vehicles have the capability to both drain and recharge the grid. Consequently, for the charging station to be used more effectively, an intelligent control strategy has to be created. Figure 2 shows the developed control technique. There are essentially two input instructions on the controller.

A. Active Power Reference Command

The need to charge or discharge the EV battery determines this. In order to generate incentives, EV owners may choose to charge or discharge their batteries to provide power to the grid at times of high demand. This active power command is controlled by the owner of the electric vehicle.

B. Reactive Power Reference Command

It controls the quantity and kind of reactive power that is transferred, regardless of whether it is capacitive or inductive. There are two main ways in which electric vehicle charging stations (VSCs) and the control of charging and discharging at these stations are categorised: grid linked mode control and freestanding mode control.

Sliding Mode Controller (SMC)

1. Introduction

A popular nonlinear control method for engineering systems with uncertainties, disturbances, and nonlinear dynamics is Sliding Mode Control (SMC). It is resilient and has been around for a while. One of the most effective control techniques for power electronics, electric cars, robotics, aerospace systems, and renewable energy applications, SMC has developed from its origins in variable structure systems (VSS) theory in the 1950s and 1960s.

It stands out because to its simple implementation, finite-time convergence, and exceptional resilience in the face of complicated system dynamics.

Systems with time-varying characteristics or those subject to inevitable external disturbances are ideal candidates for SMC. Without resorting to linearisation, SMC directly deals with nonlinearities, in contrast to standard linear controllers like PID.

2. Basic Concept of Sliding Mode Control

SMC achieves its desired effect by directing the system's trajectory to "slide" along a designated route, also known as the sliding surface. This surface depicts the expected behaviour of the system. This surface has the feature of invariance, which means that once the system enters it, it stays there regardless of disturbances or uncertainty.

The operation of SMC occurs in two key phases:

(i) Reaching Phase

From any starting point to the sliding surface, the controller drives the system states.

During this stage, the sign of the sliding variable determines how the switching control rule changes.

(ii) Sliding Phase

When the system reaches the surface, its dynamics are no longer affected by outside influences. Until it finds equilibrium, the trajectory "slides" over the surface.

Because the system cannot be pushed off the surface by disturbances, SMC is a resilient control approach.

3. Mathematical Foundation

Consider a general nonlinear system:

x˙=f(x)+g(x)u\dot{x} = f(x) + g(x)ux˙=f(x)+g(x)u

Where:

- xxx = state vector
- uuu = control input
- f(x)f(x)f(x) and g(x)g(x)g(x) = nonlinear functions representing system dynamics

Sliding Surface

Define a sliding surface S(x)S(x)S(x) such that:

S(x)=0S(x) = 0S(x)=0

A common design for a first-order system is:

S(x)=ceS(x) = c eS(x)=ce

For a second-order system:

S(x)=λe+e˙S(x) = \lambda e + \dot{e}S(x)=λe+e˙

Where:

- eee = tracking error
- λ\lambdaλ = positive constant ensuring stability

Control Law

The control input is usually defined as:

u=ueq+uswu = u_{eq} + u_{sw}u=ueq+usw

Where:

- **uequ_{eq}ueq** = equivalent control to maintain motion on the sliding surface
- **uswu_{sw}usw** = switching control to bring the system to the surface

The switching component typically uses a sign function:

usw=−K sgn(S)u_{sw} = -K \, \text{sgn}(S)usw=−Ksgn(S)

Where KKK is a positive gain.

The condition for reaching the sliding surface is:

SS˙<0S \dot{S} < 0SS˙<0

This ensures stability and convergence.

5. SIMULATION RESULTS

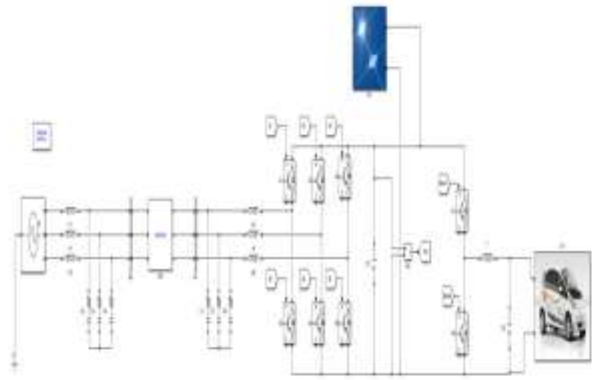


FIGURE 1. Simulink diagram of Three-phase Three wire single-stage grid connected PV system with EV

A. Performance Under Variation of Solar Insolation

Fig. shows that when the irradiation of PV arrays increases from 600 to 1000 W/m2, the production of PV arrays rises because the EV and battery are in floating mode.

Performance of System at Grid Reconnection

At grid recovery, the simulated system reaction is shown in Figure 8.3 (b). When the power grid is restored, the VSC becomes grid-synchronized, and the voltages and currents of the grid become visible. With no impact on the charging of the electric vehicle, the BES begins to discharge.

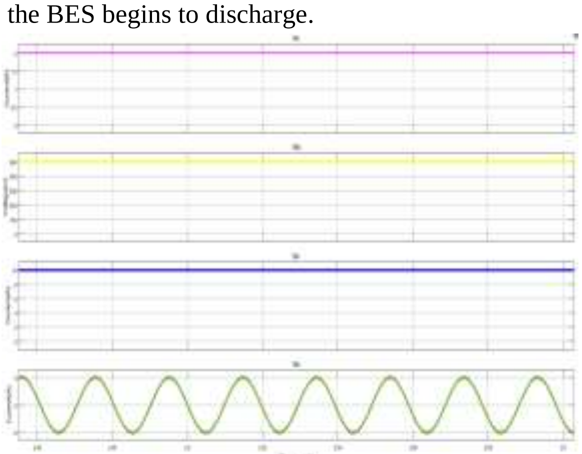
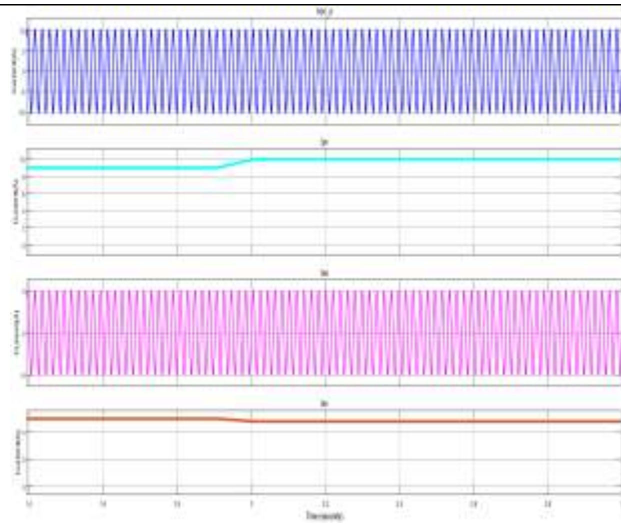


Fig (a) Increase in solar insolation



(b) Fig. 8.3 Simulated performance at (a) grid disconnection and (b) grid reconnection

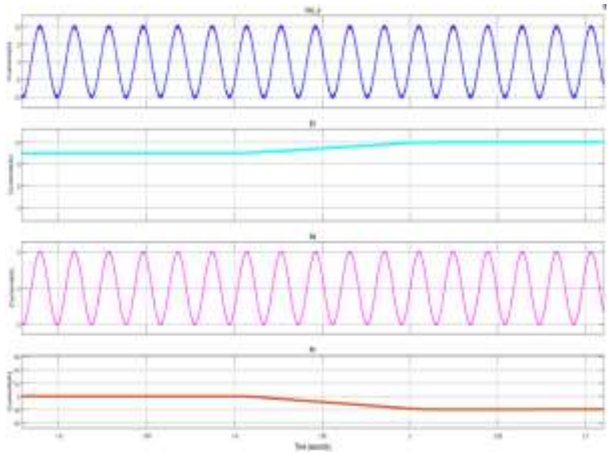
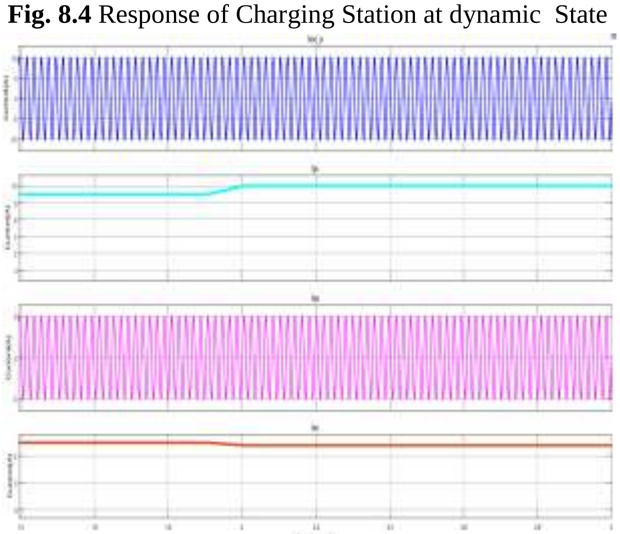


Fig. 8.4 Response of Charging Station at dynamic State



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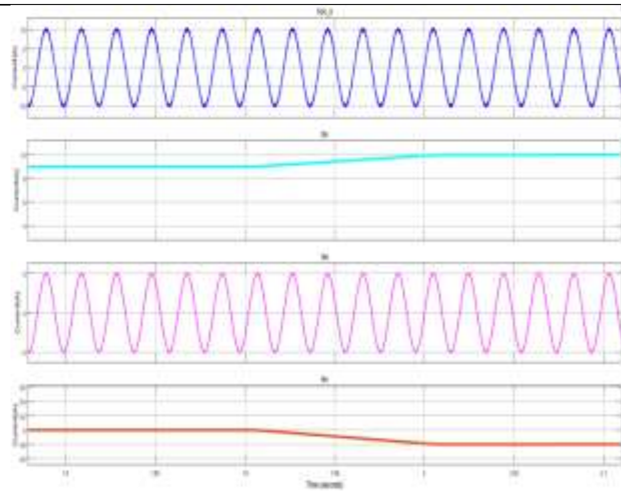
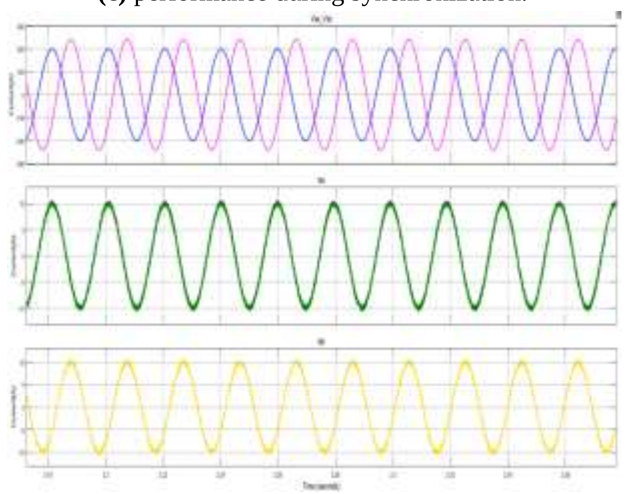


(c) performance during synchronization.



(d) Fig 3 Response of Charging Station at Steady State

6. CONCLUSION

The intention of designing a unmarried-degree PV-based totally EV charging station changed into to make it possible to synchronise with the grid, feed the electricity returned into the grid, and profit from promoting electricity throughout peak hours by means of discharging EV batteries into the grid. The reactive energy has been adjusted by using the charging station whilst it's far related to the grid. The charging station has been tested and shown to work properly both when linked to the grid and whilst used independently. Once the charging station is in sync with the grid, it can transmit returned any surplus strength when the grid is available. Experimental findings have shown that the charging station can resist dynamic conditions such grid voltage imbalances, reactive power adjustment, and fluctuations in PV insolation.

7. FUTURE SCOPE

System overall performance, dependability, and grid support abilties have plenty of room to grow, thanks to the proliferation of electric motors (EVs) and charging infrastructures powered by using renewable power assets. The following areas of ability future studies and improvement can be investigated so that it will decorate the power high-quality of the proposed PV-based EV charging station:

1. Integration of Energy Storage Systems (ESS) for Enhanced Grid Support

Supercapacitors, lithium-ion batteries, or hybrid energy storage systems (ESS) may be used in future development. These systems can:

- Its functions include: bolstering grid voltage and frequency management;
- Providing peak shaving and valley filling;
- Acting as backup power in the event of grid breakdown; and
- Improving DC bus voltage stability.

A coordinated PV–ESS–EV model can significantly enhance power quality and energy management.

2. Implementation of Advanced Control Strategies

Beyond the existing compensation strategy, more sophisticated controllers may be created, including:

- Adaptive sliding mode control
- Model predictive control (MPC)
- Controllers based on artificial intelligence (AI) or machine learning Robust nonlinear controllers

These controllers can improve harmonic mitigation, dynamic response, and efficiency under various operating conditions.

3. Vehicle-to-Grid (V2G) and Bidirectional Power Flow

Using V2G technology, future systems will be able to provide bidirectional charging. Because of this, EVs may do things like:

- Contribute to grid stability by injecting power back into the system during peak loads
- Take part in demand-response programs
- Help with reactive power correction

By integrating V2G, the charging station may be converted into a distributed energy resource that contributes to the grid.

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