

# Grid Connected Photovoltaic Systems

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**Abstract - Solar electricity – or photovoltaic (PV) – is the world's fastest growing energy technology. It can be used on a wide variety of scales, from single dwellings to utility-scale solar farms providing power for whole communities. It can be integrated into existing electricity grids with relative simplicity, meaning that in times of low solar energy users can continue to draw power from the grid, while power can be fed or sold back into the grid at a profit when their electricity generation exceeds the amount they are using. The falling price of the equipment combined with various incentive schemes around the world have made PV into a lucrative low carbon investment, and as such demand has never been higher for the technology, and for people with the expertise to design and install systems. Energy demand has increased enormously, and the consumption of fossil fuel nuclear energy has caused many environmental problems. In fact, fossil fuels are exhaustible, polluting and rather expensive. However, the developments of clean and renewable energies such as wind, biomass, geothermal and photovoltaic, are a promising solution to overcome problem of conventional energy sources. One of these sources is the photovoltaic (PV) power generation system, which is a clean, quiet and an efficient method for generating electricity, the main objective of this work is to study the solar PV systems and model the Grid-connected solar power system using Matlab simulation. The Matlab simulation system consists of PWM (Pulse with Modulation) Voltage source inverter circuit and a DC capacitor connected at one end. A grid –connected PV system consists of solar panels, inverters, a power conditioning and grid connection. It has effective utilization of power that is generated from solar energy as there are no energy storage losses. The grid –connected PV system supplies the excess power, beyond consumption by the connected load to the utility grid through smart meters. The electric grid is a complex network that is an integral part of our society. Running the grid in the presence of increasing fuel costs and growing environmental concerns will require new technologies and ways to use them.**

*Keywords – grid system; photovoltaic (PV); simulink model.*

## I. INTRODUCTION

There are typically two types of system: commercial and residential. Commercial systems are generally greater than 10kWp and are located on buildings such as factories, commercial businesses, office blocks and shopping centers. The power generated by these systems is typically consumed by the loads within the building, so no excess power is exported to the electricity grid. Residential systems refer to those installed on homes and are generally smaller than commercial systems, typically between 1 and 5kWp. The power generated by these systems is first consumed by any loads operating in the house during the day; excess power is fed into the grid providing electricity to nearby buildings. Grid-connected systems are normally found in urban areas that have readily available mains supply and instead of storing the electricity generated by the PV system in batter-

ies, the power is fed back into the grid. In this way the grid acts as a kind of storage medium and when power is needed in the building it can be imported from the grid. The property can be powered by the PV system, the electricity grid or a combination of the two, meaning that the system can be as small or large as the owner desires. Excess power generated by the PV system will be exported to the power grid and in many areas the system owner is paid for the exported power.

**Off-grid systems:** -They are most commonly used in rural or remote areas where mains power is not available due to the high cost of grid extension. Off-grid systems use solar power to charge batteries that store the power until it is needed for use. Off-grid systems can range in size from a single PV module, battery and controller to very expensive large systems incorporating sophisticated control equipment and large back-up generating sets.

**Central grid-connected PV systems:** - A central grid-connected PV system operates in the same way. A large PV array is directly connected to the transmission lines. Grid-connected central PV systems can be as small as 50kWp, while systems as large as 60MWp have been installed in recent years in Europe. There are also companies planning grid-connected PV power plants over 1GWp, with many plants to be completed in the near future.

**Geometry for installing solar arrays:** -The position of a solar module is referred to as its orientation. This orientation of the solar array is very important as it affects the amount of sunlight hitting the array and hence the amount of power produced. The orientation generally includes the direction the solar module is facing (i.e. due south) and the tilt angle, which is the angle between the base of the solar module and the horizontal. The amount of sunlight hitting the array also varies with the time of day because of the sun's movement across the sky. It then becomes apparent that if the sun is overhead and the solar panel is laid flat on the ground, it will capture all the sun's rays, as shown in the image above. Solar modules should be installed so that as much radiation as possible is collected. To achieve this, the solar modules should be installed facing either true south (northern hemisphere location) or true north (southern hemisphere location). There will be some exceptions for installation depending on the local environment (i.e. array's installed in a valley in the southern hemisphere may not necessarily face north). To point a module directly towards the sun at all times would require a solar tracking frame to be installed. This can be expensive, so it is not common practice for most PV applications.

## II. SOLAR POWER IN THE UAE

The UAE (United Arab Emirates) is in the 'sunbelt region' in which solar irradiation levels (the amount of solar

radiation which falls on the Earth) are very high. This means that a solar panel in the UAE can potentially produce double the electrical energy compared to a country with relatively lower irradiation levels such as Germany.[5]The UAE is also in a region where bad weather rarely affects solar power production, making it an ideal location for solar installations. Being in a region with nearly 365 days of sunlight a year, the UAE can easily become one of the largest producers of solar energy per capita.

The UAE is also part of a region rich in fossil fuels. Since the 1970s, the country underwent rapid economic growth powered by readily available oil and gas, and has attained high living standards with a per capita income amongst the highest in the world. However, this also led to very high per capita energy consumption as cities grew and became very energy intensive. When the governments of the UAE and other GCC (Gulf Cooperation Council) countries realized that their conventional energy reserves were rapidly depleting they set out to make their economies less reliant on fossil fuel-based energy and more on renewable energy, helping the UAE to achieve energy security.

The development of large scale solar power installations as well as renewable energy goals for 2020 and 2030 also reflect the UAE’s ambition to move forward. Various solar power projects and organizational initiatives are under development including the following:

**Mohammad Bin Rashid Al Maktoum Solar Park:**

Implemented by the Dubai Supreme Council of Energy (DSCE) is part of the DSCE Integrated Energy Strategy 2030 and aims to reach a capacity of 1000 megawatts by 2030, providing 5% of Dubai’s total power needs.

Abu Dhabi’s Shams 1, officially inaugurated in the first quarter of 2013, is the largest Concentrated Solar Power project in the world. With an approximate cost of 2 billion UAE Dirhams (1 US Dollar = 3.673 UAE Dirhams) it is intended to generate enough energy to power 20,000 homes. The Masdar Project (also known as Masdar City) is an \$18 billion self-sustaining solar-powered city planned near Abu Dhabi that will support 30,000 residents. IRENA (International Renewable Energies Agency), set up under the aegis of the United Nations, is headquartered in Abu Dhabi. Although this is not specific to solar energy, it shows the UAE’s keenness to play a leadership role in the global renewable energy arena. PAGE | 13 However despite these large multi-billion dollar solar installations planned for the near future, barely any solar energy market exists at present and demand among residents and even commercial entities is very low. To truly develop a solar power market, solar energy must be applied beyond the industrial level and put to use by residential as well as commercial establishments, as highlighted by Germany’s example.

**The Road Ahead for the UAE:**

Although the UAE government is investing billions of DHs for solar power generation, so far not much has been done at the consumer level. For a country that is energy intensive and relying on reducing its dependence on fossil fuels as a source of energy, taking solar power production to the residential level is very relevant and is well supported by the weather, environment, and natural surroundings. Currently regulation is being developed to facilitate the

adoption of residential rooftop systems. The plummeting PV panel prices, the development of new solar technologies and the rapidly expanding worldwide solar power industry suggests that this is the perfect time to do so.

**III. SYSTEM DESCRIPTION**

The given system comprises of a PV Solar array, DC to DC boost converter and a 3-phase voltage source inverter with grid synchronization control schemes.

**DC/DC Boost Converter:**

The primary component of grid-connected PV systems is power conditioning unit (PCU). The PCU converts the DC power produced by the PV array into AC power as per the voltage and power quality requirements of the utility grid. A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance. This allows the AC power produced by the PV system to either supply on-site electrical loads or to back-feed the grid when the PV system output is greater than the on-site load demand. This safety feature is required in all grid-connected PV systems, and ensures that the PV system will not continue to operate and feed back into the utility grid when the grid is down for maintenance or during grid failure state in grid-connected systems, switching of AC power from the standby.

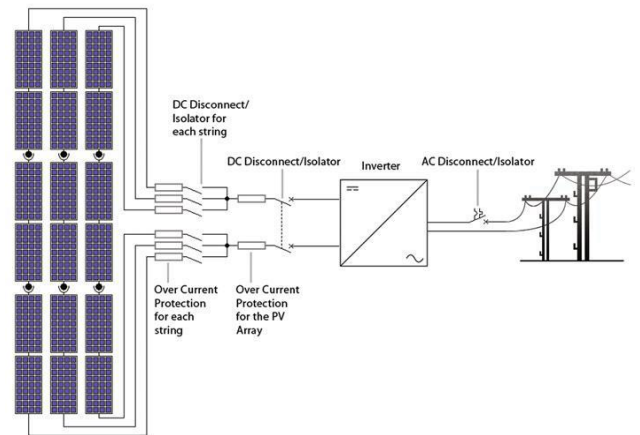


Fig. 1. PV System

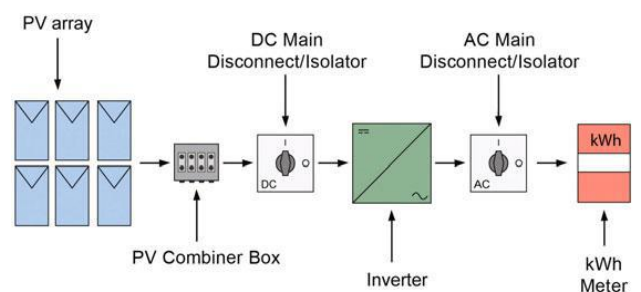


Fig. 2. Grid connection

Generator and the inverter to the service bus or the connected load is accomplished by internal or external automatic transfer switches. One of the important components of a grid-connected system is net metering. Inverters are the main difference between a grid-connected system and a standalone system. Inverters must have line frequency synchronization capability to deliver the excess power to the

grid. (MPPT) is used between the array and load to help better utilize the available array maximum power output

and also for matching the impedance of the electrical load to the maximum power output of the PV array.

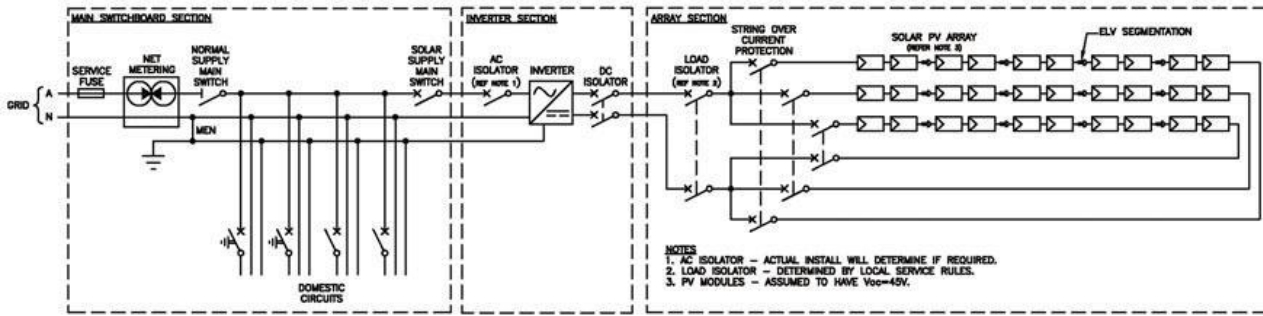


Fig. 3. System Description

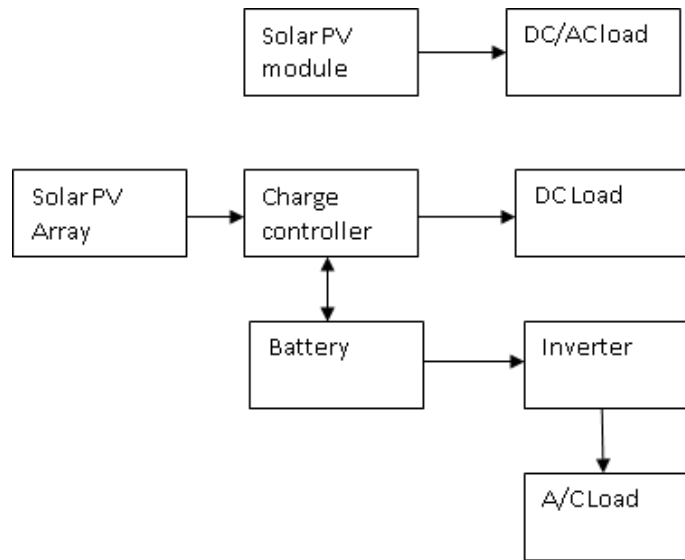


Fig. 4. Solar PV System

Solar PV array: The most commonly known solar cell is configured as a large-area p-n junction made from silicon; the electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation.

The equivalent circuit of PV cell is as shown in (1)

The an ideal solar cell, it is assumed that  $R_s=0$ ,  $R_{sh}=\infty$ . The net current of the cell is the difference

between the photocurrent  $I_{ph}$  and normal diode current

$$I = I_{ph} - I_o \left\{ \exp \left\{ \frac{q \cdot (V + IR_s)}{nK \cdot N_s T} \right\} - 1 \right\} - I_{sh} \quad (1)$$

Module photo-current:

$$I_{ph} = [I_{sc} + K_1(T - 298)] \cdot G/1000 \quad (2)$$

Module saturation current  $I_o$  varies with the cell temperature, which is given by:

$$I_o = I_{rs} \left( \frac{T}{T_n} \right)^3 \cdot \exp \left\{ \frac{q \cdot E_{go} \left( \frac{1}{T_n} - \frac{1}{T} \right)}{nK} \right\} \quad (3)$$

Module reverse saturation current:

$$I_{rs} = \frac{I_{sc}}{\exp \left\{ \frac{qV_{oc}}{N_s K n T} \right\} - 1} \quad (4)$$

Current through shunt resistor:

$$I_{sh} = \left[ \frac{(V + IR_s)}{R_{sh}} \right] \quad (5)$$

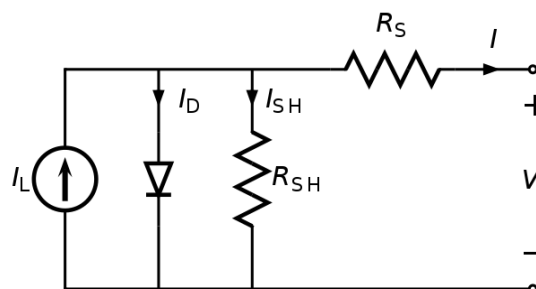


Fig. 5. PV Cell modeled as diode circuit

IV. MATLAB MODELING

MATLAB simulated model of 3-phase grid connected system is shown in the figure 5 which incorporate a PV array connected to DC-DC converter, a DC to AC 3-Phase voltage source inverter, a three phase 400 V grid with 50 KW and frequency 50Hz connected load. The PV module design depends upon the irradiance, temperature, number of PV cells connected in series and parallel. Photovoltaic panel convert solar radiation to electricity with peak efficiencies in the range of 5-20%, depending on the type of the PV cell .The efficiency of the solar cells drops with increasing operating temperatures .The temperature of PV module increases by the absorbed solar radiation that is not converted to electricity, causing a decrease in their efficiency.

V. SIMULATION RESULTS

The functioning of a photovoltaic array is impacted by temperature, solar irradiance, shading, and array configuration. Frequently, the PV arrays get shadowed, wholly or partially, by the moving clouds, adjacent buildings and

towers, trees, utility and telephone poles. The situation is of special interest in case of big PV installations such as those used in distributed power generation systems. Under partly shaded conditions, the photovoltaic characteristics get more complex with more than one peak. Yet, it is very crucial to understand and predict them in order to draw out the maximum possible power. Here, we present a MATLAB-based modeling and simulation scheme. The Matlab simulation system consists of PWM (Pulse with Modulation) Voltage source inverter circuit and a DC capacitor connected at one end. In the Distribution voltage level, the switching element is usually the integrated gate bipolar transistor (IGBT), due to its lower switching losses and reduced size. Moreover, the power rating of custom power devices is relatively low .Consequently; the output voltage control may be executed through the pulse width modulation (PWM) switching method. IGBT based PWM inverter is implemented using Universal bridge block from Power Electronics subset of Simulation Power Systems. RC snubber circuits are connected in parallel with each IGBT for protection. Such a model consists of a six-pulse voltage-source converter using IGBTs/diodes,

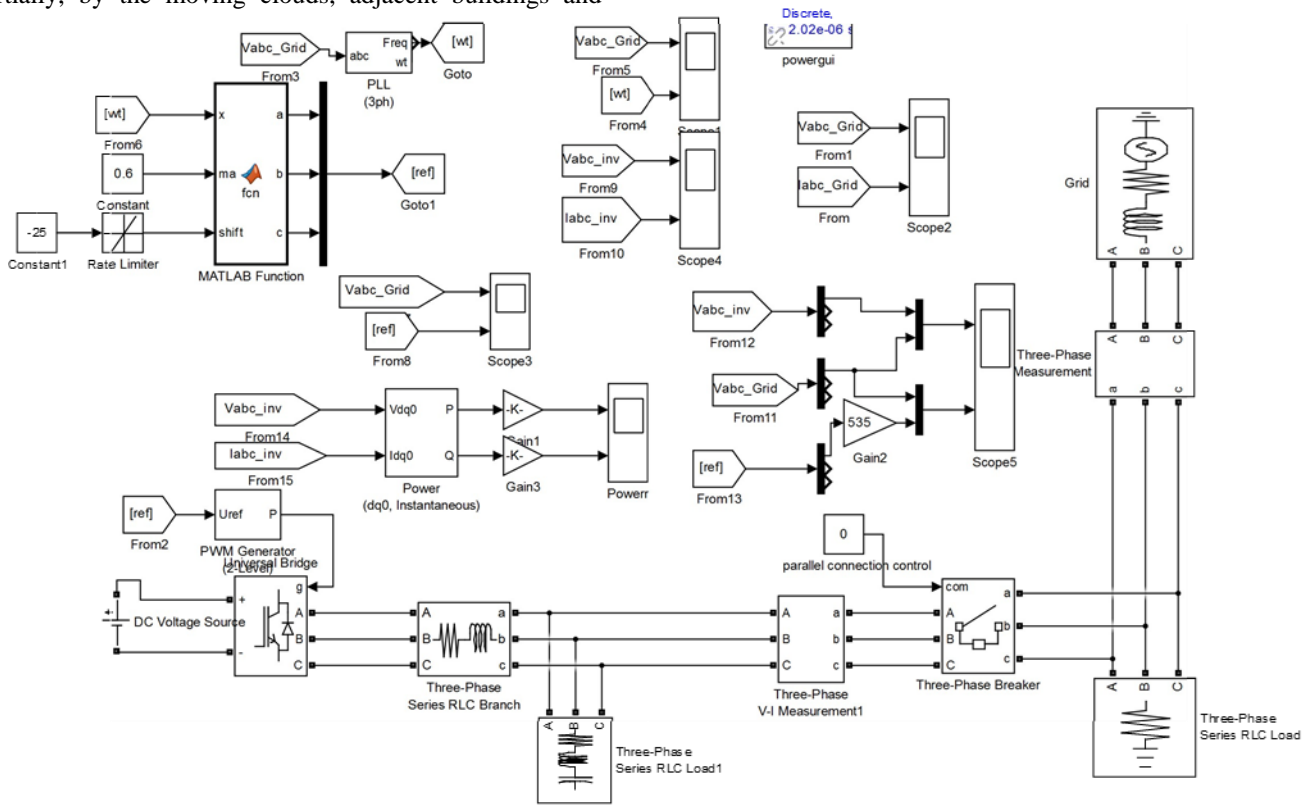
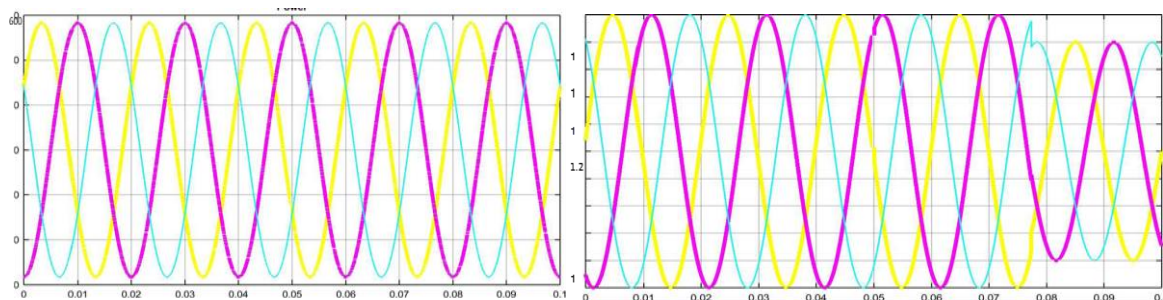


Fig. 6. MATLAB Simulation of Grid Connected Solar PV



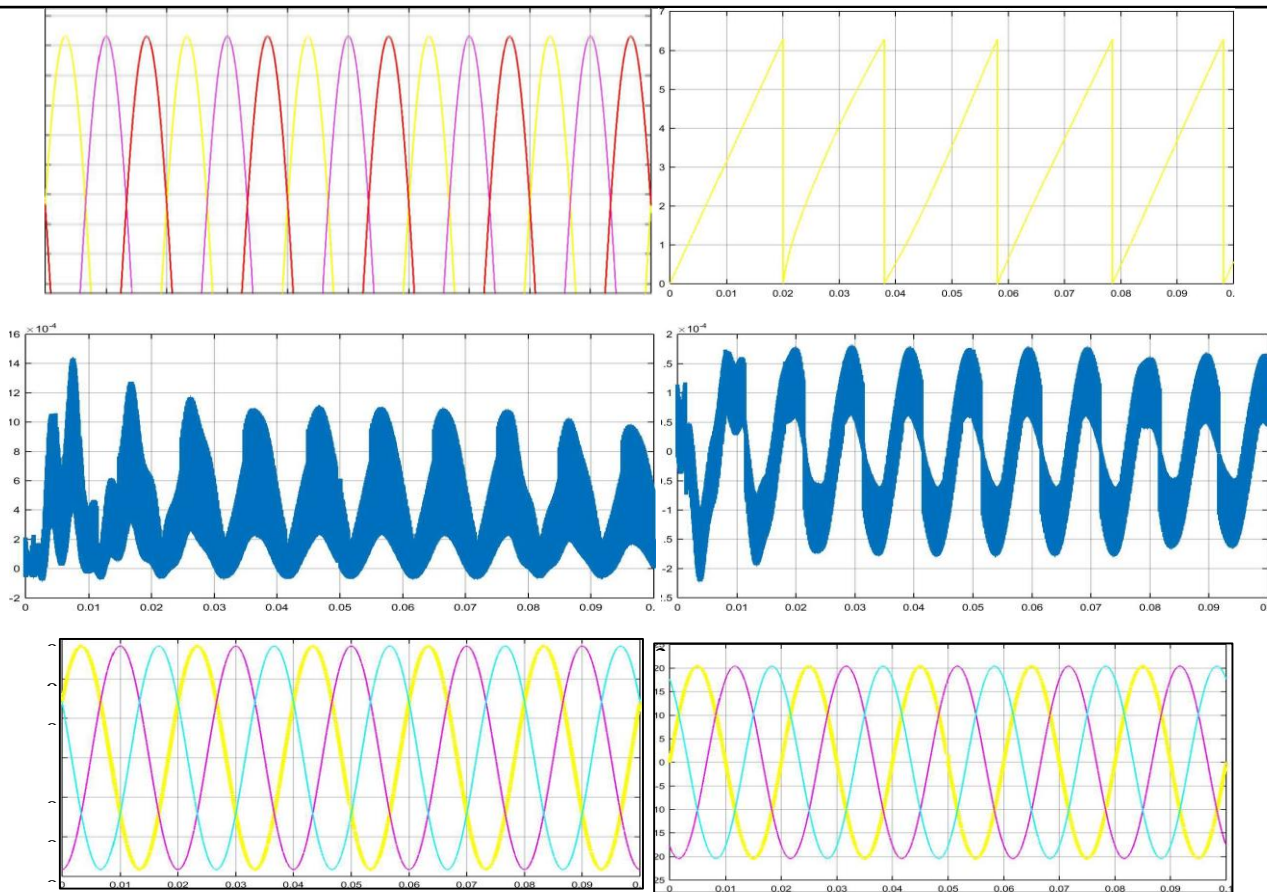


Fig. 7. Simulation result of Grid connected Solar PV

Figure 7 shows the PV array characteristics, the block diagram and recorded waveforms for tests of the Grid Smart inverter system: The waveforms begin with the PV array model characteristics; block diagram for AC power management; and then voltage, current, and power curves for various conditions

#### Inverter output and Grid Voltage

The waveforms of the inverter in Figures show, the stable response of the grid Voltage and output current. It can be seen that the phase of the output current with clean sinusoidal waveform is  $180^\circ$  out of phase with the grid voltage, which means in this case, the electricity generation is realized by the string inverter system. The slightly phase shift between the output is due to the filter output phase.

**PV Voltage and current:** Solar PV current and voltage are most important parameters for the working of solar photovoltaic systems. Power supplied by solar PV systems is dependent on the voltage and the current of the solar panel which in turn are dependent on the irradiance and temperature.

#### VI. CONCLUSION

The electric grid is a complex network that is an integral part of our society. Running the grid in the presence of increasing fuel costs and growing environmental concerns will require new technologies and ways to use them. While renewable power technologies will be an essential part of our energy future, no one technology can provide all of the energy and services we need. Careful integration of distributed generation and careful deployment of utility-scale

generation will be needed to provide the mix of power and reliability that we require for a healthy electric supply as renewable.

Contribute an increasingly larger share of our energy needs. The system performance will largely depend on the geographical location, the weather and other atmospheric conditions at the installation site. The direction your panels face, the temperature they reach, the angle of tilt they are on, the amount of dust and shading they encounter all affect the ability of the system to perform at its peak level.

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## Фотоелектричні системи, підключені до електромережі

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Сонячна електрика - або фотоелектрична (PV) - це найшвидша в світі енергетична технологія. Вона може використовуватися в самих різних масштабах - від осель до сонячних ферм, що забезпечують живлення цілих громад. Вона може бути інтегрована у існуючі електромережі з відносною простотою, це означає, що в часи низької сонячної енергії користувачі можуть продовжувати черпати енергію з електромережі, в той час як електроенергію можна подавати або продавати назад в мережу з отриманням прибутку при виробництві електроенергії. перевищує суму, яку вони використовують. Падіння ціни на обладнання в поєднанні з різними схемами заощадження по всьому світу перетворило PV у вигідні інвестиції з низьким вмістом вуглецю, і як такий попит ніколи не був вищим на технології, а також для людей, які мають досвід розробки та встановлення систем. Попит на енергію надзвичайно збільшився, а споживання ядерної енергії, викопного палива спричинило багато екологічних проблем. Насправді викопні види палива є вичерпними, забруднюючими та досить дорогими. Однак розвиток чистих та поновлюваних джерел енергії, таких як вітер, біомаса, геотермальна та фотоелектрична, є перспективним рішенням для подолання проблеми звичайних джерел енергії. Одним із таких джерел є фотоелектрична (ПВ) система генерації електроенергії, яка є чистим, тихим та ефективним методом отримання електроенергії. Основна мета цієї роботи - вивчення сонячних фотоелектричних систем та моделювання підключеної до Грід сонячної енергії Система симуляції з використанням модуляції Matlab. Симуляційна система Matlab складається з ШІМ (імпульсу з модуляцією) ланцюга, інвертора, джерела напруги та конденсатора постійного струму, підключеного на одному кінці. Сітка, підключена до мережі, складається з сонячних панелей, інверторів, кондиціонування та підключення до мережі. Вона має ефективне використання енергії, що виробляється від сонячної енергії, оскільки втраг накопичувача енергії немає. Підключена до сітки фотоелектрична система подає надмірну потужність, крім споживання підключеним навантаженням до комунальної мережі через розумні лічильники. Електрична мережа - це складна мережа, яка є невід'ємною частиною нашого суспільства. Запуск енергосистеми за наявності зростаючих витрат на пальне та зростаючих проблем щодо навколишнього середовища вимагатиме нових технологій та способів їх використання

*Ключові слова - сітчаста система; фотоелектрична система; модель Simulink.*