INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume3, Issue5)
Available online at www.ijariit.com

Synchronization of Photovoltaic Systems in Single-Phase Grid-Connected Under Grid Faults

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Abstract: The highly increasing penetration of single-phase photovoltaic (PV) systems pushes the grid requirements related to the integration of PV power systems to be updated. These upcoming regulations are expected to direct the grid-connected renewable generators to support the grid operation and stability both under grid faulty conditions and under normal operations. Grid synchronization techniques play an important role in the control of single-phase systems in order to fulfill these demands. Thus, it is necessary to evaluate the behaviors of grid synchronization methods in single phase systems under grid faults. The focus of this paper is put on the benchmarking of synchronization techniques, mainly about phase locked loop (PLL) based methods, in single-phase PV power systems operating under grid faults. Some faulty mode cases are studied at the end of this paper in order to compare these methods. It is concluded that the Enhanced PLL (EPLL) and the Second Order Generalized Integrator based PLL (SOGI-OSG PLL) technique are the most promising candidates for future single-phase PV systems due to their fast adaptive-filtering characteristics.

Keywords- AC, DC, Solar Photovoltaic Modules, Phase Locked Loop, 555 Timer, and Synchronization.

I INTRODUCTION

Recently, the matured PV technology and the declined price of PV panels make more and more PV generation systems connected to the medium voltage or high voltage networks. However the grid connected PV generation units might cause severely negative impacts on the whole systems, because they cannot act like the conventional power plants composed of conventional synchronous generators. Thus, many grid requirements have been released in order to regulate inter connected renewable power generation .Some basic requirements are defined in the grid regulations, like power quality, frequency stability and voltage stability, and some specific demands for wind power systems have also been issued. Now a days, the high penetration of grid connected single phase PV systems really raises the concern about PV integration of low voltage power systems. Therefore reasonably technical requirements are in an urgent need to be put forward. Like the grid requirements for wind turbines, it is expected that the future grid connected single phase PV systems can not only maintain in the stability and quality of the grid, but also have some ancillary functions, such as reactive power support and Fault Ride through (FRT) capability. In that case, the grid monitoring and synchronization techniques and the control strategies should be ready for single phase PV applications. Many papers discuss the monitoring and synchronization for three phase systems synchronization PV systems should also be investigated in details. The phase locked loop (PLL) based synchronization takes much more attention. Nowadays, there are mainly four different PLL-based synchronization techniques.

In the present day energy scenario, for meeting the ever-increasing energy demand, efforts have come into focus with a view to develop new generation technologies. The major goals of these approaches are to have reduced environmental damages, conservation of energy, exhaustible sources and increased safety. In this context during the past few years renewable energy sources have received greater attention and considerable inputs have been given to develop efficient energy conversion and utilization techniques.

Majority of the population in our country are located in villages and a large number of the villages are still not served by National Grid due to cost involved for laying of the transmission line in relation to their power consumption and because of the distance involved. Due to this quality of life, availability of cold storage for Medicine, TV coverage and other aspects are adversely affected. Conventional sources of energy have a long generation period, draw heavily on exhaustible deposits and adversely affect ecological balance. New and Renewable sources of energy are not only economically viable but do not suffer from any of the above disadvantages.

1.1 NEW GENERATION TECHNOLOGIES & RENEWABLE ENERGY SOURCES

The requirement for developing new generation technologies and renewable energy sources are:
1. Ever-increasing energy demand
2. Reduced environmental damages and increased safety
3. Conversion of energy and inexhaustible sources
4. Adequately available, least impact on environment and ecology.
5. The future of fossil fuels has a limited time for their availability i.e. estimated that it could be around 70 to 100 years.
6. The cost of generation goes on decreasing as time passes.
7. Environmental friendly project

1.2 PROBLEM FORMULATION

The output of the solar and voltage of the grid is required for proper synchronization of frequency voltage and by using PLL technique.

II BLOCK DIAGRAM

2.1 BlOCK DIAGRAM

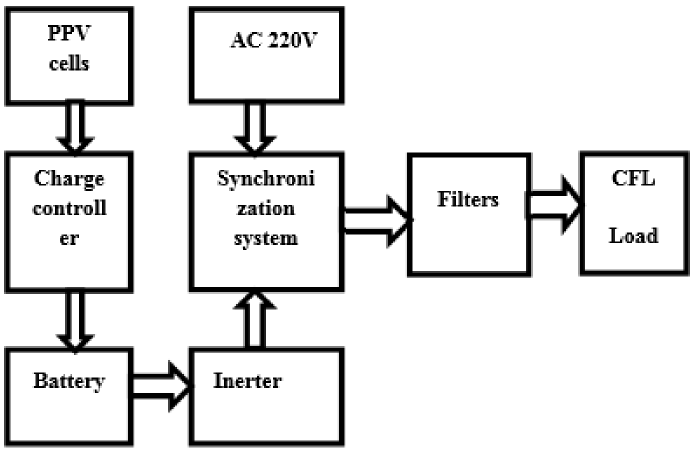

Fig. 2.1 Block diagram

The hardware connections are made as shown in the above block diagram. A photovoltaic cell (PV cell) is a specialized semiconductor diode that converts visible light into direct current (DC). Charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents over charging and may protect against over voltage, which can reduce battery performance or life span and may pose a safety risk it may also prevent completely draining ("deep discharging") a battery, or perform control discharges depending on the battery technology, to protect battery life. Battery storage, in which the solarly generated electric energy is to be stored.

Inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). Inverter usually solid state which converts the battery bus voltage to ac of frequency and phase to match that needed to integrate with the utility grid. Thus it is typically a dc, ac inverter. It may also contain a suitable output step-up transformer, perhaps some filtering and power factor correction circuits and perhaps some power conditioning that is circuitry to initiate battery charging to prevent over charging. Synchronization is the process of matching the frequency of other source to a running network. Synchronization techniques, mainly about phase locked loop (PLL) based methods. A phase locked loop or phase lock loop (PLL) is a control system that generates an output signal whose phase is related to the phase of an input signal. The LM 324 consisting of four independent, high gain, internally frequency compensated operational amplifier which were designed specifically to operate from a single power supply over a wide voltage range operation from split power supplies is also possible so long as the difference between the two supplies

Filter is a device or process that removes from a signal some unwanted component or feature. Filtering is a class of signal processing, the defining feature of filters being the complete or partial suppression of some aspect of the signal. Most often, this means removing some frequencies and not others in order to suppress interfering signals and reduce background noise.

Compact florescent lamps (CFL), are energy saving lamps design to reduce the power consumption by old incandescent lamps.

2.2 MAJOR COMPONENTS OF BLOCK DIAGRAM

1. solar photo voltaic module
2. charge controller
3. 12 V Battery
4. Inverter

III. SOLAR PHOTOVOLTAIC MODULES

A solar cell (also called a photovoltaic cell) is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. It is a form of photoelectric cell (in that it's electrical characteristics—e.g. current, voltage, or resistance—vary when light is incident upon it) which, when exposed to light, can generate and support an electric current without being attached to any external voltage source.

The term "photovoltaic" comes from the Greek φῶς (*phōs*) meaning "light", and from "Volt", the unit of electro-motive force, the volt, which in turn comes from the last name of the Italian physicist Alessandro Volta, inventor of the battery (electrochemical cell). The term "photo-voltaic" has been in use in English since 1849.

Photovoltaic is the field of technology and research related to the practical application of photovoltaic cells in producing electricity from light, though it is often used specifically to refer to the generation of electricity from sunlight. Cells can be described as photovoltaic even when the light source is not necessarily sunlight (lamplight, artificial light, etc.). In such cases the cell is sometimes used as a photo detector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires 3 basic attributes:

1. The absorption of light, generating either electron-hole pairs or exactions.
2. The separation of charge carriers of opposite types.
3. The separate extraction of those carriers to an external circuit

3.1 ADVANTAGES AND DISADVANTAGES OF PHOTOVOLTAIC SYSTEM

A). Advantages

1. Direct room temperature conversion of light to electricity through simple solid state devices.
2. Absence of moving parts
3. Ability to function unattended for long periods as evidence in space program.
4. Power levels – voltage/current can be achieved by more integration.
5. Maintenance cost is low, as they are easy to operate
.6.They do not create pollution, They have a long effective life
7. They consume no fuel to operate, as the Sun's energy is free.
8. It is an environmentally clean source of energy.

b). Disadvantages

1. The solar radian flux availability is a low value 1 kW / m^2 for technological utilization.
2. Large collecting area required and Cost is more.
3. Availability varies with time.
4. In many applications, energy storage is required at night.
5. The relatively poor conversion efficiency.

IV. CHARGE CONTOLLER

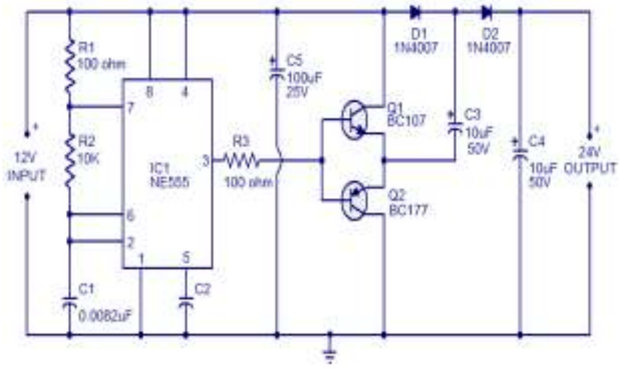

Fig 4 (a) Circuit diagram for charging controller

4.1 Description

The circuit diagram of a very simple voltage doubler using NE555 timer is shown here. Here IC NE555 is wired as an astable mutivibrator operating at around 9 KHz. The base of the two transistors (Q1 and Q2) is shorted and output of the astable multivibrator (pin 3) is connected to it. When the output of astable multivibrator is low, Q1 will be OFF and Q2 will be ON. The negative terminal of the capacitor C3 will be shorted to ground through T2 and it will be charged to the input supply voltage. When the output of the astable multi vibrator is high, transistor Q1 will be ON and transistor Q2 will be OFF. The capacitor C4 will be charged to the voltage across capacitor C3 plus the input supply voltage (that is double the input voltage). This is how the circuit works.

This voltage doubler circuit can deliver only up to 50mA output current and above that current limit the output voltage will be dramatically reduced. The actual output voltage will be around 19V for a 12V DC input and also the output voltage will be a bit unstable. Anyway, for low current applications this circuit is well enough diagram of ic 555

The 555 timer IC is an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications

The 555 timer IC was introduced in the year 1970 by Signetic Corporation and gave the name SE/NE 555 timer. It is basically a monolithic timing circuit that produces accurate and highly stable time delays or oscillation. When compared to the applications of an op-amp in the same areas, the 555IC is also equally reliable and is cheap in cost. Apart from its applications as a monostable multivibrator and astable multivibrator, a 555 timer can also be used in dc-dc converters, digital logic probes, waveform generators, analog frequency meters and tachometers, temperature measurement and control devices, voltage regulators etc. The timer IC is setup to work in either of the two modes – one-shot or monostabl or as a free-running or astable multivibrator. The SE 555 can be used for temperature ranges between – 55°C to 125°. The NE 555 can be used for a temperature range between 0° to 70°C.

4.2 IMPORTANT FEATURES OF THE 555 TIMER

- It operates from a wide range of power supplies ranging from + 5 Volts to + 18 Volts supply voltage.
- Sinking or sourcing 200 mA of load current.
- The external components should be selected properly so that the timing intervals can be made into several minutes along with the frequencies exceeding several hundred kilo hertz.
- The output of a 555 timer can drive a transistor-transistor logic (TTL) due to its high current output.
- It has a temperature stability of 50 parts per million (ppm) per degree Celsius change in temperature, or equivalently 0.005 %/ °C.
- The duty cycle of the timer is adjustable.

The maximum power dissipation per package is 600 mW and its trigger and reset inputs has logic compatibility.

4.3 VOLTAGE DOUBLER

The electronic circuit is basically a square wave generator using the common LM555 timer IC. It is followed by a final stage made of transistors T1 and T2. The actual doubler circuit is made of D1, D2, C4 and C5 components.

The 555 dc voltage doubler timer *IC* works as an astable multivibrator and generates a frequency of about 8.5 kHz. The quare wave output drives the final stage made of T1 and T2. This is how the doubler works: by a low amplitude of the signal, transistor T1 blocks while T2 conducts. The minus electrode of the capacitor C4 is grounded and charges through D1. By a high amplitude of the signal, transistor T1 conducts while T2 blocks. However, capacitor C4 cannot discharge because it is blocked by D1. The following capacitor C5 is therefore charged with a combined voltage from C4 and the power supply (12V input).

4.4 CURRENT LIMITED 6V CHARGER

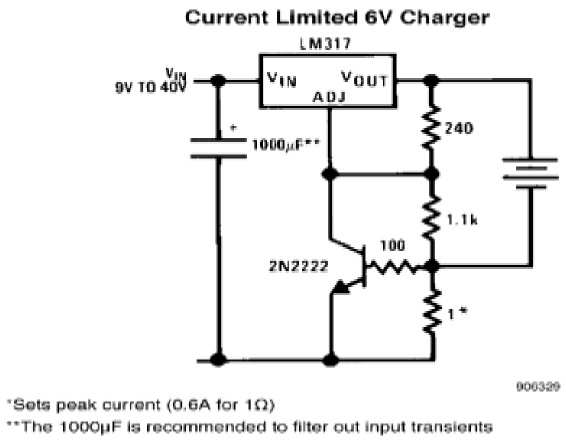

Fig 4.4(a) Current limited 6V charger

When want to build the lead-acid battery charger project for 6V battery or 12V using IC LM317 because easy to use, with minimal equipment. Cheap and good. Today, I try to collection ideas for the battery charger circuit.

4.5 Description

All miniature electronic devices operate off batteries. Some of them need higher than the standard battery voltages to operate efficiently. If the battery of that specific voltage is unavailable, we are forced to connect additional cells in series to step up the DC voltage. Thus, the true meaning of miniaturization is lost. A simple way to overcome this problem is to employ a voltage doubler, if the device under consideration can operate at a small current. Here we present a low-power voltage doubler circuit that can be readily used with devices that demand higher voltage than that of a standard battery but low operating current to work with. The circuit is quite simple as it uses only a few components. Yet, the output efficiency is 75 to 85 percent along its operating voltage range. The available battery voltage is almost doubled at the output of the circuit.

The 2N2222 is a common NPN bipolar junction transistor used for general purpose low-power amplifying or switching applications. It is designed for low to medium current, low power, medium voltage, and can operate at moderately high speeds. It is made in theTO-18 metal can as shown in the picture. Replacements are commonly available now in the cheaper TO-92 packaging, where it is known as the PN2222 or P2N2222, which has similar specifications except for the lower maximum collector current.

The 2N2222 is considered a very common transistor and is used as an exemplar of an NPN transistor. It is frequently used as a small-signal transistor and it remains a small general purpose transistor of enduring popularity.

4.6 BATTERY

Once the power output from solar is converted to DC, it is supplied to batteries and the batteries get charged. Depending upon the load requirement and the number of hours of operation of loads the adequate battery size is calculated.

The battery we have used in our project is 12V, 7.58 Ah Battery.

Specification:
Volt: 12V
Current: 7.5AhC
Type: Lead Acid.

To charge the battery input voltage is require more than 13.5 V solar cells produce 18V, solar

Power generates below 6 it will not work. So we are using charging controller

V INVERTER

Inverter is a small circuit which will convert the direct current (DC) to alternating current (AC). The power of a battery is converted in to' main voltages' or AC power. This power can be used for electronic appliances like television, mobile phones, computer etc. the main function of the inverter is to convert DC to AC and step-up transformer is used to create main voltages from resulting AC.

5.1 INVERTER DESIGN TIPS

The maximum allowed output power of an inverter depends on two factors. The maximum current rating of the transformer primary and the current rating of the driving transistors.

For example ,to get a 100 Watt output using 12 V car battery the primary current will be ~8A ,(100/12) because P=VxI.So the primary of transformer must be rated above 8A.

Also here, each final driver transistors must be rated above 4A. Here two will be conducting parallel in each half cycle, so I=8/2 = 4A.

These are only rough calculations and enough for this circuit.

VI .PLL TECHNIQUE

6.1 Description

This paper presents an analysis and comparison of Phase Locked Loop techniques used in grid utility applications to find the voltage vector angle generated from the supply voltages. The Phase Locked Loop (PLL) has a wide range of applications as Distributed Generation (DG), Flexible AC Transmission Systems (FACTS), static VAR compensators, cycloconverters, Active Power Filters (APF's) and others systems connected to the utility. The performance of these systems in grid connected applications is strongly influenced by the adopted PLL strategy. For this reason, the goal of the proposed paper is to present a comparison of different PLL-based techniques for utility applications to indicate the appropriate solution dedicated to a specific application. The criteria to compare the Phase Locked Loops techniques is the performance under distorted and unbalanced supply voltages.

6.2 IC LM324

LM324 is a 14 pin ic consisting of four independent operational amplifier (op-amps) compensated in a single package op-amps are high gain electronic voltage amplifier with differential input and usually a single ended output. The output voltage is many times higher than the output difference between input terminals of an op-amp these op-amps operated by a single power supply LM324 and need for a dual supply is eliminated. They can be used as amplifier comparator, oscillater, rectifier etc. the conventional op-amps applications can be more easily implemented with LM324.

6.3 LM324 OPERATIONAL AMPLIFIER - COMPARATER

The LM324 is a low voltage (2.7–5.5V) version of the dual and quad commodity op amps, The LM324 is the most cost effective solution for the applications where low voltage operation, space saving and low price are needed. The LM324 has rail-to-rail output swing capability and the input common-mode voltage range includes ground.

The small package saves space on PC boards, and enables the design of small portable electronic devices. It also allows the designer to place the device closer to the signal source to reduce noise pickup and increase signal integrity.

6.4 SYNCHRONIZING RELAYS

Synchronizing relays allow unattended synchronization of a machine with a system. Today these are digital microprocessor instruments, but in the past electromechanical relay systems were applied. A synchronizing relay is useful to remove human reaction time from the process, or when a human is not available such as at a remote controlled generating plant. Synchroscopes or lamps are sometimes installed as a supplement to automatic relays,for possible manual use or for monitoring the generating unit.

Sometimes as a precaution against out-of-step connection of a machine to a system, a "synchro check" relay is installed that prevents closing the generator circuit breaker unless the machine is within a few electrical degrees of being in-phase with the system. Synchro check relays are also applied in places where several sources of supply may be connected and where it is important that out-of-step sources are not accidentally paralleled.

6.5 SYNCHRONIZATION OPERATION

When the generator is synchronized, the frequency of the system will change depending on load and the average characteristics of all the generating units connected to the grid. Large changes in system frequency can cause the generator to fall out of synchronism with the system. Protective devices on the generator will operate to disconnect it automatically.

A phase-locked loop or phase lock loop (PLL) is a control system that generates an output signal whose phase is related to the phase of an input signal. While there are several differing types, it is easy to initially visualize as an electronic circuit consisting of a variable frequency oscillator and a phase detector. The oscillator generates a periodic signal. The phase detector compares the phase of that signal with the phase of the input periodic signal and adjusts the oscillator to keep the phases matched. Bringing the output signal back toward the input signal for comparison is called a feedback loop since the output is 'fed back' toward the input forming a loop.

Keeping the input and output phase in lock step also implies keeping the input and output frequencies the same. Consequently, in addition to synchronizing signals, a phase-locked loop can track an input frequency, or it can generate a frequency that is a multiple of the input frequency. These properties are used for computer clock synchronization, demodulation, and frequency synthesis, respectively.

Phase-locked loops are widely employed in radio, telecommunications, computers and other electronic applications. They can be used to demodulate a signal, recover a signal from a noisy communication channel, generate a stable frequency at multiples of an input frequency (frequency synthesis), or distribute precisely timed clock pulses in digital logic circuits such as microprocessors. Since a single integrated circuit can provide a complete phase-locked-loop building block, the technique is widely used in modern electronic devices, with output frequencies from a fraction of a hertz up to many gigahertz.

6.6 APPLICATIONS

Phase-locked loops are widely used for synchronization purposes; in space communications for coherent demodulation and threshold extension, bit synchronization, and symbol synchronization. Phase-locked loops can also be used to demodulate frequency-modulated signals. In radio transmitters, a PLL is used to synthesize new frequencies which are a multiple of a reference frequency, with the same stability as the reference frequency.

6.7 TRANSFORMER

A transformer is a static device in which electric power in one circuit is transferred into electric power of same frequency in another circuit .It can raise or lower the voltage in the circuit but with a corresponding decrease or increase in current. It works with the principle of mutual induction. In this project a step-down transformer is used to provide necessary supply of 5 V for the electronic circuits

6.8 RECTIFIER

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Physically, rectifiers take a number of forms, including vacuum tube diodes, mercury-arc valves, copper and selenium oxide rectifiers, semiconductor diodes, silicon-controlled rectifiersand other silicon-based semiconductor switches. Historically, even synchronous electromechanical switches and motors have been used. Early radio receivers, called crystal radios, used a "cat's whisker" of fine wire pressing on a crystal ofgalena (lead sulfide) to serve as a point-contact rectifier or "crystal detector".

6.9 APPLICATIONS

The primary application of rectifiers is to derive DC power from an AC supply (AC to DC converter). Virtually all electronic devices require DC, so rectifiers are used inside the power supplies of virtually all electronic equipment.

Converting DC power from one voltage to another is much more complicated. One method of DC-to-DC conversion first converts power to AC (using a device called an inverter), then uses a transformer to change the voltage, and finally rectifies power back to DC.

VII FILTER

A filter capacitor is an electronic component that removes voltage or signal spikes in electronic circuits. Capacitors are used as filter devices due to their ability to absorb and effectively store electrical charges at predetermined values. This characteristic is used in a filter capacitor application to soak up or buffer voltage values which exceed set parameters. Filter capacitors are typically placed across a load or as a path to ground in circuits. Several different filter capacitor types include electrolytic, ceramic, and tantalum.

VIII COMPACT FLUORESCENT LAMP (CFL)

A compact fluorescent lamp (CFL), also called compact fluorescent light, energy-saving light, and compact fluorescent tube, is a fluorescent lamp designed to replace an incandescent lamp; some types fit into light fixtures formerly used for incandescent lamps. The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb, and a compact electronic ballast in the base of the lamp.

Compared to general-service incandescent lamps giving the same amount of visible light, CFLs use one-fifth to one-third the electric power, and last eight to fifteen times longer. A CFL has a higher purchase price than an incandescent lamp, but can save over five times its purchase price in electricity costs over the lamp's lifetime. Like all fluorescent lamps, CFLs contain toxic mercury which complicates their disposal. In many countries, governments have established recycling schemes for CFLs and glass generally.

CFLs radiate a spectral power distribution that is different from that of incandescent lamps. Improved phosphor formulations have improved the perceived color of the light emitted by CFLs, such that some sources rate the best "soft white" CFLs as subjectively similar in color to standard incandescent lamps.

8.1 DESIGN

There are two types of CFLs: integrated and non-integrated lamps. Integrated lamps combine the tube and ballast in a single unit. These lamps allow consumers to replace incandescent lamps easily with CFLs. Integrated CFLs work well in many standard incandescent light fixtures, reducing the cost of converting to fluorescent. 3-way lamp bulbs and dimmable models with standard bases are available.

Non-integrated CFLs have the ballast permanently installed in the luminaire, and only the lamp bulb is usually changed at its end of life. Since the ballasts are placed in the light fixture, they are larger and last longer compared to the integrated ones, and they don't need to be replaced when the bulb reaches its end-of-life. Non-integrated CFL housings can be both more expensive and sophisticated.

APPLICATIONS AND ADVANTAGES

- Grid synchronization techniques play an important role in the control of single-phase systems in order to fulfill demands to support the grid operation and stability both under grid faulty conditions and under normal operations.
- PHOTOVOLTAIC (PV) power supplied to the utility grid is gaining more and more visibility, while the world's power demand is increasing; hence the need for synchronization techniques to support these demands.
- The ever-increasing energy consumption, fossil fuels' soaring costs and exhaustible nature, and worsening global environment have created a booming interest in renewable energy generation systems, one of which is photovoltaic.
- Application of photovoltaic (PV) as a source of electrical energy have showed a tendency to increase in terms of generation capacity and in terms of its spread in large areas around the world.
- Photovoltaic-generated energy can be delivered to power system networks through grid-connected inverters.
- Techniques such as Enhanced PLL (EPLL) and the Second Order Generalized Integrator based PLL (SOGI-OSG PLL) technique are the most promising candidates for future single-phase PV systems due to their fast adaptive-filtering characteristics.

- Present consumption pattern
- predominantly -fossil fuel
- Limited fossil reserves
- Adverse environmental impacts
- Unsustainable
- Need for transition to clean technology
- (renewable energy systems, efficiency)
- Nuclear

CONCLUSION

This paper presents the future requirements for single phase grid connected pv systems under grid faults. It can be concluded that the future grid connected pv systems will be more active and more smart, which means the future grid connected pv systems should have some ancillary functionalities as the unconventional power plants do in presence of an abnormal grid condition. Thus this paper discussed one essential part of the control of such a smart pv system monitoring and synchronization.

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