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SOLAR POWER SYSTEMS AND DC TO AC INVERTERS

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Abstract: In this article solar power systems architecture along with the brief overview of the DC to AC inverters and their utilization as a power electronics device in solar photovoltaic systems is provided. The study provides details regarding the types of the inverters, single phase half bridge inverters, single phase full phase inverters and three phase inverters. As pulse width modulation (PWM) is widely used in inverters which works as a solar charge controllers so the principles of PWM along with carrier based and carrier less modulation techniques is also mentioned. A comprehensive simulation and implementation of a three phase PWM inverter in Simulink Matlab is also provided.
Keywords: solar power systems, inverters, pulse width modulation, smart grids, control strategies, simulation model

INTRODUCTION

The major sources of producing electricity in the world include fossil fuels and coals which are increasing the greenhouse gases (GHG) emissions. These GHG emissions are the main reason behind the climate change. As the population of world is increasing this is also resulting in increase in demand of the electricity as well. After the Paris agreement on climate change, the countries have decided to cap the carbon emissions up to certain levels and to reduce the production of the GHG gases by stop using conventional fossil fuels to produce electricity.

One of the clean options was the Nuclear power but after the meltdown of the Fukushima Daiichi nuclear plant in Japan due to the tsunami caused by severe earthquake on March 2011 the governments around the world are now no more considering Nuclear as an option for environmental production of energy instead the only option for the clean energy production with the unlimited natural resources left is through the renewable energies [1]. The incentives provided by the governments is helping in more installations of solar power plants around the world at residential and commercial levels.

Therefore in order to achieve the targeted goals regarding climate change set by UNFCC [2] the increase in PV generation facilities can be play an important role. As there is abundance of sun and solar energy in the world so we can consider photovoltaic (PV) energy effect to be an important sustainable resource because of this the photovoltaic systems are widely used, as the source of electricity in urban and rural areas. In this study, solar power system types are discussed with the types and classifications of DC to AC inverters and their importance regarding the integration of DC solar power systems with the AC side of the utilities as well is discussed. Also in this paper using Matlab model simulation of the PWM inverters is discussed.

TYPES OF PHOTOVOLTAIC SYSTEM

The solar power systems can be branded into different types depending upon the electric production ability and according to the end user energy requirements.

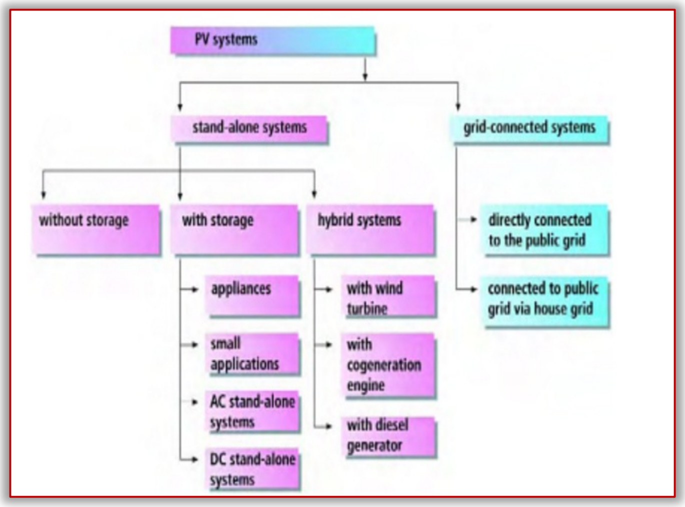

Figure 1. Types of PV systems source (The German Energy Society, Deutsche Gesellschaft für sonnen energie (DGS LV Berlin BRB), 2008)

— Standalone systems

The other term used for standalone systems is "off-grid solar power systems" as they are commonly used in areas where grid or utility power is not available. These systems are independent of any other source of energy and the energy produced by sun is not only utilized during the day but access is stored in battery banks to be used when there is no sun available. These systems are used where supply of electricity is immediately required and with minimum price.

The systems can be installed in shortest time periods and no hassle or rustle is needed like the provision of high transmission lines and the transformers. These systems are mostly being used in rural electrification projects and in remote areas where the grid is not available. The OFF-Grid solution is the solution in which you can simply live without the GRID and produce and use your own produced energy according to your requirements.

Following are the main components required for such kind of systems:

1. PV modules
2. Charge controllers
3. Battery bank
4. Load
5. Ac inverter for systems where alternate current is required at the loads

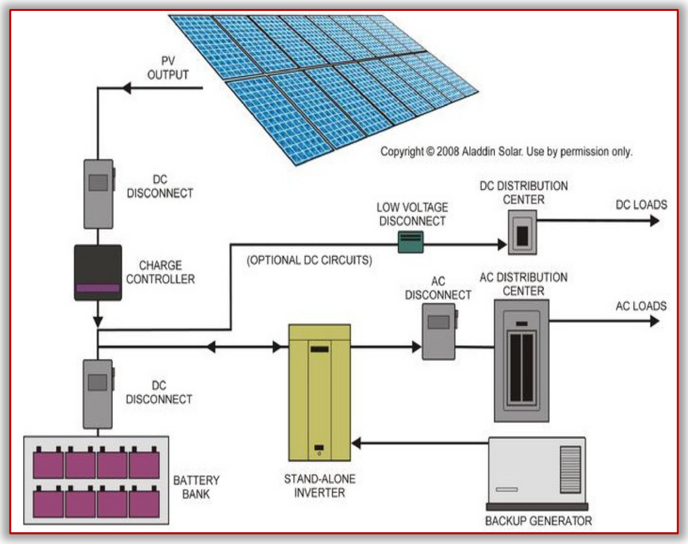

Figure 2. Schematic diagram of solar off grid system

— **Grid connected systems**

This is a solar power system which is linked to the utility grid. In unconnected systems (standalone systems) we need battery bank for energy storage but in grid connected systems the energy which is produced more than the requirement of end user is transported back to the utility grid to be used where there is shortage of energy. In grid-connected systems the community electricity grid is used as an energy store as well.

Many countries around the world prefer mostly solar PV systems to be connected to the utility grid because that helps their national grids is getting access energy from the solar systems, reduce production of cost of energy production by use of fossil fuels and in return the citizens with solar installations enjoy rebates. Feed-in tariff for production of solar electricity also helps the user to get back the initial investment on the system at the earliest.

The standard grid-connected PV systems are mostly made up of the following components:

1-PV modules/array

2-PV array combiner/junction box

1. 3-Direct current (DC) cabling
2. 4-Inverter
3. 5-AC cabling
4. 6-Meter cupboard with power distribution system, supply and feed meter, and electricity connection.

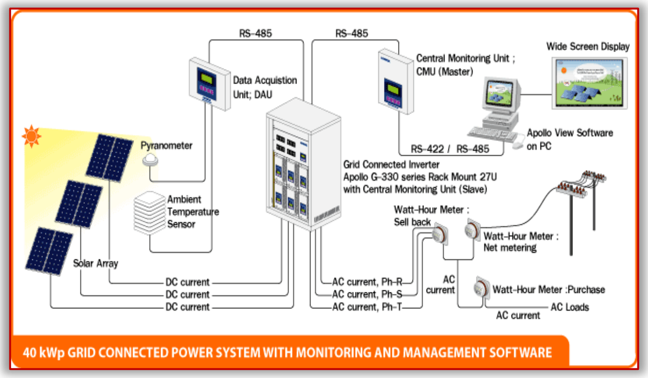

Figure 3. Grid connected PV system (source: http://www.leonics.com)

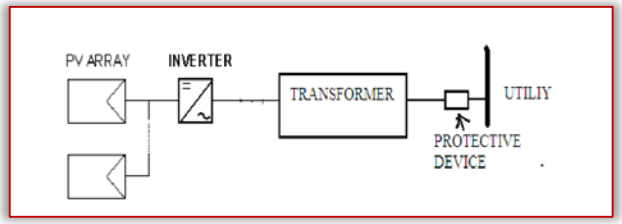

Figure 4. Block diagram Grid-Connected System

The use of transformers increases the ac output voltage when needed. Where there is no boost up of ac current required, transformer less designs are preferred. In order to prevent resistive power flow from utility to the solar system protective devices like under voltage relay, circuit breakers etc are installed. Grid-connected photovoltaic (PV) energy is one of the fastest growing and most promising renewable energy sources in the world.

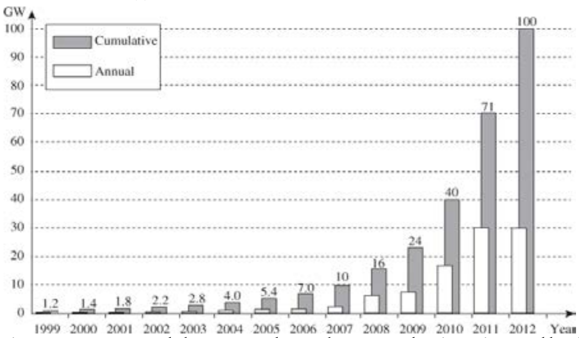

Figure 5: World annual and cumulative installed photovoltaic capacities Source: (Abu-Rub, Malinowski, & Al-Haddad, 2014

According to London based research and consulting firm GlobalData, the global collective installed solar photovoltaic (PV) capacity would increase from 175.4 Gigawatts (GW) in 2014 to approximately 223.2GW in 2015. According to GlobalData's recent report China is considered as the major market leader in PV installations with about 17.6 GW in 2015.

— **Hybrid Systems**

In hybrid systems the required output power is obtained by two or more different power generating sources. A system can be hybridized by combining different renewable energy sources such solar and wind together to get the common output required by

the end user. Solar power system can also be joined together with the diesel generator in areas where there is needed and for better performance. The main aim of hybridization is to get the stable output from the renewable energy sources and cater for fluctuations caused because of the environmental conditions while using solar and wind generation.
Sometimes hybrid systems are also known as "Integrated renewable energy systems".
Hybrid systems are generally planned to meet the peak demand when they run in combination with conventional power generation systems. For example in case of wind and PV hybrid power plant these two separate systems share a single inverter for power conversion and a single storage facility depending upon the case of grid connected system [3].

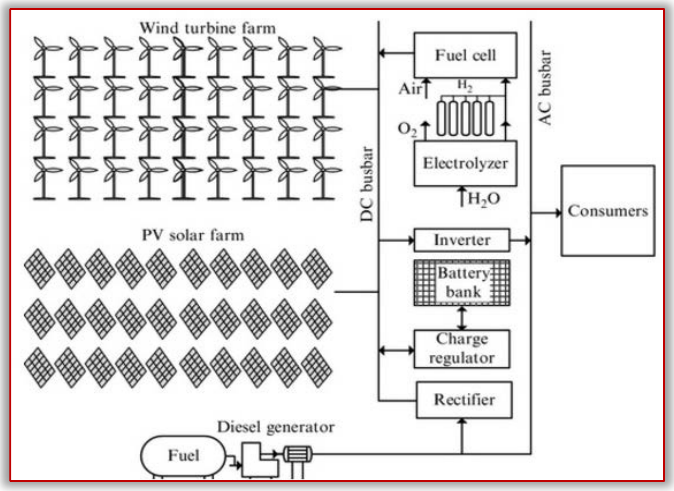

Figure 6. Hybrid Solar-PV, Wind Turbine, and Diesel Power Integrated System

DC TO AC INVERTERS

The conversion circuits that run from a DC voltage source or a DC current source and convert it into an AC voltage or Current are known as inverters. In this case the input to the inverter is a DC source or DC source produced from an AC voltage source. The principle source of input power is possibly utility ac voltage source that is transitioned to DC by an AC-DC rectifier with capacitor filter and then converted into ac supply using an inverter [4].

The dc-ac converter, also known as the inverter, converts dc power to ac power at required output voltage and frequency. We can use existing power supply network or form a rotating alternator through a rectifier or a battery, fuel cell, photovoltaic array or magneto hydrodynamic generator to provide DC power input to the inverter. We can get the constant DC link voltage by adding a filter capacitor across the input terminals of the inverter hence the inverter can be considered as an adjustable-frequency voltage source. The configuration of ac to dc converter and dc to ac inverter is called a dc-link converter.

— Classification of Inverters

Inverters can be broadly classified into two types, voltage source and current source inverters.

» Voltage Source Inverters

A voltage–fed inverter (VFI) or a voltage–source inverter (VSI) is one in which we have a dc source with a very small impedance which is negligible. The input terminals have a constant voltage. In the voltage source inverter the main input supply is voltage. The VSI are used to control the output voltages. Also the shape of the ideal VSI output voltage waveform should be autonomous of the load connected to the inverter. DC to AC inverter generates an AC output waveform from a DC source. The VSI are used in various applications such as adjustable speed drives (ASD), uninterruptible power supplies (UPS), active filters, Flexible AC transmission systems (FACTS), voltage compensators, and photovoltaic generators.

Voltage source inverters are applied in three phase or single phase applications. The half-wave and full wave Single-phase VSIs are widely used for power supplies, single-phase UPSs, and intricate high-power topologies when used in multilevel arrangements. Whereas for the sinusoidal voltage waveforms, such as adjustable speed drives(ASDs), uninterruptible power supplies (UPS), and some types of Flexible AC transmission systems (FACTS) devices such as the STATCOM we use three-phase VSIs. Commonly voltage inverters are used in the applications where arbitrary voltages are required [5]

» Current Source Inverters

In current source inverters (CSI) the input is changeable current from the dc source of high impedance that is from a constant dc source so in the current source inverter the supply to the inverter is the current source. In case of the current source inverter we control the current output. We use CSI with transistor or thyristor switches. The polarity of input current does not change and the direction of flow of power is determined by the input voltage. The AC (alternating current) wave form with fixed magnitude is produced for a given input. An inductor is connected at the input side of CSIs to maintain the current [6]. The CSIs are used in many applications such as a very high power and high voltage AC motor drives. CSIs can be also applied in motion control systems.

SINGLE PHASE INVERTERS

The voltage source inverters (VSI) are classified on the basis of their construction and their output voltage and their level of implementation. There are three main types of the VSI on the basis of their output voltage as [5]:

1) Single-phase half-bridge inverter
2) Single-phase full-bridge inverter
3) Three phase voltage source inverter

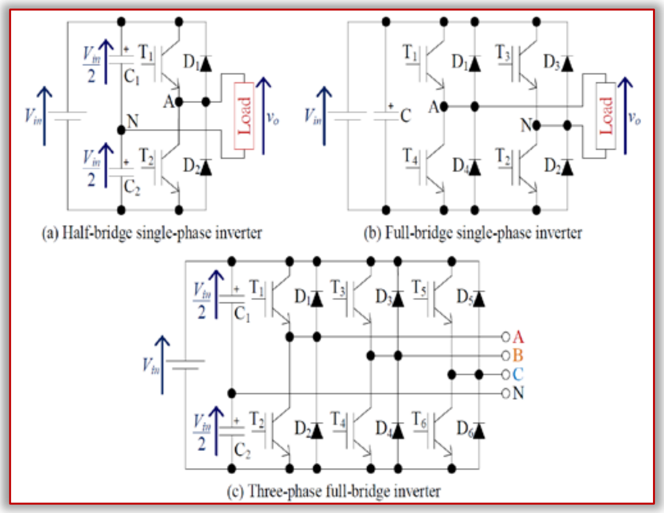

Figure 7. Circuit diagrams for power inverters

— **Single phase half bridge inverter**

For low power applications we use a Single-phase half-bridge. Fig.6 (a) shows the circuit diagram of a single-phase half-bridge inverter. This inverter consists of two switching devices, T1 and T2 and two diodes, D1 and D2. In this case, IGBTs (insulated gate bipolar transistors) are the switching devices. These two IGBTs and these two diodes build a one-leg or called a half-bridge. D1 and D2 are called anti-parallel diodes of T1 and T2, respectively. If the switching devices are MOSFETs, these diodes are built internally. The input capacitors, C1 and C2, share the input equally. Their voltage is the same and equal to Vin/2. The node between these two capacitors is the neutral point of the output of the inverter, N, and the node between two IGBTs is the live point of the output of the inverter, A. The T1 and T2 are switched ON and OFF alternatively in order operate this inverter. The duty of the gate signal of each IGBT in the ideal case is 0.5 which is the dead-time between each switching is applied to avoid short circuit in practice. The single phase half bridge inverter can be with purely resistive load and with resistive and inductive load. The idealized wave forms are shown below:

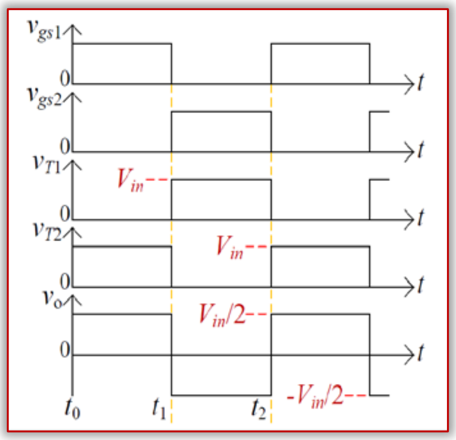

Figure 8. Idealized waveforms of a single-phase half bridge inverter with a purely resistive load

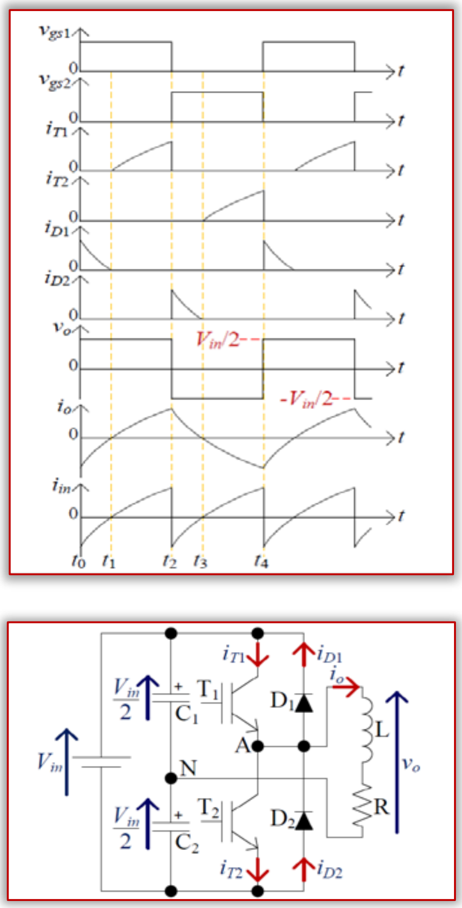

Figure 9 (a). Idealized waveforms of a single phased half bridge inverter with a resistive and inductive load (b) Circuit Diagram of a single-phase half bridge inverter with a resistive and inductive load

— **Single phase full bridge inverter**

When the connect parallel three single-phase half-bridge inverters operating with 120 degrees phase difference we make a single phase full bridge inverter. As a result, there are 3 legs built with six switching devices and six anti-parallel diodes.

This type of inverter is able to produce three-phase line voltages and phase voltages to the load. This converter is commonly operated with 180° and 120° conduction; i.e., 50% duty ratio and 33.33% duty ratio of the gate signals, respectively.

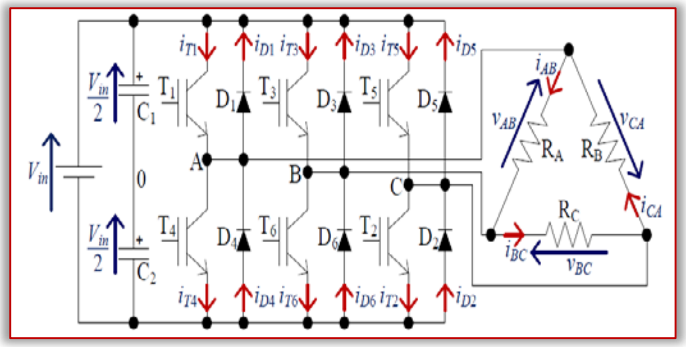

Figure 10. Circuit diagram of a three-phase full-bridge converter

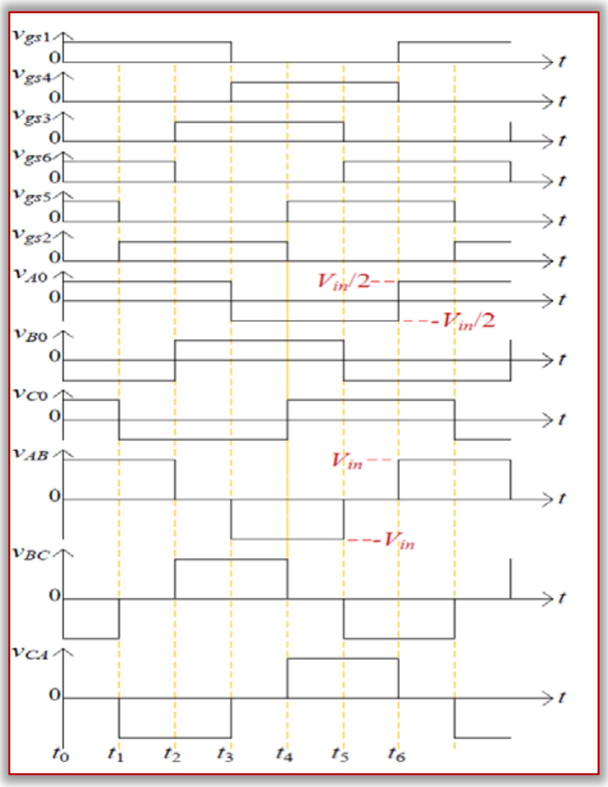

Figure 10. Idealized waveforms of a three-phase full-bridge inverter with a delta-connected resistive load for 180° conduction

The duty ratio of the gate signals of each switching devices are 50%. All the three resistors, RA, RB, and RC, are having the same resistance, R. The peak output line voltage of each phase of the inverter is Vin although the peak values of vA0, vB0, and vC0 are Vin/2. The on-state sequence is T1 & T2, T2 & T3, T3 & T4, T4 & T5, T5& T6, T6 & T1 so that each leg is like a single-phase half-bridge inverter operating with 120 degrees phase difference.

INVERTERS AS MAIN COMPONENTS OF GRID CONNECTED PV SYSTEMS

The components of grid connected systems include the PV array which converts the solar energy into DC power and an inverter which converts the DC power to AC power. The produced power can then be either used up by the load or transferred back to the utility grid. Hence array of solar panels and the inverters are considered as the building blocks of the grid connected system and their study and design is important for installation of any kind of grid connected system.

The performance of grid connected system is highly dependent upon the type of inverter used in solar power design. The inverter converts the dc current into ac for the use by the end user and the access current not required at the load flows back to the grid. When the current starts flowing from PV source to the grid the electric meter starts moving in backward direction and the phenomenon is known as "Net Metering".

The "Islanding" is a state in which part of the utility system taking care of both the loads and the distributed resources remains energized even after being cut off from the main utility.

Hence it is the major need according to the standards that grid connected inverters of solar power systems should always seize transfer of power into the grid under exact abnormal operating conditions of the grid including those leading to the islanding [7].

It is necessary for a solar power grid connected system to have inverters with an anti-islanding protection so that in case the grid fails it shuts down immediately. Also in case of fluctuations in frequency or voltage of grid power inverter must stop working. This helps the equipment to be safe from potentially damaging events from the grid or the solar grid ties system site. It is highly recommended to use an inverter with fault condition reset which turns the inverter on when grid is operating properly again or can sense and adjust voltages/frequencies appropriately. Latest grid connected inverters are available with all above features along with the internal battery backup, LCD display and maximum power point tracking (MPPT) software examine in real time the voltages and amperes.

The input values of voltages and currents have been increased along with the introduction of automatic morning wake-up and shut down in grid tied inverters. The automatic morning wake-up and shut down functions permits inverter to sleep, reducing its power requirements when there is least or no demand of power [8]

The major task of the inverter includes the control of the output voltage or current of the PV array to produce maximum power at a certain irradiance and temperature. This is called maximum power point tracking (MPPT). The grid tied systems using MPPT inverters are more stable and efficient. The grid tied inverter also controls the sinusoidal current that is transferred into the grid to have the same frequency as that of the grid and a phase shift with the voltage value between the acceptable limits is allowed at the point of connection. Currently, the research is going on to control the quality of injected power and the power factor at the grid interface [7].

The extra functions of grid tied inverter are to take into account voltage amplification in order to be matched with the voltage produced by the PV array and the grid voltage which reduces power losses.

— Inverter connection topologies of grid-connected PV system

Photovoltaic systems have various topologies based on the way PV modules are connected with power conditioning unit (PCU). Some of frequently used topologies are [9]

a. Centralized topology

In centralized topology, the centralized inverter is controlling the outputs from a huge number of different solar arrays connected to it. The high power photovoltaic systems where production is in MW can use this topology.

In such connections the cost is minimized and also the maintenance of system becomes easier. The disadvantage is the reliability, which is very low in this case as when a single inverter fails it shuts down the whole solar power system. As only one inverter is used therefore there is considerable power loss of mismatch between the modules and due to shading as tracking is done using MPPT. In effort to minimize these disadvantages and improve the reliability and performance of centralized topology a number of parallel inverters are connected to array so in case one inverter fails the other inverters can still operate and deliver power and prevents system to be shut down. This type of arrangement is called "Master –Slave" topology.

b. String topology

In string topology, single inverters are being connected to individual strings of modules separately. Therefore the combined output from number of strings is not controlled by just a single centralized inverter only. This helps to minimize the losses and increase the reliability of overall system as each string independently operate at its own maximum power point and thus overcoming the drop in power due to the shading issues.

By this kind of typology the mismatch losses are also reduced and there is always a room to add up more modules in a system and thus increasing its size any time according to the requirement. The power rating of each string can be up to 2-3KW. As we use more inverters in this topology so the cost is also increased. When string topology is combined with master slave concept we call such a combination as "team concept topology".

c. Multi string topology

This type of topology uses advantages of both previously discussed topologies to provide maximum power output. Multiple strings are connected together with their own dc-dc converters and then to a common dc-ac inverter. We can use dc-dc converters for maximum power point tracking which results in voltage amplification. The major disadvantage of using dc-dc converter is that it reduces the reliability and performance.

d. Modular topology

The modular topology is also famous as AC modules. In AC modules an inverter is embedded in each module and one large PV-Cell is connected to dc-ac inverter. The main requirement for grid connection is to have an inverter that can amplify very low voltages 0.5-1.0V and 100W per square meter up to the grid level along with acquiring higher efficiencies. The modular inverter or micro inverter topologies are used for intelligent PV system interface as shown in figure 11.

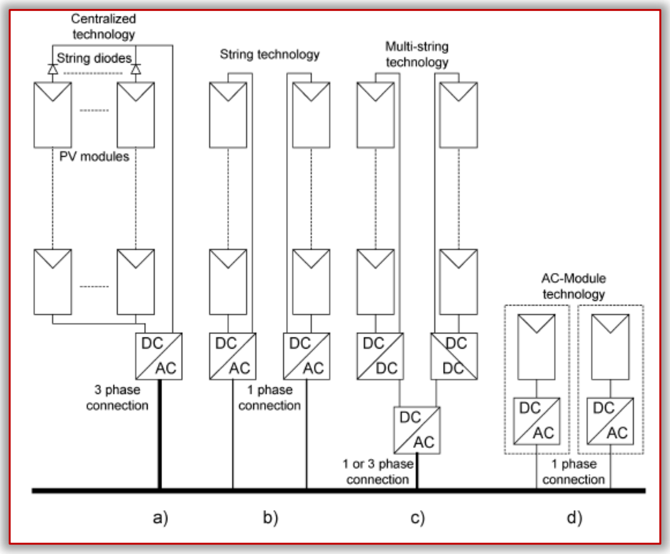

Figure 11. Connection Topologies
a) Centralized Topology b) String Topology c) Multi-String Topology d) AC-Module

— Categorization of grid connected inverters

The inverters whether single or three phased are categorized depending on the following basis:

» **Number of processing stages**

There are usually three kinds of stages in terms of processing. In the single stage all parameters such as maximum power point tracking, control of grid current, and voltage amplification all are handled by the inverter itself. In dual stage inverters we use additional DC/DC converter for MPPT. Pulse width modulation (PWM) is used to control the grid current and in third case, each module is independently connected to its own DC/DC converter and all are joined together to the same inverter which controls the grid current.

» **Use of decoupling capacitors**

In order to keep the capacitor as small as possible, electrolytic capacitor can be replaced by thin film capacitor. In case of three phase inverter the capacitor must be 10 times smaller [9].The capacitor determines the life of the inverter and it can be placed in parallel with the PV modules or in the DC link between the inverter stages.

» **Isolation between AC side and DC side**

It is very important to isolate the DC side of solar power system with the AC side of the Grid and that requirement is fulfilled by using isolated transformer installed at the output side of inverter. As transformer of a commercial frequency is required therefore that can increase the overall weight of the inverter. In order to reduce the weight of inverter, high frequency AC circuit is provided for inverter between the direct current and the commercial AC system. The transformer is then used at high frequency part of the circuit and to achieve the isolation between AC and DC sides.

Transformer less inverters can also be used and in that case no isolating transformer is required instead a circuit for detecting the DC component at AC circuit and ground detection circuit in DC circuit is required. According to [10] a utility connected inverter which has a very high performance current control scheme can be used effectively in order to improve the power quality in grid connected distribution systems when there is a lot of instability.

— Inverters to synchronize Grid Tied systems with the Utility

The gird connected inverters are used to integrate the photovoltaic power system with the main utility Grid by using the topologies and the codes for Grid Integration. The standard of power provided by the photovoltaic system for the on-site AC loads and for the power delivered to the utility is judged and governed by practices and quality standards on voltage, flicker, frequency, harmonics and power factor as per recommended by ANSI/IEEE Std 519-1981

As these inverters are useful because they can convert ac to dc and dc to ac so this characteristic also changes the sinusoidal nature of the ac power current (and consequently the ac voltage drop), resulting in the flow of harmonic currents in the ac power system that can cause interference with communication circuits and other equipments. Therefore when reactive power compensation is used with converters, resonance conditions can cause high harmonic voltages and currents when they occur at a harmonic associated with the converter [11]. Hence it is very important to have minimum harmonics and same sinusoidal waveforms in the dc side of the inverters connected with the solar power system and the ac grid side connected with the utility.

In this paper we are discussing the use of inverters in solar power system as a power device.

THE PULSE WIDTH MODULATION INVERTERS

As discussed earlier the sinusoidal waveform at the inverter side should match the waveform at the output side therefore the voltage to frequency ratio at the inverter output terminals must be kept constant. This avoids saturation in the magnetic circuit of the device fed by the inverter.

The various methods for the control of output voltage of inverters can be classified as:

(a) External control of ac output voltage
(b) External control of dc input voltage
(c) Internal control of the inverter.

In the above mentioned methods the first two methods require the use of some external components however the third method requires no external components and we can use the pulse width modulation for the internal control of the inverter.

— Principles of PWM

The pulse width modulation signals are pulse trains with static frequency and scale but with variable pulse width. There is one pulse of fixed magnitude in every PWM period. According to the same modulation signal the width of pulses changes depending on the requirements. When PWM is applied to the gate of transistor. The change in PWM period results in ON and OFF states of the transistors. It is to be noted that the frequency of a PWM signal must be much higher than that of the modulating signal, the fundamental frequency. The energy supplied to the load is mostly depend on the modulating signal.

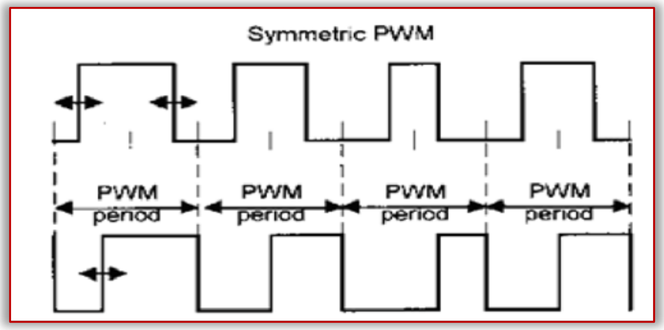

Figure 12. Symmetric and Asymmetric PWM Signals

There are basically two types of PWM signals, symmetric and asymmetric. The pulses of a symmetric PWM signal are always symmetric with respect to the center of each PWM period. The pulses of an asymmetric PWM signal always have the same side associated with one end of each PWM period. Mostly symmetric PWM signals are considered as they result in less harmonics in the output voltages and currents.

— PWM techniques

The most common method of controlling the output voltage from the inverter is termed as Pulse-Width Modulation (PWM) Control. The benefits possessed by PWM techniques include lower power dissipation, easy to implement and control, no temperature variation and aging-caused drifting or degradation in linearity, Also the output voltage control can be obtained without any additional components and with this method, lower order harmonics can be eliminated or minimized along with its output voltage control. The main drawback of this method is that silicon controlled rectifiers (SCRs) most commonly known as thyristors are expensive as they must possess low turn-on and turn-off times. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is however modulated to obtain output voltage control and to reduce its harmonic content. The modulation techniques can be classified into two types mainly carrier based modulation and carrier less modulation. The main purpose of designing these techniques is to control the PWM inverter switches so we can get the AC voltage or current very close to the sine wave form. We can say that by switching ON and OFF the dc supply at regular intervals is considered as the basic method to convert a fixed DC voltage to an AC voltage that is in pure sine wave form. We use PWM in order to achieve this. The quality of these, PWM techniques, depends on the amplitude of the fundamental component, the harmonic content in the inverter output, the effect of harmonics on the source, the switching losses, controllability and implementation.

According to [12] and [13], the main basic idea of the PWM technique is to compare a carrier signal usually a triangular signal with frequency fs with the a reference signal which is a low frequency signal known as modulating signal with frequency fm. The frequency of the reference-modulating signal fm is set the desired output frequency. In Sinusoidal Pulse width modulation technique for getting the pulses, it is required to compare sine wave with triangular wave and in similar way Trapezoidal modulation is a technique to advance the control ability by using computation of PWM patterns. The output frequency of the converter is decided with the frequency of the modulating wave. Space vector PWM (SVPWM) is a digital modulating technique because its control strategies are implemented in digital systems. The purpose of this technique is to produce PWM load line voltages which are in average equal to given (or reference) load line voltages.

Inverter with PWM is three stage separate push pull driver, which produces phase waveform independently. SVPWM inverter is used to offer 15% increase in the utilization of dc-link voltage and output which have low harmonic distortions in comparison to conventional sinusoidal PWM inverter. In SVPWM inverter is considered as single unit; specifically, the inverter can be driven to eight unique stages.

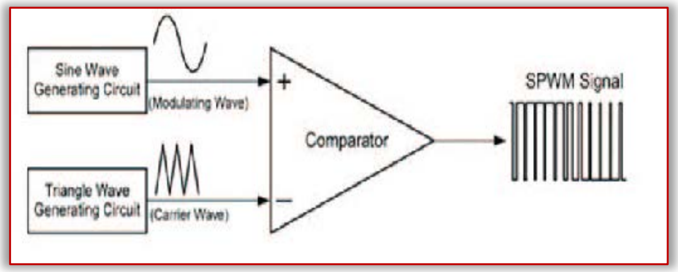

Figure 13. PWM using comparator

In order to get pure sine wave AC output voltage the multi-level PWM technique was developed and is classified as 1) 3-level PWM 2) 5-Level PWM 3) 7 level PWM 4) 9 level PWM and so on. The comparison of different PWM techniques is in following table 1.

Table 1. Comparison of different PWM techniques

No.	PWM Techniques	THD	Complexity	Efficiency
1.	PWM	High	Simple	Low
2.	SPWM	Moderare	Simple	Moderate
3.	SVPWM	Low	Complex	High
4.	Phase Disposition PWM	Moderate	Moderate	Low
5.	Simple Boost Control	Low	Complex	High
6.	Phase shifted PWM	Low	Complex	Very High

PWM Converter in Simulink

The below figure shows how the PWM controller is used to generate the high voltage PWM wave form.

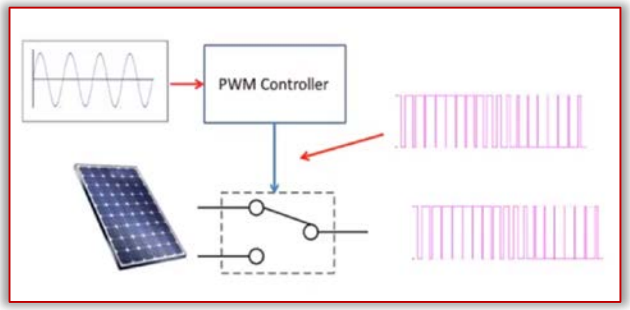

Figure 14. Generation of High Voltage PWM waveform in Solar Power System

The sine wave enters the PWM controller and a square wave signal form is generated. This signal waveform then by using the input signal waveform from the solar power panel is converted to high voltage PWM waveform using a single pole double throw (SPDT) switch. All we can vary is the time of the Switch resulting in Pulse Width Modulation.

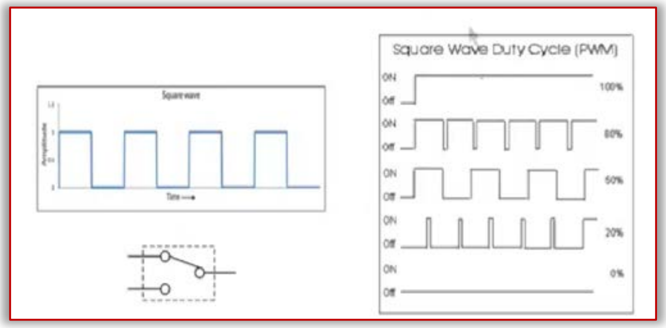

Figure 15. Square wave duty cycle and waveforms

The PWM square wave form obtained above is then passed through the LC filter in order to filter out the harmonics and generate a sine wave. It is seen that average value of the PWM is propositional to the sine wave.

The following figure shows the PWM converter in Simulink Matlab:

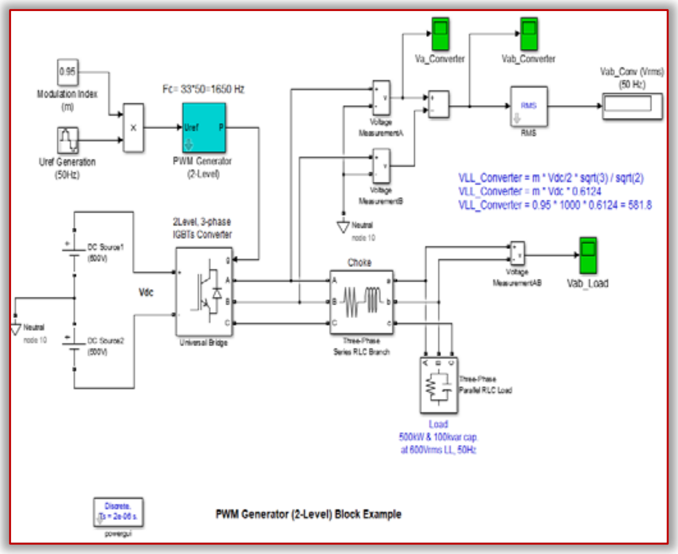

Figure 16. PWM converter in Simulink Matlab

The basic principle as discussed above is that we need a sine wave which is a reference signal at fundamental frequency(which is the frequency required at the output) and then we have a carrier wave which is at higher frequency (usually a sawtooth wave) and then reference is compared with Carrier wave. When Reference wave is greater than carrier wave, output will be high and when reference wave is less than the carrier wave the output will be low. The modulation of pulse is show below:

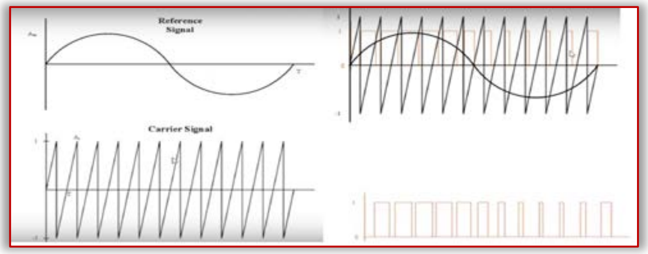

Figure 17. Generation of PWM

When we run the PWM inverter in simulink we get the following outputs for the Inverter.

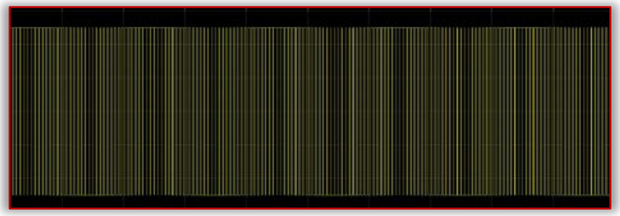

Figure 18. Inverter output

Figure 19. Inverter output after passing through Filter

The above outputs show that when modulated signal from the inverter is passed through the RLC filter, we get pure sine wave at the load side of the inverter.

Also in [14], the simulations in Matlab are done to check experimentally the power quality of an off-grid inverter and power quality of the utility network in the UK are discussed and it is observed that the power quality of off-grid system is better than that of the utility network.

CONCLUSION

In this article the inverters as integrators of the solar power system with the utility grids are discussed beside their use as DC to AC converters for the use in Off-grid solar power applications. In detail overview on PWM techniques and the inverters is also provided. The simulation has been done using PWM Generator (2 level block) in Matlab in order to see the output signal waveform at the inverter's output side with and without RLC filter. It can be seen that the output is pure sine wave (AC) after passing through RLC filer.

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