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Analysis Of Conversion Of Solar Power To Three Phase AC Power : A Review

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Abstract
This paper presents the conversion of the solar energy from the sun directly to DC electric potential by a Photo-voltaic (PV) cells arrangement. It consists of a voltage source inverter (VSI) and a boost converter (BC) in DC link to cover the whole voltage range of PV array. This DC is converted into Three phase AC with the help of Three phase Inverter. This paper presents the Simulink model for 3 phase inverter . The three-phase square wave inverter can be used to generate balanced three-phase ac voltages of desired (fundamental) frequency.
Keywords-Photovoltaic cell; boost converter; Inverter.

I. Introduction

During the last years many topologies of solar inverters have been proposed. In general, they can be classified into topologies with and without a transformer. The advantages of the transformerless topologies are higher efficiency and less volume which are the reasons to select these topologies for the marked. However, the lack of the transformer also leads to some drawbacks: The main problems are the leakage currents between the solar panel and earth. These leakage currents are a risk for humans touching the panel. Another point is that for many solar systems the output voltage of the solar array is smaller than the required DC link voltage.[1] The voltage can easily be boosted by a transformer .

In case of a transformerless topology the voltage has typically to be boosted by a DC-DC converter. Because of the leakage current at the PV arrays, typically three single phase converters are connected in parallel to achieve the three phase grid connection. In case that a three phase topology is applied, it is essential for low leakage current to connect the midpoint of the DC link to neutral (earth). Typically, the neutral point clamped (NPC) and the voltage source inverter with split capacitors and earthed midpoint are used . In this paper the three phase four wire topology is proposed and analyzed. The fourth wire that connects the midpoint of the DC-link to neutral leads to three independent phases inverter and step response. [2] System Description The Variable Output Voltage Of The Pv Array Is Fed To The Grid By The Inverter Topology. It Consists Of A voltage source inverter (VSI) and a boost converter (BC) in the DC link to cover the whole voltage range of the solar array. The MPP tracking is realized by both the BC for low and by the VSI for high input voltages. The connection to the grid is realized via an LCL filter. Special about this topology is the fourth wire which connects the midpoint of the split DC capacitors with the neutral phase of the grid. The advantage of the fourth wire is a great reduction of the leakage current at the PV array that arises due to the variation of the dc link potential to ground generated by the switching pattern. Assuming that the grid is y-connected the midpoint of the DC link has four different potentials to ground during one switching period. During one of the two zero-states all three phases of the grid are short circuited by having all upper devices conducting and the lower ones blocking or vice versa. In this state the upper or lower rail of the DC link is connected to ground so that the midpoint of the DC link is at $\pm VDC/2$. During the active states one device of each phase is conducting whereas at least one of them is in the upper half and one is in the lower half. In case that two upper devices and one lower device are conducting two phases are switched in parallel and connected to the upper DC link rail. Thus the voltage drop across the upper DC link rail of the load is only half of the voltage drop of the phase that is connected to the lower DC link rail. That leads to a midpoint voltage of the dc link to ground of −VDC 6 and to VDC 6 in case that two devices in the lower half are conducting. The reduction of the leakage current by connecting ground and the midpoint of DC link is given by the factor of CPV 2 CDC. However the fourth wire also leads to two drawbacks. The first is that the DC link voltage has to be 2 /√3 higher than for the system without the fourth wire to deliver the same grid voltage. The second issue is that the widely used current control strategy in rotating dq-reference frame is not feasible since the three phases are independent. In the next section three suitable current control strategies are proposed and compared concerning their influence on the efficiency, the harmonic distortion and leakage current at the PV array to each other. [1, 2, 3]

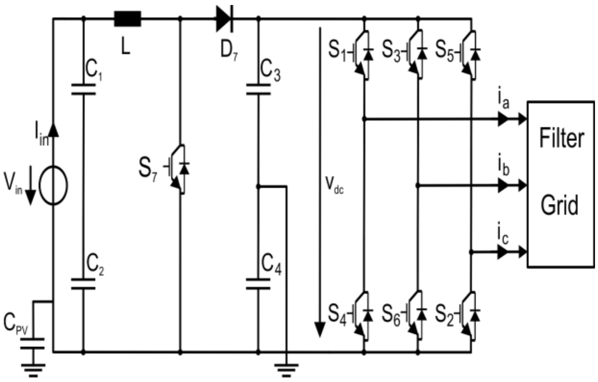


Fig. 1: Solar inverter with earthed dc link midpoint

II. Generation Of Dc By Solar Energy

The **theory of solar cells** explains the physical processes by which light is converted into electrical current when striking a suitable semiconductor device. The theoretical studies are of practical use because they predict the fundamental limits of , and give guidance on the phenomena that contribute to losses and solar cell efficiency.[1]

- Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
- Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.
- An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

Photo-generation of charge carriers

When a photon hits a piece of silicon, one of three things can happen:

- the photon can pass straight through the silicon — this (generally) happens for lower energy photons,
- the photon can reflect off the surface,
- the photon can be absorbed by the silicon, if the photon energy is higher than the silicon band gap value. This generates an electron-hole pair and sometimes heat, depending on the band structure.

When a photon is absorbed, its energy is given to an electron in the crystal lattice. Usually this electron is in the valence band, and is tightly bound in covalent bonds between neighboring atoms, and hence unable to move far. The energy given to it by the photon "excites" it into the conduction band, where it is free to move around within the semiconductor. The covalent bond that the electron was previously a part of now has one fewer electron — this is known as a hole. The presence of a missing covalent bond allows the bonded electrons of neighboring atoms to move into the "hole," leaving another hole behind, and in this way a hole can move through the lattice. Thus, it can be said that photons absorbed in the semiconductor create mobile electron-hole pairs.[1]

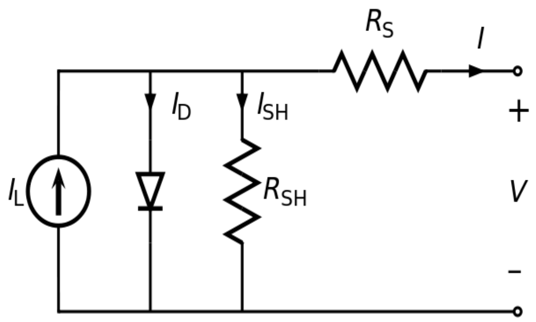


Fig. 2: **Equivalent circuit of a solar cell**

III. Three Phase Power Inverter

An **inverter** is an electronic device or circuitry that changes direct current (DC) to alternating current (AC).The input voltage, output voltage and frequency, and overall power handling, are dependent on the design of the specific device or circuitry.

A **three phase** inverter can be entirely electronic or may be a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry. **Static**

inverters do not use moving parts in the conversion process. Three-phase electric power "-phase inverters are used for variable-frequency drive applications and for high power applications such as HVDC power transmission. A basic three-phase inverter consists of three single-phase inverter switches each connected to one of the three load terminals. For the most basic control scheme, the operation of the three switches is coordinated so that one switch operates at each 60 degree point of the fundamental output waveform. This creates a line-to-line output waveform that has six steps. The six-step waveform has a zero-voltage step between the positive and negative sections of the square-wave such that the harmonics that are multiples of three are eliminated as described above. When carrier-based PWM techniques are applied to six-step waveforms, the basic overall shape, or *envelope*, of the waveform is retained so that the 3rd harmonic and its multiples are cancelled.

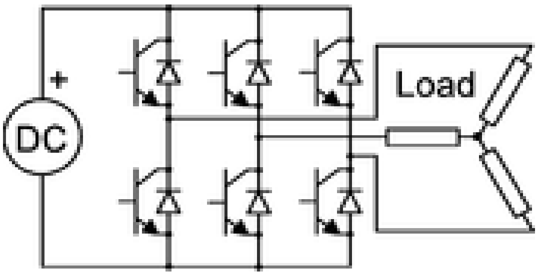
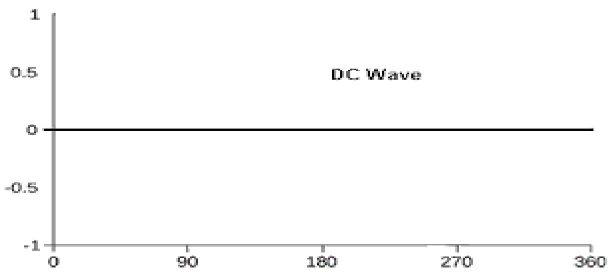


Fig. 3: 3-phase inverter with Y- connected load.

Typical applications for 3 phase inverters include:

- Portable consumer devices that allow the user to connect a battery, or set of batteries, to the device to produce AC power to run various electrical items such as lights, televisions, kitchen appliances, and power tools.
- Use in power generation systems such as electric utility companies or solar generating systems to convert DC power to AC power.
- Use within any larger electronic system where an engineering need exists for deriving an AC source from a DC source.[3,4,5]



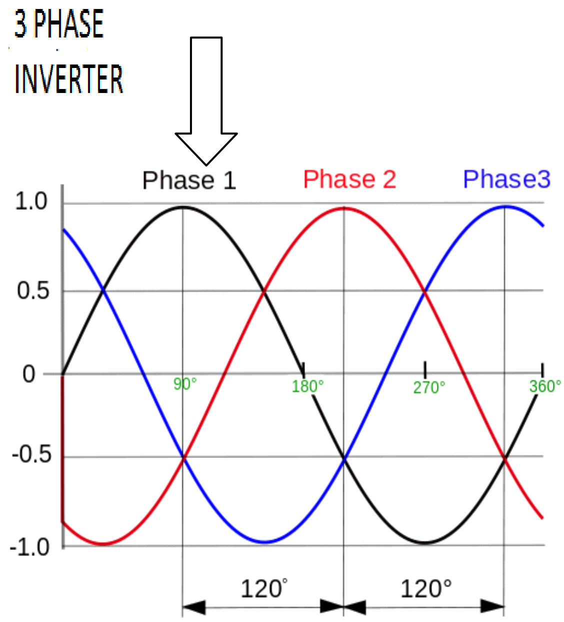


Fig. 4: Schematic output waveform of 3 phases inverter from DC source.

IV. Input And Output

a) Input voltage

A typical power inverter device or circuit will require a relatively stable **DC power source** capable of supplying enough current for the intended overall power handling of the inverter. Possible DC power sources include: rechargeable batteries, DC power supplies operating off of the power company line, and solar cells. The inverter does not produce any power, the power is provided by the DC source. The inverter translates the form of the power from direct current to an alternating current waveform.

The level of the needed input voltage depends entirely on the design and purpose of the inverter. In many smaller consumer and commercial inverters a 12V DC input is popular because of the wide availability of powerful rechargeable 12V lead acid batteries which can be used as the DC power source.

b) Output waveform

An inverter can produce modified sine wave depending on circuit design. The output waveform is shown in fig.5 There are two basic designs for producing household plug-in voltage from a lower-voltage DC source, the first of which uses a switching boost converter to produce a higher-voltage DC and then converts to AC. The second method converts DC to AC at battery level and uses a line-frequency transformer to create the output voltage.

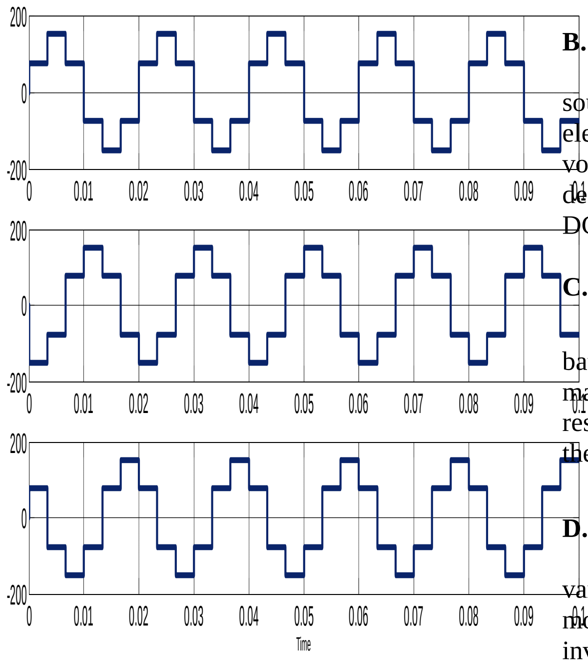


Fig. 5: Output waveform of three phase inverter

c) **Output voltage**

The AC output voltage of a power inverter device is often the same as the standard power line voltage, such as household 120VAC or 240VAC. This allows the inverter to power numerous types of equipment designed to operate off the standard line power.

The designed for output voltage is often provided as a regulated output. That is, changes in the load the inverter is driving will not result in output voltage change from the inverter.

In a sophisticated inverter, the output voltage may be selectable or even continuously variable.

d) **Output power**

A power inverter will often have an overall power rating expressed in watts or kilowatts. This describes the power that will be available to the device the inverter is driving and, indirectly, the power that will be needed from the DC source. Smaller popular consumer and commercial devices designed to mimic line power typically range from 150 to 3000 watts.Not all inverter applications are primarily concerned with brute power delivery, in some cases the frequency and or waveform properties are used by the follow on circuit or device.

V. APPLICATIONS

B. DC power source utilization

An inverter converts the DC electricity from sources such as batteries or fuel cells to AC electricity. The electricity can be at any required voltage; in particular it can operate AC equipment designed for mains operation, or rectified to produce DC at any desired voltage.

C. Uninterruptible power supplies (UPS)

A uninterruptible power supply (UPS) uses batteries and an inverter to supply AC power when main power is not available. When main power is restored, a rectifier supplies DC power to recharge the batteries.

D. Electric motor speed control

Inverter circuits designed to produce a variable output voltage range are often used within motor speed controllers. The DC power for the inverter section can be derived from a normal AC wall outlet or some other source. Control and feedback circuitry is used to adjust the final output of the inverter section which will ultimately determine the speed of the motor operating under its mechanical load. Motor speed control needs are numerous and include things like: industrial motor driven equipment, electric vehicles, rail transport systems, and power tools.

E. Power grid

Grid-tied inverters are designed to feed into the electric power distribution system. They transfer synchronously with the line and have as little harmonic content as possible. They also need a means of detecting the presence of utility power for safety reasons, so as not to continue to dangerously feed power to the grid during a power outage.

F. Solar power

A solar inverter can be fed into a commercial electrical grid or used by an off-grid electrical network. Solar inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection. Micro-inverters convert direct current from individual solar panels into alternating current for the electric grid. They are grid tie designs by default.

G. Induction heating

Inverters convert low frequency main AC power to higher frequency for use in induction heating. To do this, AC power is first rectified to provide DC power. The inverter then changes the DC power to high frequency AC power.

H. HVDC power transmission

With HVDC power transmission, AC power is rectified and high voltage DC power is transmitted to another location. At the receiving location, an inverter in a static inverter plant converts the power back to AC. The inverter must be synchronized with grid frequency and phase and minimize harmonic generation.

VI. CONCLUSION

As we know that our non-renewable sources of energy are going to decrease day by day, so we have to move a step ahead for future aspects by using solar energy. From the above description, we can conclude that how the DC power generated through solar energy can be converted into three phase AC power with help of Three phase inverter (Power Inverter). It can be explained with the help of Matlab simulated output waveform.

Acknowledgment

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