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Analysis and Observation of Grid Connected Single Phase Inverter Integration

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Abstract

This paper summarized the behavior of the inverter as we know the Photovoltaic (PV) has several advantages such as less harmless to the environment. Furthermore, grid-connected PV energy generation represents a renewable energy growing alternative that is becoming more competitive due to the new favorable governmental laws and policies as recently introduced. In this regard, PV systems that supply power directly to the grid are becoming more popular because of the cost reduction due to the lack of a battery subsystem. The main components of a grid-connected PV (GPV) system include a series-parallel connection arrangement of the available PV panels and a power conditioning system in charge to extract and properly transfer the maximum available power present at the PV generator to the grid. A GPV system based on a single central inverter is one of the most prevailing configurations since, under uniform irradiance conditions of the PV panels; it represents a good trade-off between the extracted energy and the design complexity of the power inverter. In this configuration all of the available PV panels are connected to a single power stage. One of the most typical central inverter power converter topology is the single-phase single-stage full-bridge inverter.

Keywords: Photovoltaic (PV), inverter, panels, grid-connected PV (GPV).

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تحليل ومراقبة عمل العاكس احادي الطور المتصل بالشبكة

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الملخص

لخصت هذه الورقة سلوك العاكس وعمله وكما نعلم أن الخلايا الكهروضوئية (PV) لها العديد من المزايا فهي اقل ضرراً على البيئة وذات صفر انبعاثات ملوثة واستدامتها حيث يمثل توليد الطاقة الكهروضوئية المتصلة بالشبكة بديلاً متناميًا للطاقة المتجددة والذي أصبح أكثر تنافسية في اغلب الدول. حيث أصبحت الأنظمة الكهروضوئية التي توفر الطاقة مباشرة للشبكة أكثر شعبية بسبب انخفاض التكلفة عدم وجود نظام فرعي للبطارية. تشتمل المكونات الرئيسية للنظام الكهروضوئي المتصل بالشبكة (GPV) على ترتيب اتصال متوازي متسلسل للألواح الكهروضوئية المتاحة ونظام تحويل وتحكم في الطاقة المتاحة من الخلايا الكهروضوئية اذ يعد نظام GPV المعتمد على عاكس مركزي واحد أحد أكثر التكوينات السائدة والمتميزة في تحويل الطاقة. في هذا التصميم، يتم توصيل جميع الألواح الكهروضوئية المتوفرة بعاكس طاقة واحدة. محول الطاقة العاكس المركزي الأكثر شيوعًا هي العاكس ذو الجسر الكامل أحادي الطور.

الكلمات المفتاحية: الخلايا الكهروضوئية – العاكس – الالواح الشمسية – الخلايا الكهروضوئية المتصلة بالشبكة

I. Introduction

Actuality the majority of contributor to greenhouse emissions on the earth are power generation and transportation. The permanent usage of conventional power plants has confirmed to be unsuitable for the environment. The extreme use of fossil fuels has resulted in decrease of its reserves. The increase of demand from power has

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led to the exhaustion of non-replenish able conventional resources. It is critical to decrease these emissions through incorporate renewable sources as they lead to a less polluted [1]. The increase of using renewable energy sources (RES) is also due to growth in electricity grids with rising load demand. The different types of RES include hydropower; wind, wave/tidal and solar energy make the electricity mare and clean [2].

The regular recommend for development in our standard of living has improved the utilization of electrical energy by increase the usages of renewable energy [3]. This rise in energy utilization, demanding of traditional fuels and humiliating global environment has make the creation of the green power generation systems.

In recent times, the focus has shifted to the increase of the small and average level of power plants integrating renewable energy sources in the meadow of power distribution. It is recognized as Distributed Generation (DG) plant [4]. Power electronic converters are accountable for aligning the RES based plant with the distribution grid. [5].

The inverter connects the PV panel to the utility grid as a potential element. The main issue associated with the global receipt of the PV panels on a great scale has been its cost. [6].

II. Photovoltaic (PV) Systems

The developments in the power and digital electronics market lead to the incredible development in small level distributed generation systems integrating wind, hydro and solar energy. The cause behind unparalleled attention gained by PV systems is its attendance in abundance and the existence of global concern about the extinction of fossil fuels with the growing demand. Furthermore, the cost was difficulty but now the PV modules are inexpensive and comprise of a power electronic converter for ac grid interfacing distributed generation (DG) systems. It is clear that the solar power is the most abundant energy. Fascinatingly, solar energy is become to 15,000 times of annual energy utilization of the earth. PV equipment could be a promising renewable energy for the future electric demand with the lessening in cost [7]. As shown in the figure (1).

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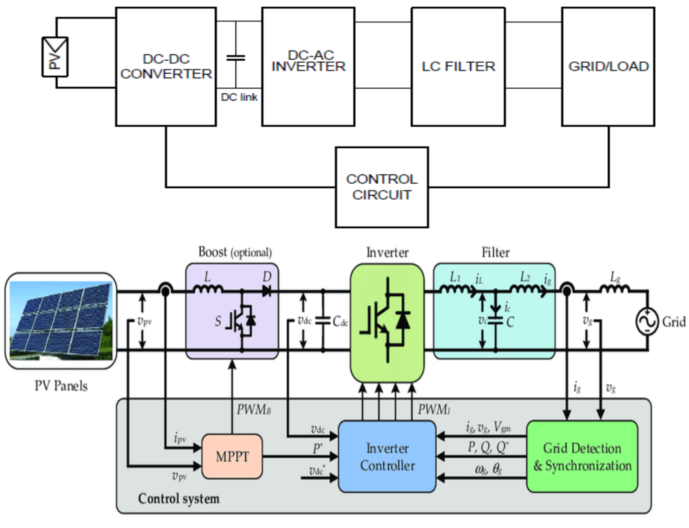


Figure 1. Energy flow process from source to main load (grid)

a- Grid-Connected (GC) PV Systems

Grid-connected PV systems are usually single-phase roof top systems with a power array of up to 10 kW [6]. Grid-interfaced PV systems are ideal over outside systems as former are cost-effective, needs low protection and do not need batteries for storage. It is measured to use PV power in a professional way and surrender more energy. The essential ingredient in the grid-tied PV System is power electronics based DC/AC inverter. It is mostly confidential into string inverter, centralized inverter, and micro inverter or AC-module inverter [8].

It could be grouped based on purpose, power rating, and system configuration. The micro inverter interfacing PV modules have to guarantee that the modules are operated at Maximum Power Point (MPP) and sinusoidal current must be injected into the grid. [9].

b- Stand-alone Photovoltaic (PV) Systems

The off-grid solar system is not connected to the grid and operates in self-sustained mode. It consists of PV modules, which are used to charge the batteries. These rechargeable batteries as storage devices and deliver stored power to electrical loads. It also covers a charge controller as a control component and a DC/AC converter for AC loads [10]. It can be used for applications such as cabins in distant areas where the grid is not near, recreational vehicles, solar-powered water pumps, emergency phones and many more. As per given estimation by the International Energy Agency (IEA), the surplus population of 1.7 billion added to urban areas would increase the global demand by more than a quarter by 2040 [11].

III. Types of Grid-Connected PV Inverter

The inverter is the most essential element for converting the DC electricity created by solar panels into AC electricity for housing purposes or to the grid. Approximately the mid-1970s, grid-connected PV inverter was introduce, they are m label as centralized, string and micro inverter. The micro inverters are low power evaluation where from 150 to 400W. They are assigned to character PV module of the system. The central inverter has a life span of ten years and it has replacement cost almost twice that of PV micro inverter. The multi-central inverter might be comprehended as a parallel connection of output from many middle inverters. [12]- [13].

The inverter interfacing AC grid and PV panel must have the following characteristics:

- The dynamic response should be fast.
- Unity factor close to unity.
- Output should have fewer harmonics.

a- Central Inverter

This inverter has a design of a series connection of PV panels to form a string of PV panels in order to raise the voltage evaluation of the inverter. These PV strings are then connected in parallel distribution the same voltage to increase the power stage as shown in Figure 2 part (a). By end of the 1980s, they grow to be famous and different development incorporating it began [9]. Afterward, it changed to switch mode inverters due to access to the high-frequency switching devices. Even though this design provides common MPPT for PV array, it is generally considered for huge level power generation. Although its advantages such as low initial capital, high efficiency, it has some loopholes like more noise, bigger in size and a fault at any single point is sufficient for entire unit failure [14].

b- String Inverter

A string inverter is a balanced down topology of the central inverter. It is most usually used an inverter for the grid-tied PV system. Since it has a configuration of a number of PV modules connected in as shown in Figure 2 part (c), it provides more precise MPPT [15]. They are appropriate for medium scale (up to 5 kW) PV power generation systems. It would lead to lower part shading or clouding result. Therefore, string inverter supply higher efficiency by delivering higher power to the utility grid and is considered superior to the centralized inverter. Still, it has some shortcomings as if the shading in one of the modules would hamper the entire operation of that PV string.

An extension of this topology is multi-string inverter as shown in Figure 2 part (d).

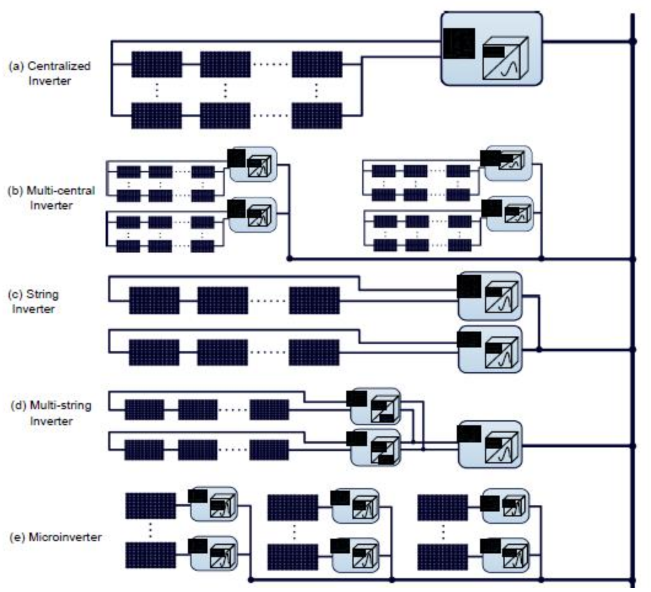
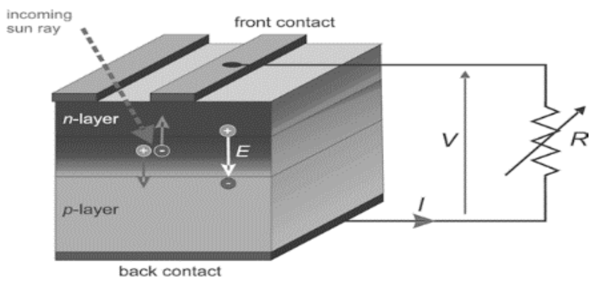


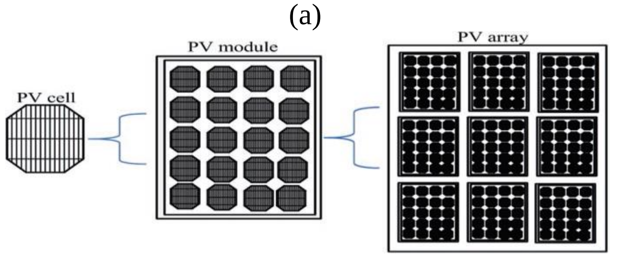
Figure. 2 Grid-connected PV technologies

IV. Photovoltaic (PV) Conversion Systems

With no pollution or green house gas emission, a PV conversion system adapted the sunlight directly into electricity. The basic element of a PV conversion system is the PV cell. The PV cell is essentially made up of a semiconductor material (P-N junction) that able to generate the electric current when being exposed to the sunlight irradiation. Figure 4(a) is illustrates the photocurrent generation principle of the PV cell. These PV modules can be group din series and/ or parallel to forma PV arrays depicted in (b). The PV modules are connected in parallel to increase the output current and connected in series to provide a greater output voltage [15].



(a)



(b)

Figure 4. (a) Photocurrent generation principle of the PV cell
(b): PV cell, PV module, and PV array

a- The Main Components of Stand-Alone PV Systems

The block diagram of a stand-alone PV system is apparent in Figure (5).The essential element of a stand-alone PV system is the PV array, which converts the solar energy directly in to the electric energy. Then, the DC/DC boost converter is employed to step up

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the output voltage from PV array to be compatible with the electrical loads. Moreover, the MPPT technique is implemented on the boost converter to extra at the maximum power from the PV system during variation of the solar irradiance. In the following, the basic elements that employed in stand-alone PV systems are discussed in detail [15].

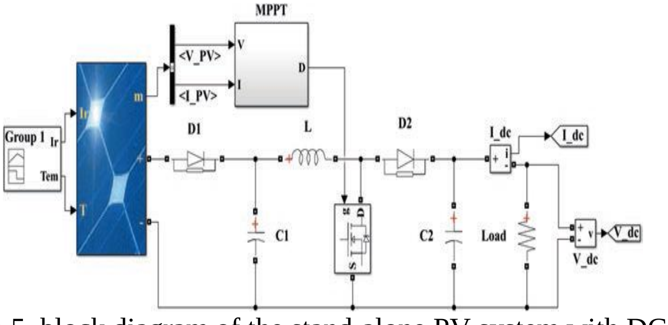

Figure 5. block diagram of the stand-alone PV system with DC/DC converter from Matlab software

b- The Equivalent Circuit of the PV Model

The basic element of the PV conversion system is the PV cell, which is a just simple P-N junction. The equivalent circuit of the PV cell based on the well-known single-diode model is shown in Figure (6). It includes the current source (photocurrent), a diode (D), and series resistance (Rs) that describes the internal resistance to flow of current and parallel resistance (Rsh) that represents the leakage current. The current-voltage (I-V) characteristics of the PV cell can be expressed as follows [11]:

$$I = I_{ph} - I_s\left\{exp\left[\frac{q(V+IR_s)}{A.K.T}\right]-1\right\} - \left(\frac{V+IR_s}{R_{sh}}\right) \qquad (1)$$

The light-generated current (Iph) mainly depends on the solar irradiance and working temperature of PV cell, which is expressed as follows:

$$I_{ph} = \left[I_{sc} + K_i\left(T - T_{ref}\right)\right].\left(\frac{G}{1000}\right) \qquad (2)$$

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The PV saturation current (Is) varies as a cubic function of the PV cell temperature (T), and it can be described as follows:

$$I_s = I_{rs}\left(\frac{T}{T_{ref}}\right)^3 exp\left[\frac{q.E_g}{K.A}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right] \quad (3)$$

The reverse saturation current (Irs) can be approximately obtained as follows:

$$I_{rs} = \frac{I_{sc}}{\left[exp\left(\frac{qV_{oc}}{N_{scr}.K.A.T}\right) - 1\right]} \quad (4)$$

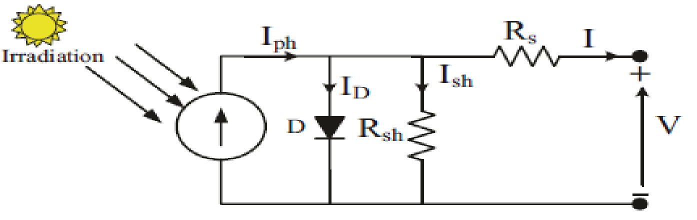

Figure 6. Equivalent circuit of the PV cell

V. Single-Phase DC/AC Inverter

Inverters are circuits that convert DC to AC. More precisely, inverters transfer power from a DC source to an AC load. The controlled full-wave bridge converters can function as inverters in some instances, but an AC source must preexist in those cases. In other applications as show in figure (7).

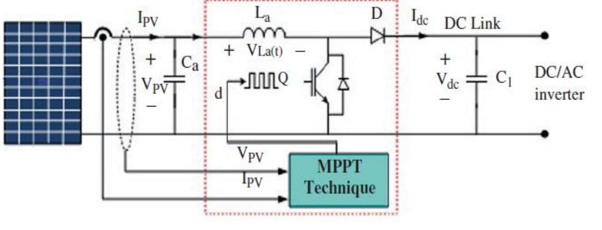

Figure 7. The PV array with the DC/DC boost converter

The single-phase inverters that create an AC output from a DC input. Inverters are used in applications such as adjustable-speed

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AC motor drives, uninterruptible power supplies, PV systems. Inverters are power electronic devices used in various PV system configurations [16].

- Grid-connected systems
- Stand-alone systems with rechargeable batteries
- Pumping systems without storage batteries

The full-bridge converter of Figure (8.a) is the basic circuit used to convert DC to AC. In this circuit, an AC output is synthesized from a DC input by closing and opening these witches in an appropriate sequence. The output voltage VO can be+Vdc,−Vdc, or zero, depending on which switches are closed. Figure (8.b-e) shows the equivalent circuits for switch combinations. Note that S1 and S4 should not be closed at the same time or should S2 and S3. Otherwise, as short-circuit would exist across the DC source. Real switches do not turn on or off instantaneously. Therefore, switching transition times must be accommodated in the control of the switches. Overlap of switch "on" times will result in a short circuit, sometimes called shoot-through fault, across the DC voltage source. The time allowed for switching is called blanking time [13]

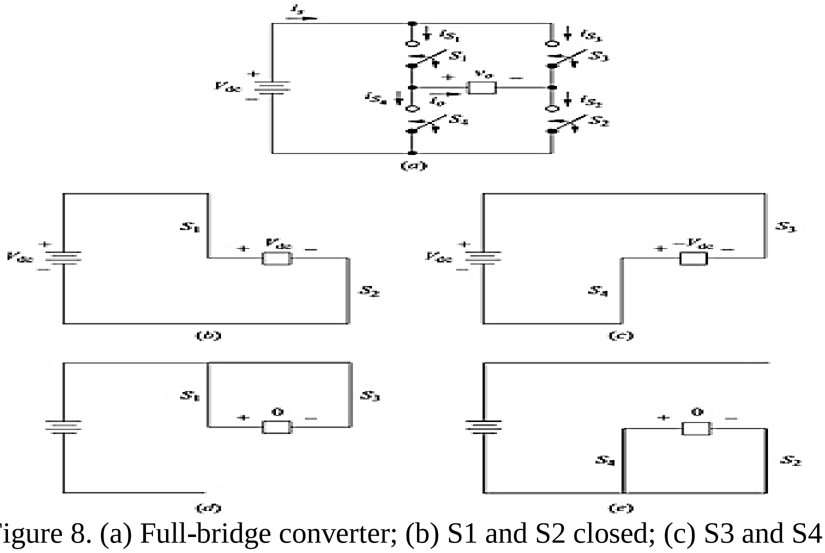

Figure 8. (a) Full-bridge converter; (b) S1 and S2 closed; (c) S3 and S4 closed; (d) S1 and S3 closed; (e) S2 and S4 closed

a- Filter Design

The improvement of renewable energy technologies has been increase speed, creation the simultaneous growth of power conversion devices for applications, such as wind and PV systems, very important the improvement of these technologies is actively happening. The harmonics caused by the switching of the power conversion devices are the main factor-causing problems to sensitive equipment or the connected loads, especially for applications above several kilowatts, where the price of filters and total harmonics distortion (THD) is also an important consideration in the systems design phase [17]. The inductance of the input or out-put circuits of the power conversion devices has conventionally been used to reduce these harmonics. However, as the capacity of the systems has been increasing, high values of inductances are needed, so that realizing practical filters has been becoming even more difficult due to the price rises and the poor dynamic responses.

b- Grid synchronize techniques

The contribution of solar photovoltaic (PV) in the electrical power sector is increasing expeditiously. Recent interest in the integration of solar PV into the grid raises concerns about the synchronization technique. Continuous research has successfully replaced the small stand-alone system with a grid-tied PV system. A grid-tied PV system is popular due to the abundance of solar light and advanced power electronics techniques. Synchronization is a crucial problem in grid-tied inverters operation and control research indicates that frequency, phase, and amplitude of voltage are the most crucial parameters that need to be measured and controlled for grid-tied application. A phase-locked loop (PLL) is a popular grid synchronization approach, which needs to sustain power system oscillations as its vulnerability influences the produced reference signal. Traditional PLL catches the frequency and phase through feedback loop-filter (LF) to improve steady-state capability during adverse grid conditions [16].

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c- Single-phase synchronization system

Synchronization unit plays critical role to control single phase converters as is responsible for level interconnection of inverter with the grid and monitoring utility condition. Single-phase system can be additional categorized as open-loop and closed-loop systems. Open-loop methods directly estimate the magnitude, phase and frequency of the input signals although in closed loop system estimated value of phase is updated adjusting through a feedback loop mechanism. This loop locks the estimated value of signal to its actual value [17].

V. Result and Discussion

This paper uses to identify solar PV which will be connected to grid and the way to be converting the power from DC which is solar PV creates that energy and converts it to AC using single phase inverter and synchronizes the grid. MPPT controller will be useful the Matlab software which uses to simulate the PV system to test the single phase inverter to convert the DC power to AC power as shown in figure 9.

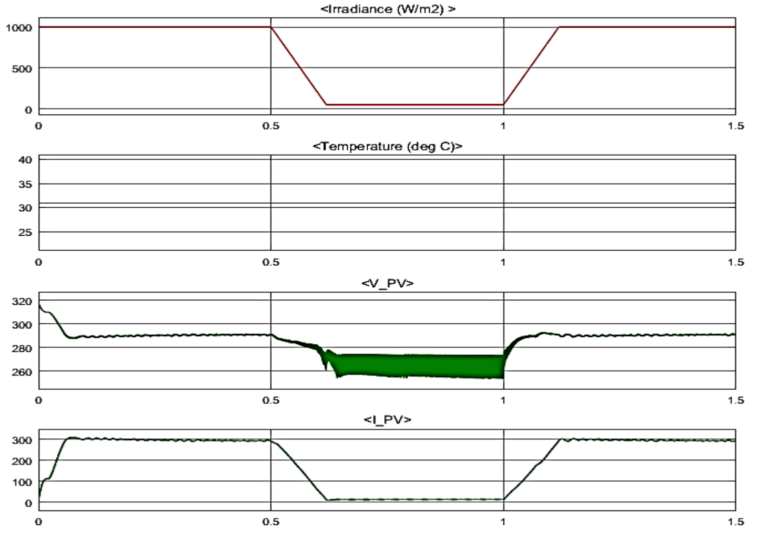

Figure 9. The output voltage and current for PV

Figure (9) shows the output current and voltage. Irradiance and temperature are fixed values we can change them any time. With own wish and the results of PV will be changed, the PV cell voltage and currents have a relation to give power. Firstly current start from zero and power also start from zero then the single phase inverter start to converter the output power which are effect of load the voltage drops then start to work to multiple of both gives the power to make the voltage will be stable it is reach to 290v and the current at 300A.

VI .Conclusion

Single phase inverter is still very much at the developing stage grid connected PV systems. PV inverter technology has changed rapidly, and many inverters have been developed to explore the most effective, efficient system configuration, and the most cost-effective design.

A single-phase inverter suitable for grid connected applications also that can be converter consists of a simple DC-DC boost stage and single-phase DC-AC inverter stage.

The system is modeled in the MATLAB- Simulink environment. The simulations results confirm that energy collect from PV arrays is fed to the grid in an efficient manner and the single-phase PV inverter operating in grid connected which the voltage and current is tracking the references perfectly.

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