Model of Grid Connected 6KWp Photovoltaic Solar Power System

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ABSTRACT

An installation of solar photovoltaic (PV) systems has been witnessed worldwide. It is mainly driven by the demand of "clean" power generation. Grid-connected PV systems will become an even active player in the future mixed power systems, which are linked by a vast of power electronics converters. In order to achieve a reliable and efficient power generation from PV systems, stringent demands have been imposed on the entire PV system. It in return advances the development of power converter technology in PV systems. This paper thus takes an overview of the advancement of power electronics converters in three phase PV systems, being commonly used in residential applications. Demands to three phase grid-connected PV systems as well as the general system control strategies are also addressed in this paper.

Keywords:- Inverters, hybrid topologies, CHB, THD, phase shift pulse width modulation, PWM, sinusoidal pulse width modulation, Solar System, Renewable Energy, Solar power, Boost converter, Solar panel, MPPT.

INTRODUCTION

Traditional power generations that are on a basic of fossil fuel resource are considered to be unsustainable in long-term national strategies. This has been one of the main driving forces for an increasing installation of renewable energies like wind power, solar Photovoltaic (PV) power, hydropower, biomass power, geothermal power, and ocean power, etc. into the public grids [1], [2]. Among the major renewable, the solar PV power generation has continued to expand at a rapid rate over the past five years [3], [4]. Therefore, as the typical configuration for residential PV applications, the three-phase grid-connected PV systems have been in focus in this paper in order to describe the technology catering for a desirable PV integration into the future mixed power grid. Power electronics technology has been used as the enabling technology for more renewable energies in the grid, including solar PV systems [8]. Associated by the advancements of power semiconductor devices [9], the power electronics part of the entire PV systems (i.e., power converters) holds the responsible for a reliable and efficient energy conversion from the clean, pollution-free, and inexhaustible solar PV energy. As a consequence, a vast of grid-connected PV power converters have been developed and commercialized widely [10]-[15].

According to the state-of-the-art technologies, there are mainly four configuration concepts [2], to organize and transfer the PV power to the grid, as it is shown in Fig. 1. Each of the grid-connected concepts consists of series of paralleled PV panels or strings, and they are configured by a couple of power electronics converters (DC-DC converters and DC-AC inverters) in accordance to the output voltage of the PV panels as well as the power rating. A central inverter is normally used in a three-phase grid connected PV plant with the power kWp,. This technology can achieve a relatively high efficiency with a lower cost, but it requires high voltage DC cables [10]. Besides, due to its low immunity to hotspots and partial shading, power mismatch issue is significant in this concept (i.e. low PV utilization). In contrast, the MPPT control is achieved separately in each string of the string/multi-string PV inverters, leading to a better total energy yield. However, there are still mismatches in the PV panels of each string, and the multi-

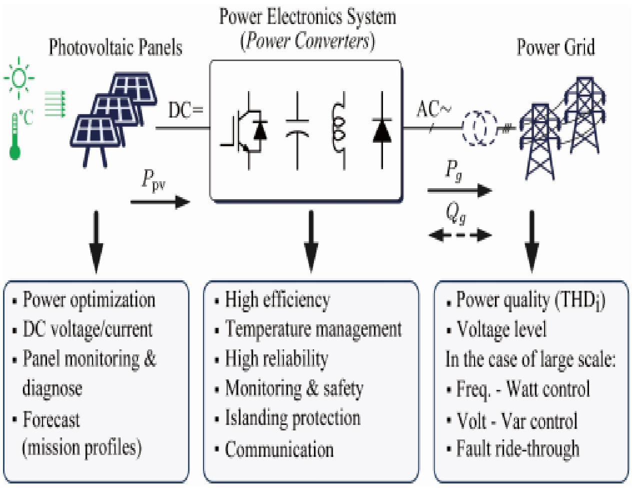

Fig 1: Block Diagram of Solar System.

String technology requires more power electronics converters, resulting in more investments. Considering the above issues, the module converters (DC-module converters and/or AC-module inverters) are developed, being a flexible solution for the PV systems of low power ratings and also for module-level monitoring and diagnostics.

This module integrated concept can minimize the effects of partial shadowing, module mismatch, and different module orientations, etc., since the module converter acts on a single PV panel with an individual MPPT control. However, the low overall efficiency is the main disadvantage of this concept, that the module concept, the string inverter, and multi-string inverters are the most common solutions used in single-phase PV applications,

Since the power of a single PV module is relative low and is strongly dependent of the ambient conditions (i.e., solar irradiance and ambient temperature), the trend for AC-module inverters is to integrate either a boost or a buck-boost converters into a full-bridge or half-bridge inverter in order to achieve an acceptable DC-link voltage As it is presented in a single-stage module integrated PV converter can operate in a buck, boost, or buck-boost mode with a wide range of PV panel output voltage. Where inverter has an *LCL*-filter is used to achieve a satisfactory total harmonic distortion of the injected current. A variant AC module inverter has been introduced in [14], which is however a resultant integration of a boost converter and a full-bridge inverter.

The main drawback of the integrated boost AC-module inverter is that it will introduce a zero cross current distortion. In order to solve this issue, the buck-boost AC module inverters are preferable. Similar principles are applied to the buck-boost integrated full-bridge inverter, which operates for each half-cycle of the grid voltage. This AC-module inverter is using a common source. In addition to the topologies that are mainly based on relatively independent DC-DC converters integrated in an inverter, other AC-module inverters are proposed. Most of these solutions are developed in accordance to the impedance-admittance conversion theory as well as an impedance network.

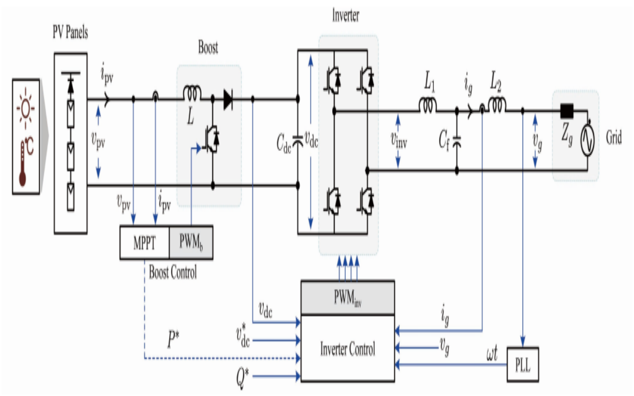

Fig 2: Block Diagram of Solar System.

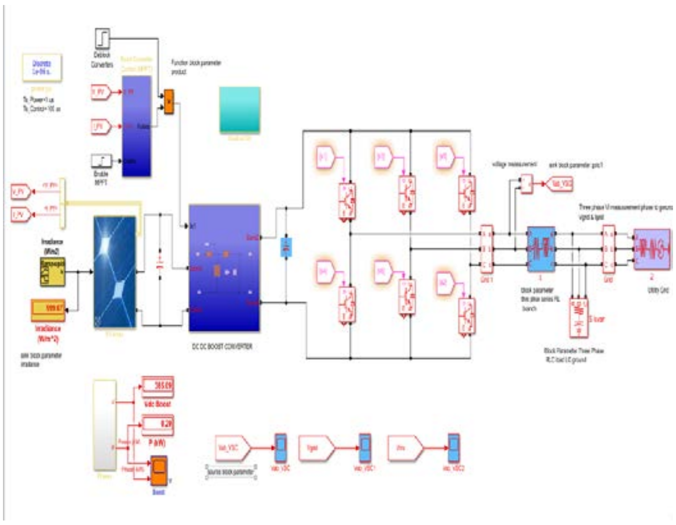

Fig 3: Simulated Model.

II SIMULATION MODELLING

The modeled PV system shown in Fig. 3 consists of component models of a PV array, a voltage source converter (VSC), an LCL filter, a dc-dc boost converter and a model of a power distribution grid. Component level models of the PV system are described in this section including the MPPT algorithm.

1) PV Array and MPPT Algorithm

The single-diode PV array model is adopted from [10]. The V-I characteristic curves of the PV array are shown in Fig. 3 for different solar irradiance levels while the ambient temperature is at 25◦ C. The voltage at the maximum power point (MPP), V_{mpp}, at each irradiance level is marked in Fig. 4. The amount of maximum power that can be extracted from the PV array at a given time is a function of the solar irradiance and the ambient temperature. Since the solar irradiance and the ambient temperature is continuously changing, an MPPT algorithm is necessary to track the MPP. Among the available MPPT algorithms, the perturb and observe (P&O) method and the incremental conductance (In C) method are two well known MPPT algorithms. The P&O method has been identified as a simple tracking MPPT algorithm.

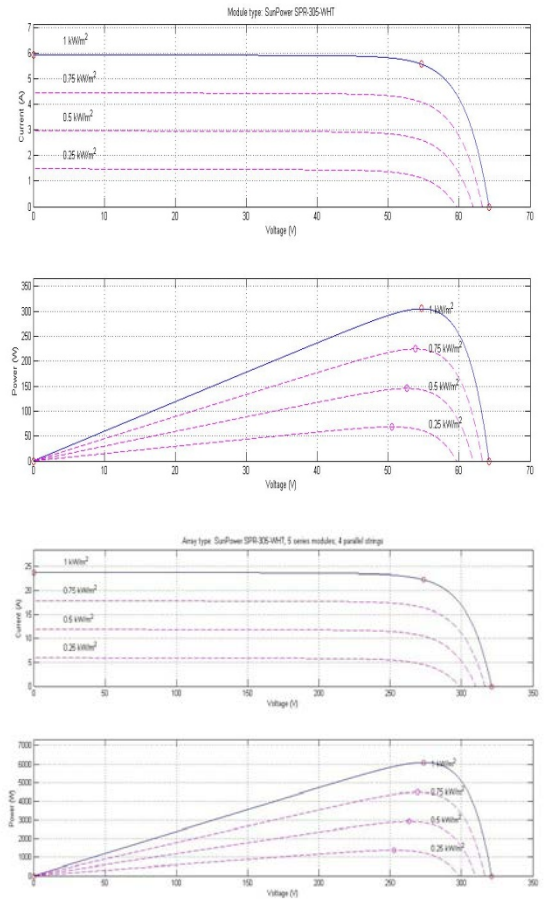

Fig 4: VI characteristics of PV module.

2) Voltage Source Converter

The VSC in Fig. 5 is a full-bridge converter that is made of insulated gate bi-polar transistor switches. The VSC is able to operate in all four quadrants. The rated apparent power capacity of the VSC, *S*r, is 5.4 kVA. The spare capacity of the VSC when injecting a certain amount of active power is used for injecting or absorbing reactive power. The switching frequency of the VSC, *f*sw, is 1 kHz and a unipolar sinusoidal pulse width modulation technique is used [13].

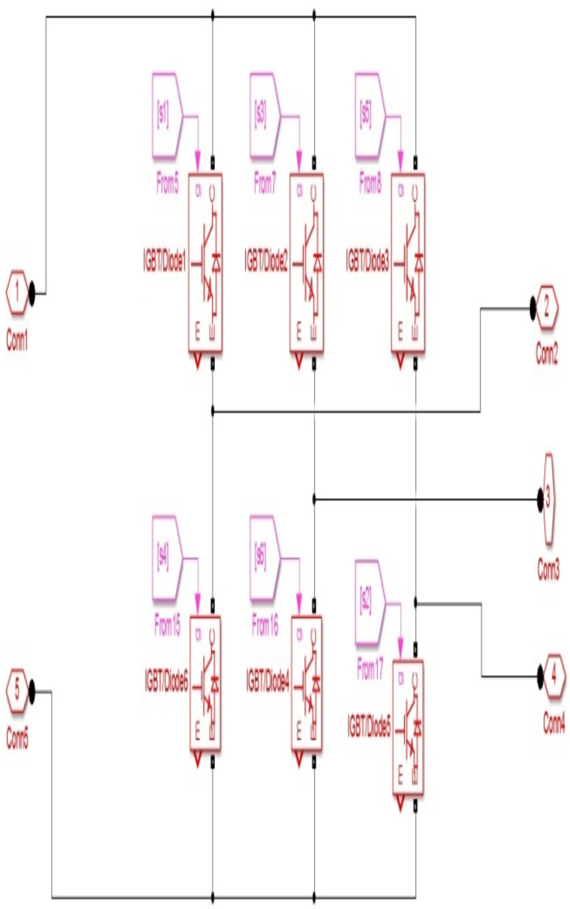

Fig 5: Full-bridge converter.

3) **Selection of Dc-link Capacitor**

The dc-link voltage, V_{dc}, consists of an average dc component, V_{dc} avg, as well as a 100 Hz voltage ripple. An expression for the peak-to-peak 100 Hz voltage ripple, ΔV_{dc}, of the dc-link can be derived as (1) [16]. In (1) *P*g is the active power injected to the grid C_{dc} is the dc-link capacitor and is the fundamental angular frequency of the grid voltage, *v*g. V_{dc} avg is 400 V of the modeled PV system.

In the modeled PV system, C_{dc} is calculated as 12000 μF to limit ΔV_{dc} to approximately 5% of V_{dc} avg when the VSC is injecting 5.4 kW of active power to the power distribution grid.

4) **Dc-dc Boost Converter**

The rated capacity of the dc-dc boost converter shown in Fig. 6 is 5 kW and the switching frequency, *f*dc, is 5 kHz. The inductor, *L*dc, can be calculated as given in (2) to limit the current ripple, Δ*I*, of the current that is flowing through the inductor [13]. In (2), *V*pv is the voltage across the PV array.

*L*dc = *V*pv(*V*dc avg - *V*pv)/Δ*If*dc*V*dc avg ……………………………………(2)

If the PV array is operated close to the MPP, *V*pv is close to 300 V as per Fig. 4. Hence the inductor, *L*dc = 9 mH, can be calculated to limit Δ*I* to 5% when the dc-dc boost converter is operating at the rated capacity. The dc-dc boost converter decouples the PV array from ac-side dynamics [16]. Therefore, in modeling the grid connected PV system, the capacitor C_{pv} at the PV array output is chosen to be 2.5 times the dc-link capacitor, C_{dc}. With the selected value for C_{pv}, the 100 Hz voltage ripple that is appeared across the

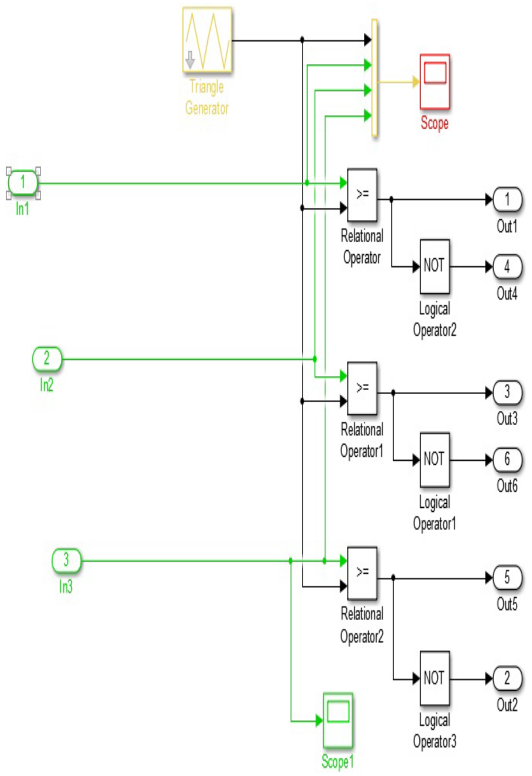

Fig 6: DC to Dc Boost Converter.

PV array is reduced to 10% of the 100 Hz voltage ripple of the dc-link when the VSC is operated at the rated capacity. The high time constant of C_{pv} effectively decouples the ac-side and the dc-side of the grid-connected PV system. The capacitor, C_{pv} also minimizes the switching ripple current that is drawn from the PV array.

III RESULTS & ANALYSIS

The simulation model of the grid-connected Three-phase PV system was developed in the Matlab simulation program. Simulation studies were performed to evaluate the effectiveness of models and controllers of the PV system. The surface temperature of the PV array was considered constant at 25 ◦C in all simulation scenarios. The VSC was operated at the rated capacity with and without the low-order HC.

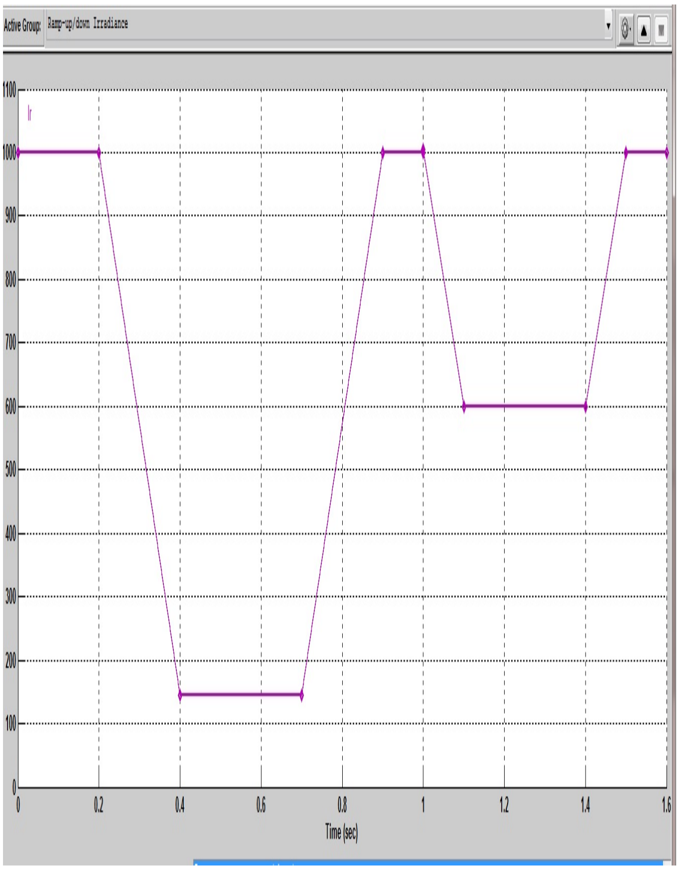

Fig 7: Irradiation variations for solar system.

The total harmonic distortion (THD) of the simulated grid voltage was not ideal. The magnitudes of low-order current harmonics injected to the power distribution grid as a percentage of the fundamental current is shown in Fig. Illustrates the response of the closed-loop current controller and the dc-link voltage controller for step changes of solar irradiance (from 1000 to 200 W/m2 at t = 0.4 s). In the designed PV system, a new current reference is generated upon a operating state change. As the closed-loop current controller closely tracks the generated current reference, the steady state error is almost zero. Illustrates the capability of the designed current controller to independently control the injected active and reactive power.

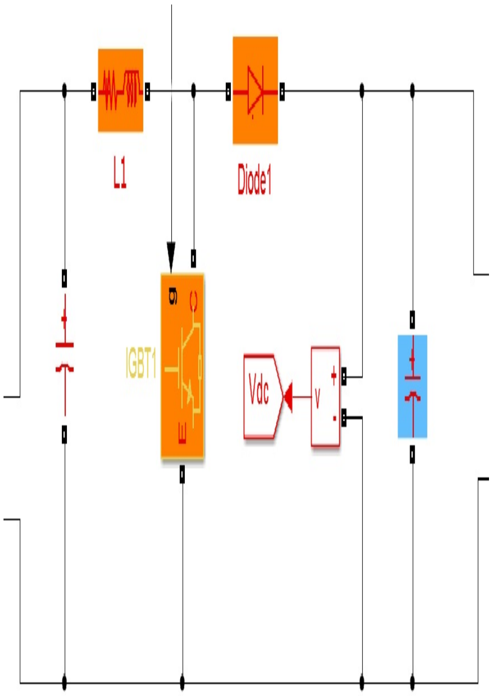

Fig 8: PWM technique Used for Inverter.

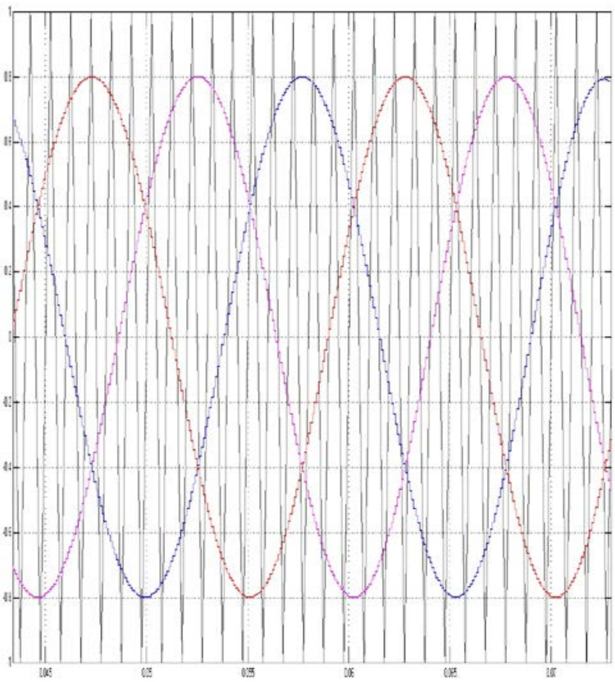

Fig 9: Comparative Wave for Used for PWM.

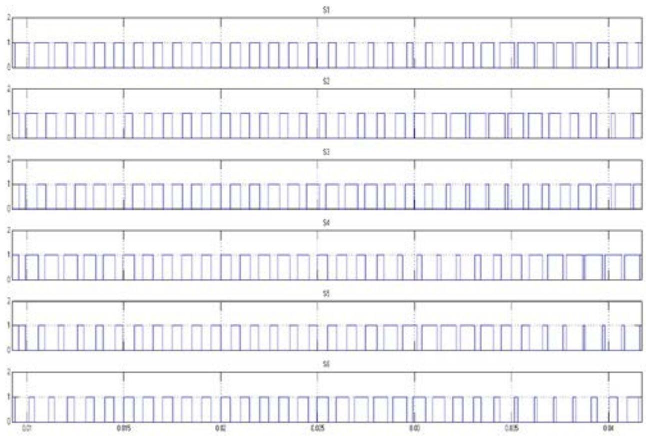

Fig 10: Gate firing Pulses for Three Phase Inverter.

The performance of the MPPT algorithm, controller of the dc-dc boost converter and the power factor controller of the VSC are shown with the variation of solar irradiance illustration, the controller of the dc-dc boost converter has closely regulated the PV array voltage, V_{pv} at V_{ref} by adjusting the duty cycle of the dc-dc boost converter. The MPP tracking path of the considered variations in the solar irradiance. But once the solar irradiance is stabilized, the actual MPP has been found accurately by the MPPT algorithm.

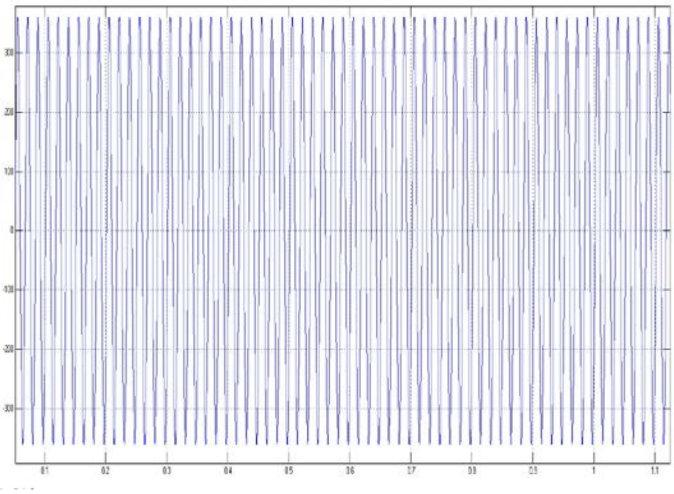

Fig 11: Output voltage of Inverter.

IV CONCLUSIONS

In this paper, a review of the recent technology of three phase PV systems has been conducted. Demands to the three phase PV systems, including the grid-connected standards, the solar PV panel requirements, the ground current requirements, the efficiency, and the reliability of the three phase PV converters, etc. have been emphasized in this paper. Since achieving higher conversion efficiency is always of intense interest, (with an integrated DC-DC converter) and the transformer less PV topology have been focused. The review reveals that The AC-module inverter concept is very flexible for small PV units with lower power ratings, when a DC-DC boost stage is included, the MPPT control becomes more convenient, and the operating time of the PV systems is then extended. Finally, the general control structures for transformer less PV systems are presented, as well as a brief discussion on the synchronization and monitoring technologies.

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