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Simulation of High Power Factor Single Phase Inverter For PV Solar Array: A Survey

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Abstract— **Photovoltaic (PV) systems are solar energy supply systems, which either supply power directly to an electrical equipment or feed energy into the public electricity grid. This paper focuses on the latest development of modelling and control of grid connected photovoltaic energy conversion system. In the photovoltaic system, power electronic conversion is necessary to improve the efficiency of PV panels and system stability. In these systems, the backstage power circuit consists of a high step-up DC-to-DC converter and a full-bridge inverter to convert DC to AC, as the grid voltage is AC in nature. Modelling of photovoltaic systems include modelling of SPV array, power electronics inverter/converter based on MATLAB/SIMULINK. This present control algorithm of a single-phase grid-connected photovoltaic (PV) system including the PV array and the electronic power conditioning (PCS) system, based on the MATLAB/Simulink software. It also discussed advances in MPP tracking technologies, the synchronization of the inverter and the connection to the grid.**

Index Terms— **Boost converter, Full-Bridge Voltage Source Inverter, Photovoltaic Array, LCL filter, photovoltaic system.**

I. Introduction

The world constraint of fossil fuels reserves and the ever rising environmental pollution have impelled strongly during last decades the development of renewable energy sources (RES). The need of having available sustainable energy systems for replacing gradually conventional ones demands the improvement of structures of energy supply based mostly on clean and renewable resources. At present, photovoltaic (PV) generation is assuming increased importance as a RES application because of distinctive advantages such as simplicity of allocation, high dependability, absence of fuel cost, low maintenance and lack of noise and wear due to the absence of moving parts. Furthermore, the solar energy characterizes a clean, pollution free and inexhaustible energy source. In addition to these factors are the declining cost and prices of solar modules, an increasing efficiency of solar cells, manufacturing technology improvements and economies of scale [1].

The increasing number of renewable energy sources and distributed generators requires new strategies for the operation and management of the electricity grid in order to maintain or even to improve the power-supply reliability and quality. In addition, liberalization of the grids leads to new management structures, in which trading of energy and power is becoming increasingly important.

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The power-electronic technology plays an important role in distributed generation and in integration of renewable energy sources into the electrical grid, and it is widely used and rapidly expanding as these applications become more integrated with the grid-based Systems. During the last few years, power electronics has undergone a fast evolution, which is mainly due to two factors. The first one is the development of fast semiconductor switches that are capable of switching quickly and handling high powers. The second factor is the introduction of real-time computer controllers that can implement advanced and complex control algorithms [2].

Photovoltaic (PV) power supplied to the utility grid is gaining more and more visibility, while the world's power demand is increasing [3]. Not many PV systems have so far been placed into the grid due to the relatively high cost, compared with more traditional energy sources such as oil, gas, coal, nuclear, hydro, and wind. Solid-state inverters have been shown to be the enabling technology for putting PV systems into the grid [4].

II. Literature Review

India has become the top country in the world to make a law of minister called Minister of New and Renewable energy for non-conventional energy resources. Being the tropical country India has high solar isolation so the best renewable green energy source is solar energy. Our country is the 5th largest producer. From research it is noted that, by March 2017, the demand of electricity will be increased from 900 billion kilowatt-hours to 1400 billion kilowatt-hours. Consequently it is in verge of energy lack with a huge gap of demand and supply. To fulfill the required demand, solar energy is needed. It is the1only entirely available renewable energy alternate energy source with the1fundamental1capability2to5satisfy the energy6needs of our country. Based on PV installed capacity, India has become fourth After Japan, Germany and U.S. A major drive has also been initiated by the Government to trade Indian PV products, systems, technologies and services.

Peterson K. Hinga [1] and fellows introduced that a novel multi-step PWM Inverter for a solar power generation system. The new type of PWM inverter presented has many features such as the good output waveform. Small size of filter, low switching losses, low acoustic noise. The circuit configuration, control method and the characteristics of the system has described in their paper and also investigate the relation between the inverter and the solar cell characteristics. Martina Calais. Vassilios G. Agelidis [2] provided an overview on different multilevel topologies and investigated their suitability for single-phase grid connected photovoltaic systems. The need of several sources on the DC side of the converter makes multilevel technology attractive for

photovoltaic applications. They discussed and compared the Half Bridge Diode Clamped. Full Bridge Single Leg Clamped, Cascaded (CC), Step, Magnetic Coupled and Flying Capacitor (FC) multilevel converter topologies.
Chem Nayar [3] and fellows described a novel power converter capable of extracting maximum power from solar photovoltaic panels. This proposed dual converter (combination of VCVSI and CCVSI) has able to provide uninterruptible power supply feature, load voltage stabilization, unity power factor operation, maximum power point tracking as well as reactive power support. The overall efficiency has higher than the conventional system with a dc-dc converter between the PV panels and the battery.

J.S.Siva Prasad and B.G.Femandes [4] proposed a new three phase active commutated thyristors current source inverter (CSI) topology for grid connected photovoltaic systems. The basic active commutated thyristor CSI with pulse width modulation (PWM) capability has recently implemented with a resistive load. To suppress the natural frequency of oscillations of LC filter and to ensure stability of the system, a charge controller in synchronous rotating reference frame is described. It allows easy design of PI controller gains.

Anastasios Ch. Kyritsis, Nikolaos P. Papanikolaou [5] and fellows proposed a new design and control strategy of the Fly back Inverter for decentralized grid connected PV systems. It achieves high power density, high efficiency, and high power factor regulation. The design and control strategy has investigated to the achievement of a converter with the smallest possible volume for a given power or to the maximization of the power transfer for given converter parameters. In contrast to the classic converter topologies this proposed scheme has presented a very high efficiency, due to its simplified structure.

Qingrong Zeng, Liuchen Chang [6] introduced that the Space vector pulse-width modulation is widely used in the current control of three-phase voltage-source inverters. In grid-connected distributed generation systems, HCCPWM introduce the drawbacks to current controllers, such as the compromised output current due to the grid harmonic disturbance and nonlinearity of the system, the lack of inherent over-current protection etc. It gives high performance even under the influence of the grid harmonics. It also offers an improved response for over-current protection to the system.

Juan Jose Negroni, Francesc Guinjoan [7] and fellows described the analysis, modelling and design of a Buck-based inverter control for grid-connected photovoltaic (PV) systems. On one hand a linear digital voltage controller is designed from a large-signal linear sampled-data model of the system to maximize the steady state input-output energy transfer ratio. On the other hand, a sliding-mode current controller is also designed to assure a unity power factor.

III. SOLAR ENERGY

Solar energy is a non-conventional type of energy. Solar energy has been harnessed by humans since ancient times using a variety of technologies. Solar radiation, along with secondary solar-powered resources such as wave and wind power, hydroelectricity and biomass, account for most of the available non-conventional type of energy on earth. Only a small fraction of the available solar energy is used.

Solar powered electrical generation relies on photovoltaic system and heat engines. Solar energy's uses are limited only by human creativity. To harvest the solar energy, the most common way is to use photo voltaic panels which will receive photon energy from sun and convert to electrical energy. Solar technologies are broadly classified as either passive solar or active solar depending on the way they detain, convert and distribute solar energy. Active solar techniques include the use of PV panels and solar thermal collectors to strap up the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties and design spaces that naturally circulate air. Solar energy has a vast area of application such as electricity generation for distribution, heating water, lightening building, crop drying etc.

IV. SYSTEM COMPONENTS

A. Modelling Of Photovoltaic Module/Array

The photovoltaic module is the result of associating a group of photovoltaic cells in series and parallel, with their protection devices, and it represents the conversion unit in this generation system. The manufacturer supply PV cells in modules, consisting of NPM parallel branches, each with NSM solar cells in series shown in Figure 1

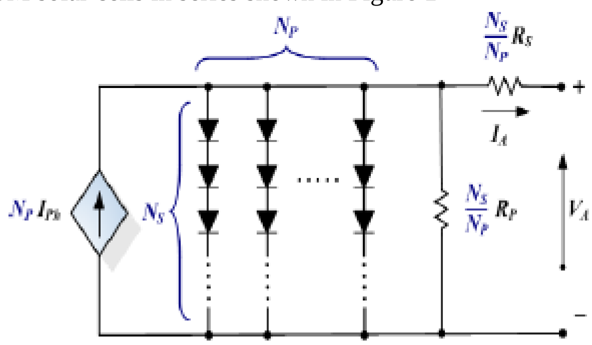

Figure 1 Equivalent circuit of a PV array.

Although the mathematical and simulation photovoltaic modules development began time ago, improvements of these models are analyzed and presented continually. One of the objectives of this study is a review of those existing methods and models.

$$I_A = N_P I_{Ph} - N_P I_{RS}\left\{\exp\left[\frac{q}{AkT_C}\left(\frac{V_A}{N_S}+\frac{I_A R_S}{N_P}\right)\right]-1\right\} - \frac{N_P}{R_P}\left(\frac{V_A}{N_S}+\frac{I_A R_S}{N_P}\right)$$

Where: *IA*: PV array output current
VA: PV array output voltage
IPh: Solar cell photocurrent
IRS: Solar cell reverse saturation current (aka dark current)
q: Electron charge, 1.60217733e–19 Cb
A: P–N junction ideality factor, between 1 and 5
k: Boltzmann's constant, 1.380658e–23 J/K
TC: Solar cell absolute operating temperature, K
RS: Cell intrinsic series resistance
RP: Cell intrinsic shunt or parallel resistance

The photocurrent *IPh* for any operating conditions of the PV array is assumed to be related to the photocurrent at standard test conditions (STC) as given in equation (2).

$$I_{Ph} = f_{AM_a} \, f_{IA} \left[I_{SC} + \alpha_{Isc} \left(T_C - T_R \right) \right] \frac{S}{S_R}$$

B. DC to DC Boost Converter

DC-to-DC Converters are used for converting one level of DC voltage (usually unregulated) to another level of DC voltage (regulated). This transformation is done with the help of a network consisting of storage elements like inductor and capacitor [1].

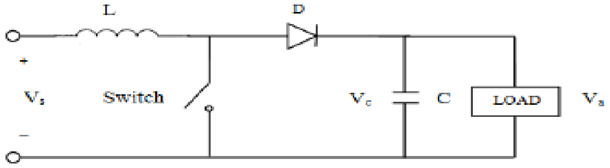

Figure 2 Boost Converter

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost converter is shown in Fig. 2. Here, MOSFET is used as a switch. When the switch is turned-ON, the current flows through the inductor and energy is stored in it. When the switch is turned-OFF, the stored energy in the inductor tends to collapse and its polarity
changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series
and together charge the output capacitor to a voltage higher than the input voltage.

C. Control of DC to DC converter

The output voltage of DC-to-DC converter is controlled or regulated by switching ON and OFF the switch, in a periodic manner. The regulation is normally achieved by Pulse Width Modulation (PWM) technique at a fixed frequency. The constant switching frequency ft is given by [1],

$$f_t = \frac{1}{T_t}$$

Where Tt is the time period of switching device and it is nothing but the addition of ON and OFF time of a switching device which is given by

$$T_t = T_{on} + T_{off}$$

As the ratio Ton/Tt is duty ratio and as this duty ratio varies, the output voltage also varies. This is called constant frequency, variable duty ratio control [1].

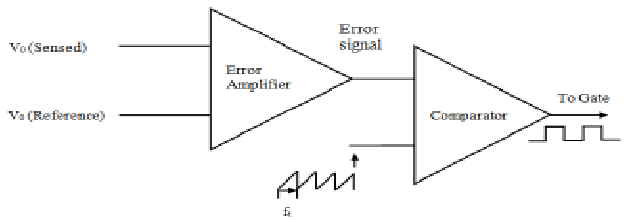

Figure 3 Control circuit of boost converter

Control circuit of boost converter is shown in Fig.3. For regulation purpose, output voltage is continuously sensed Vo (sensed) and compared with a reference voltage Vo (reference).The resulting error signal is compared with a saw tooth waveform having frequency ft. The output of a comparator is fed to the switch or fed into the gate of a power MOSFET [1]. Usually, frequency in kilohertz is selected so as to maximize the efficiency of a converter.

D. Voltage Controller

In general using electrolytic capacitors are less desirable for their short operational lifetime. Hence Long lifetime film capacitors serve as a substitute, however their high prices limit the size that can be used in PV inverters. This causes a significant double line frequency ripple on the DC link voltage which may further couple through the control loop. Therefore a band stop filter is placed on the dc voltage feedback loop to attenuate the ripple. Fig. 4 shows the block diagram of the outer voltage control loop. A simple PI controller is used as a voltage controller *G* (*s*) *v* to regulate the dc link voltage.

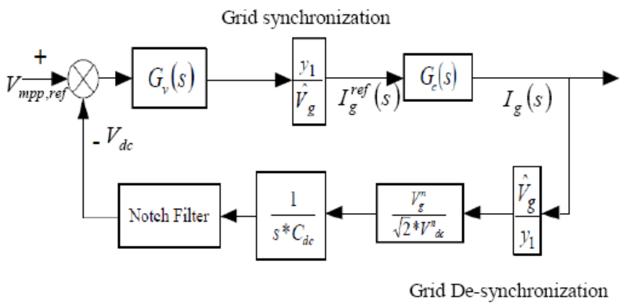

Figure 4 Block diagram of outer voltage loop.

V. CONCLUSION

Designing of single-phase grid connected solar PV system is carried out in this work. System parameters are calculated and from these parameters model is formulated and simulation results are presented. Modeling of the PV cells is one of the mature areas in the field. There are a variety of models available in the literature and can be divided into two main categories; detailed and simplified models. Detailed models attempt to represent the physics of the PV cell and are usually suitable for studies that require the detailed cell information such as implementation of maximum power techniques and analysis of the effect of change in irradiance and temperature on the performance of the PV cell. On the other hand, simplified models usually provide a direct estimate of the maximum power generated from the PV cell at certain operating conditions.

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