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SIMULATION STUDY OF A PHOTOVOLTAIC GRID CONNECTED SYSTEM WITH A RATED POWER OF 1 MW

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Abstract

Traditional electric power systems are designed in large part to utilize large base load power plants, with limited ability to rapidly ramp output or reduce output below a certain level. The increase in demand variability created by intermittent sources such as photovoltaic (PV) presents new challenges to increase system flexibility. This paper addresses modeling and simulation of a grid-connected 1MW photovoltaic system (GCPS) to analyze its grid interface behavior and control performance in the system design. A simple circuit model of the solar array is used to easily simulate its inherent characteristics with the basic specification data.

Introduction

Now a days the demand of Electrical power in increasing day by day but the presence of coal and fossils fuels are towards the end.[1] So it is the time to find another way to generate the power. Sometimes it is also difficult to transmit power to the remote and hilly places which are far away for the main generating station. In order to improve energy efficiency and power quality issues. The use of photovoltaic (PV) systems as a safe and clean source of energy from the sun has been rapidly increasing. The application of PV systems in power systems can be divided into two main fields: off-grid or stand-alone applications and on-grid or grid-connected applications [2].

Fundamental disadvantage of renewable energy generations is the fluctuation of output power. The power fluctuation is a serious problem for power grid companies or transmission system owners. Power system frequency stability relies on the balance between the active power output of the generators and the active power consumed by the loads. Therefore, it is essential to mitigate the renewable energy power fluctuation up to a certain range [2].

In this work we present a simulation study of a photovoltaic grid connected system with a rated power of 1 MW. The studied PV system is composed by a photovoltaic generator and a three phase grid connected inverter.

Grid-Connected PV Systems

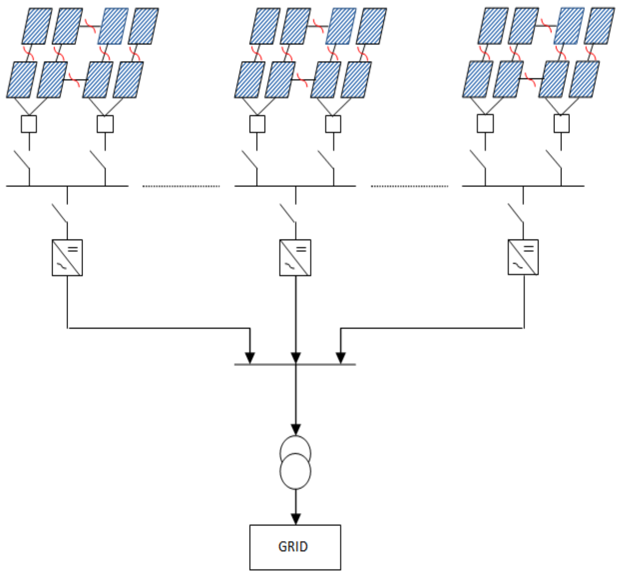

Figure 1. Grid-Connected Photovoltaic System With A Rated Power Of 1 MW

Mathematical Model of The System

A. Photovoltaic Generator Model

Photovoltaic cell models have long been a source for the description of photovoltaic cell behaviors. The most common model used to predict energy production in photovoltaic cell modeling is the single diode circuit model [3]. This model includes a current source, which depends on solar radiation and cell temperature, a diode which the inverse saturation current I_0 depends mainly on the operating temperature, a series resistance and a shunt resistance, taking into account the resistive losses. The current–voltage relationship of a photovoltaic cell is given by:

$$I = I_{ph} - I_0\left(\exp\left(\frac{V + R_s.I}{A}\right) - 1\right) - \frac{V + R_s.I}{R_{sh}} \quad (1)$$

where I_{ph} is the photocurrent in (A), I_0 the diode saturation current (A), $A = \frac{n.K.T}{q}$ modified ideality factor, n the diode ideality factor, k the Boltzmann constant $\left(1.38\times10^{-23} JK^{-1}\right)$, q the electronic charge $\left(1.602\times10^{-19} C\right)$, T the cell temperature (K), V_t the thermal voltage $\left(V_t = \frac{k.T}{q}, V\right)$, R_s the series resistance (Ω) and R_{sh} is the shunt resistance (Ω).

B. A Three-phase PWM Inverter

Figure 2 shows a typical configuration of a three-phase full-bridge UPS inverter. If switching frequency is high enough, the PWM inverter is considered as a voltage source inverter (VSI) and dynamic response of the UPS inverter is mainly determined by the elements of the filter. SPWM techniques are applied to inverters in order to obtain a sinusoidal output voltage with minimal undesired harmonics.
Semiconductor switching devices (1–6) of the inverter are controlled by PWM signals to obtain three-phase near sinusoidal ac voltages of the desired magnitude and frequency at the inverter output. The operation of three-phase inverter can be defined in eight modes as shown in Table I which shows status of each switch in each operation mode.
Three-phase switching state functions Sa, Sb and Sc of the inverter are used to calculate the line output voltages of PWM inverter which is described by the help of Figure 2 [4].

$$[U_{AB}\ U_{BC}\ \ U_{CA}]^T = [T_{AV}\ T_{BV}\ \ T_{CV}]^T U_{dc} \qquad (2)$$

$$\begin{pmatrix} T_{AV} \\ T_{BV} \\ T_{CV} \end{pmatrix} = \frac{1}{2}\begin{pmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{pmatrix}\begin{pmatrix} S_a \\ S_b \\ S_c \end{pmatrix} \qquad (3)$$

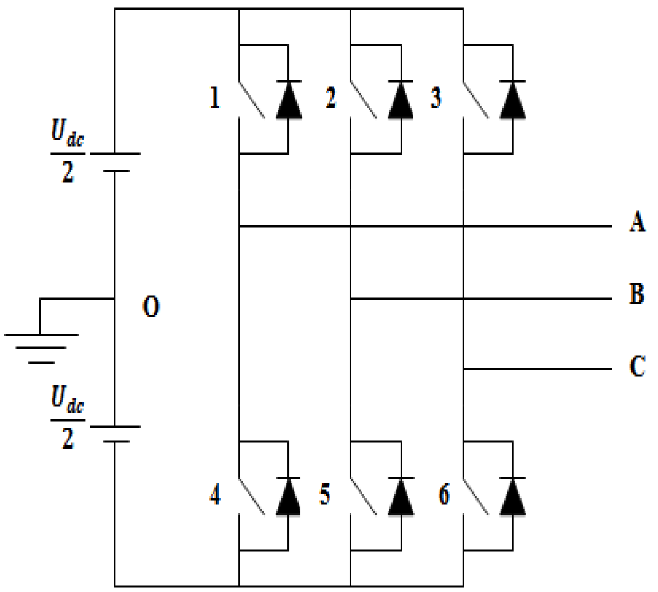

Figure 2. Basic Three-Phase Voltage Source Inverter

Table 1. Reference frame dq voltage.

Mode	V_{qs}	V_{ds}	V_{os}
A	0	0	$\frac{V_{dc}}{2}$
B	$\frac{V_{dc}}{3}$	$-\frac{V_{dc}}{\sqrt{3}}$	$\frac{V_{dc}}{6}$
C	$\frac{V_{dc}}{3}$	$\frac{V_{dc}}{\sqrt{3}}$	$\frac{V_{dc}}{6}$
D	$\frac{2V_{dc}}{3}$	0	$-\frac{V_{dc}}{6}$
E	$-\frac{2V_{dc}}{3}$	0	$-\frac{V_{dc}}{6}$
F	$-\frac{2V_{dc}}{3}$	$-\frac{V_{dc}}{\sqrt{3}}$	$-\frac{V_{dc}}{6}$
G	$-\frac{V_{dc}}{3}$	$\frac{V_{dc}}{\sqrt{3}}$	$-\frac{V_{dc}}{6}$
H	0	0	$-\frac{V_{dc}}{2}$

The switching functions can be mathematically represented as follows [5]:

$$\begin{cases} S_a(wt) = \sum_{k=1,3..}^{\infty} A_k \sin kwt \\ S_b(wt) = \sum_{k=1,3..}^{\infty} A_k \sin(kwt - \frac{2\pi}{3}) \\ S_c(wt) = \sum_{k=1,3..}^{\infty} A_k \sin(kwt - \frac{4\pi}{3}) \end{cases} \qquad (4)$$

C. Voltage Control Modelling

The main purpose of this modelling is to accomplish the input voltage clamping Vi(t), in order to control the power flow between the grid and the PV system. With the voltage clamping technique it is possible to accomplish the Maximum Power Point Tracking (MPPT) of the PV panels. The Constant Voltage Method is accomplished by keeping the voltage in the PV terminals constant and close to the MPP.
In Figure 3 an example of the current and voltage characteristics of a PV cell for different values of solar irradiation is presented. Observing the MPP points (MPP Line), it is possible to observe that the voltage values vary very little even when the intensity of the solar irradiation suffers great alterations. With the voltage clamped in a value "inside" of the MPP Region, when a variation of the solar irradiation happens, the current of PV cell will vary, however the output voltage of the PV will not be altered.

This results in a control of the power flux of the PV cell to the grid.

Implementation Of The Control Methodology

The control methodology of the inverter output currents and input voltage, as well as the modulation used in this work is shown in Figure 3.

This methodology is implemented in the following way: the inverter output currents (I1, I2 and I3) are acquired through sensors. In the line currents it is applied dq Transformation.

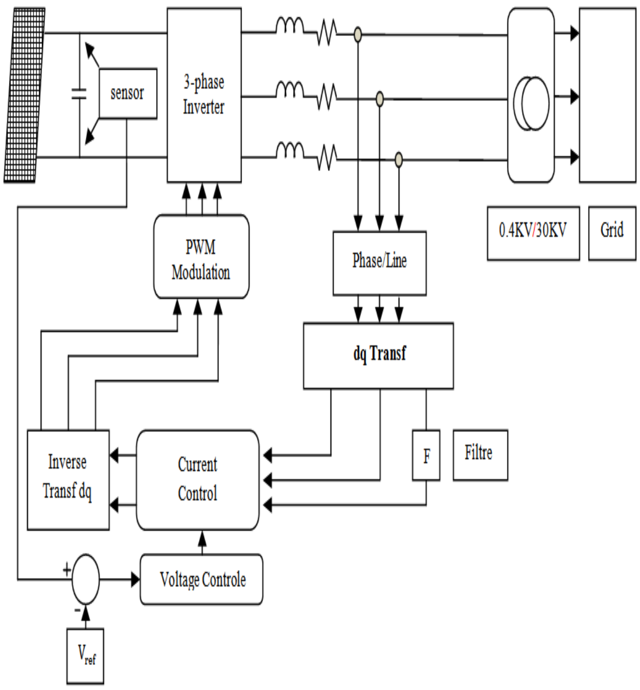

Figure 3. Diagram of the control system.

Simulation Results

Parameters: P = 110 KVA - Inverter Power ; V= 700 V - Input Voltage (DC) ; V= 380 V - Output voltage rms (grid);

Figure 4 shows the simulation results. Voltage and Current (Phase 1) before and after filtering for insulation (1000W/m) in Figure 4.1 and figure 4.2,

Figure 4.3 represents the Solar radiation. Temperature is assumed to be 25°.

Figure 4.4 and figure 4.5 show Voltage and Current (Phase1) before and after filtering for insulation variable has varied smoothly in response to changes in radiation.

The Voltage wave form before transformer is shown in Figure 4.6. The Voltage wave form after transformer is shown in Figure 4.7.

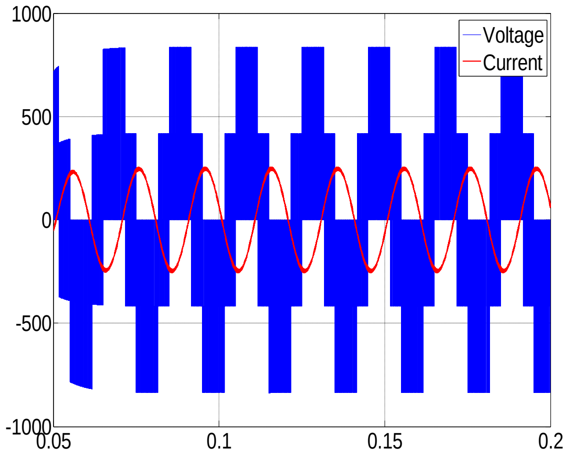

Figure 4.1. Voltage and Current (Phase 1) before filtering for insulation (1000W/m)

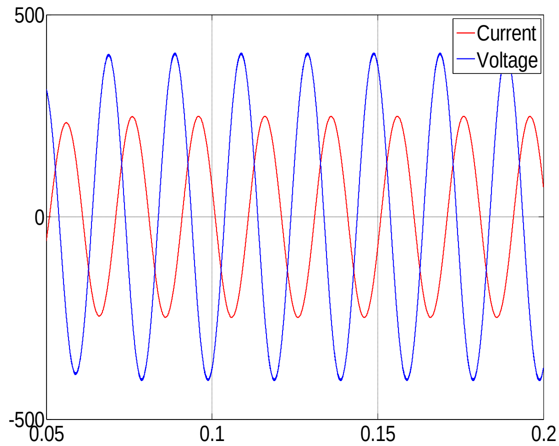

Figure 4.2. Voltage and Current (Phase 1) after filtering for insulation (1000W/m)

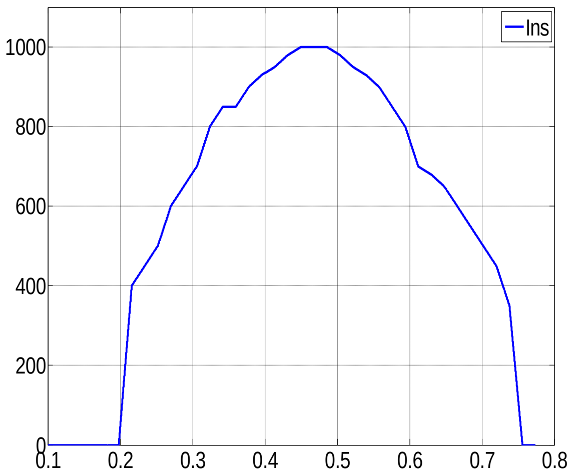

Figure 4.3. Solar radaition

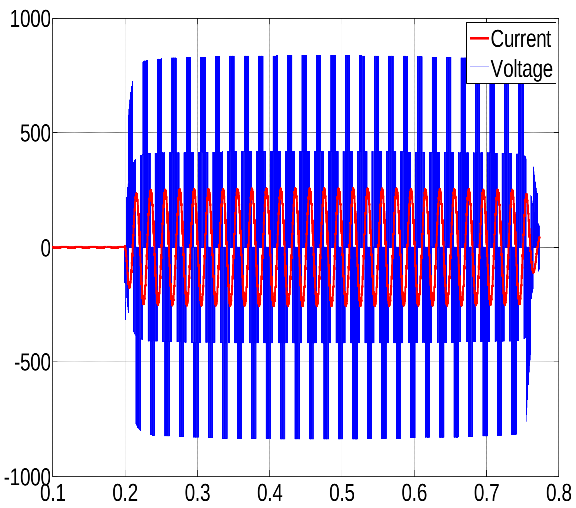

Figure 4.4. Voltage and Current (Phase 1) before filtering for insulation variable

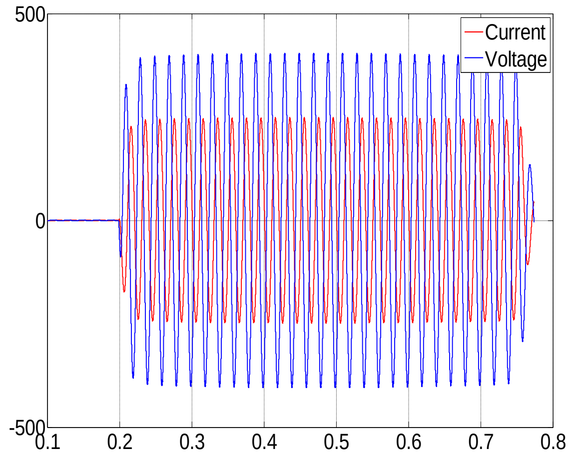

Figure 4.5. Voltage and Current after filtering

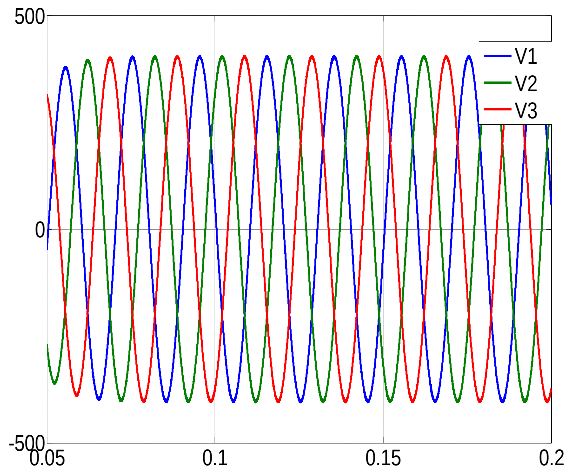

Figure 4.6. Voltage wave form before transformer

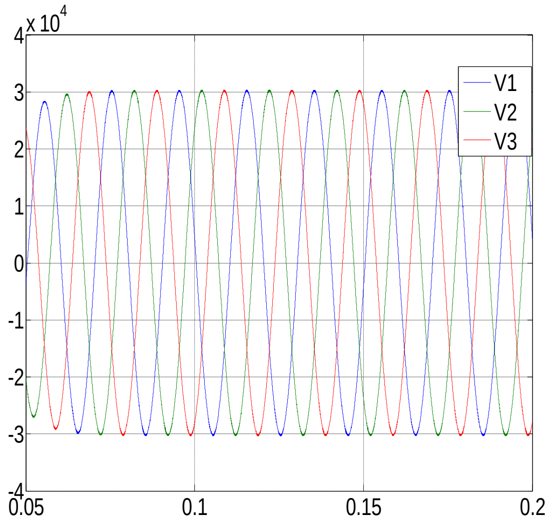

Figure 4.7. Voltage wave form after transformer

Conclusion

This paper presented in a simple way the modeling and the control strategy of grid connected photovoltaic generation system. The main purpose of this modeling is to accomplish the input voltage clamping Vi(t), in order to control the power flow between the grid and the PV system. To prove the structure operation some simulation results were presented and they show theoretical viability of the proposed model, as well as the control strategy used for PV systems.

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Biographies

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