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Study on Grid Connected Photovoltaic System Using PSIM Program

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Abstract: ***At the present, the renewable power systems are quickly developing in many countries to replace the fossil power sources and mitigate the environment pollution. Grid-tied solar power system is one of the most promising as a renewable energy technology but solar panels are dependent on sunlight to effectively gather solar energy. Technical innovations in solar power sector would allow investors to reduce the costs of installation and operation. Understanding the structure of grid-tie inverter technologies could affect on the costs of investment and operation as well as the efficiency of solar power plants. This paper presents a simulation model of single phase grid connected photovoltaic system in PSIM software.***

Keywords: solar power system, P&O MPPT, DC/DC bidirection converter, grid-tied inverter

1. Introduction

As energy demands around the world increase, the need for a renewable energy sources that will not harm the environment has been increased. As energy demands around the world increase, the need for a renewable energy sources that will not harm the environment has been increased. Grid tie solar power system is one of the most promising as a future energy technology but solar panels are dependent on sunlight to effectively gather solar energy.

A grid-tied solar power system is an electricity generating solar power system that is connected to the utility grid. The size of this system from small residential and commercial rooftop systems to large utility-scale solar power stations.

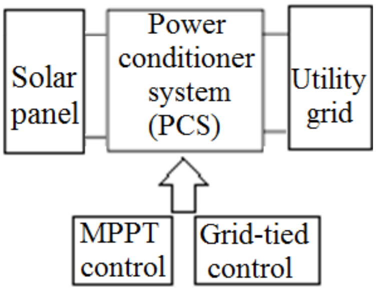

Figure 1: Small grid-tied solar power system

Figure 1 displays the configuration of the small scale grid-tied solar power system [1] with the PCS, including the DC/DC converter and the grid-tied DC/AC inverter. The solar panel generates the DC power to the PCS, in which the maximum power point tracking (MPPT) is performed by the boost-type DC/DC converter while the power at the output terminals of the solar array is supplied into the utility grid by the grid-tied DC/AC inverter. At any time of the day, a customer's solar system may produce more or less electricity than they need for their home or business. When the system's production exceeds the customer demand, the excess energy generation automatically goes through the electric meter into the utility grid, running the meter backwards to credit the customer account with the support of Net-metering policy [2]. At other times of the day, the customer's electric demand may be higher than the renewable energy system is producing, and the customer relies on additional power needs from the utility grid. Switching between solar system's power and the utility grid power is instantaneous and customers never notice any interruption in the flow of power.

Figure 2 shows a typical configuration of a large scale grid-tied solar system. The solar modules are connected in series to form strings, and in parallel to form an array connected to the grid-tied DC/AC inverter. The DC/AC inverter performs the MPPT of the solar array by controlling the DC-link voltage to maximum power point voltage, and synchronizing the AC grid currents with the grid voltage for active and reactive power control [3]. Then, the DC/AC inverter is connected to the grid via an inductive grid filter and a transformer to increase the voltage from low voltage (LV) to medium voltage (MV) of a few thousand volts (LV/MV) to decrease losses in supplying electricity to the utility grid.

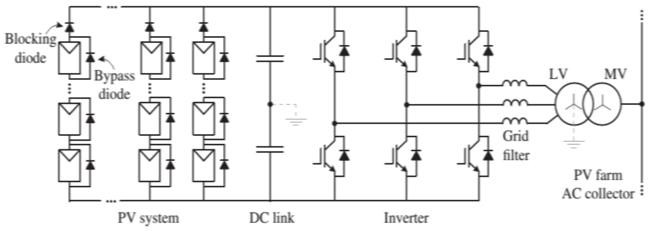

Figure 2: Large scale grid-tied solar power system [3]

In addition, with the support of a feed-in tariff policy [4], eligible solar farm investors are paid a cost-based price for the electricity from solar farms transmitting to the utility grid.

Study of the structure of grid-tie inverter technologies could affect on the costs of investment and operation as well as the efficiency of solar power plants. PSIM is an Electronic circuit simulation software package, designed specifically for use in power electronics simulations but can be used to simulate any electronic circuit.

Thus, this paper has presented the design and simulation of a typical grid-tied PV system to understand more about operation principle of this system in case of using PSIM program.

2. Grid-tied DC/AC inverter

The solar module which is composed of many connected PV cells can generate the direct current (DC) after absorbing the sunlight. The PV cell is modeled by the equivalent electrical circuit as shown in Figure 3:

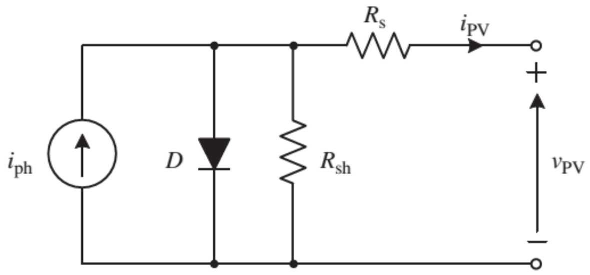

Figure 3: The electrical model of PV cell

The equation [5] that describes a PV cell is:

$$i_{pv} = i_L - i_0\left(e^{\frac{q(v_{pv}+i_{pv}R_s)}{nKT}} - 1\right) - \frac{v_{pv} + i_{pv}R_s}{R_{sh}} \qquad (1)$$

where the parameters are listed in table 1 as below

Table 1: PV cell parameters

Variable	Parameter
v_{pv}	output voltage of PV cell (V)
i_{pv}	output current of PV cell (A)
R_s	Cell series parasitic resistance (Ω)
R_{sh}	Cell shunt parasitic resistance (Ω)
q	Electronic charge: 1.6×10^{-19}(Coulombs)
K	Boltzmann constant: 1.38×10^{-23} (J/K)
T	Absolute temperature in unit Kelvin
i_0	Cell reverse saturation current: 10^{-12} (A/cm^2)
i_{ph}	Cell photocurrent
n	Ideality factor of diode

The DC/AC inverter is used to convert direct current (DC) into an alternating current (AC) and transmit the power from the solar array to the utility grid with the support of grid-tied control system.

There are many types of grid-tied DC/AC inverter, but the H-bridge or full-bridge (FB) inverter is widely used in actual systems because this topology is very versatile, low-cost, can be used for both DC–DC and DC–AC conversion and also be executed in full-bridge form (with two switching legs) or in half-bridge form (with one switching leg) [6]. Some typical H-bridge inverter topologies are presented in Figure 4, Figure 5 and Figure 6.

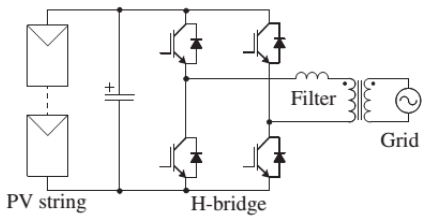

Figure 4: H-bridge topology with low-frequency isolation transformer [3]

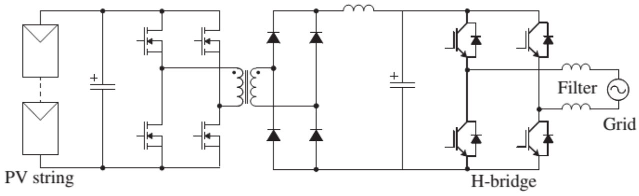

Figure 5: H-bridge topology with high-frequency isolation transformer in DC–DC stage [3]

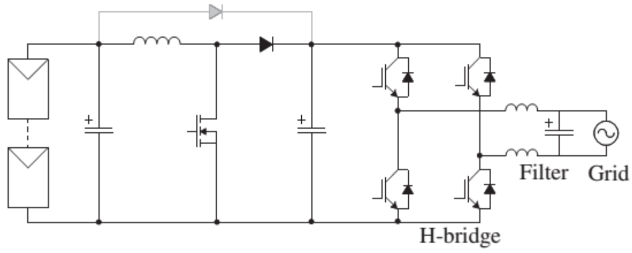

Figure 6: H-bridge topology with DC/DC converter [3]

The control system of a typical grid-connected solar power system is illustrated in Figure 7. The solar array is connected to the DC-DC converter in boost mode, which is used to perform the Maximum power point tracking (MPPT). The electrical energy from the solar array is injected into the grid by using the DC/AC inverter. A low-pass filter allows only the fundamental and some minor voltage harmonics to appear at the connection point with the utility grid [7].

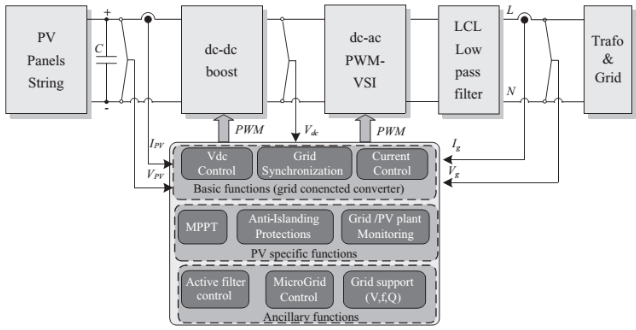

Figure 7: Control system of grid-tied solar power system [6]

The output current of the DC/AC inverter is regulated to synchronize with grid voltage to supply the active power into the utility grid by the support of the hysteresis band method and the Phase Locked Loop (PLL) method in the grid-tied control system of the DC/AC inverter. Figure 8 shows the equivalent circuit of a single phase grid-tied DC/AC inverter while Figure 9 displays the phasor diagram of grid voltage, output voltage and output current of the DC/AC inverter. The magnitude of the inverter output voltage (V_{inv}) should be larger than the grid voltage (V_{grid}) to allow the inverter output current (I_{out}) to be transmitted to the utility grid [8, 9, 10, 11]. In addition, the inverter output voltage (V_{inv}) has to conduct the grid voltage (V_{grid}) with the angle α in order to get the inverter output current (I_{out}) in phase with the grid voltage in order to obtain unity power factor.

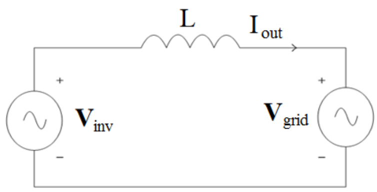

Figure 8: Equivalent circuit of grid-tied DC/AC inverter [8]

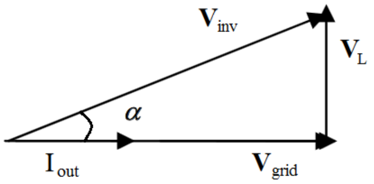

Figure 9: Phasor diagram

3. Simulation model in PSIM

Simulation of grid tie solar panel with MPPT block is shown in Figure 10 and Figure 11. It consists of solar panel block, bi-direction converter circuit, MPPT control block, full-bridge inverter, L filter and Grid-tied control block. Solar irradiance is given to the solar panel by square wave signal block. This block is connected to the input terminal S of solar panel. Irradiance can be varied from 800 W/m^2 to 1000 W/m^2. Temperature is given to the solar panel with the help of voltage source block connected to the input terminal T of the solar panel. Standard temperature of 25^{0}C is maintained for this simulation block. Solar power is high at upper value of solar irradiance and it starts decreasing as the solar irradiance value reduces.

The bi-direction converter in boost mode is connected between the solar panel and the load. The output of the MPPT block controls the switching cycle of the MOSFET used in converter.

A DC/AC power inverter is required to convert the DC voltage gathered by the photovoltaic cell into AC voltage. The single phase grid voltage is of 110Vrms and the output voltage of solar PV array is around 100 V. So before inverting the DC voltage to AC voltage, we first require to step up the DC voltage up to around 230V. On inverting it to AC voltage, we get 155Vp (peak voltage) which is equivalent to 110Vrms. The PV system is grid-connected by a full-bridge inverter with L type filter.

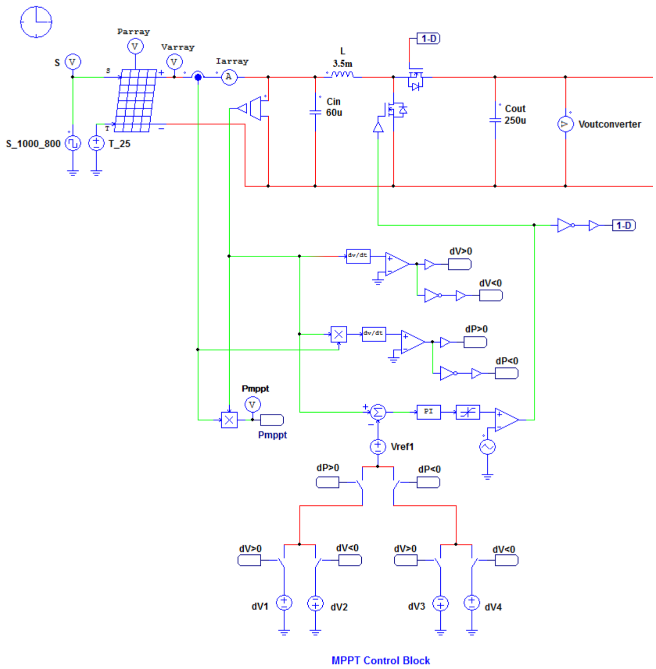

Figure 10: MPPT control with bi-direction DC/DC converter

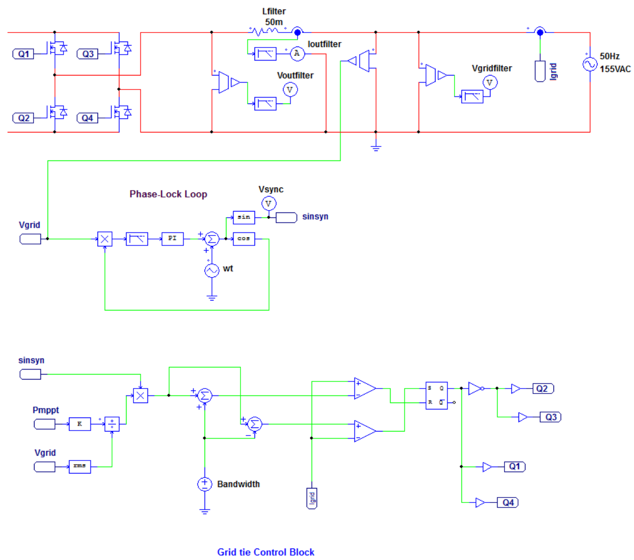

Figure 11: Grid-tied control with DC/AC inverter

Table 1: System parameter for simulation

No	*Parameter*	*Value*
1	Power of PV system P_{array} (including 6 solar panels 60Wp)	360 Wp
2	Voltage of solar panel system V_{array}	100 VDC
3	Output Voltage of DC/DC converter	230 VDC
	MPPT control block	
4	Input capacitor C_{in}	60 µF
5	DC bus capacitor C_{out}	250 µF
6	Inductor L	3.5 mH
	Grid tie control block	
7	Peak grid voltage	155 VAC
8	RMS grid voltage	110 VAC
9	Grid frequency	50 Hz
10	Filter Inductor L	50 mH

4. Study result

Figure 12 shows simulation result of the PV system with MPPT technique. The system was tested in irradiation 1000 W/m^2 and 800 W/m^2. It shows that output power of solar panel array almost reached the maximum power and the MPPT system could produce a maximum output power of solar panel even though under different (high/low) irradiation conditions. Figure 13 and Figure 14 show the simulation result of output voltage and current parameters of grid tie inverter as follows:

1) The magnitude, phase and frequency of the output voltage from the grid tie inverter approximate the grid voltage parameters.
2) The output current is sinusoidal and in phase with the grid voltage after high fluctuation in short first time

period.

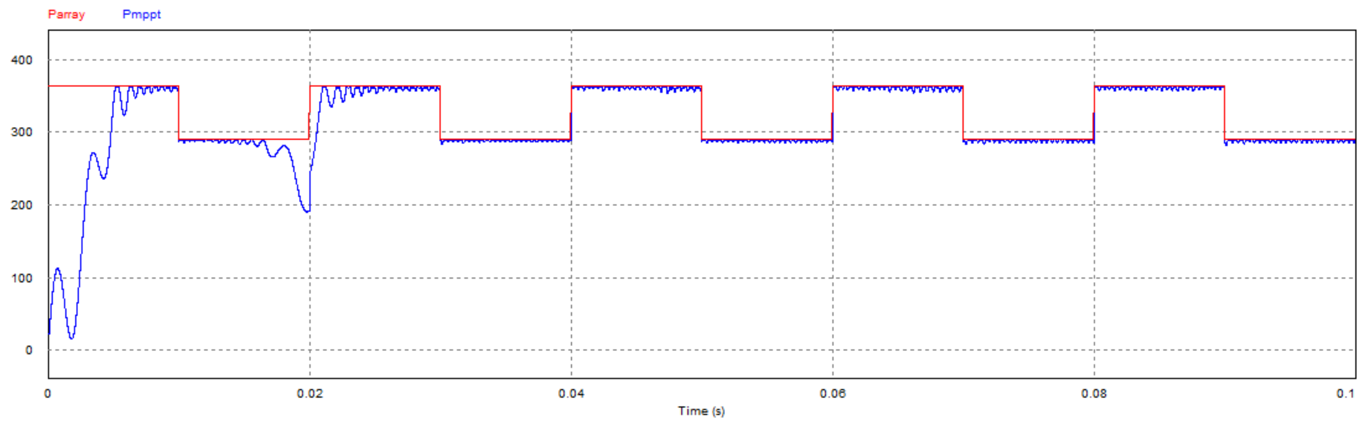

Figure 12: PV system with MPPT technique

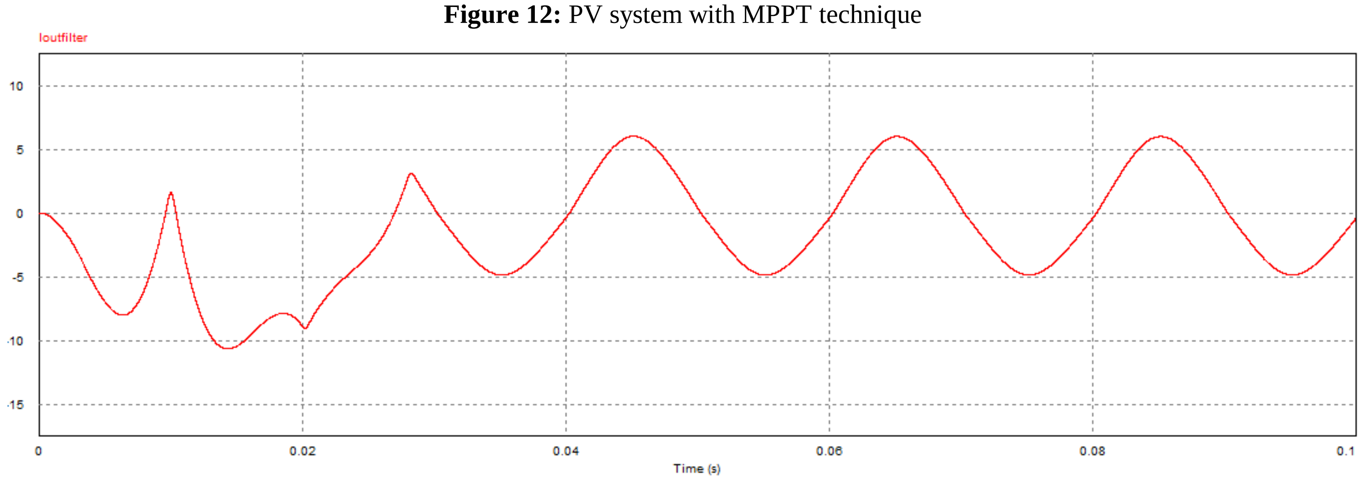

Figure 13: Output voltage of grid tie inverter versus grid voltage

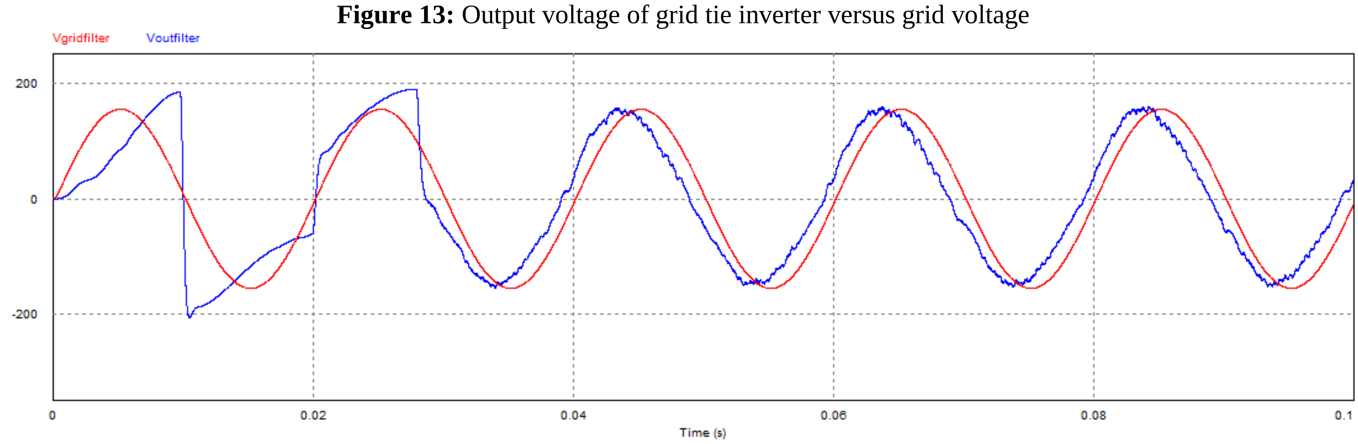

Figure 14: Output current waveform of grid-tied inverter

5. Conclusion

This paper has presented the design and simulation of grid-tied PV system with MPPT technique. By using MPPT algorithm and DC/DC bi-direction converter, solar array is operated at maximum power point irrespective of variations of solar irradiance.

The design can be turned into a fully functional grid tie inverter for establishing connection between the source and the utility grid for transmitting power to an electrical grid. The simulation result using PSIM [12] ensures that the frequency of the inverter output voltage is 50 Hz with a magnitude of 110 V rms and the inverter output current is in phase with the grid voltage.

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