



PV Inverter Monitoring using Dspace

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Abstract

A massive amount of energy is needed, and the need for energy is rising daily. Power generation, distribution, and utilization are all steadily rising. The effectiveness of the conversion from direct current (DC) solar modules to alternating current (AC) inverters determines the overall efficiency of photovoltaic (PV) systems connected to the grid. This study shows the dSPACE DS1104 platform simulation modeling of an inverter controller for photovoltaic application. The controller platform connects its prototype hardware to the simulation model created in the MATLAB/Simulink environment. The effectiveness of the dSPACE application in connecting the PV system to the grid is validated by the results that are displayed.

Keywords: dSPACE, LC Filter, 555 Timer, PV Panel, Potentiometer, Sinusoidal Pulse Width Modulation.

1. Introduction

There is an enormous demand for electricity, and that demand is growing every day. The distribution, generation, and use of power are all increasing steadily. The total efficiency of photovoltaic (PV) systems connected to the grid is based on how well direct current (DC) solar modules are converted to alternating current (AC) inverters. This study presents the simulation modeling of an inverter controller for a solar application using the dSPACE

DS1104 platform. Developing clean, renewable energy is currently one of the primary objectives of modern engineering and science. Photovoltaic energy is the most promising energy source for the future. It is pollution-free and easily accessible everywhere in the world. To successfully use PV DC power, DC electricity needs to be transformed into AC power.

For this, an inverter—which houses the PV modules without any moving parts—is necessary. These days, power electronics provide interfaces for DC to AC power conversion. The overall efficiency of grid-connected photovoltaic (PV) systems is determined by the efficiency of the conversion from the direct current (DC) of the solar modules to the alternative current (AC) of the inverter. The harmonic components of the output voltage are determined by the switching functions and carrier frequency.

Two reference signals are used by the PV system to generate the PWM signals for the inverter switches. A proportional-integral (PI) current control method is used in light of the inverter's application in solar systems in order to preserve the desired output sinusoidal current waveform for end users.

The essential element of every PWM control system is the switching method that produces the switching edges of the PWM control waveform. The converter's main job is to inject sinusoidal current into the grid system, which is how it connects the PV system to the grid via voltage synchronization. PV system failure is usually caused by inverter failure, thus design engineers can develop advanced inverter controllers. for the inverter's typical output voltage. To make solar system use easier, a better kind of inverter is needed.

Here, MATLAB/SIMULINK is used to simulate the inverter and its converter in a closed loop system. The c code is then generated by linking this model to the dSPACE 1104. The build function in the control parameter window is then used to load the code straight into the LED panel. This paper describes the results of developing a simulation model.

2. Modeling of PV System

A solar cell can be simulated using an electrical equivalent circuit that consists of a current source anti-parallel with a diode, a shunt resistance, and a series resistance. When exposed to light, the DC current I_g is generated, and its variation with solar intensity is linear. A significant amount of the PV cell's nonlinear I-V characteristics are generated by the current I_d passing through the anti-parallel diode.

2.1. PV Cell

The PV module is an electrical gadget that produces electricity when it is under direct sunlight.

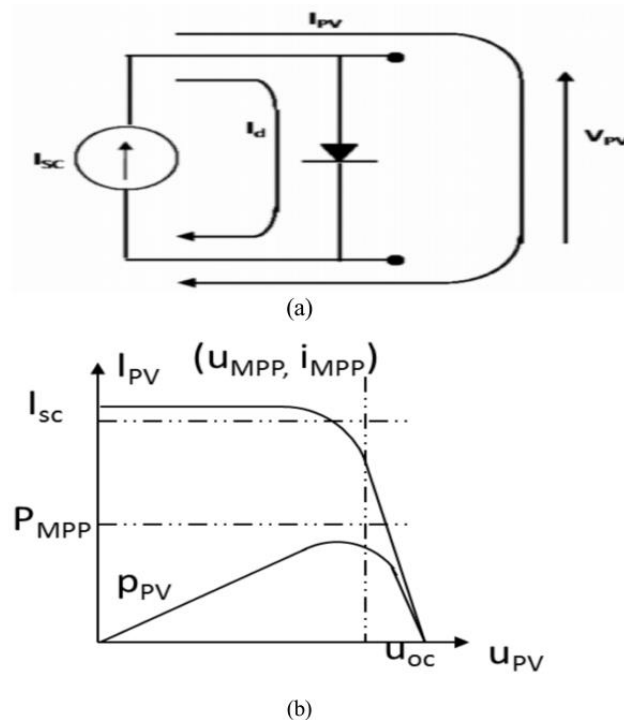


Figure.1. Electrical Model and Model with PV Cell

Its lack of a moving part and decreased wear are what account for its nearly 22-year lifespan. Photovoltaic cell assemblies are used to build solar energy-harvesting devices that generate electricity. A solar photovoltaic panel or module is made up of several linked cells placed in a single plane. One form of solar energy is solar power, which is the electrical energy produced by solar modules.

2.2. dSPACE Platform

The controller board's I/O ports and real-time hardware, which is based on power PC technology, making it the perfect choice for controller development in a variety of industries, including automobiles, robotics, aerospace, and drives. Your PC becomes a potent development system with the DS1104, enabling quick control prototyping. Simulink blocks for graphical configuration of A/D, D/A, digital I/O lines, incremental encoder interface, and PWM generation are provided via the real-time interface. Virtually any PC with a free 5-V PCI slot may install the board. You may simply execute your function model on the DS1104 R&D Controller Board by using Real-Time Interface (RTI). By dragging RTI blocks, you may graphically setup all I/O and minimize the amount of time needed for implementation. The inverter is controlled by a dSPACE DS1104 controller, which also serves as the linkage platform by the use of dSPACE between the real hardware and the MATLAB simulation inverter models. I/O block functions are performed by the ADC and DAC. The MATLAB/SIMULINK model window's build function, which is located under the model configuration parameter, allows the SIMULINK model to generate C-code automatically. Following compiler compilation, the real-time dSPACE DS1104 processor board was connected.

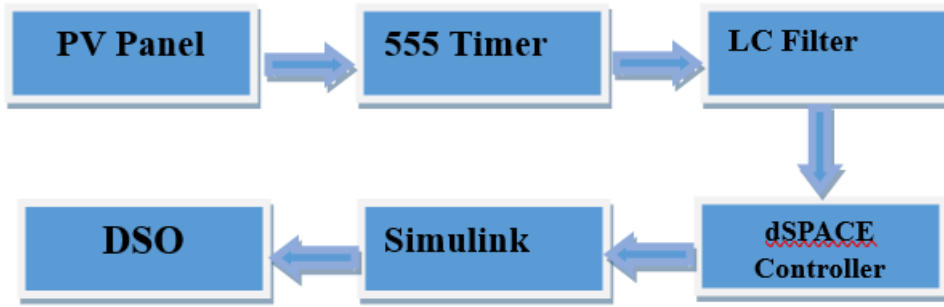


Figure.2. Block Diagram of Simulation Model

2.3. Working Principle

The setup depicted in Fig. 2 makes up the suggested PV inverter simulation model. PV system, Inverter, Filter, Step-Up Transformer, Load, Measurement, and Additional components Controller is the primary component.

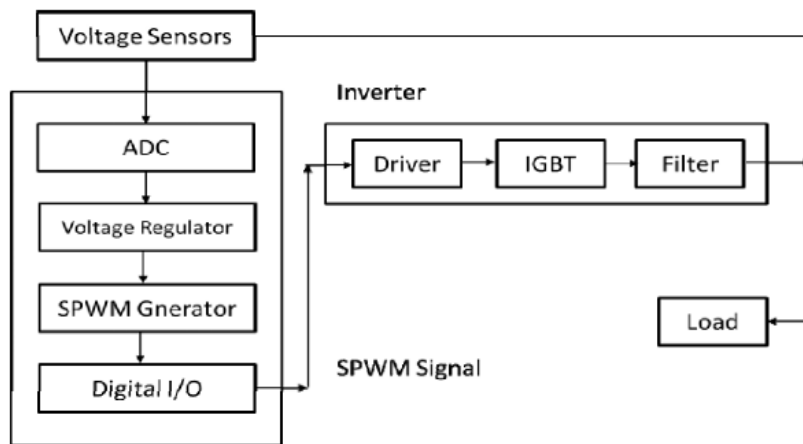


Figure.3. Block Diagram of DS1104 Controller Inverster

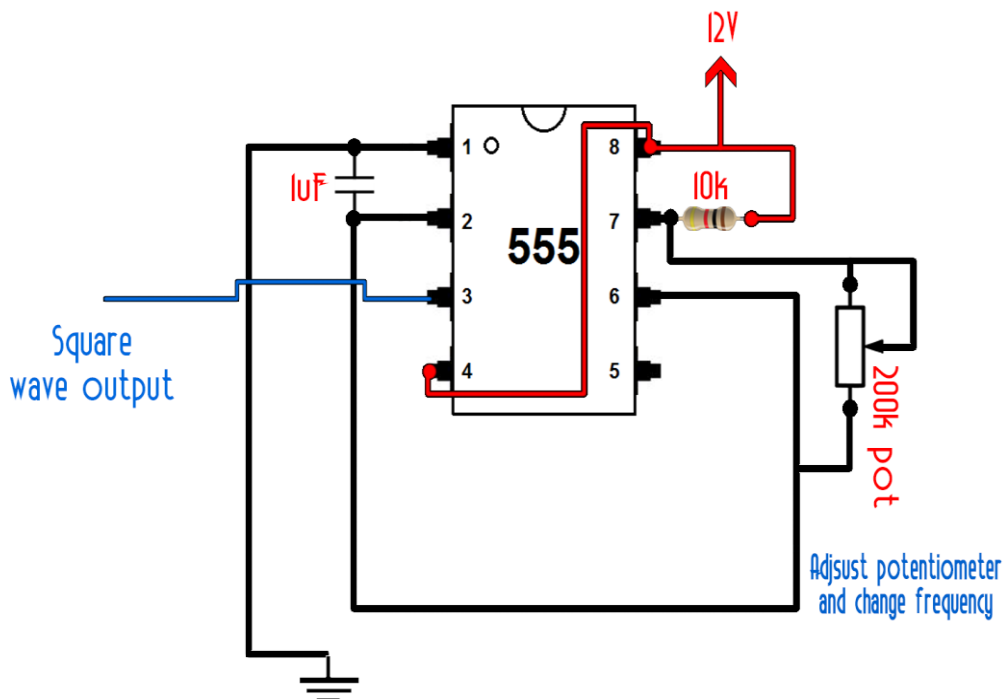


Figure. 4. AC Inverter Circuit

When this device is powered using the 12V battery, the 555 timer connected in astable mode produces square wave signal of 50Hz frequency. When the output is at logic high level, diode D2 will conduct and the current will pass through diode D1, R3 to the base of transistor Q1. Thus transistor Q1 will be switched on. When the output is at logic low level, diode D1 will conduct and current will flow via and D1 and R4 to the base of Q2, causing it to be switched on. This allows the DC voltage to be produced across the primary of the transformer at alternate intervals. The capacitor ensures that the frequency of the signal is at the required fundamental frequency. This 12V AC signal across the primary of the transformer is then stepped up to 220V AC signal across the transformer secondary.

An astable multivibrator can be used as an oscillator. Here an astable multivibrator using 555 timer is designed. We know, frequency of oscillations for a 555 timer in astable mode is given by:

$$f = 1.44 / (R1 + 2 * R2) * C$$

where R1 is the resistance between discharge pin and Vcc, R2 is the resistance between discharge pin and threshold pin and C is capacitance between threshold pin and ground. Also the duty cycle of the output signal is given by:

$$D = (R1 + R2) / (R1 + 2 * R2)$$

Since our requirement is $f = 60\text{Hz}$ and $D = 50\%$ and assuming C to be $0.1\mu\text{F}$, we can calculate the values of R1 and R2 to be 3K and 3K Ohms respectively. Here we prefer using a 150K potentiometer to fine tune the output signal. Also a ceramic capacitor of $10\mu\text{F}$ is used between the control pin and ground.

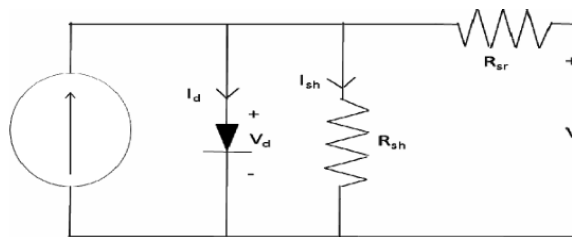


Figure. 5. PV Simulation

In single-phase systems, a single-phase inverter is a device that converts DC (direct current) power into AC (alternating current) power. These inverters are frequently utilized in situations where the end user needs AC electricity, such as in home appliances or grid-connected devices, but the power source, such as solar panels or batteries, produces DC electricity. Semiconductors such as MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) or IGBTs (Insulated Gate Bipolar Transistors) are commonly used in single-phase inverters, coupled with control circuitry to oversee the conversion process. They receive DC electricity from an input source, like a solar panel array, and transform it into AC power at a particular

voltage and frequency that is appropriate for the intended use. In renewable energy systems such as solar photovoltaic (PV) installations, these inverters are essential because they transform the DC electricity generated by solar panels into AC electricity that can be used with domestic appliances or the grid. They are also utilized in a number of other applications needing DC to AC power conversion in single-phase systems, such as electric car charging stations and uninterruptible power supply (UPS).

2.4. Simulation Modelling

The inverter and controller's thorough simulation model. The PV simulator is included. An electrical equivalent circuit of a current source antiparallel with a diode, a shunt resistance, and a series resistance can be used to simulate a solar cell. The inverter comes next, where a controller receives switching signals. To lessen harmonics, the low pass LC filter is connected.

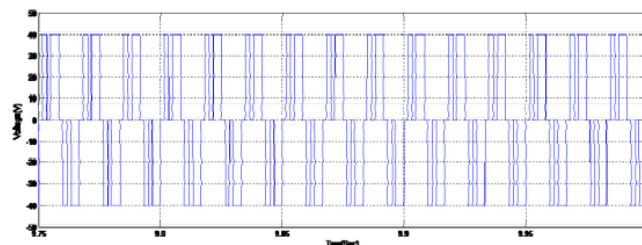


Figure.6. PWM Input Signal

The output voltage of the inverter is monitored both before and after the filter. The inductor's value is 25 mH, while the capacitor's value is 30 kVAR. Next, o/p is linked to the load. Since the system is closed loop, three phase voltages are measured, sent to the PLL, and the controller receives the signal from the PLL. The simulation is conducted at the dSPACE1104 Controller Board's sample frequency of 80 usec. A controller that measures the inverter's voltages controls the system.

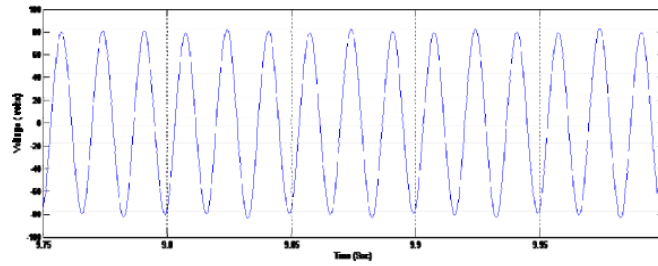


Figure.7. AC Sinusoidal waveform

3. Results

The simulation has been run and evaluated using Matlab/Simulink. The performance of the inverter and its controller model under various conditions was investigated using MATLAB/SIMULINK tools. As a result, the filter comes before the waveforms of the three-phase inverter output voltage. Each phase waveform was produced by the PWM switching method of the recommended inverter controller as a sequence of voltage pulses with a range of 0 V to ± 40 V. an enhanced image of the inverter's singlephase voltage, or v_a , waveform. Most of the higher-order harmonic components were reduced and eliminated by applying the LC filter. only the fundamental and lower order harmonics are displayed in the three-phase ac output voltage waveforms of the inverter after the filtering circuits. The output line voltage waveform (v_{ab}) of the inverter. The waveform patterns were sinusoidal. The frequency of the output waveform was calculated taking into account the time T, which was 0.02 seconds, or 50 Hz. Furthermore, there is a 120-degree separation between the three-phase waveforms, which represent the inverter output voltages v_a , v_b , and v_c . The phase waveform of the load current. Similar to the voltage waveform, this current waveform has sinusoidal characteristics. For solar applications, it can be concluded that the enhanced inverter controller was adequately efficient.

4. Conclusion

This page shows a three-phase PV inverter controller that is built on MATLAB/SIMULINK. The results showed that at 50 Hz, the inverter controller produces a stable and almost sinusoidal line voltage and current. Because of the controller's design, the block name carrier generator will compare the carrier wave with the modulating wave. By effectively suppressing the higher order harmonics and generating a sine waveform, the low pass filter is working well. The results of the simulation showed that there was a useful reference plan for verifying the controller's intended operation. The closed loop system of the inverter is presented along with the results.

REFERENCES

- [1]. G. E. Ahmad, H. M. S. Hussein, and H. H. El-Ghetany, "Theoretical analysis and experimental verification of PV modules," *Renewable Energy*, vol. 28, no. 8, pp. 1159-1168, 2003.
- [2]. F. Blaabjerg, Z. Chen, and S. B. Kjaer, "Power electronics as efficient interface in dispersed power generation systems," *IEEE Transactions on Power Electronics*, vol. 19, no. 5, pp. 1184-1194, 2004.
- [3]. L. Hassaine, E. Olias, J. Quintero, and M. Haddadi, "Digital power factor control and reactive power regulation for grid-connected photovoltaic inverter," *Renewable Energy*, vol. 34, no. 1, pp. 315-321, 2009.
- [4]. S. El-Barbari and W. Hofmann, "Digital control of a three-phase 4 wire PWM inverter for PV applications," in *Proceedings of the IEEE Industrial Electronics Society Conference (IECON '00)*, 2000.
- [5]. R. Frederick and B. H. Thomas, "A McMurray inverter controller," *IEEE transactions on industrial electronics and control instrumentation*, vol. 26, no. 3, pp. 156-160, 1979.
- [6]. J. Selvaraj and N. A. Rahim, "Multilevel inverter for grid-connected PV system employing digital PI controller," *IEEE Transaction on Industrial Electronics*, vol. 56, no. 1, pp. 149-158, 2009.
- [7]. S. Mekhilef and N. A. Rahim, "Xilinx FPGA based three-phase PWM inverter and its application for utility connected PV system," in *Proceedings of the IEEE Region 10 Conference on Computers, Communications, Control and Power Engineering (TENCON '02)*, pp. 2079-2082, October 2002.
- [8]. N. Hamrouni, M. Jraidi, and A. Chérif, "New control strategy for 2-stage grid-connected photovoltaic power system," *Renewable Energy*, vol. 33, no. 10, pp. 2212-2221, 2008.