Prototype Development And Testing of A Power Electronics Converter For Green Energy Using dSPACE

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Abstract- Green energy like Solar, Wind etc. which includes green electricity, is clean energy. In this case we use solar cell. It is produced with little-to-no environmental impact and does not dispense greenhouse gases into the air that contribute to global warming, the way fossil fuels do. By observing this advantages this paper presents a simulation modeling for hardware development of single-phase inverter using dSPACE DS1202 controller board for photovoltaic application. The controller acquired the advantage of linking the simulated model in MATLAB/SIMULINK environment to a prototype. It generates the pulse-width modulation signals for the switching of the Mosfet switches. The controller managed to stabilize 50 Hz sinusoidal ac output voltage of the inverter. The result obtained is near to expected ones, it suggests that the developed control system exhibits a good performance. Thus, it justified that the develop control strategy can be translated into the inverter prototype by utilizing the dSPACE platform.

Keywords: PV, dSPACE, Boost converter, Single-Phase Inverter, SPWM, MATLAB/SIMULINK

I. INTRODUCTION

Electricity produced by solar cell is clean and silent. Because they do not use fuel other than sunshine, PV systems do not release any harmful air or water pollution into the environment, deplete natural resources, or endanger animal or human health. PV cells were originally developed for use in space, where repair is extremely expensive, if not impossible. PV still powers nearly every satellite circling the earth because it operates reliably for long periods of time with virtually no maintenance. In order to exploit this pv direct current (dc) power source a inverter is used to convert the variable direct current (dc) output of a photovoltaic solar panel into a utility frequency alternating current (ac) that can be fed into a commercial electrical grid or used by local, off-grid electrical network.

There are many types of controllers employed in the implementation of PWM techniques, e.g. SPWM (Sinusoidal Pulse-Width Modulation), SVPWM (Space Vector Pulse-Width Modulation), for generating and regulating output of inverters. The SVPWM method is more complex compared to SPWM especially for multi-levels inverters [1]. Some of the controllers includes analogue circuit controllers, microcomputers, digital circuit controllers field programmable gate arrays (FPGA) and digital signal processors (DSP) [2]-[5]. Globally, researchers continue to develop and improve various areas of inverter, e.g. control algorithm, in effort to support the application of renewable energy. The opportunities are still exist for improving the inverter controller, since inverter failure remains one of the primary causes for PV system failure [6]. Thus, enhanced inverter controllers are necessary for improving the inverter performance in PV or renewable energy application. The DSP TMS320F2812 and FPGA-based PV inverters utilizing proportional-integral (PI) and PWM control algorithm have been developed in [4]-[5]. However, it requires users to develop a quite lengthy software programming or codes for the control algorithm. Perhaps, it is a time consuming task, especially for those with little or no experience dealing with the software programming. A different approach to this is by adopting the dSPACE DS1202 control platform which enables the user to employ the MATLAB/SIMULINK link tools for the development of control algorithm and simulation as well as hardware implementation. The dSPACE DS1202 control platform simplifies the control algorithm programming task by means of its library block sets. Moreover, the data and codes of the successfully simulated model can be linked and loaded directly to the controller for real time hardware operation. Using the graphical object-oriented package, a dSPACE system has enables the development of user-friendly inverter control panels for on-line monitoring and supervision [7]. A dSPACE system is quite popular in controlling platform and is widely used in automation systems and car manufacturing industries [8]. Besides the car manufacturing area, the dSPACE system can also be used as a control platform in the PV standalone inverter development. In this paper, the modeling for the hardware is developed and simulated in MATLAB/SIMULINK. Upon simulation success, it will be linked to the dSPACE DS1202 controller which enabling the inverter hardware control. In this paper, the modeling for the hardware is developed and simulated in MATLAB/SIMULINK. Upon simulation success, it will be linked to the dSPACE DS1202 controller which enabling the inverter hardware control. The model generates the SPWM
switching signals for the voltage control scheme to justify the implementation of the real inverter hardware. A detail control strategy of dSPACE platform has been discussed. The real-time implementation of the inverter controller is carried out with the integration of the dSPACE DS1202 platform.

II. DSPACE PLATFORM

The dSPACE DS1202 acquires the ability of linking MATLAB/SIMULINK model to the real hardware which is suitable to be used as an inverter control platform. This feature is accomplished by introducing the dSPACE RTI (Real-Time Interface) library blocks into the MATLAB/SIMULINK inverter model. An example of such blocks is the input-output (I/O) interface block. This blocks contain many library blocks such as DS1202ADC_Cx (analog to digital converter), DS1202DAC_Cx (digital to analog converter), DS1202BIT_OUT_Cx, DS1204SL_DSP_PWM (single-phase PWM signal) and DS1204SL_DSP_PWM3 (three-phase PWM signal) block. Using the MATLAB/SIMULINK Real-Time Workshop (RTW) function, the SIMULINK model with the dSPACE interface blocks is converted to the C-code automatically. Then this code is compiled by a compiler and linked to the real-time dSPACE DS1204 processor board. With the application of the dSPACE graphical user interface software, the monitoring of the performance and behavior of the inverter in real-time is made possible [9].

Moreover, user is able to change the controller parameters and observe the performance in a real time as well. The dSPACE DS1202 controller board has been utilized in the design of high frequency link inverter [10]. Another different way to control and regulate the ac output voltage is by utilizing the PI controller. A block diagram of the dSPACE DS1202 controller board is illustrated in Fig. 1.

It consists of a master processor PowerPC603 with speed of 250 MHz, 64-bit floating-point processor, and 16-bit DSP with processor of Texas Instruments TMS320F240 (slave). This controller is used since it is an ideal platform for prototype development system especially for cost-sensitive rapid control prototyping. It is specially designed for the development of high-speed multivariable digital controllers and real-time simulations in various fields [9].

![Fig.1 Block diagram of dSPACE Controller Board](image1)

![Fig.2 dSPACE 1202 Controller Board](image2)

III. SYSTEM CONFIGURATION

The system configuration for the single-phase inverter hardware development consists of system model and simulation model.

3.1 System Model

Fig. 3 Shows the block diagram of the PV inverter system model used in this work.
Fig. 3 Block diagram of the PV inverter system model used in this work.

This system model consists of PV array, dc boost converter, single phase inverter, filter, transformer, dspace control and load.

Boost converter steps up the input voltage magnitude to a required output voltage magnitude without the use of a transformer. The main components of a boost converter are an inductor, a diode and a high frequency switch. The duty cycle of a PWM signal determines the ratio between the input and output voltage. In case of an ideal switching device and when losses are neglected, the ratio between $V_i$ and $V_o$ can be calculated with formula:

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

Here $D$ = Duty cycle of the PWM signal and has between 0 and 1.

$V_0$ = output voltage of boost converter

$V_I$ = input voltage of boost converter.

Fig. 4 Fundamental circuit of PV inverter

As we can see that in formula as duty cycle increase $V_o$ increases. We shall use this property to adjust the output of the boost converter.

An inverter is basically a device that converts dc power into ac power at desired output voltage and frequency. The need of running AC loads on Solar energy leads us to the design of solar power inverter. Since the majority of modern conveniences all run on ac power, the inverter will be the heart of the solar energy.

By pulse width modulation technique which is characterized by the generation of constant amplitude pulse by modulating the pulse duration by modulating the duty cycle. Analog PWM control requires the generation of both reference and carrier signals that are feed into the comparator and based on some logical output, the final output is generated. The reference signal is the desired signal output maybe sinusoidal or square wave, while the carrier signal is either a sawtooth or triangular wave at a frequency significantly greater than the reference. There are various types
of PWM techniques and so we get different output and the choice of the inverter depends on cost, noise and efficiency. Here we are using SPWM technique for generating true sine wave. This SPWM single is used to control the high frequency Mosfet switches.

The rms output voltage of inverter is $V_{or} = V_s \sqrt{2d/\pi}$. So by changing the magnitude of sinusoidal reference wave in SPWM the duty cycle changes and rms output voltage changes and by changing the frequency of sinusoidal reference wave we can change the output frequency of inverter.

Through an LC filter, the output of Full Wave Bridge Inverter with SPWM signal will generate a wave approximately equal to a sine wave. This technique produces a much more similar AC waveform than that of others.

IV. SIMULATION MODEL AND CONTROL STRATEGY MODEL

This is the simulink model of converter. Here we are using dc voltage source of 12v in place of 12v pv cell.

When the sunlight falls on a PV cell a dc voltage is generated. This output voltage of PV cell depends on solar irradiation and temperature. So when these variable changes the output of PV cell changes.

By controlling the duty cycle of the PWM generator of boost converter we get desire output voltage.

Now the output of the boost converter fed into universal bridge (Mosfet bridge). Here we select Mosfet switch because due to some property like bidirectional, high frequency switch and low cost.

This simulink model shows the dSPACE control circuit mode,
The link of the Matlab Simulink with real inverter is done with the help of dSPACE.DS1202 control board using ADC block is used for reading the analog signal whereas DAC interface helps to take the pulse out to subsequent drive the Mosfet gate. The two type of PWM switching signals that generated from the dSPACE1202 controller board are used for the dc boost converter an inverter. The switching frequency of PWM generator of boost converter is 20khz and for inverter 50hz and carrier triangular frequency is 5khz. In fig.9 and 10 the upper and lower block generate SPWM signal and fed into inverter and boost converter gate driver circuit respectively.

4.1 Spwm Generator Model:

![Fig.9 SPWM Generator Model](image)

To cater the dc boost converter PWM the dSPACE controller board generates the required duty cycle and transfer it to digital input block. The output of the dSPACE controller can not provide the output current required to drive the gate capacitance of the associated Mosfet. So we have to use gate driver circuit. Driver circuit also helps to make isolation between system
control circuit which deals with low voltage and high voltage of inverter. Now the output of the driver circuit fed into Mosfet gate of boost converter and inverter. The output of the inverter connected to a filter and a step up transformer and finally a resistive load is connected across the transformer. Here the value of R and L is 0.1 ohm and 250 micro henry and R and C is 1ohm and 250microfarad respectively. First of all boost converter boost the voltage level of 12v to 24v and fed into inverter and the output of inverter goes into a step up transformer which rating is 12v to 220v,60w. and a 30w resistive load is connected across it.

V. RESULTS

These are the waveforms of dSPACE output for inverter and boost converter.

Fig.11 PWM and SPWM pulses

These signal fed into the gate driver circuit which is a power amplifier that accepts a low power input from a controller IC and produces the appropriate high current gate drive for power Mosfet. Finally we get the output from boost converter which is similar to dc and from inverter which is similar to ac.

Fig.13 Output Voltage waveform of boost converter

Fig.14 Inverter output voltage and current waveform
VI. CONCLUSION

The paper describes the prototype development and testing of SPWM inverter for PV application using dSPACE. An accurate SPWM inverter and its controller was simulated in the Matlab Simulink environment and prototype was tested in laboratory. The result obtained is near to expected ones. Further development process may be continue to reduce harmonics, regulation waveform based on the actual application environment like different type of load, local solar installation, module characteristics system with storage battery or without storage battery, grid connected hybrid stand alone system.

VII. REFERENCES


