Modeling of a novel power control scheme for Photovoltaic solar system

Sung-Joon Park*, *Member, KIMICS*

Abstract— Solar electric systems have very little impact on environment, making them one of the cleanest power-generating technologies available. While they are operating, PV systems produce no air pollution, hazardous waste, or noise, and they require no transportable fuels. In PV system design, the selection and proper installation of appropriately-sized components directly affect system reliability, lifetime, and initial cost.

In this research, we have studied the PWM(Pulse Width Modulation) signals. I proposed an efficient photovoltaic power interface circuit incorporated with a DC-DC converter and a sine-pwm control method full-bridge inverter.

In grid-connected solar power systems, the DC-DC converter operates at high switching frequency to make the output current a sine wave, whereas the full-bridge inverter operates at low switching frequency which is determined by the ac frequency. Thus, it can reduce the switching losses incurred by the full-bridge inverter.

Full-bridge converter is controlled by using microprocessor control method, and its operation is verified through computer aided simulations.

Index Terms—DSC, solar power system, sine-PWM

I. INTRODUCTION

In recent year, the utilization of natural energy has become an attractive alternative to fossil fuels because of the negative impact on the environment. As the conventional fossil fuel is depleting at a faster rate while the cost of electrical energy is increasing due to growing consumer demand, Photovoltaic energy becomes a promising renewable alternate source[1]-[3]. The emerging renewable energy, Solar and wind are expected to play a major role I supplying at least 5~10% of total electrical energy demand worldwide. Over 2 billion people in the developing world have no access to electricity. For these people, PV is probably the most economical and abundant power source today. It is anticipated that within the next 10 years, PV solar arrays will become cost competitive with traditional power sources in countries with extensive electrical infrastructure[4]-[5].

Still the PV modules have relatively low conversion efficiency.

I propose sine-PWM method. Because duty is controlled by sine wave, it is reduced harmonics distortion and increased power efficiency.

II. Design concept

An inverter is a dc to ac converter, it can be converter dc. voltage into ac for feeding into an ac utility network. It is possible to obtain a single-phase or a three-phase output from a power device[6].

Fig. 1 shows a general configuration of the inverter circuit. It consists of the dc input, the power circuit of four switches and the control circuit for switches. Also, the inverter power circuit consists of the main switching devices, which carry the load current and are subjected to the dc link voltage. The power circuit also includes protection circuits, such as reverse conduction diodes, when inductive loading is expected. Such a reactive feedback diode is characteristic of a voltage-source inverter, providing a reverse current path for load current that permits an energy flow from a reactive load, through the inverter, to the ac supply. These components are subjected to the same order of voltage magnitudes and currents as the main switching devices. Fig. 2(a) shows the input voltage waveforms of input dc source(Vi) and full-bridge switching waveform(S1~S4). Fig. 2(b) displays the PWM voltage patten.

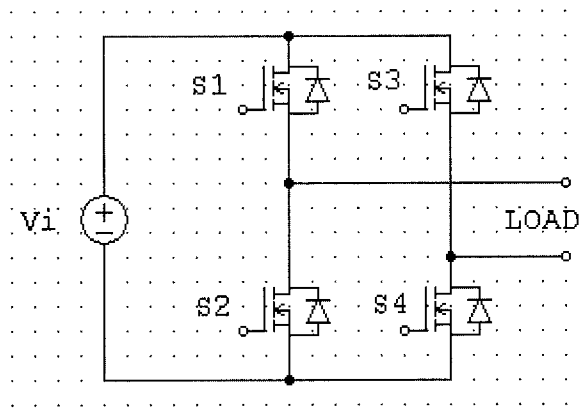
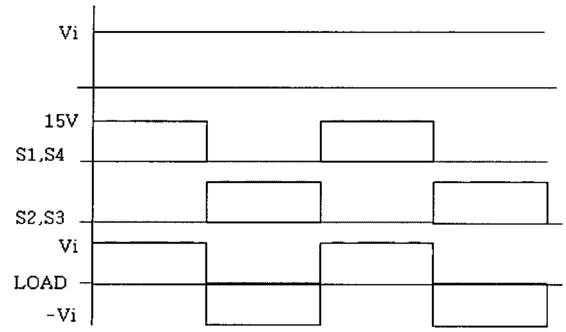
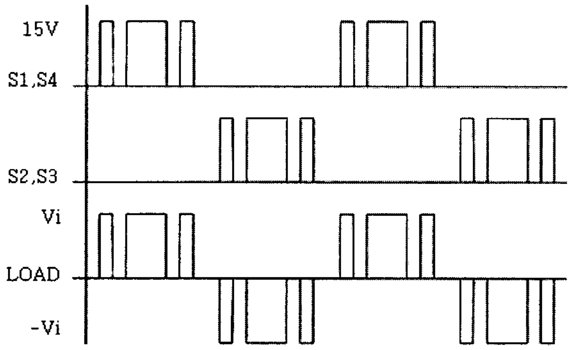


Fig. 1 A general configuration of the inverter circuit.

Manuscript received August 27, 2008; revised October 21, 2008. * Corresponding author Sung-Joon Park is with Power Generation Division, Korea Hydro-Nuclear Power, Busan, 619-711, Korea (Tel: +82-51-782-6080, Fax:+82-51-200-3235) Email: co2laser@chol.com



(a)

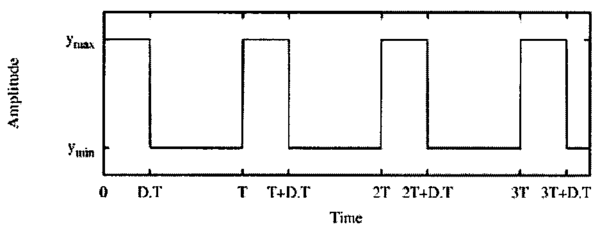


(b)

Fig. 2 (a) The input voltage waveform and
(b) the corresponding values of PWM voltage

PWM(Pulse-width modulation) uses a square wave whose pulse width is modulated resulting in the variation of the average value of the waveform.

If we consider a square waveform f(t) with a low value , a high value and a duty-cycle D (see figure 5-3), the average value of the waveform is given by:



y_{min} y_{max} D

Fig. 3 A square wave, showing definitions of $y_{\min}$, $y_{\max}$, D

$$y_{avg} = \frac{1}{T}\int_0^T f(t)dt$$

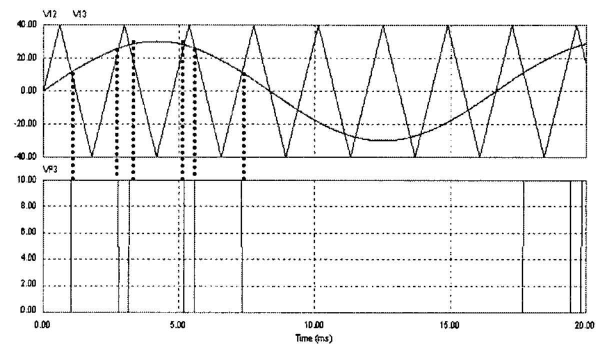
as $f(t)$ is a square wave, its value is $0 < t < D$ and $y_{\min}$ for $0 < t < DT$. The above expression then becomes:

$$y_{avg} = \frac{1}{T}\left(\int_0^{DT} y_{\max}dt + \int_{DT}^{T} y_{\min}dt\right) = \frac{D \cdot T \cdot y_{\max} + T \cdot (1-D)y_{\min}}{T}$$
$$= D \cdot y_{\max} + (1-D)y_{\min}$$

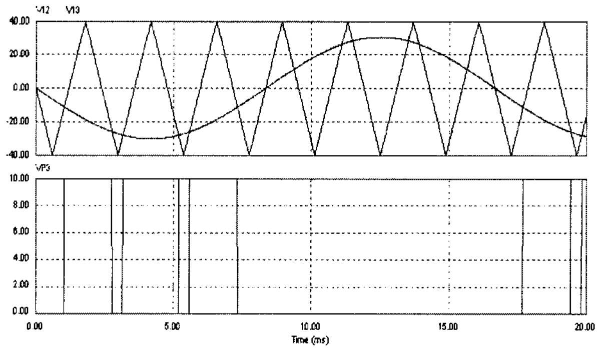
This latter expression can be fairly simplified in many cases where $y_{\min} = 0$ as $y_{avg} = y_{\min}D$. From this, it is obvious that the average value of the signal (y_{avg}) is directly dependent on the duty cycle D.

The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator.

When the value of the reference signal (the red sine wave in figure 4) is more than the modulation waveform (blue), the PWM signal is in the high state, otherwise it is in the low state.



(a)



(b)

Fig. 4 A typical method PWM pulse train

Fig. 4. A simple method to generate the PWM pulse train corresponding to a given signal is the intersective PWM: (a) signal S1, S4 (b) signal S2, S3

Fig. 4(a) and (b) show a simple method to generate the PWM pulse train corresponding to a given signal is the intersective PWM.

The signal (here the red sinewave) is compared with a triangle waveform (blue). When the latter is less than the former, the PWM signal (magenta) is in high state (1). Otherwise it is in the low state (0).

This method is hard to control switching and eliminate harmonics distortion.

Many digital circuits can generate PWM signals (e.g many microcontrollers have PWM outputs). They normally use a counter that increments periodically (it is connected directly or indirectly to the clock of the circuit) and is reset at the end of every period of the PWM. When the counter value is more than the reference value, the PWM output changes state from high to low (or low to high).

The incremented and periodically reset counter is the discrete version of the intersecting method's sawtooth. The analog comparator of the intersecting method becomes a simple integer comparison between the current counter value and the digital (possibly digitized) reference value. The duty cycle can only be varied in discrete steps, as a function of the counter resolution.

Fig. 5 displays the waveforms of the linear control PWM. It is easy to control harmonic distortion, but average voltage is linearly increased or decreased because of duty variation.

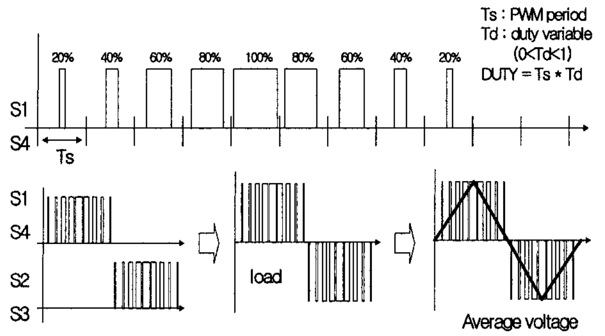


Fig. 5 Gate signal waveforms of linear PWM method

Fig.6 shows waveforms of the proposed sine-pwm. Because duty is controlled by sine wave, it is reduced harmonics distortion and increased power efficiency.

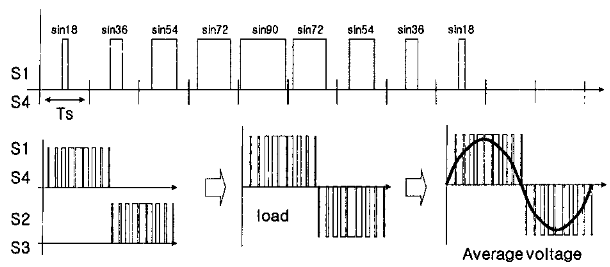


Fig. 6 Gate signal waveforms of sine PWM method

Fig.6 shows waveforms of the proposed sine-pwm. Because duty is controlled by sine wave, it is reduced harmonics distortion and increased power efficiency.

III. Simulation results

To assess the performance of the proposed interface circuit for photovoltaic power-generation, computer-aided simulation by PSpice is implemented first, and then a prototype was manufactured.

Fig. 7 shows simulated wavefrom of the output voltage. In this based simulation results, we installed a prototype.

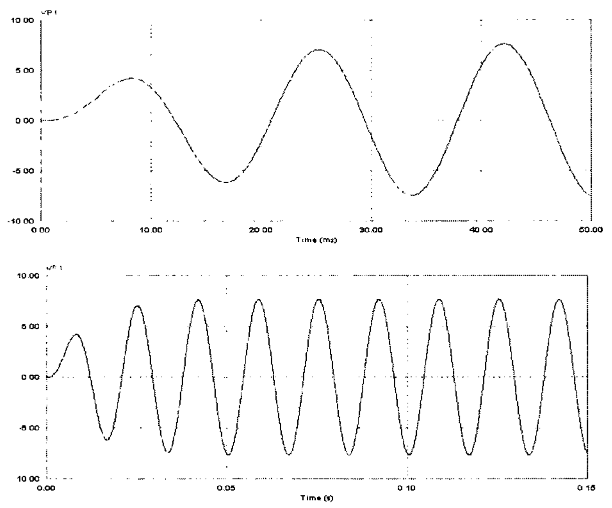


Fig. 7 The proposed inverter output simulation waveform

IV. Conclusion

A new sine PWM based on a stepping control method for Photovoltaic module Inverter was developed. Using this method, it is possible to adapt the load to the PV modules and to connect the high efficiency dc-dc converter.

Experimental results of the new approach showed that sine PWM method is better than that obtained with classic linear PWM method. Stepping switch Sp makes the output current a sinusoidal wave, it performs high frequency switch functions perfectly well. In order to more improve the efficiency, several experiments will be considered. This is being considered as future works.

REFERENCES

[1] International Energy Agecy, "World Energy Oulook," 2002.
[2] British Petroleum Statistical, "Renewables in Global Energy Supply An IEA Fact Sheet," 2002.
[3] International Energy Agency, "Trends in Photovoltaic applications, In selected IEA countries between 1992 and 2001, in Photovoltaic Power Systems Programme," Report IEA PVPST1-11, 2002.

[4] Green M.A., "Photovoltaics: Technology Overview", Energy Policy, Vol.28, pp. 989-998, Elsevier Sciency Ltd., 2000.
[5] MESSENGER R., VENTRE J., "Photovoltaic System Engineering", CRC Press LLC, Boca Raton, Florida, 2000.
[6] GREEN M. A., "Silicon Solar Cells" Centre for Photovoltaic Devices and Systems, University of South Wales, Sydney, 1995.

Sung-Joon Park
He received his B.S. degree in Electrical Engineering from Dongeui University in 2000. He received his M.S. degree in Electrical Engineering from Pusan National University in 2002. He worked at the LG Electronics Institute of Technology as a research engineer(LG Elite). He is currently working toward a Ph.D. in Electrical Engineering at Pusan National University. At present, he is employed by the Korea Hydro-Nuclear Power Company.