Demonstration of Real and Reactive Power Control Using SPWM Full Bridge Inverter for Grid Connected PV System

Muhammad Hosnee Mobarak, Tanvir Ahmed Majumder, MD Mahmudul Hassan

Abstract— When a number of generators are connected to bus bar, real power can be varied by changing the speed of the prime mover and reactive power can be varied by changing the excitation of the field. Similarly, when an inverter is connected to grid to supply power, proper process must be introduced to control the real and reactive power flow from the inverter. SPWM (sinusoidal pulse width modulation) can be a solution in this case. The main purpose of this paper is to use a real life SPWM module with a Full Bridge Resonant Inverter to observe the impact of SPWM that is how much real and reactive power can be controlled by this process. The effect of SPWM on sine wave output of inverter will also be observed whether it distorts the sine wave in any case or not. The system consists of an SPWM module, a Full Bridge Resonant Inverter, Impedances, Watt meters, Oscilloscopes etc.

Index Terms— Full Bridge Resonant Inverter, Grid Connected PV System, Load Sharing, Smart Grid System, Real Power, Reactive Power, SPWM

1 INTRODUCTION

LOAD sharing is defined as the proportional division of the kW and kVAR total load between multiple generator sets in a paralleled system [1], [2]. When generator sets operate in parallel, the engine speed governor of each generator set determines the proportional sharing of the total active power requirements (kW) of the system. The kW load sharing is achieved by increasing or decreasing the speed of prime mover. The control system of the generator sets (via the engine speed control system) monitors and controls the sharing of the total kW load in proportion to the relative rating of the engines on the systems' generator sets. When generator sets operate in parallel, the alternator field excitation system of each generator set controls the proportional sharing of the total reactive power requirements (kVAR) of the system. The kVAR load sharing is achieved by increasing or decreasing the field excitation to the systems' alternators. The voltage control system of the generator sets (via the alternator voltage control system) monitors and controls the sharing of the total kVAR load in proportion to the relative rating of the alternators on the systems' generator sets. Load sharing is essential to avoid overloading and stability problems on the systems' generator sets [3], [4]. To meet the very increasing demand of power in a developing country, the existing generators are not sufficient. More source of power must be added to system. The sources must be of low cost and more convenient to use. Renewable energy sources can be used in this case. Energy can be stored in DC batteries, converted into AC power and supplied to the grid when needed [5]. For grid connected inverters, SPWM can be a proper way to control real and reactive power. This research has been done predominantly for grid application. The system and arrangements described in this paper demonstrates how real and reactive power flow from an inverter to grid can be controlled using SPWM.

- *Muhammad Hosnee Mobarak has completed Bachelor of Science in Electrical and Electronic Engineering from Ahsanullah University of Science and Technology, Dhaka, Bangladesh.Email: m.hosnee@live.com*
- *Tanvir Ahmed Majumder has completed Bachelor of Science in Electrical and Electronic Engineering from Ahsanullah University of Science and Technology, Dhaka, Bangladesh.Email: actanvir@gmail.com*
- *Md Mahmudul Hassan has completed Bachelor of Science in Electrical and Electronic Engineering from Ahsanullah University of Science and Technology, Dhaka, Bangladesh.Email: mhsetu@hotmail.com*

2 LITERATURE REVIEW

Pulse-width modulation (PWM) is a modulation technique that conforms the width of the pulse based on modulator signal information. Though this modulation technique can be used to encode information for transmission, its main use is the controlling power to electric devices. PWM is a way of delivering energy through a succession of pulses rather than a continuously varying (analog) signal. By increasing or decreasing pulse width, the controller regulates energy flow. PWM has a wide range of applications like telecommunication, power delivery, voltage regulation, audio effects and amplification, electronics etc. In telecommunications, PWM is a form of signal modulation where the widths of the pulses correspond to specific data values encoded at one end and decoded at the other. PWM is widely used to control the amount of power delivered to a load without incurring the losses that would result from linear power delivery by resistive means. Special types of PWM like SPWM

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(Sinusoidal pulse width modulation) signals are used in micro inverter design which is used in solar or wind power applications [5], [6]. Our main objective is to find a proper solution of controlling real and reactive power flow from the inverter connected to grid. For that purpose, we have run a lot of experiments in our laboratory. There we have found SPWM could be a solution in this case. Afterwards, we have run further research to observe how real and reactive power can be controlled using SPWM.

3 The Experimental Set Up for Power Control and Results

To see the impact of SPWM on real and reactive power, we have used a real life SPWM generator with a Full Bridge Resonant Inverter [5]. The system also consists impedances, watt meters, and oscilloscope etc. for measurement purpose. The arrangement is according to the following circuit diagram:

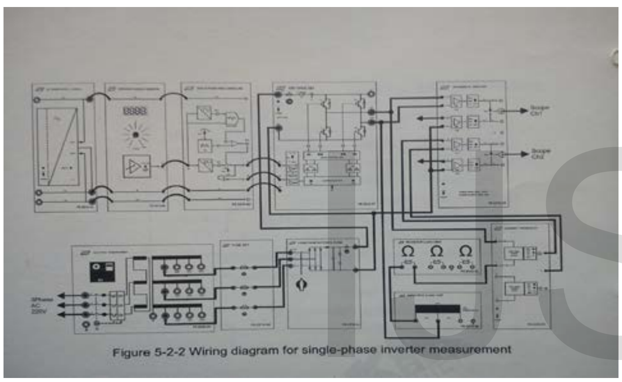

Fig. 1. Circuit diagram for Single phase inverter measurement

The real life image of the modules which we have used in our laboratory is given below:

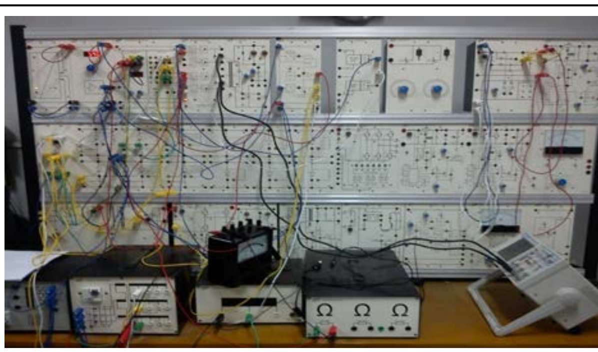

Fig. 2. System arrangement to control real and reactive power

Surprisingly, we have noticed that SPWM has a great impact on real power variation. We have got 3 sets of data of variation of real power. The sets are given below:

Low Range Data Table 1:

I/P Voltage(Volts)	Control Voltage(Volts)	Real power(Measured in Watt when frequency is 1x)	Real power(Measured in Watt when frequency is 5x)	Real power(Measured in Watt when frequency is 15x)
36	10	2.70	2.12	1.85
36	9	2.45	1.82	1.60
36	8	2.25	1.5	1.30
36	7	2.10	1.25	1.05
36	6	1.97	1.02	0.90
36	5	1.90	0.85	0.72
36	4	1.80	0.70	0.60
36	3	1.75	0.60	0.51
36	2	1.72	0.52	0.45

Low Range Data Table 2:

I/P Voltage(Volts)	Control Voltage(Volts)	Real power(Measured in Watt when frequency is 1x)	Real power(Measured in Watt when frequency is 5x)	Real power(Measured in Watt when frequency is 15x)
20	10	0.92	0.72	0.65
20	8	0.78	0.52	0.45
20	6	0.68	0.35	0.30
20	4	0.62	0.25	0.22
20	2	0.60	0.18	0.18

Moderate Range Data Table (Real life voltage):

I/P Voltage(Volts)	Control Voltage(Volts)	Real power(Measured in Watt when frequency is 1x)	Real power(Measured in Watt when frequency is 5x)	Real power(Measured in Watt when frequency is 15x)
168	10	85	79	63
168	9	75	67.5	60
168	8	64	54	51
168	7	53.5	43	40
168	6	46	34.5	31
168	5	39	25.5	23.5
168	4	33	19	16
168	3	29	13	12
168	2	26	10.5	9.5
168	1	23.5	9	8

Change of duty cycle with the change of control voltage can be viewed from the following figures:

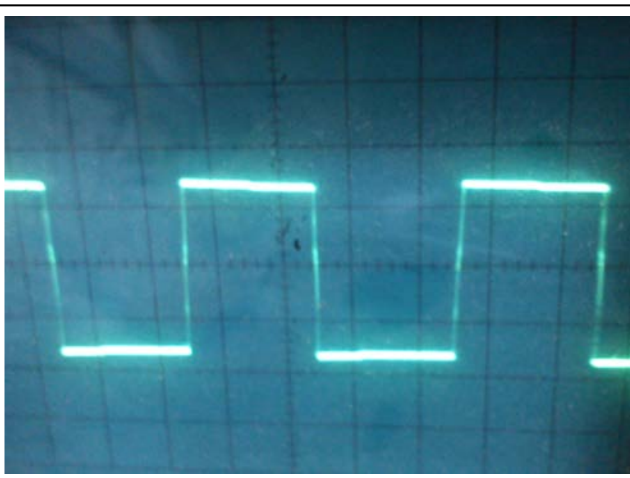

Fig. 3(a). Wave shape of duty cycle when control voltage is set to minimum

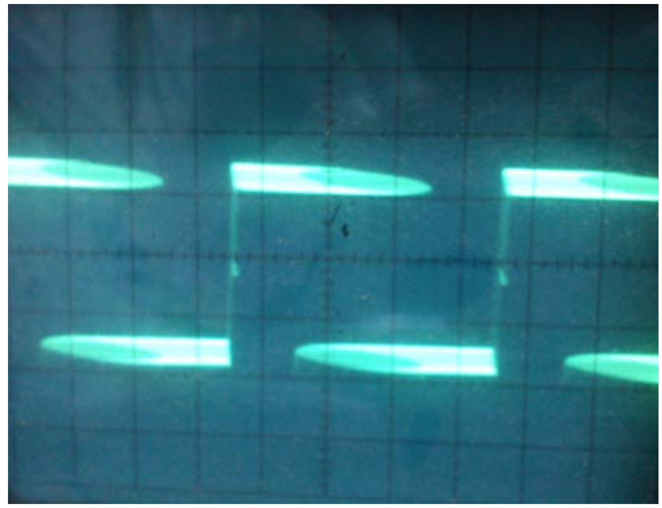

Fig. 3(b). Wave shape of duty cycle when control voltage is set to medium position

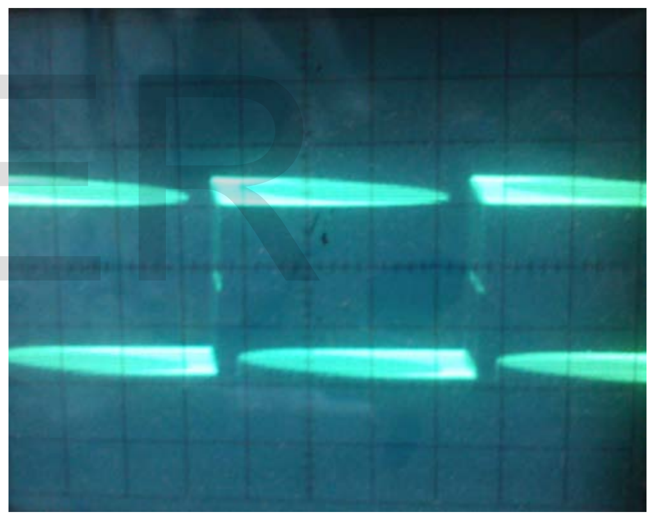

Fig. 3(c). Wave shape of duty cycle when control voltage is set to maximum

4 Analysis of Experimental Data and Decision

We have used MATLAB to plot the output real power vs. the control voltage for different frequencies. The plots and their corresponding findings are given in the following page with a brief description:

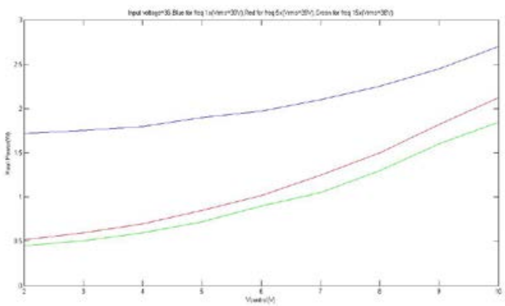

Fig. 4(a). Output real power vs. the control voltage (according to low range data table 1 for different frequencies; Blue for freq 1x, Red for freq 5x, Green for freq 15x)

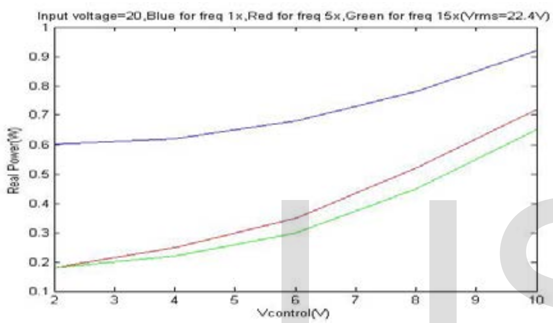

Fig. 4(b). Output real power vs. the control voltage (according to low range data table 2 for different frequencies; Blue for freq 1x, Red for freq 5x, Green for freq 15x)

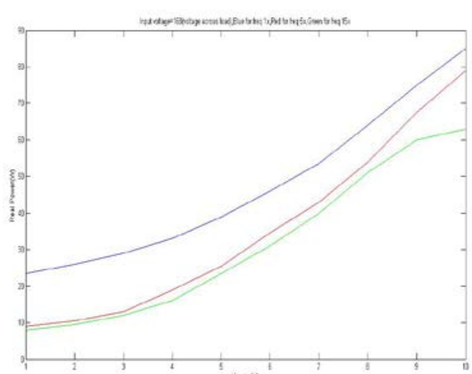

Fig. 4(c). Output real power vs. the control voltage (according to moderate range data table for different frequencies; Blue for freq 1x, Red for freq 5x, Green for freq 15x)

In this research, we have only observed the effect of varying the modulation index on the variation of output voltage and real power. By increasing the modulation index, we have found an increasing trend in output real power in a proportional manner. In addition to that, we have also seen the effect of frequency modulation of the SPWM controller. At higher frequency, the loss is higher but the harmonic distortion is minimized. At lower frequency, we have found that the loss is less but the harmonic distortion is much higher. Moreover, at lower frequency it seems to be a lot noisier. The effect of variation on reactive power is not yet observed due to lack of proper equipment needed for the experiment. But it is our assumption that reactive power can also be controlled using SPWM. The effect of a filter is also to be examined in the future.

5 Conclusion

In a smart grid system, comprising of different types of renewable energy sources and conventional power plants, a robust control strategy for proper load sharing for the grid-connected PV system is necessary. In our research, we have investigated the use of SPWM inverter for load sharing purposes. The load sharing task can be performed by controlling both modulation index and phase angle of the inverter. Sine PWM technique is adopted for generating switching signals for the inverter. It is proposed through simulation that by adjusting modulation index and phase angle, the real power delivered by the inverter branch can be adjusted keeping reactive VAR constant. The reactive VAR is also shown to be adjusted keeping real power constant. Again both the real power and reactive VAR are shown to be adjusted keeping the currents in phase or out of phase. The PV inverter can supply the total load or share a portion of it according to the demand. The excess power developed by the PV array can be fed back to the utility.

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