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Simulation Based on Open Loop and Close loop Three Phase Sinusoidal Pulse Width Modulation Inverter

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Abstract- *High frequency triangular carrier wave is compared with sinusoidal reference wave for desired frequency. The width of each pulse is varied in proportion to the amplitude of a sine wave called SPWM. The inverter should work in voltage control mode in standalone operation. SPWM techniques reduce the harmonics of output voltage compared to single pulse width modulation and multi pulse width modulation. Inverter with single stage three phase using bipolar SPWM modulation gives good performance and efficiency because it offers the advantage of effectively doubling the switching frequency of the inverter voltage and reducing the harmonics on output voltage.. The dc link voltage has got stable voltage irrespective of AC load parameter. The single stage three phase Inverter scheme employs a VSI inverter across R Load. The two stage topology will be decided on the basis of simulation using the MATLAB/PSIM software and hardware implementation. The control algorithm for the system will be implemented on a low cost microcontroller [7].*

Index Terms- *PV cell, SPWM, Harmonics, Grid connected inverter (GCI).*

I. INTRODUCTION

The renewable energy such as Photovoltaic (PV), Fuel cell, micro turbines and other conversion technologies for distributed power (DP) generator [2]. Due to the switching action of the inverter there is a distortion of sinusoidal voltage and current waveform caused by harmonics from grid connected inverter is one of the major power qualities. SPWM technique is quite simple and reduces the harmonics content as compare to multiple pulse width modulation. The gating signals are generated by comparing a sinusoidal reference signal with a triangular carrier wave.

In This paper introduces design for the VSI inverter simulation with MATLAB. This method quite simple and give benefits to reduce the design period Photovoltaic based 3 phase VSI inverter shown in Fig.1.

Energy crisis and environmental pollution make people pay much attention to renewable energy. Specifically, solar energy is considered to be one of the most useful natural energy sources because it is free, abundant, pollution-free, and most widely distributed and photovoltaic (PV) grid-connected generation system is the trend of solar energy application. To achieve high efficiency of power converter is the key technologies of the power converter interface for the grid connected generation system. In PV grid-connected system, a PWM inverter used for a grid-connected scheme is controlled in order to produce an output current in phase with the utility voltage thus to obtain a unity Power Factor. Fig .1 shows a single-stage system. The solar cell array converts the solar energy from the light energy into dc power, and the dc power serves the input of the grid connected inverter (GCI) [2][6].

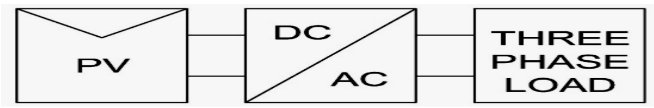

Fig.1 Single-stage three phase inverter with no isolated.

II. MAIN CIRCUIT CONFIGURATION

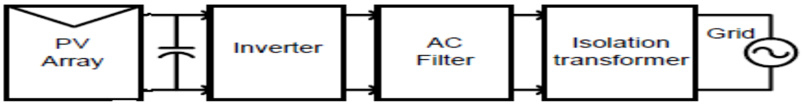

Fig.2 Block diagram of single-stage photovoltaic system.

A. The Principle of System

In this paper, the topology of single-stage system is mainly considered. The configuration of the grid-connected power System is shown in Fig.3.

The whole system is composed of the PV array, three phase VSI inverter, which includes six power semiconductors switches.VSI inverter is converted to photovoltaic dc energy to ac energy using spwm control technique.

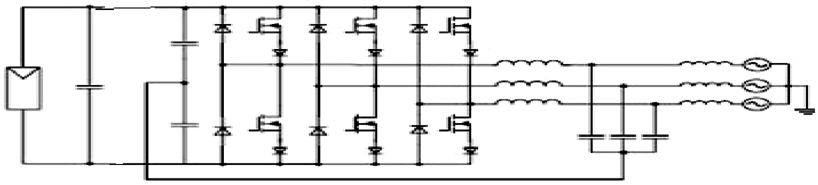

Fig.3 Power Schematic of the proposed grid connected single-phase photovoltaic inverter.

III. CONTROL STRATEGY

A. Sinusoidal PWM technique

Inverter has to produce pure sine wave Three-phase output, which should be according to standard. Also it has to control power control according to weather condition and grid parameters. Micro Controller will do the control for the entire inverter system. The reason Micro Controller is important is that inverter control functions that have traditionally been accomplished with hardware can now be accomplished with software. Mainly two PWM modulation scheme is popular for control inverter,

1. PWM with unipolar and bipolar operation.
2. Sinusoidal PWM with three phase inverter.

1.1 PWM with unipolar and bipolar operation

If the half-cycle sine wave modulation, the triangular carrier only in a positive or negative polarity range of changes, the resulting SPWM wave only in a polar Range, called unipolar control mode. If the half-cycle sine wave modulation, triangular carrier in continuous change between positive and negative polarity, the SPWM wave is between positive and negative changes, known as bipolar control. Unipolar and bipolar modulations are shown in Fig. 3.15 An improved frequency spectrum with less input ripple current is possible with unipolar PWM switching. In unipolar switching the inverter output voltage is made to swing between 0 and for the positive half cycle and zero and for the negative half cycle of the fundamental frequency. Here each

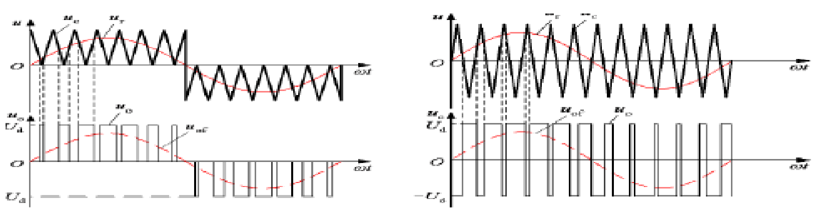

Fig.4: PWM with unipolar and Bipolar switching for a single-phase full bridge inverter

Inverter legs are switched independently with a 180^0 phase-shift between the switching patterns for the two legs. A typical waveform is shown in for both the inverter legs same triangular waveform is used. But the sine waves used are of the same amplitude, with a 180^0 phase-shift. Here the output voltage will have maximum fundamental amplitude of VDC and it swings between zeros and V_{DC} for the positive half cycle and zero and-V_{DC} during the negative half cycle.

1.2. Sinusoidal PWM with three phase inverter

In sine-triangle three-phase PWM inverter, three sinusoidal reference voltage waveforms at each phase are compared to the same triangular carrier. The three-reference voltages are 120° apart,

$$V_{a.ref} = V_{ref} \sin (2 \text{ f x t})$$
$$V_{b.ref} = V_{ref} \sin (2 \text{ f x t} - 2\pi/3)$$
$$V_{c.ref} = V_{ref} \sin (2 \text{ f x t} + 2\pi/3)$$

With this method, switch S1 is ON when triangular carrier is less than $V_{a,ref}$ and S4 is OFF. The output voltage is equal to V_{dc}. The same principles apply for other legs of the converter. To summarize the principles.

$$V_{a.ref} > V_{tri} = \text{S1 is ON}$$
$$V_{a.ref} < V_{tri} = \text{S4 is ON}$$
$$V_{b.ref} > V_{tri} = \text{S3 is ON}$$
$$V_{b.ref} < V_{tri} = \text{S6 is ON}$$
$$V_{c.ref} > V_{tri} = \text{S5 is ON}$$
$$V_{c.ref} < V_{tri} = \text{S2is ON}$$

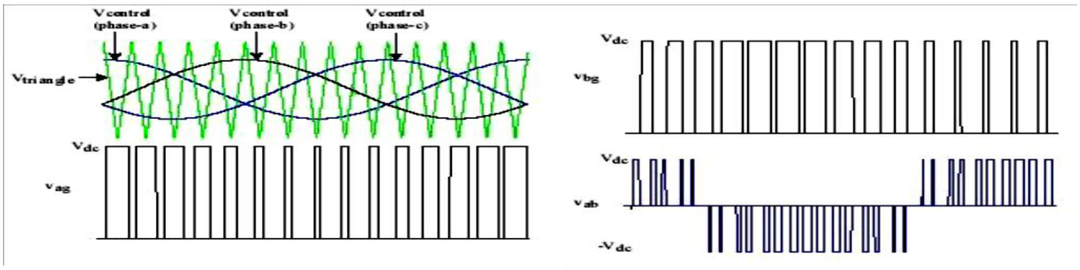

Fig.5 Sine triangle, voltage reference and phase voltage

Fig. 5 shows the waveform of the sine triangle and the voltage reference comparison. In sine triangle PWM, the amplitude modulation ratio (or index) ma is defined by,

$$m_a = \frac{peak\ amplitude\ of\ Vtri}{amplitide\ of\ Vref}$$

The frequency of the triangular waveform fpwm is the frequency of the inverter. The frequency of the reference is the fundamental output frequency. For a grid connected PV, it is the frequency of the grid 60 Hz. The ratio of those two frequencies gives the frequency modulation index.

$$m_f = \frac{PWM\ frequency\ fpwm}{fundamental\ frequency\ f1}$$

The line to neutral fundamental frequency output voltage of the inverter is defined by,

$$Van.1 = \frac{MaVdc}{2} \sin (2\pi f * t)$$
$$Vbn.1 = \frac{MaVdc}{2} \sin (2\pi f * t - \frac{2\pi}{3})$$
$$Van.1 = \frac{MaVdc}{2} \sin (2\pi f * t + \frac{2\pi}{3})$$

The switching frequency should be higher to reduce the harmonics at the output. Thus, less filter harmonics will be used. However, switching losses increase in proportion to the switching frequency. In PV system, the DC voltage that is the output from the PV cell is the input for the inverter. A controller should be implemented in order to maintain theDC voltage in a constant manner. In addition, the voltage reference determines the output frequency and amplitude desired.

The function of inverter DC/AC is to generate AC output current I_{ac} in phase with the AC grid voltage V_{ac} switching frequency F_{pwm} is much greater than the AC line frequency (60Hz or 50Hz). By controlling the switch duty ratio D of the inverter, it is possible to generate a sinusoidal current Iac in phase with the AC line voltage. The input DC voltage Vdc must be greater than the peak AC line voltage.

III. SIMULATIONS OF OPEN LOOP/CLOSE LOOP THREE PHASE INVERTER USING MATLAB

A. Simulation on open loop three phase spwm based vsi inverter across R load

Using the MATLAB simulation program achieved the result for three phase voltage source inverter using SPWM Techniques across R load.VSI Inverter is a converted 400 V DC Voltage to 312V AC line to line voltage and 166 V phase AC voltage. (Load Resistance R=10 Ohms).

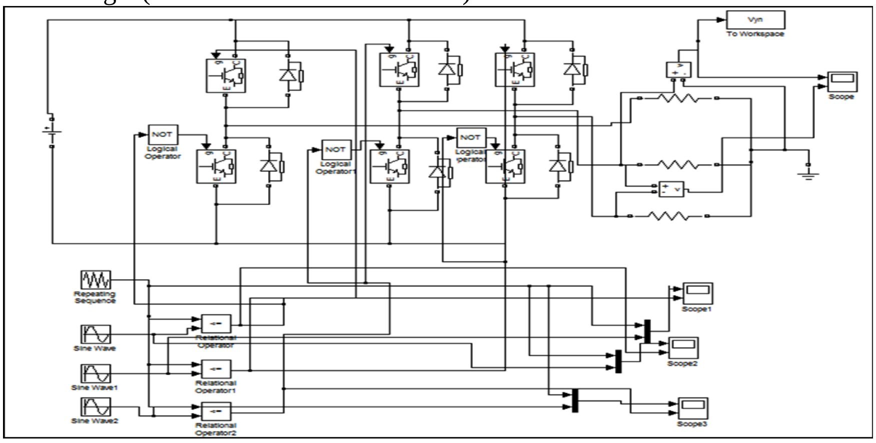

Fig 6: Simulation on open loop three phase Spwm based VSI inverter with R load.

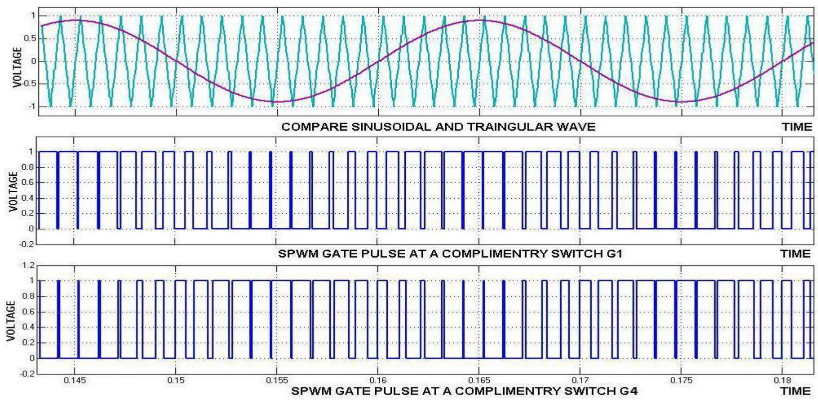

Fig 7: Gate Pulse on Complimentary IGBT Switches G1 and G4.

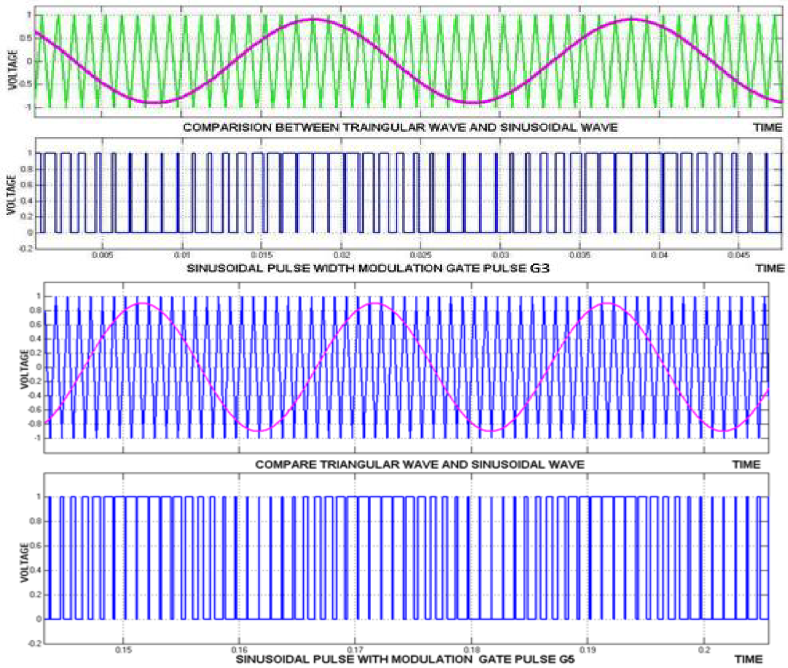

Fig 8: Gate Pulse on IGBT Switches G3 and G5.

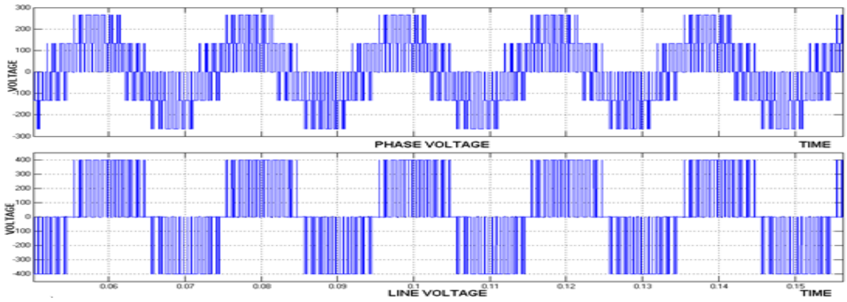

Fig. 9: Phase Voltage and Line Voltage across R Load.

IV. SIMULATION ON CLOSE LOOP THREE PHASE SPWM BASED VSI INVERTER ACROSS R LOAD

Using the MATLAB simulation program achieved the result of close loop three phase voltage sourse inverter using SPWM Technique across R Load. VSI Inverter is a converted 400 V DC Voltage to 312V AC voltage line to line and 165V phase AC voltage. Close loop control algorithm is made up of several functional blocks such as phase-locked loop PLL, axes transformation unit (abc/dq frame), voltage regulations, proportional-integral (PI) controllers and PWM signals generation unit. (Load Resistance R=10 Ohms)[5][6].

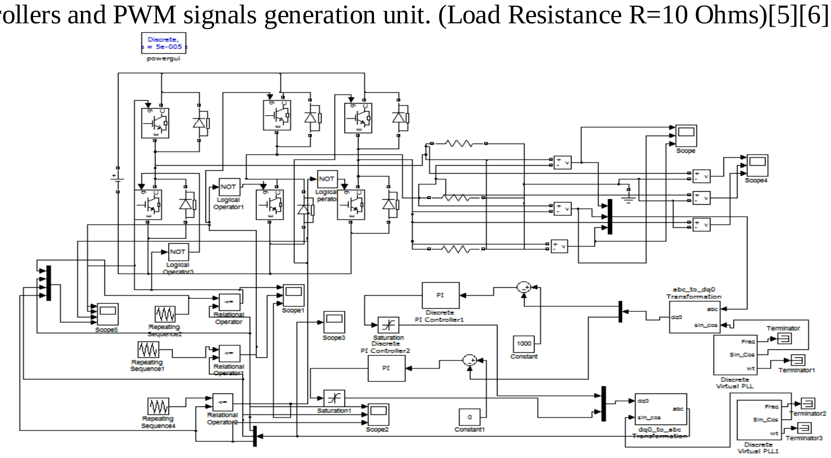

Fig. 10: Simulation on a close loop Three Phase SPWM based VSI Inverter across R Load

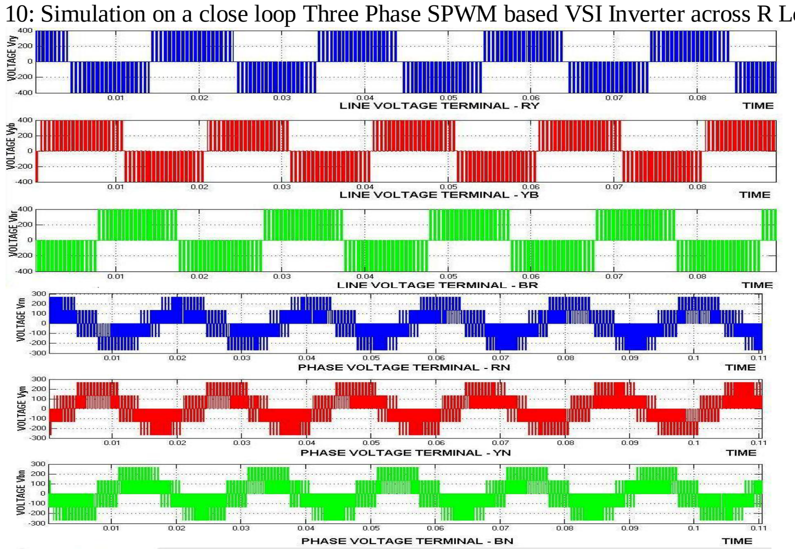

Fig.11: Line Voltage and Phase Voltage across R Load

CONCLUSION

The SPWM method offers a good opportunity for the realization of the three-phase inverter control and reduced harmonic distortion. In case of the three-phase inverters it is better to use the SPWM method with three carrier waves.

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