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A Voltage Control Technique for Single Phase Inverter

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Abstract: This paper describes an improved voltage control technique for single phase inverter. Voltage control technique is a single loop control technique. It has simplicity, outstanding stability, easy implementation and robustness. In this study, output voltage of an inverter is controlled by comparing it with a reference voltage on an instantaneous basis to produce switching pulses for the inverter. In order to maintain constant switching frequency of these pulses, switching logic is applied and it is implemented in FPGA. Simulation and experimental results show that output voltage of the inverter matches almost exactly to the reference voltage with the proposed technique.

Keywords: - voltage control technique, inverter, switching logic, reference voltage, Field Programmable Gate Array (FPGA).

I. INTRODUCTION

A standalone system defines system voltage and frequency on its own. In case of standalone system, the current of the load is limited as the load has limited power consumption. At the same time, load demands constant voltage [1]. Therefore it is required to regulate the output voltage of an inverter.

Most popular method of controlling the output voltage of an inverter is Pulse-Width Modulation (PWM). In this method, a fixed dc input voltage is applied to the inverter and a controlled ac output voltage is produced by adjusting the on and off periods of the inverter switches. Commonly used PWM techniques are sinusoidal PWM, Overmodulate PWM, Selective-Harmonic-Elimination etc [2]. Among these, sine-triangle PWM is the conventional method.

Sine-triangle PWM is a method of controlling the output voltage of a Voltage Source Inverter (VSI) where a high frequency triangular carrier signal is compared with a sinusoidal modulating signal to produce on-off signals for the inverter as shown in fig.1. The triangular and sinusoidal signals are fed to the inverting and the non-inverting terminals of the comparator respectively. The comparator output as shown in fig 1 is then used to control the high side and low side switches of the particular pole [3-4]. In sine-triangle PWM inverter the widths of the pole-voltage pulses, over the output cycle, vary in a sinusoidal manner.

In this method, higher order harmonics can be filtered easily. But the main drawback of this method is when DC bus voltage or load changes output voltage cannot be adjusted. To overcome this issue, a switching logic based voltage control technique of a single phase inverter is proposed here. In this technique, the reference voltage and output voltage of the inverter are compared on an instantaneous basis in order to maintain constant amplitude and frequency of the voltage across the load.

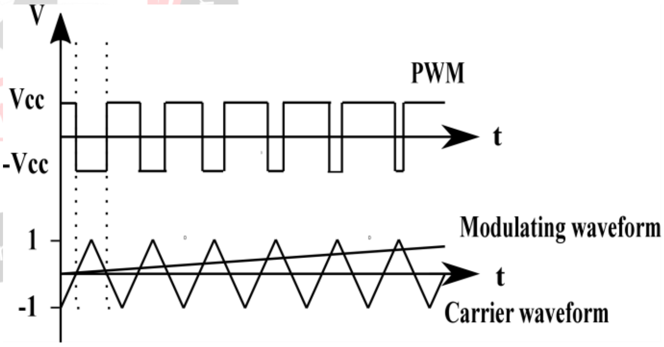

Fig.1.Sine-triangle PWM

This paper is organized as follows: Section II presents proposed voltage control technique. Simulation result of the proposed control technique is shown in section III. In section IV, experimental results are shown to illustrate the good performances of the proposed method. Section V presents conclusion. Future scope is given in section VI.

II. PROPOSED VOLTAGE CONTROL TECHNIQUE

Consider a single-phase full-bridge inverter circuit shown by fig.2, which may be used in stand-alone battery or photovoltaic systems [5-6]. Using a dc source, a dc voltage of V_{dc} is supplied to the inverter and R_L is connected as load to the inverter. The inverter output is filtered by using LC filter. The output voltage of the inverter is controlled by the switches S_1, S_2, S_3 and S_4.

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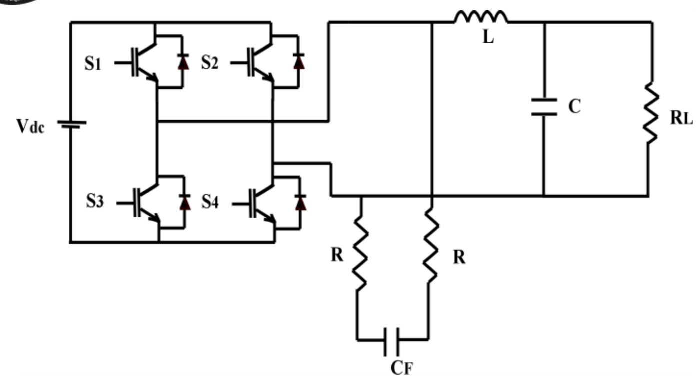

Fig.2.Single phase inverter

In the proposed technique, there is a feedback as shown in fig.2 for output voltage regulation with the change in input dc link voltage and load. The feedback mechanism involves RC filter. To obtain a sinusoidal voltage profile at the output, a sinusoidal reference is required. In this technique, constant frequency switching signals are produced for the inverter switches by comparing output voltage of the inverter with the reference voltage [7-8]. For making constant switching frequency, a constant time interval is set for two consecutive rises or falls of feedback voltage. This is performed in the switching logic block as shown in fig 3.

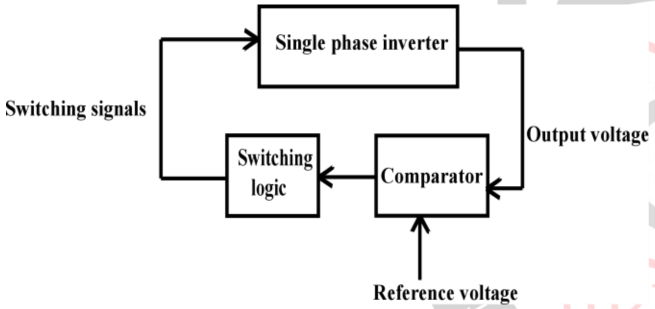

Fig.3.Block diagram

When switches S_1 and S_4 are ON and S_2 and S_3 are OFF as show in fig.2, capacitor C_F will charge. Voltage across C_F, V_C is

$$V_C = (V_{dc} - V')\left(1 - e^{-\frac{t}{2RC_F}}\right) \qquad (1)$$

$$\frac{dV_C}{dt} = \frac{(V_{dc} - V')}{2RC_F}\, e^{-\frac{t}{2RC_F}} \qquad (2)$$

When switches S_2 and S_3 are ON and S_1 and S_4 are OFF, capacitor C_F will discharge. Voltage across C_F, V_C is

$$V_C = (-V_{dc} - V')\left(1 - e^{-\frac{t}{2RC_F}}\right) \qquad (3)$$

$$\frac{dV_C}{dt} = \frac{-(V_{dc} + V')}{2RC_F}\, e^{-\frac{t}{2RC_F}} \qquad (4)$$

where V_{dc} is the dc link voltage, V' is the instantaneous reference voltage and $2RC_F$ is the time constant of the circuit.

$$V' = \begin{Bmatrix} +V' \text{for} + \text{ve half cycle} \\ -V' \text{for} - \text{ve half cycle} \end{Bmatrix} \qquad (5)$$

From equations (2), (4) and (5), it can be seen that rising and falling slopes of output voltage is different in positive half cycle and negative half cycle of the reference voltage. The time interval between consecutive high slope edges of the output voltage needs to be controlled in order to follow the reference voltage. Therefore in the positive half cycle, time interval between two consecutive falls are controlled and in the negative half cycle, time interval between two consecutive rises are controlled.

Consider a portion of the positive half cycle of the reference voltage as shown in fig.4. At an instant t_0, when the output voltage goes below the reference voltage. The switches S_1 and S_4 are turned ON. When it goes above the reference, these switches will be turned off only if sum of the previous OFF period and present ON period is greater than or equal to switching period, T_{sw}.

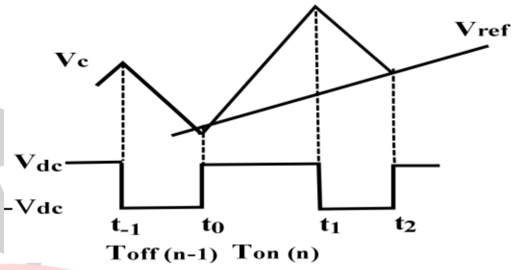

Fig.4.Positive half cycle of the reference voltage

$$T_{off(n-1)} + T_{on(n)} \geq T_{sw} \qquad (5)$$

Similarly consider a portion of negative half cycle of the reference voltage as shown in fig.5. At an instant t_0, when the output voltage goes above the reference, switches S_1 and S_4 are turned off .When it goes below the reference, these switches will be turned on only if sum of the previous ON period and present OFF period is greater than switching period, T_{sw}.

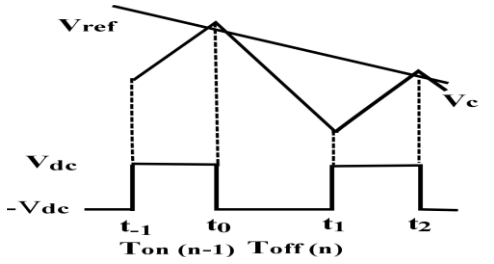

Fig.5.Negative half cycle of the reference voltage

$$T_{on(n-1)} + T_{off(n)} \geq T_{sw} \qquad (6)$$

Equations (5) and (6) ensure the constant switching frequency in the positive and negative half cycles of the reference voltage. Even some variations can be observed at the zero crossing of the output voltage which can be overcome by subtracting and adding an offset value from positive and negative half cycles of the reference voltage respectively. Hence, in the proposed control technique,

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output voltage of the inverter is compared with the modified reference voltage to maintain constant amplitude and frequency of the voltage across the load.

III. SIMULATION RESULT

Simulations have been carried out for the single phase full-bridge inverter using Matlab-Simulink software with the parameters given as $V_{dc} = 100V$, R= 1K Ω, $C_F = 0.159$ μF, L= 5mH, C = 0.1 μF and $R_L = 100$ Ω. The desired constant switching frequency is at $F_{sw} = 20$ KHz, and the sampling frequency of the analog/digital converter is at 10MHz. The reference voltage used in this technique is given as ac voltage as

$$V_{ref} = 70\sin(100\pi t) \tag{7}$$

Fig.6 shows that when the switching logic based control technique is applied, output voltage follows the reference voltage.

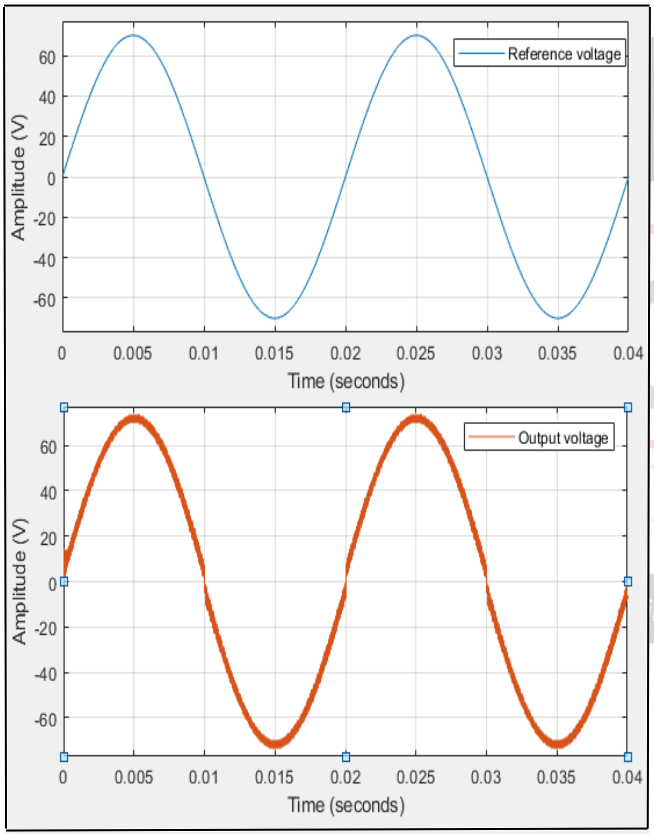

Fig.6.Reference voltage and output voltage waveforms

However, some variations can be observed in the output voltage of the inverter which is more visible at the zero crossing as shown in fig.7. To avoid these issues, a modified reference voltage, presented in section II, is generated. Fig.8 shows the output voltage with the modified reference voltage.

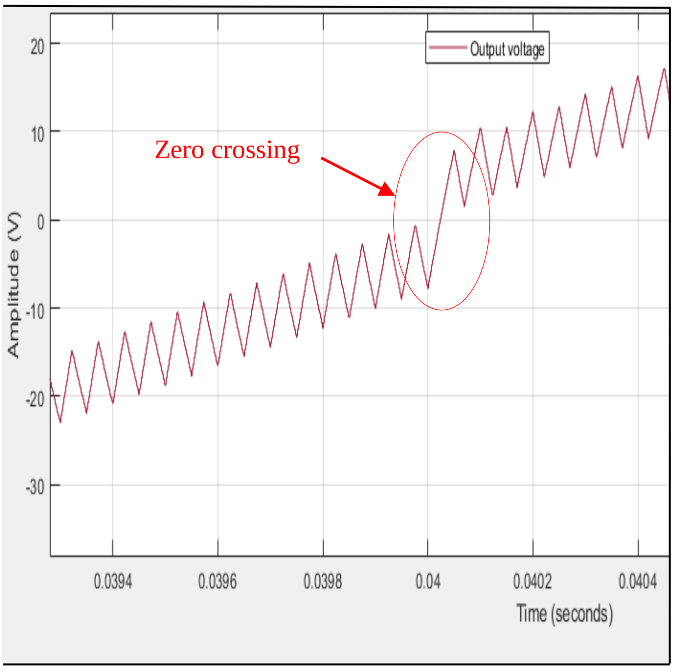

Fig.7.Variation at the zero crossing of the output voltage waveform

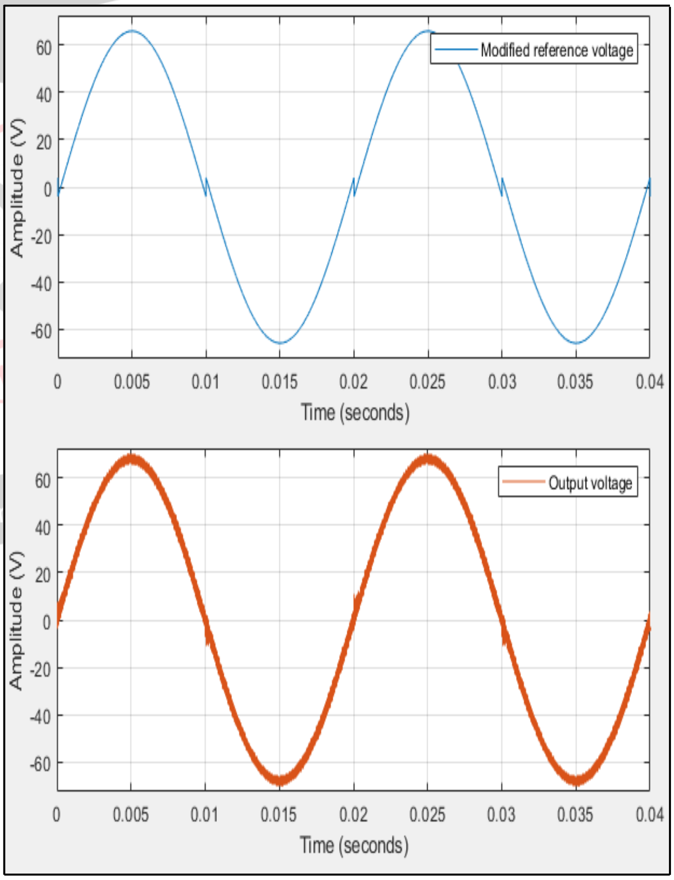

Fig.8.Modified reference voltage and output voltage waveforms

FFT analysis of the voltage control technique is performed and fig.9 shows that this proposed l technique has less THD (Total Harmonic Distortion) of 3.79%

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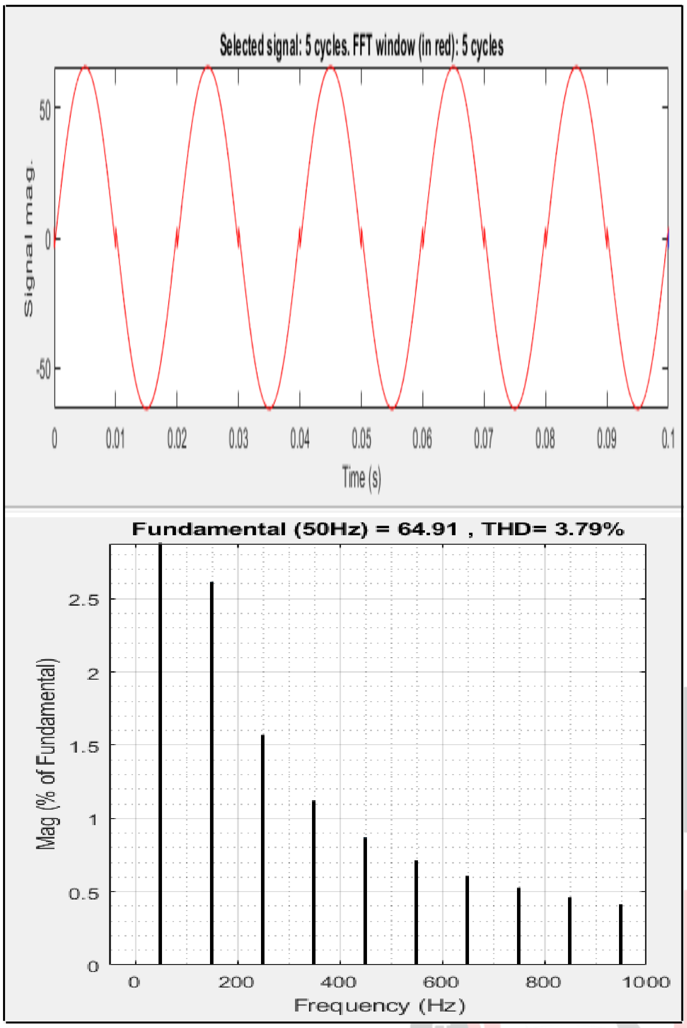

Fig.9.FFT analysis of the voltage control technique

Simulation results show that the proposed control technique yielded output voltage, which matches with the reference voltage almost exactly.

IV. EXPERIMENTAL RESULT

The control technique discussed so far has been implemented in FPGA and tested experimentally on a single-phase full bridge inverter with the following parameters: $V_{dc} = 12V$, $R = 1K\ \Omega$, $C_F = 0.15\mu F$, $L = 1mH$, $C = 1\ \mu F$ and $R_L = 10\ \Omega$, 20 W. The desired constant switching frequency is at $F_{sw} = 20KHz$. The reference voltage used in this technique is given as ac voltage as

$$V_{ref} = 1.65 + 1.65\sin(100\pi t) \qquad (8)$$

Fig.10 shows that when the switching logic based control technique is applied, output voltage follows the reference voltage.

Fig.10.Reference voltage and output voltage waveforms

Experimental result shows that the proposed control technique yielded output voltage, which matches with the reference voltage almost exactly.

V. CONCLUSION

A voltage control technique is proposed for single phase inverter. In this technique, output voltage of an inverter is controlled by comparing it with a reference voltage on an instantaneous basis to produce constant frequency switching signals for the inverter. The proposed technique has advantages such as simplicity, fast and stable response. Proposed voltage control technique is simulated using Matlab-Simulink and it is implemented in FPGA. Simulated and experimental result show that output voltage of the inverter matches almost exactly to the reference voltage with the proposed technique.

VI. FUTURE SCOPE

A simple logic is used to maintain the constant switching frequency in order to follow the reference voltage. Therefore even some variations can be seen in the output voltage of the inverter with respect to the reference voltage. Output voltage can be further improved by modifying the above logic. Noise in the output voltage can also be avoided by using accurate voltage sensors.

VII. ACKNOWLEDGMENT

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