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ANALYSIS OF SINGLE PHASE SPWM INVERTER

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ABSTRACT

This project deals with study the of a Sinusoidal Pulse Width Modulated Inverter (SPWM), its Simulink modelling, estimating various designing parameters and various instabilities. The project will be commenced by a basic understanding of the circuitry of the SPWM Inverter, the components used in its design and the reason for choosing such components in this circuitry. After this, it will be attempted to simulate a model circuit on any simulating software e.g. MATLAB and analyse the output waveforms for various values of the elements used in the circuit and hence study the system response and instabilities.

I. INTRODUCTION

The DC-AC inverters usually operate on Pulse Width Modulation (PWM) technique. The PWM is a very advance and useful technique in which width of the Gate pulses are controlled by various mechanisms. PWM inverter is used to keep the output voltage of the inverter at the rated voltage (depending on the user's choice) irrespective of the output load .In a conventional inverter the output voltage changes according to the changes in the load. To nullify this effect of the changing loads, the PWM inverter correct the output voltage by changing the width of the pulses and the output AC depends on the switching frequency and pulse width which is adjusted according to the value of the load connected at the output so as to provide constant rated output. Voltage Source Inverter has independently controlled ac output is a voltage waveform. The output voltage waveform is mostly remaining unaffected by the load. Due to this property, the VSI have many industrial applications such as adjustable speed drives (ASD) and also in Power system for FACTS (Flexible AC Transmission). There are three basic PWM techniques: Single Pulse Width Modulation ,Multiple Pulse Width Modulation , Sinusoidal Pulse Width Modulation

Designing a single phase inverter for household purpose or UPS (Uninterruptible Power Supply) of rating 220V or 230V, the basic things we have to design are: LC Filter ,PI controller and we have to choose an appropriate step-up Transformer.

II. LC FILTER DESIGN

A low pass LC filter is required at the output terminal of Full Bridge VSI to reduce harmonics generated by the pulsating modulation waveform. While designing L-C filter, the cut-off frequency is chosen such that most of the low order harmonics is eliminated Therefore, the capacitance value should be maximized and the inductance value should be minimized at the selected cut-off frequency of the low-pass filter.Each value of L and C component is determined to minimize the reactive power in these components because the reactive power of L and C will decide the cost of LC filter and it is selected to minimize the cost, then it is common that the filter components are determined at the set of a small capacitance and a large inductance and consequently the output

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impedance of the inverter is so high. Figure 14 shows the power circuit of the single phase PWM-VSI with any linear or nonlinear load. The load current flows differently depending on the kind of loads such as linear and nonlinear load. Therefore it is difficult to represent the transfer function of inverter output voltage to load current. The plant composed of L-C low-pass filter satisfies linear property, so it is possible to represent the system which has two inputs of inverter output voltage and load current.

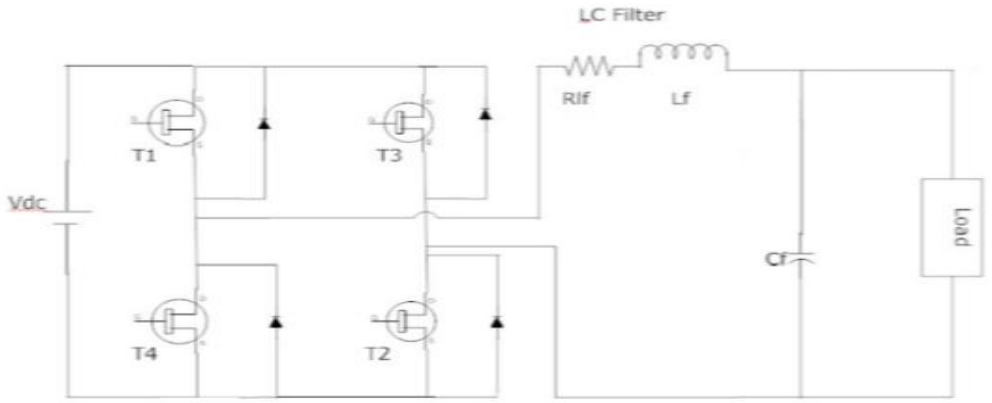

Fig:LC Filter

Using the closed relation between the filter capacitor value and the system time constant, the capacitor value can be calculated. The effect of the load current to the voltage distortion can be calculated from the closed form.

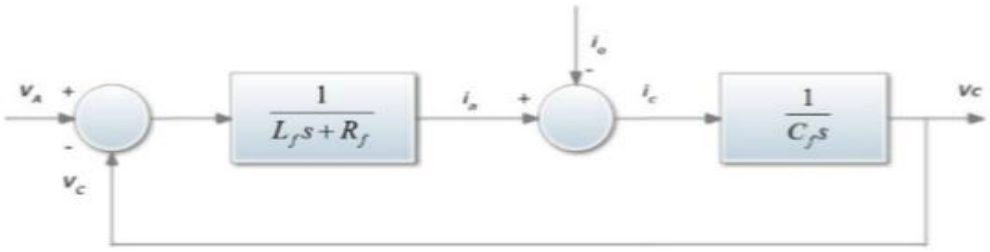

Fig:Block diagram of single phase PWM-VSI

The frequency transfer function can be expressed as

$$V_c(j\omega) = \frac{1}{1 - L_f C_f \omega^2 + jR_f C_f \omega} V(j\omega) - \frac{jL_f\omega + R_f}{1 - L_f C_f \omega^2 + jR_f C_f \omega} I_o(j\omega)$$

Now, through transfer function we can find the step response, corner or cross over frequency from bode plot and stability from root locus method. The above equation can be simplified by neglecting the imaginary part in both the terms as equivalent series resistance of inductor is very small that means

$$| 1 - L_f C_f \omega^2 | >> | R_f C_f \omega |$$

.

$$V_c(j\omega) = \frac{1}{1 - L_f C_f \omega^2} V(j\omega)$$

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The filter output to input voltage harmonics must be less than 3%.So,

$$\frac{V_C(j\omega)}{V_A(j\omega)}=3\%$$

$$\frac{1}{1-L_fC_f\omega^2}=0.03$$

$$\left|\frac{1}{f^2\frac{X_L}{X_C}-1}\right|\leq 0.03$$

$$\frac{X_L}{X_C}\geq\frac{34.2}{f^2}$$

Where, f=corner or cutoff frequency

So, from this we can find out the L and C for the filter.

III. MATHEMATICAL MODELLING

This is the proposed model of single-phase full–bridge inverter with parasitic elements. The analysis is divided into two parts; one is for turn-on state and the other is for turn-off state.

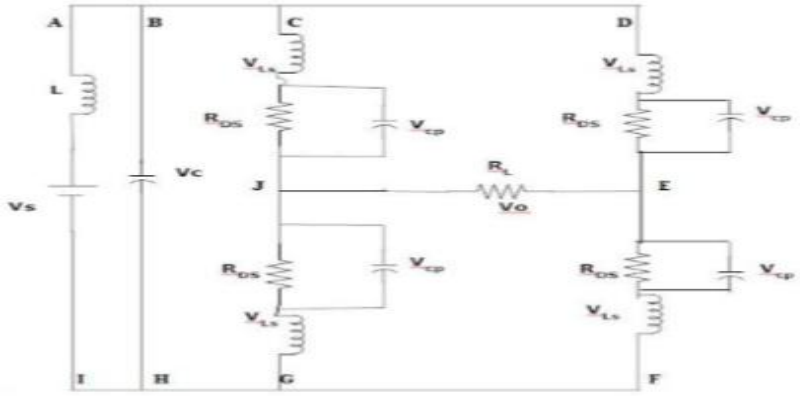

Fig:VSI with parasitics

A.Parasitic Capacitance Voltage

$$\frac{v_c-v_o}{2L_sC_p}=\frac{d^2v_{Cp}}{d^2t}+\frac{dv_{Cp}}{R_{DS}C_pdt}+\frac{v_{Cp}}{L_sC_p}$$

B.Parasitic Inductive Current

$$\frac{v_c-v_o}{2R_{DS}L_sC_p}=\frac{d^2i_{Ls}}{dt^2}+\frac{di_{Ls}}{R_{DS}C_pdt}+\frac{i_{Ls}}{L_sC_p}$$

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The design should be proposed in such a way to minimise the parasitics effects to maintain the efficiency of the inverter and smooth energy flow in the circuits.

IV. PI CONTROL

Proportional Integral (PI) control in VSI provides superior control over traditional Pulse Width Modulation or Sinusoidal Pulse Width Modulation (SPWM). In order to obtain a smooth desirable waveform at the output side, the switching frequency must be constant and should be independent of output frequency can be achieved by PI Control.

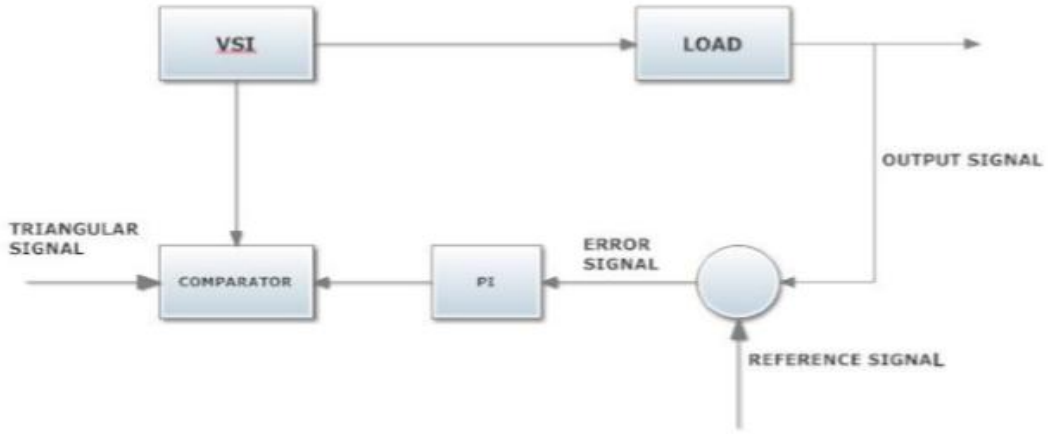

Fig:VSI PI Control

PI controller is a feedback controller which detects the error value which is the difference of the output signal and the desired or reference signal. PI controller works to minimise this error by controlling the system inputs. PI controller has two elements namely Proportional (P) and Integral (I). Proportional part reduces the error while Integral part reduces the offset. P depends on present error and I depends on past errors. So, step response of a system can be improved by using PI controller.

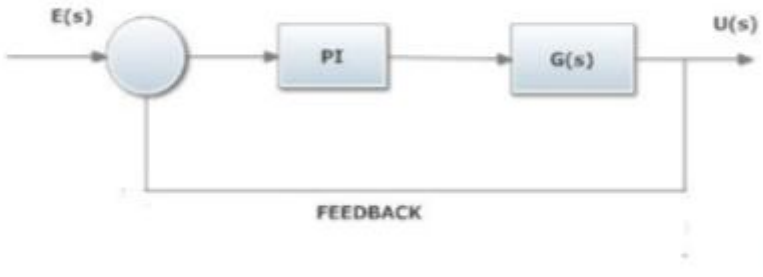

Fig:PI Control

After installing a PI Controller block the new response of the system will be

$$\frac{U(s)}{E(s)} = (Kp + \frac{Ki}{s}) * G(s)$$

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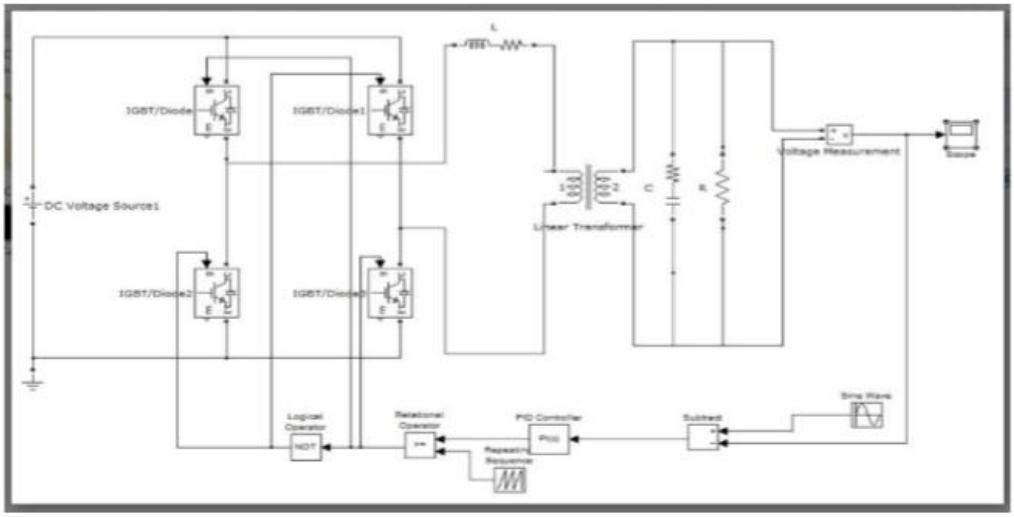
PI element gains, Kp(proportional gain) and Ki(integral gain) should be tuned to obtain a better system response.

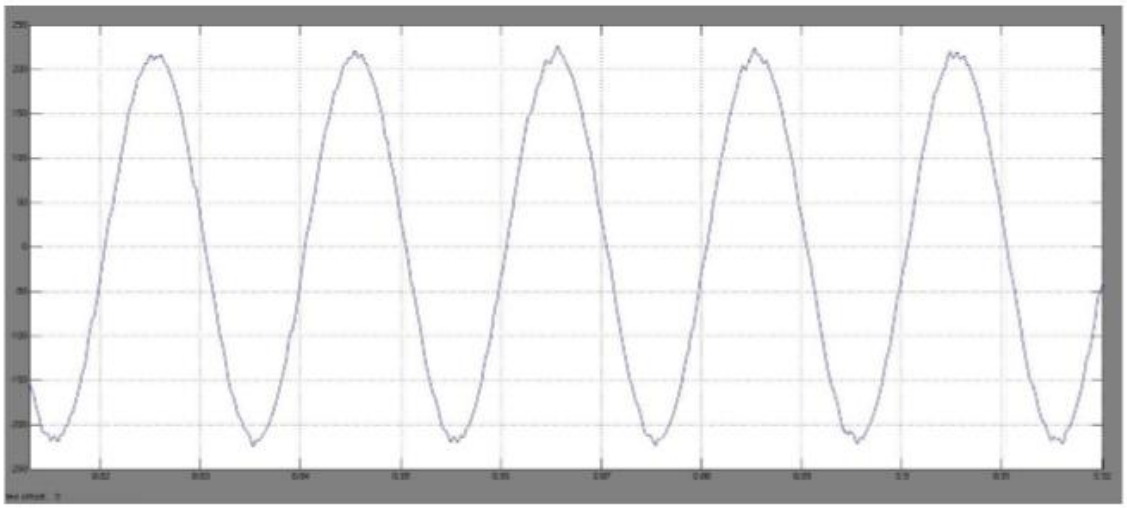
V. PRACTICAL INVERTER (SIMULINK MODEL)

(RL=1mΩ, L=152mH,Rc=10Ω,C=3200μF,R=1800Ω)



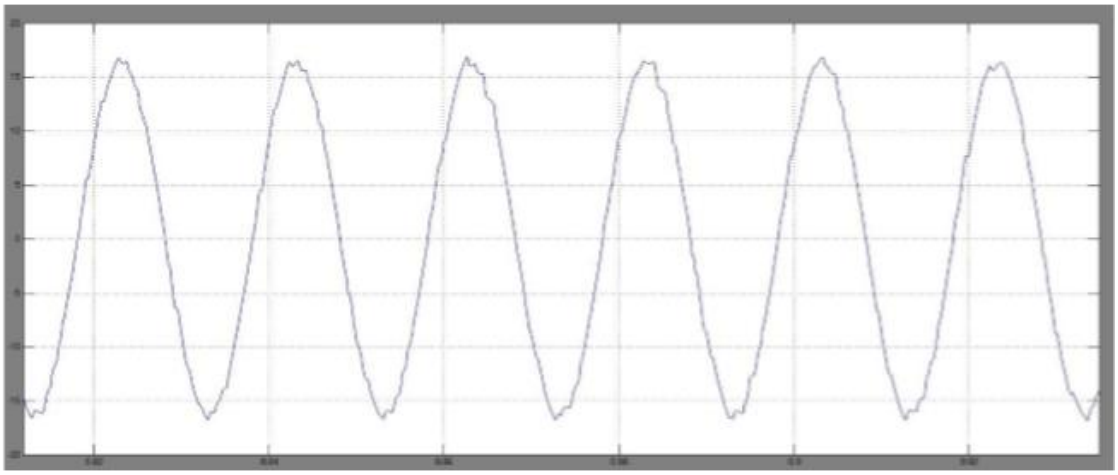
VI. CONCLUSION

6.1 Voltage Waveform



Inverter input in 24Vdc and output is 220V AC nd can be used for household appliances.

6.2 Current Waveform



The current value depends on load and its waveform is also sinusoidal.

The Simulink model for both practical inverter has been simulated in MATLAB. Its various parameters such as L and C for LC Filter design, kp and ki for PI controller. These parameters are varied and the resulting voltage and current graphs has been studied.

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