International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 1, January - 2014

Implementation of A Novel Switch-Mode DC-To-AC Inverter with Non-Linear Robust Control Using MATLAB

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ABSTRACT: A switch-mode d.c to a.c inverter based on d.c to d.c converter topology using a novel non-linear robust control to generate a sinusoidal output waveform will be presented.

The function control law for buck converter will be derived to achieve zero voltage regulation of the output voltage. The control scheme is based on simultaneous feed back of the output voltage and feed forward of the input voltage and inductor voltage. The stability of the closed loop system using proportional and differential controller will be analyzed. The effect of the supply voltage and the load current disturbance will also be studied.

A new method to retrieve the low frequency component of the inductor voltage is also proposed and analyzed. As a result the output voltage remains dynamically unchanged when there are large disturbances in the input voltage or load current. The proposed switch mode dc to ac inverter using the buck converter configuration with non-linear robust control Strategy has been modeled to improve the performance and it will be simulated by using MATLAB (SIMULINK).

1. INTRODUCTION

The previously proposed control strategies such as direct duty ratio, current mode control, discrete data sampling control etc, have not achieved the desired dynamic stabilization of the output voltage. Hence, a new control technique is proposed to obtain the dynamic stability of the output.

2. IMPLEMENTATION OF SWITCH-MODE DC-TO-AC INVERTER

The proposed switch mode dc-to-ac inverter using Buck converter topology with the Non-linear robust control strategy is shown in Figure 2.

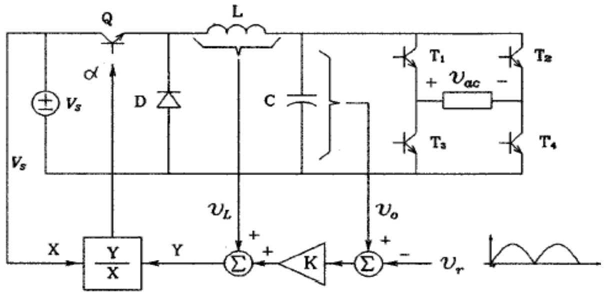

Fig. 2. Proposed dc-to-ac inverter using Non-linear robust control system

The proposed circuit is composed of three basic parts

1. Chopper circuit
2. Control circuit
3. Bridge type synchronizer

The chopper circuit is of a Buck converter topology with the averaged output voltage given as, $v_o = \alpha v_s$.

In the control circuit, the control scheme is based on the feedback of the output voltage and the feed forward of the input voltage and the inductor voltage. The reference voltage to the control circuit is chosen to be a fully rectified sinusoidal wave, i.e..,

$$v_r = V_{rm}|\sin\omega_a t|$$

The frequency 'fa' is much lower than the switching frequency. The output voltage of the Buck converter can be derived as per the function control law (from equation 3.5) as

$$v_o = \frac{K}{K+1} V_{rm}|\sin\omega_a t|$$

Representing a fully rectified sinusoidal waveform having the same frequency as the reference signal 'Vr'.

The bridge-type synchronizer composed of T1-T4, as shown in Fig. 4.1, is used to generate a sinusoidal a.c voltage waveform. In this synchronizer, the switching cycle of the diagonal pair of switches, (T1, T4) or (T2, T3), is synchronized with that of the reference signal 'Vr'. For example, T1 and T4 are turned on at 0, T, 2T,, etc.., and T2and T3 are turned on at T/2, 3T/2, etc. Therefore, the fully rectified sinusoidal voltage 'Vo' can be unfolded into a sinusoidal output voltage 'Vo'. This sinusoidal output voltage 'Vac' is immune to disturbances in the input voltage or output current.

3. SIMULINK MODEL

The proposed switch mode dc to ac inverter using the buck converter configuration with non-linear robust control strategy has been modeled to improve the performance was simulated by MATLAB (SIMULINK) show in figure. The Buck converter is replaced by its low frequency average model, the control circuit and bridge inverter is replaced by subsystems.

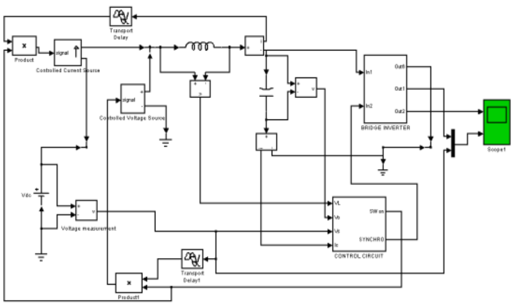

Figure3. Simulink model of the proposed dc-to-ac inverter with robust control

The proposed switch mode dc to ac inverter using the buck converter configuration with non-linear robust control strategy has been modeled to improve the performance was simulated by MAT LAB (SIMULINK) show in fig. 3.

In fig3. the buck converter is replaced by its low frequency averaged equivalent model. In this averaged circuit model, the active switch is modeled by a controlled current source with its value equal to the averaging current flowing through it over one switching cycle, i.e., $\dot{i}_s = \alpha \dot{i}$, for the buck converter, where 'i' denotes the averaged inductor current .

The diode is modeled by a controlled voltage source is value is the equal to the averaging voltage across it over one switching cycle, i.e., $v_d = \alpha v_s$,

The control circuit and the bridge Inverter are replaced by the subsystems. The Inverter output voltage and load current and feedback of supply voltage was connected to the scope.

3.1 SUBSYSTEM FOR CONTROL CIRCUIT

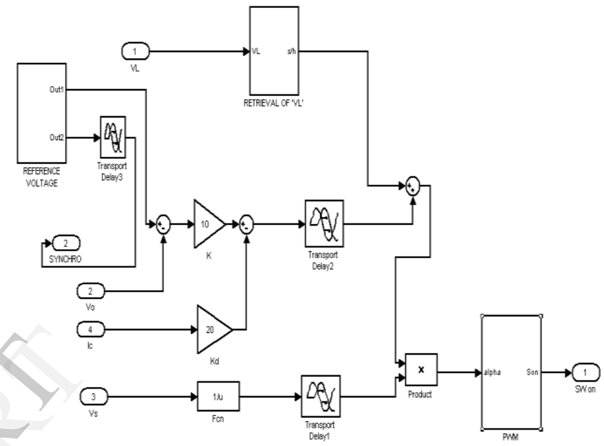

Figure 3.1 Control circuit for the proposed converter

The above fig3.1 shows the subsystem for the control circuit in the main simulink model diagram of the dc to ac Inverter with non-linear robust control system. This control circuit is further consists of the references voltage (fully rectified sine wave), retrieval of "V_L" (low frequency component of Inductor voltage) are replaced by subsystems. The PWM circuit is also replaced by subsystem.

In this circuit the value of alpha is given by

$$\alpha_c = \frac{v_L' + K(V_r - v_o) - K_d \frac{dv_o}{dt}}{v_s}.$$

3.2 SUBSYSTEM FOR REFERENCE VOLTAGE

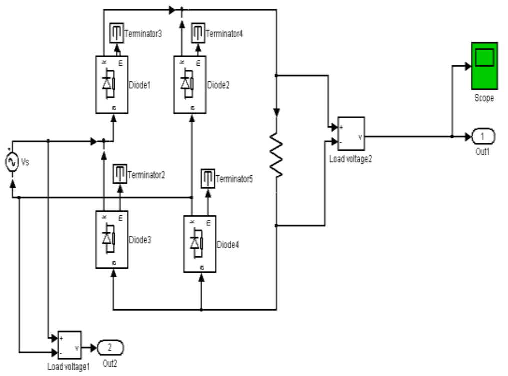

Figure3.2 Subsystem for reference voltage

The above fig3.2 shows the subsystem for the reference voltage in the control circuit of fig3.2. It consists of four diodes incorporate with its snubber circuits and resistive load.

3.3 SUBSYSTEM TO RETRIEVE VL IN THE CONTROL CIRCUIT

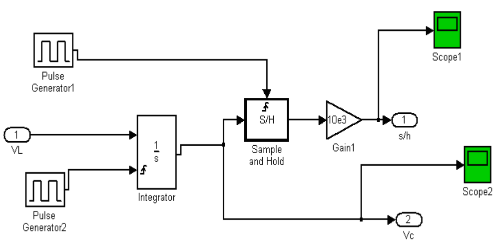

Figure3.3 Subsystem to retrieve the low-frequency of inductor voltage V_L

The above fig3.3 shows the subsystem to retrieve "V_L" in the control circuit of fig3.2. This circuit is used to retrieve the low frequency component of inductor voltage so as to implement the function control law. In this circuit because of sampling and resetting, the high frequency component of inductor voltage is greatly attenuated. The pulse generators are used for the input to sample and hold circuit and integrator.

3.4 SUBSYSTEM FOR SWITCH IN THE CONTROL CIRCUIT

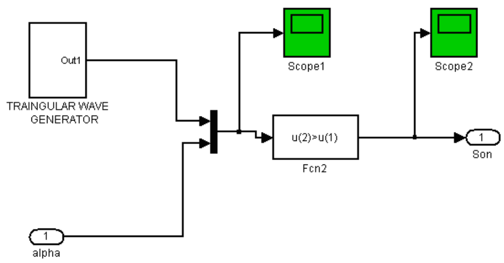

Fig.3.4 Circuit to generate alpha in the form of pulses to the switch

The above fig3.4 shows the subsystem in the control circuit of fig 3.3. In this circuit the triangular wave generator is replace by subsystem. From this circuit, alpha is generated in the form of pulses to switch.

3.5 SUBSYSTEM OF TRIANGULAR WAVE GENERATOR

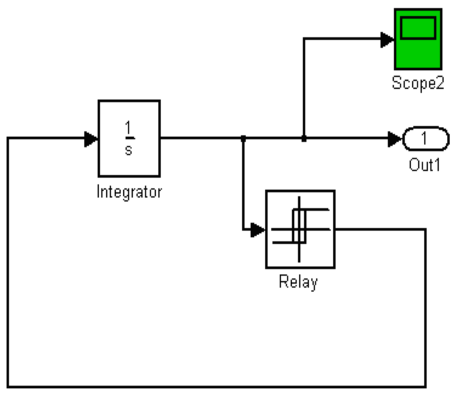

Figure 3.5 Triangular wave generator circuit

The above figure3.5 shows the subsystems of the triangular wave generator of figure3.4 In this circuit the output voltage of the inverter was feedback to the input of the integrator through the relay, and then the output of the integrator gives the triangular waveform.

3.6 SUBSYSTEM OF THE BRIDGE INVERTER

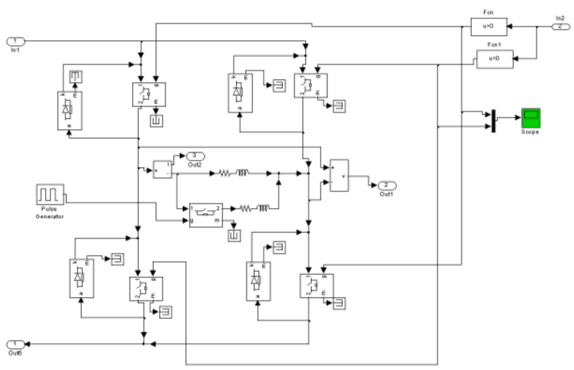

Figure 3.6 Bridge synchronizer

The above fig3.6 shows the bridge type synchronizer. In this circuit, the bridge inverter is synchronized with that of a fully rectified sine wave. It consists of four ideal switches in parallel with the diodes incorporate with its snubber circuits. The RL load connected in show in figure. The output voltage was measured and observed at “out1”, similarly the output load current was measured and observed at “out2”. The four ideal switches are fed from respective pulses for the ON and OFF operation.

4. SIMULATION RESULTS

The proposed switch-mode dc-to-ac inverter using a Buck converter topology with the non-linear robust control strategy shown in figure is simulated using MATLAB(SIMULINK).

4.1 Effect of large disturbance in the load

The response of the control system to a large disturbance in the load is also studied by the simulation. The result is illustrated in the following figures.

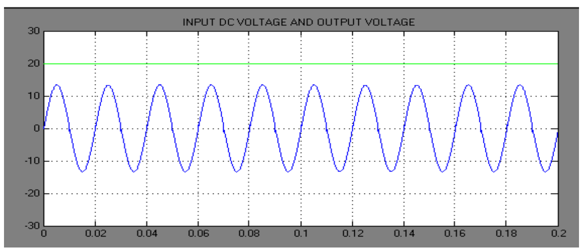

Figure 4.1 Input DC voltage and output voltage waveforms for a step change in load

International Journal of Engineering Research & Technology (IJERT)
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The above figure 4.1 represents that the output voltage is not affected by the deviation in the load from 0.05 sec to 0.1 sec, and from 0.15 sec to 0.2sec.

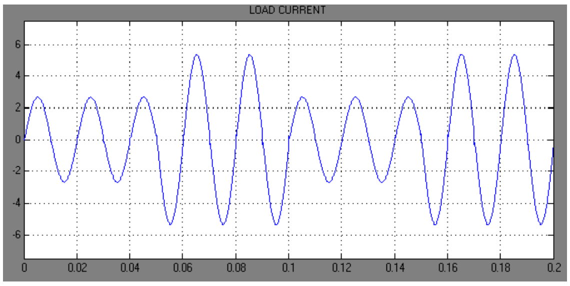

Figure 4.2 Output current waveform for a step change in load

From the above figure 4.2, the output current is increased from 0.05 sec to 0.1 sec, and from 0.15 sec to 0.2 sec., when the load is increased.

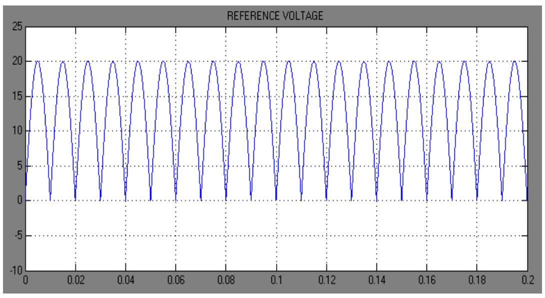

Figure 4.3. Reference voltage waveform for a step change in load

The above figure 4.3 represents the reference voltage waveform which is a fully rectified sinusoidal wave.

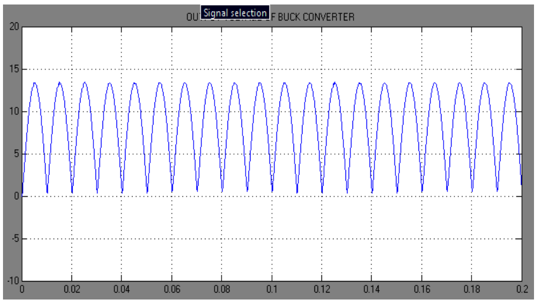

Figure 4.4 Output voltage of the Buck converter for a step change in load

The output voltage of the Buck converter is shown in the above figure 4.4. The output of the Buck converter follows the reference voltage which does not affected by the step change in the load.

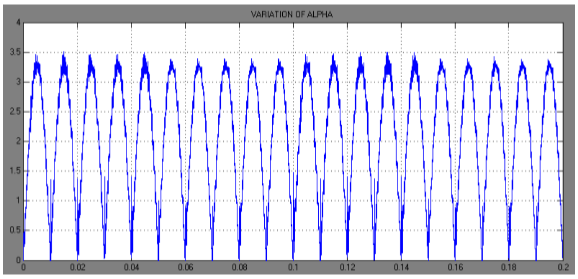

Figure 4.5 Waveform for the variation of alpha for a step change in load

The above figure 4.5 represents that the variation of the alpha is sinusoidal. So, the output voltage of the Buck converter is also sinusoidal.

4.2 Effect of step change in supply voltage

The effect of step changes in the supply voltage has been analyzed for the proposed switch-mode dc-to-ac inverter. The simulated result is shown in the following figures.

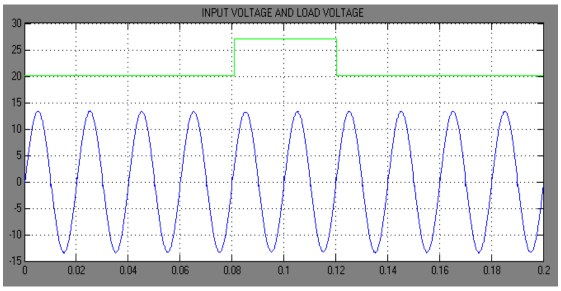

Figure 4.6 Input DC voltage and Output voltage waveforms for a step change in the input voltage

The above figure 4.6 represents the input voltage and output voltage waveforms. The input DC voltage is changed from 20V to 27V at 0.08sec, but the output voltage of the inverter does not change.

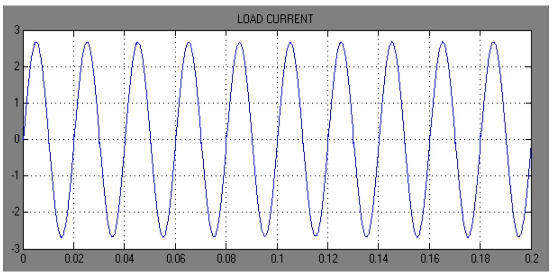

Figure4.7.Load current waveform for a step change in the input voltage

From the above figure 4.7. the load current does not change even though there is a step change in the input DC voltage.

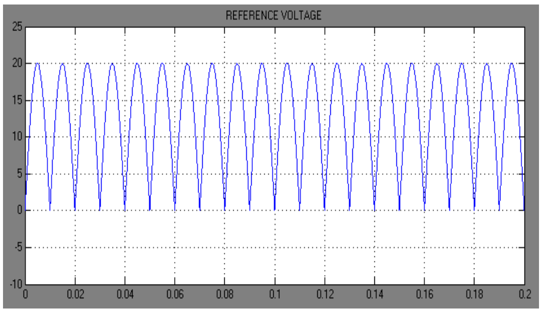

Figure 4.8 Reference voltage wave form for a step change in the input voltage

The above figure 4.8 represents the reference voltage waveform which is a fully rectified sinusoidal waveform.

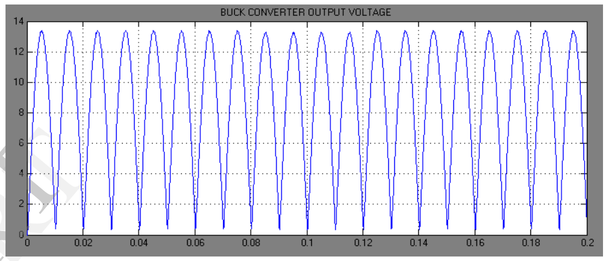

Figure 4.9 Buck converter output voltage for a step change in the input voltage

The Buck converter output voltage does not affected by the step change in the input voltage which follows the reference voltage as shown in the above figure 4.9.

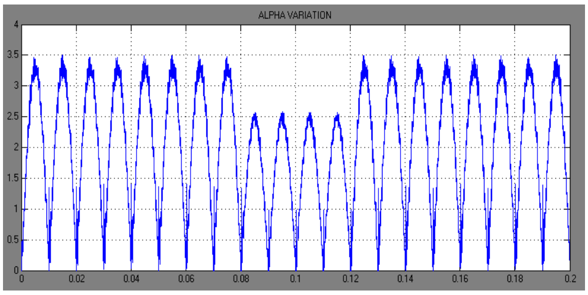

Figure 4.10 Variation of alpha for a step change in the input voltage

From the above figure 4.10, we conclude that with the change in the input voltage at 0.08 sec., the value of the alpha changes in order to provide the output voltage does not affected by the change in the input voltage.

4.3 Effect of step change in the reference voltage

The response of the control system to a step change in the reference signal is also analyzed by the simulation. The simulated results are shown in the following figures.

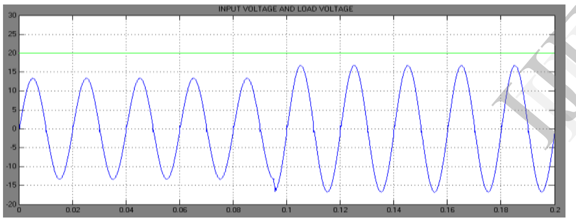

Figure 4.11 Input DC voltage and Load voltage waveforms for step change in the reference voltage

The above figure 4.11 represents the input DC voltage waveform and Load voltage waveforms for a step change in the reference voltage. The output voltage changes with a change in the reference voltage. The reference voltage is changed at 0.095 seconds, and then the load voltage is also follows the reference voltage.

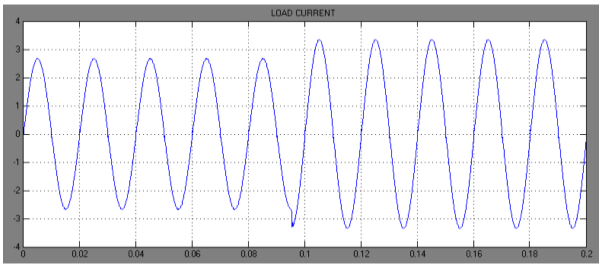

Figure 4.12 Load current waveform for a step changes in the reference voltage

The above figure 4.12 represents the load current waveform for a step change in the reference voltage.

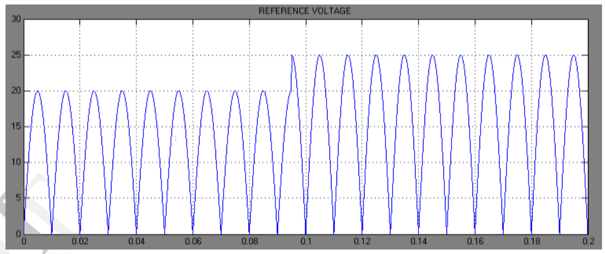

Figure 4.13., Reference voltage waveform

The above figure 4.13 represents the reference voltage waveform which is a fully rectified sinusoidal waveform. The reference voltage is increased at 0.095 sec.

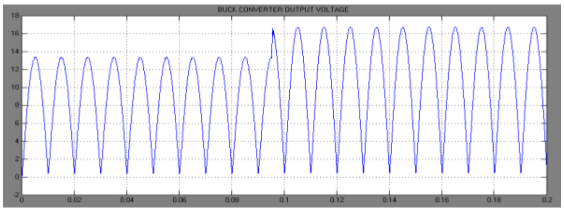

Figure 4.14 Buck converter output voltage for a step change in the reference voltage

The Buck converter output voltage follows the reference voltage as shown in the above figure 4.14. The reference voltage is increased at 0.095 sec and then the Buck converter output voltage is also increased at 0.095 sec.

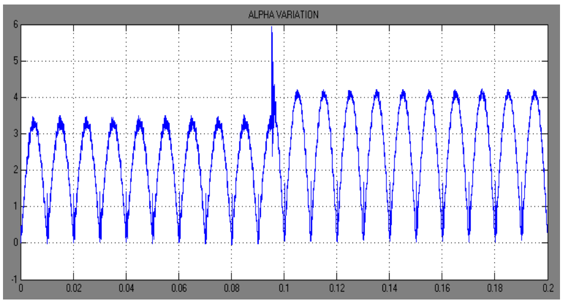

Figure 4.15 Variation of alpha for a step change in the reference voltage

From the above figure 4.15, we conclude that with the change in the reference voltage at 0.095 sec., the value of the alpha changes in order to provide the output voltage does not affected by the change in the reference voltage.

5. CONCLUSION

The study of our project shows that a switch-mode d.c to a.c inverter using a Non-linear robust control technique (i.e.., the zerovoltage regulation of the output voltage) canbe obtained by the function control law.

A method to retrieve the low frequency component of the inductor voltage and at the same time suppress greatly its high frequency component is proposed and analyzed in order to implement the function control law. The results indicate that this method is very effective in retrieving the low frequency component of the inductor voltage, which is crucial to achieve zero voltage regulation of the output voltage.

The Non-linear function control law converts the non-linear Buck converter into a linear closed loop system. Therefore, the closed loop dynamic analysis is greatly simplified. The stability of the closed loop system is ensured by the proper selection of the controller parameters based on the analysis presented in our project.

The analysis of the control technique reveals that the output voltage of the switch-moe d.c to a.c inverter is not affected by supply and load disturbances.

A Buck converter followed by a bridge synchronizer was used to implement the Non-linear robust control. Computer simulation using MATLAB (SIMULINK) show that the output voltage is immune to large disturbances in the supply voltage and the load current, and the system has fast dynamic response.

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