CHAPTER 6

CONCLUSION

6.1 INTRODUCTION

This chapter is aimed at reviewing the significant results obtained during the course of this work and making some suggestions for the future line of research in this area. Before reviewing the work done, the objectives of this investigation are recapitulated below.

- To design a three element resonant converter capable of driving the voltage and current type load with load independent operation.
- To compare the performance of LCL and LCC resonant inverters.
- To investigate the performance evaluation of LCL resonant converter.
- To analyze the steady state stability of resonant converter topologies using state space model.
- To examine the performance of LCL resonant converter with fuzzy logic and PI controller.
- To analyze the performance of LCL resonant converter using Lyapunov method and phase plane method.
• To compare the simulated results with experimental results.

• To analyze the stability of fuzzy controlled LCL resonant converter using Z-domain analysis.

6.2 REVIEW OF THE WORK DONE

Analysis on LCL and LCC resonant inverters was carried out. The aim of this analysis was to select which was superior in performance than inverter for aero space applications. This was done both by simulation and experimentally. To the outcome of the research, LCL resonant inverter scores over LCC inverter. The THD for various load conditions, the operating efficiency and the ability to handle varying loads were better met with LCL resonant inverter.

Analysis of performance of the converter clearly project in favour of LCL resonant converter in terms of efficiency than LCC resonant converter at all load conditions. It was also observed that the closed loop technique can be employed to have constant output voltage.

In this work, from the examination of the stability criteria using nyquist and root locus plots, it is concluded again that LCL resonant converter was better stability margin (Figures 3.4 to 3.9).

Comparison of PI and Open Loop Controller was carried out and concluded that PI based LCL resonant converter has effective output voltage regulation and high efficiency.

To improve the dynamic response of the controller fuzzy logic based controller was tried. Using fuzzy logic controller, sudden variation of load and dynamic response of LCL resonant converter, was experimentally verified. Comparison of performance estimation for open loop and FLC was
carried out. The results obtained indicate that the FLC was an effective approach for the output voltage regulation and high efficiency of the LCL DC-DC resonant converter. ARM processor was used as the controller for both PI and fuzzy based resonant converter.

The system stability was analyzed using Lyapunov technique and State plane analysis. The above stability techniques clearly support the fuzzy controller based LCL resonant converter.

Results obtained from simulation (Table 6.1), clearly indicate that fuzzy control is better in rise time and in settling time than open loop and PI control. In the same way fuzzy control has less steady state error than other controller.

Table 6.1 Summary of dynamic response (simulated) for LCL resonant converter

<table>
<thead>
<tr>
<th>Types of Controller</th>
<th>Rise Time in milliseconds</th>
<th>Settling Time in milliseconds</th>
<th>Steady State Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Loop</td>
<td>0.51</td>
<td>0.57</td>
<td>0.075</td>
</tr>
<tr>
<td>PI Control</td>
<td>0.057</td>
<td>0.055</td>
<td>0.056</td>
</tr>
<tr>
<td>Fuzzy Control</td>
<td>0.055</td>
<td>0.04</td>
<td>0.014</td>
</tr>
</tbody>
</table>

From Figure 6.1, it could be inferred that rising time and settling time during dynamic response of fuzzy control is much lower than PI control and open loop control.
Figure 6.1 Dynamic response for open loop, PI control and fuzzy control (simulated results)

The simulated results were verified with experimental setup and the results were tabulated in Table 6.2.

Table 6.2 Summary of dynamic response (experimental) for LCL resonant converter

<table>
<thead>
<tr>
<th>Types of Controller</th>
<th>Rise Time in milliseconds</th>
<th>Settling Time in milliseconds</th>
<th>Steady State Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Loop</td>
<td>0.52</td>
<td>0.58</td>
<td>0.079</td>
</tr>
<tr>
<td>PI Control</td>
<td>0.059</td>
<td>0.058</td>
<td>0.058</td>
</tr>
<tr>
<td>Fuzzy Control</td>
<td>0.057</td>
<td>0.05</td>
<td>0.016</td>
</tr>
</tbody>
</table>
From the above comparison, it could be concluded that the FLC exhibits better performance in terms of reduced settling time and rise time.

![Graph showing steady state error](image)

**Figure 6.2** Steady state error for open loop, PI control and fuzzy control (Both simulated and experimental results)

From the graph shown in Figure 6.2, steady state error value is very less for fuzzy logic controller.
Figure 6.3  Percentage efficiency versus load for open loop, PI control and FLC control

From the above efficiency plot (Figure 6.3), fuzzy control has full load an efficiency of 92.83% was obtained. As the load was decreased, efficiencies remain high. However, at 11% load, the efficiency of the circuit was measured as 79.9%.

From the above comparisons, it could be concluded that the FLC exhibits better performance in terms of percentage efficiency.

To conclude, following observations are arrived:

- The LCL Resonant converter has better stability margin compared to LCC and LCL-T converter.
• FLC based LCL resonant converter provides better voltage regulation even under sudden variation of load and the reduction in switching power losses enhances the efficiency.

• The dynamic response and steady state errors of FLC based LCL resonant converter are compared with PI controller and open loop both by simulation and experiment. Studies also confirmed that, the superiority of FLC based LCL resonant converter.

• An added advantage of the FLC is that, with minor modification, the same controller coding could be extended to control any type of DC–DC converters since their behavior can also be described by the similar set of linguistic rules.

6.3 FUTURE LINE OF RESEARCH

Based on the results obtained in the present investigations, the following line of research seems to be worth pursuing for further research work.

• Study for other intelligent controllers like ANN, Neuro-fuzzy controller, etc., for LCL resonant converter can be implemented and compared.

• An adaptive control law can be extended to study the stability and dynamic characteristics of the LCL resonant converter.

• Meta-heuristic based search techniques like GA, PSO, etc. can be used to find the modulation index of the LCL resonant converter to improve the performance.