CHAPTER 5

THESIS RESULTS AND ANALYSIS

5.1 INTRODUCTION

This chapter describes the simulation results of multi-level inverter subjected to irradiance variation and THD comparison of multi-level inverter with PWM and SVPWM control techniques. This chapter presents the THD comparison of multi-level inverter with different MPPT techniques.

Figure 5.1 shows the output waveform of current without fuzzy logic controller where the amplitude of current is reduced because of insolation level (G) is changed from 800 to 600 W/m² at 0.08 s and then changed from 600 to 1000 W/m² at 0.15 s as shown in Figure 2.25.

Figure 5.2 shows the output current waveform with fuzzy logic controller in which the current is constant irrespective of the variation of solar insolation.

![Figure 5.1 Output current without fuzzy logic controller](image-url)
Figure 5.2 Output current with fuzzy logic controller

Figure 5.3 shows the output voltage and current waveform and fuzzy control pulse of five-level DCMI to track the maximum power for the duration for which the irradiance is varied.

Figure 5.4 shows the output voltage waveform with and without filter and fuzzy control pulse of five-level DCMI to track the maximum power for the duration for which the irradiance is varied.

Figure 5.5 shows the output voltage and current waveform and fuzzy control pulse of seven-level DCMI to track the maximum power for the duration for which the irradiance is varied.
Figure 5.3  Output of five-level DCMI with Fuzzy MPPT
Figure 5.4 Output voltage of five-level DCMI with and without filter
Figure 5.5 Output of seven-level DCMI with MPPT
(a) Line voltage \( (V_a) \), (b) Three-phase Line-to-Line voltage

Figure 5.6 Experimental result of three-level DCMI with SPWM

The output line voltage and three-phase line-line voltage is presented in Figure 5.6. The experimental output voltages of three-level SVPWM inverter are shown in Figure 5.7.
(a) Line voltage ($V_a$), (b) Three-phase Line-to-Line voltage

Figure 5.7 Experimental result of three-level DCMI with SVPWM

These oscilloscope graphs demonstrate the good quality of the obtained voltage waveforms, confirming simulation results.
The MPPT using P&O, INC and FLC tracks the working point rapidly and precisely in both conditions i.e. with and without change in irradiance level. Figure 5.8 shows the results MPPT tracking pulse output voltages. It proves that the voltages are maintained constant.

![Graph showing MPPT tracking pulse output voltages](image)

Figure 5.8 MPPT tracking pulse output voltages

5.2 THD MEASUREMENT WITH MODULATION TECHNIQUES

The THD measurement of the three-level inverter is 35.27%. The THD for the proposed seven-level inverter and five-level inverter are 8.14% and 11.94% respectively. It is concluded that as the number of level increases the THD values is reduced.
(a) THD measurement with SPWM for three-level inverter

The THD measurement using SPWM for three-level inverter both experimental and simulation are shown Figure 5.9.

(b) Experimental THD measurement with SPWM for three-level inverter

Figure 5.9 THD measurement of three-level inverter with SPWM
Figure 5.10 THD measurement with SPWM for five-level inverter

The THD measurement using SPWM for the proposed five-level inverter is shown Figure 5.10 which shows the THD is 11.94%.

Figure 5.11 THD measurement with SPWM for seven-level inverter
The THD measurement using SPWM for the proposed seven-level inverter is shown Figures 5.11 which shows the THD is 8.14%.

(a) THD measurement with SVPWM for three-level inverter

![Image](image1)

b) Experimental THD measurement with SVPWM for three-level inverter

Figure 5.12 THD measurement of three-level inverter with SVPWM

The THD measurement using SVPWM for three-level inverter both experimental and simulation are shown Figure 5.12. The results clearly indicate that the output voltage is with lower THD and these THD values are the same as simulation results. The THD for three-level inverter with
SPWM is 37.6%. The THD for three-level inverter with SVPWM is 24.7%.

![Figure 5.13 THD measurement with SVPWM for five-level inverter](image)

The THD measurement using SVPWM for the proposed five-level inverter is shown Figure 5.13 which shows the THD is 10.85%.

![Figure 5.14 THD measurement with SVPWM for seven-level inverter](image)

The THD measurement using SVPWM for the proposed seven-level inverter is shown Figure 5.14 which shows the THD is 7.15%.
Table 5.1 THD for the proposed system

<table>
<thead>
<tr>
<th>Number of Levels</th>
<th>SPWM (%)</th>
<th>SVPWM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Simulation</td>
<td>Hardware</td>
</tr>
<tr>
<td>3</td>
<td>35.27</td>
<td>37.6</td>
</tr>
<tr>
<td>5</td>
<td>11.94</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>8.14</td>
<td>-</td>
</tr>
</tbody>
</table>

The THD levels of three-phase seven-level DCMI, five-level DCMI and three-level DCMI are compared in the Table 5.1. The results from seven-level PWM inverter and five-level PWM inverter are compared with those from three-level PWM inverter in terms of THD. By comparison, the THD measurement for three-level inverter is much higher when compared with five-level inverter and seven-level inverter. This proves that multi-level inverters can reduce the THD which is necessary criterion for grid-connected PV systems.

The above conclusions are based on simulations and the reported results in the literature. No experimental validation could be done for five-level and seven-level inverter that should be the next step to confirm the results from the simulations.

5.3 THD MEASUREMENT USING SPWM WITH DIFFERENT MPPT TECHNIQUES

In this part of the chapter, different MPPT techniques like P&O, INC, FLC is applied to PV array fed five-level inverter with and without output filter to study the harmonic profile using SPWM.

To study the harmonic profile a 11-order low pass filter (LPF) whose cut-off frequency 100 Hz and damping factor 0.707 is used in the Simulink model.
Figure 5.15 THD measurement using SPWM-P&O algorithm
(a) Without filter (b) With filter

The THD was measured for the fundamental frequency of 50 Hz using SPWM for the proposed five-level inverter with and without filter for P&O algorithms are shown in Figure 5.15, where the THD values with filter is 2.92% which is less than that of without filter.
The THD measurement is done for the proposed five-level inverter with and without filter for INC algorithm for the fundamental frequency of 50 Hz using SPWM is shown in Figure 5.16, where the THD values with filter is less that is 2.53%. It is concluded that INC algorithm is better than P&O algorithm in terms of THD values.
The THD measurement was done for the fundamental frequency of 50 Hz using SPWM for the proposed five-level inverter with and without filter for FLC is shown in Figure 5.17, where the THD values with filter is less that is 2.16%. It is concluded that FLC algorithm is better than P&O and INC algorithm in terms of THD values.
5.4 THD MEASUREMENT USING SVPWM WITH MPPT DIFFERENT TECHNIQUES

There is a 83% of THD reduction was observed for the fundamental frequency of 50 Hz using SVPWM for the proposed five-level inverter with for P&O algorithm shown in Figure 5.18, where the THD values with filter is 2.43%.

Figure 5.18 THD measurement using SVPWM-P&O algorithm
(a) Without filter (b) With filter
Figure 5.19 illustrates the THD measurements for the fundamental frequency of 50 Hz using SVPWM for the proposed five-level inverter with and without filter for INC algorithm, where the THD values with filter is 2.00%.

![THD measurement diagram](image)

(a)

(b)

Figure 5.19 THD measurement using SVPWM-INC algorithm (a) Without filter (b) With filter
The THD measurement was done for the fundamental frequency of 50 Hz using SVPWM for the proposed five-level inverter with and without filter for FLC algorithm is shown in Figure 5.20. It depicted the THD values with filter is 1.33%.

![Graph](image1.png)

(a)

![Graph](image2.png)

(b)

**Figure 5.20** THD measurement using SVPWM-FLC (a) Without filter (b) With filter
THD levels of three-phase five-level DCMI with and without filters are compared in the Table 5.2.

Table 5.2 THD values for different MPPT algorithms in percentage

<table>
<thead>
<tr>
<th>Methods</th>
<th>Without filter</th>
<th></th>
<th>With filter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P&amp;O</td>
<td>INC</td>
<td>FLC</td>
</tr>
<tr>
<td>SPWM (%)</td>
<td>17.00</td>
<td>15.94</td>
<td>14.84</td>
</tr>
<tr>
<td>SVPWM (%)</td>
<td>14.21</td>
<td>13.01</td>
<td>5.20</td>
</tr>
</tbody>
</table>

This proves that the proposed scheme can reduce the THD which is significant condition for grid connected PV system. The results from the table reveal that FLC MPPT is best MPPT technique in terms of THD as compared to P&O and INC techniques since THD value is 1.33%. This proves that multi-level inverters can reduce the THD which is necessary criterion for grid-connected PV systems.

5.5 CHAPTER SUMMARY

The THD measurement is measured for the proposed system and the results were compared with three-level system. It is found that the current and voltage waveforms are constant irrespective of the variation in solar irradiation. Finally comparison is made with respect to THD measurement for all the MPPT techniques such as P&O, INC and FLC methods with and without filter. It is concluded that the FLC method have low THD value with filter.