Simulation Of LCL Filter For Shunt Active Power Filter In Single Phase Power Line Using Matlab

Devesh R. Saxena, Prof. A. R. Soman
B.V.D.U.C.O.E pune

Abstract—Among all the filters the LCL filter is more suited for high-power low-switching –frequency application than the L filters due to its better attenuation characteristics on high frequency. But LCL filter parameter design is more complex due to the effect of high -frequency harmonic current as well as the controller response performance of the converter. In this paper LCL filter is been connected in the single phase supply, and different parameters of the system is been analysis. The control technique used in this paper is SPWM (sinoidal pulse width modulation). The effectiveness of the filter is proved by the simulation result and Experimental result of the single phase system is given at the End of this paper.

I. INTRODUCTION

A SHUNT active power filter (SAPF) use to compensate the harmonic current from harmonic sources. SAPF is placed either near the harmonic source or at the point of the common coupling. The main objective of Shunt Active Power Filter is to detect the current harmonics and to cancel them, leaving only the fundamental current supplied by the power system. As a converter, the use of PWM (pulse width Modulation) in SAPF will cause the switching and multiple switching frequency harmonics, of the high order which may disturb the voltage of other sensitive loads/equipment tying to the grid. In order to sufficiently attenuate the switching frequency harmonic, an effective filter is needed. The LCL filter when compare with the L filter provides the more attractive solution. Using this, a more satisfactory attenuation effect of current harmonics will be obtained with much smaller values of inductors, which is important in decreasing the device size and cost. Therefore, the LCL filter effectively replaces the L filter in high-power low-switching frequency grid-connected devices.

As the LCL filter has many advantages, there are still challenges in practical implementations. As the number of filter parameters increases from one to three while on the other hand the L filter has only one parameter, which makes the design more complex. Also the impedance is close to zero at the LCL filter resonant frequency, there is a risk that the filter will start oscillating with the power grid. That is why, the parameters of the LCL filter should be treated carefully in order to get the good performance as well as the low cost.

II. Model of LCL filter

In LCL filter there is the advantage that is provides effective decoupling among the filter and grid impedance and moreover reduces the dependence of the filter on the various grid parameters and a lower ripple of the current stress across the grid inductor.
Fig. 1. Single phase circuit with LCL filter

Transfer function from the fig.1.

\[ G_i(s) = \frac{i_i}{u_i} = \frac{L_g C_f s^2}{a_3 s^3 + a_2 s} \]

Where:-
- \( i_i \): inverter side current
- \( u_i \): inverter side voltage
- \( i_g \): grid current
- \( u_g \): grid voltage
- \( L_g \): grid side inductance
- \( C_f \): Capacitance

\[ G_g(s) = \frac{i_g}{u_i} = \frac{1}{a_3 s^3 + a_2 s + a_1 s} \]

Where:-
- \( a_3 = L_i L_g C_f \)
- \( a_2 = R_i L_g + R_g L_i \)
- \( a_1 = L_i + R_i R_g C_f \)
- \( R_a = R_i + R_g \)
- \( L_a \): the total inductance of the inverter side
- \( L_g \): the total inductance of the grid side

Now, the \( R_a \) can be neglected as its value is very small as compare with \( L_g \) and \( L_a \) for medium and high frequencies, therefore the transfer will become:

\[ G_i(s) = \frac{i_i}{u_i} = \frac{L_g C_f s^2 + 1}{L_i L_g C_f s^3 + L_a s} \]

\[ G_g(s) = \frac{i_g}{u_i} = \frac{1}{L_i L_g C_f s^3 + L_a s} \]

\[ \omega_r = \sqrt{\frac{L_a}{L_i L_g C_f}} \]

let \( \lambda \) and \( K \) represents the respective ratios given below

\[ \lambda = \frac{L_i}{L_a}, \quad K = \frac{\omega_r}{\omega_s} \]

Now the value of \( H_i \) and \( H_g \) is calculated

\[ H_i = \left| G_i(s) \right|_{s=j\omega_s} = \left| \frac{i_{is}}{u_{is}} \right|_{s=j\omega_s} \]

Fig. 2:- Block Dia. of the LCL Filter.
Various range is selected in order to calculate the values of $L, C, L$.

\[ H_g = \left| G_{gs} \right|_{g = j\omega_s} = \left| \frac{i_{gs}}{u_{il}} \right| \]

\[ H_g = \frac{K^2}{L_a (1 - K^2)\omega_s} \]

Range of $K$

\[ 0.245 < K < 0.5 \]

Maximum limitation of total inductance and Total Capacitance

\[ L_a \frac{d i_g}{d t} < V_{dc} - 1.1V_{gm} \]

\[ L_a < \frac{V_{dc} - 1.1V_{gm}}{2A_{40}\omega_{40}} \]

\[ C_f < \beta \frac{S_N}{2\pi f_1 V_{dc}^2} \]

**TABLE 1**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Symbol</th>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$V_{dc}$</td>
<td>D.C Link voltage</td>
<td>400V</td>
</tr>
<tr>
<td>2</td>
<td>$V_g$</td>
<td>Grid Voltage</td>
<td>220Vrms</td>
</tr>
<tr>
<td>3</td>
<td>$f_1$</td>
<td>Grid Frequency</td>
<td>50Hz</td>
</tr>
<tr>
<td>4</td>
<td>$f_s$</td>
<td>Switching frequency</td>
<td>10kHz</td>
</tr>
<tr>
<td>5</td>
<td>$S_N$</td>
<td>Rated Capacity</td>
<td>3kVA</td>
</tr>
<tr>
<td>6</td>
<td>$F_n$</td>
<td>Maximum compensated frequency</td>
<td>2450Hz</td>
</tr>
<tr>
<td>7</td>
<td>$I_{gs}$</td>
<td>Grid-side current ripple switching frequency component</td>
<td>&lt;0.1A</td>
</tr>
<tr>
<td>8</td>
<td>$I_{is}$</td>
<td>Inverter-side current ripple switching frequency component</td>
<td>&lt;=2A</td>
</tr>
</tbody>
</table>
III. Model and simulation result

A. Models

Model 1: Single phase model with LCL filter

Model 2: Active power filter diagram

Model 3: Control circuit diagram
B. Simulation result

Grid Current without filtering

Grid voltage without filtering

Load current without filtering
Inverter D.C voltage

Inverter voltage before filtering

Grid voltage THD without LCL
Grid Current THD without LCL filter

Load current THD without filter

Inverter Switching pulse
Load Voltage with LCL Filter

Grid Current THD with LCL filter

Load current THD with LCL filter
IV. RESULT

TABLE 2
% THD of Different Parameters With and Without LCL Filter

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Quantity</th>
<th>Without LCL Filter</th>
<th>With LCL Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grid Current</td>
<td>43.26</td>
<td>9.56</td>
</tr>
<tr>
<td>2</td>
<td>Load Current</td>
<td>43.26</td>
<td>6.71</td>
</tr>
<tr>
<td>3</td>
<td>Inverter</td>
<td>43.62</td>
<td>0.11</td>
</tr>
<tr>
<td>4</td>
<td>Grid Voltage</td>
<td>0.11</td>
<td>0.11</td>
</tr>
</tbody>
</table>

V. CONCLUSION

As we have seen from the table no 2 that the total harmonics has been reduce a lot, so we can say that the given model is valid and effective.

REFERENCE


