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Stabilized Power AC-DC-AC Converter using Different Type of Passive Filters

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***Abstract*—** Passive filters are used to filter the specific harmonics from AC voltage/current waveform and to reduce the ripple contents in DC voltage/current. Different filter topologies in converter fed loads may be C, LC, LCL or a combination of these. The basic criteria to design of such filters are based on analysis of the harmonic frequencies generated by the conversion system. In this paper, design methods for AC and DC side filters in AC-DC-AC converters are presented to optimize the size of filter components to optimize the filter cost and system performance. The performance of the filter designed are verified by simulation in terms of voltage/current THD, ripple content in DC voltage, fundamental value of voltage/current and RMS value of output voltage/current. LCL filters given the better performance.

***Keywords*—** Passive filters, LC- filter LCL-filter, L + LC- filter.

I. INTRODUCTION

Increased use of the nonlinear and time varying devices has led to distortion of voltage and current waveforms.

As a consequence, recently the issue of power quality has become important. Both electric utility and end users of electric power are becoming increasingly concerned about the quality of electric power. The term “power quality” has been used to describe the variation of the voltage, current and frequency on the power system beyond a limit .

Most recent problems involve electronic equipment that is very sensitive to pollution of power line. In the presence of harmonics, equipments such as computers, telephone systems, and controllers may respond incorrectly to normal inputs, not respond at all, or give false outputs. Following are the detrimental effects of harmonic injection into the utility –

1. Excessive losses and heating in motors, capacitors and transformers connected to the system,
2. Insulation failure due to the overheating and over voltages,
3. Overloading and overheating of the neutral conductors with loss of conductor life and possible risk of fire.
4. Malfunctioning of sophisticated electronic equipments,
5. Interference with the communication network.

Restrictions on current and voltage total harmonic distortions are being maintained in many countries according to IEEE 519-1992, IEC 61000-3-2/IEC 61000-3-4 standards. Various standards are set to limit the harmonics generated by nonlinear loads. The 5% voltage distortion limit was recommended below 69 kV, while the limit on current distortion is fixed in the range of 2.5% to 20% depending upon the size of the customer and the system voltage. The available harmonic reduction techniques are based on passive components, mixing single and three-phase diode rectifiers and PWM techniques such as active filters, multi-pulse rectifiers and PWM rectifiers.

In this paper, design methods for AC and DC side filters in AC-DC-AC converters are presented to optimize the size of filter components to optimize the filter cost and system performance. The performance of the filter designed are verified by simulation in terms of voltage/current THD, ripple content in DC voltage, fundamental value of voltage/current and RMS value of output voltage/current.

The effect in output current, output voltage, and supply current and ripple in dc component with different values of capacitor and inductor have been presented.

II. CLASSIFICATION OF PASSIVE FILTERS

A different type of passive filters is used in ac-dc-ac converter they may be classified as:

A. *D.C. Passive Filters*

- Capacitive D.C. Filter
- Inductive D.C. Filter
- Inductive & Capacitive D.C. Filter

B. *A.C. Source Side Passive Filters*

- A.C. Shunt Filter
- Single Tuned &High Pass Filter
- A.C Series Inductive & Capacitive Filters

C. *A.C. Inverter Side / lode side Filters*

- LC filter
- LCL filter
- L+LC-filter.

III. DESIGN CRITERIA OF PASSIVE FILTERS

(a.) Capacitive D.C. Filters

A DC choke and an electrolytic capacitor bank on the DC bus filter the voltage and the current ripples and improve the input power factor. Capacitor and choke values are derived to optimize overall filter performance [1].

The design sequence for the filter consists of the following steps:

Steps 1 - Calculate the capacitance needed to manage a certain level of ripple voltage: for a depiction of the rectifier output waveform. The peak ripple voltage (V_{max}) is first calculated

$V_{max} = V_{rms} \times \sqrt{2}$

If the maximum acceptable ripple voltage is 80 volts, then $V_{min} = V_{max} - V_{ripple}$

A calculation is made assuming all the energy is taken from the capacitor. The energy in a capacitor is typically defined as 1/2 x C xV_{max}. Based on this formula the following calculation can be made

$$P_{load} = (1/2 \times C_{dc} \times V^2_{max} - 1/2 \times C_{dc} \times V^2_{min}) / t \text{ watts}$$

A capacitor load bank can be made up several ways. We have chosen to use a capacitor value of 500uf to 10000uf for 500 V.

Step 2 - Calculate the ripple factor of DC voltage from the AC Line and from load

$$\text{Ripple factor } RF = V_{ac} / V_{dc}$$

Step 3 – calculate the ripple voltage .

(b.)A.C. Shunt source side Filter

Three-phase harmonic filters are shunt elements that are used in power system for decreasing voltage distortion and for power factor correction. In order to achieve an acceptable distortion, several banks of filters of different types are usually connected in parallel. consists of tuned LC filters and/or high pass filters are used to suppress the harmonics. The shunt passive filters are tuned most of the time on a particular harmonic frequency to be eliminated. So that it exhibits low impedance at the tuned frequency than the source impedance, to reduce the harmonic current flowing into the source.i.e. The filtering characteristics are determined by the impedance ratio of the source and passive filter**.** The most commonly used A.C. shunt filters are:

(i) Single tuned shunt LC:

These are used to filter lowest order harmonics such as 5th, 7th, 11th, 13th, etc. Band-pass filters can be tuned at a single frequency (single-tuned filter) or at two frequencies (double-tuned filter) as shown in Fig.(1)

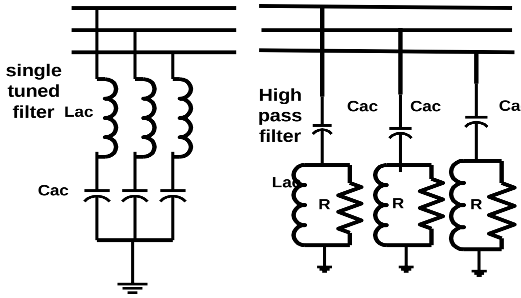


Fig 1 single tuned & high pass Shunt LC Filter

(ii) High-pass filters:

Which are used to filter high-order harmonics and cover a wide range of frequencies. A special type of high-pass filter, the C-type high-pass filter, is used to provide reactive power and avoid parallel resonances as shown in Fig (1).

(iii) AC-series Inductive-Capacitive Filter:

Inductive element (L_r) of series filter is chosen so that the inductive element should not be bulky capacitive element (C_r) of series filter can be selected as:

$$C_r = \frac{1}{(6\text{л}f)^2 L_r}$$

The passive elements of series harmonic filter selected on the basis of resonating frequency Compensating capacitor is selected such that the input power factor at the rated output reaches its maximum value

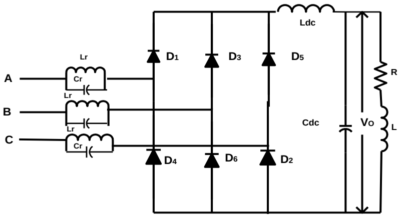


Fig 2. AC-series Inductive-Capacitive Filter

(c.) A.C. Inverter Side / lode side Filter:

(i) LC filters design:

The simplest filter is the single section LC filter .The series element's an inductance and the shunt element a capacitance. In the series inductance, harmonics voltages are developed and harmonics current flow through the shunt capacitance.. The load power factor should be considered in selecting the individual values of L and C

Resonance frequency

$$f_{res} = \frac{1}{2\text{л}\sqrt{LC}}$$

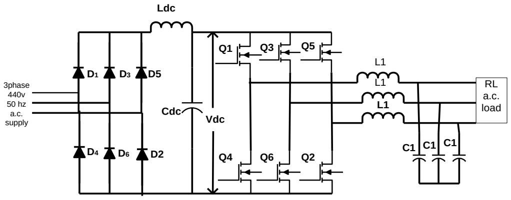


Fig 3 A.C. Inverter side filter

(ii)LCL-filter design:

A topology of an LCL-filter used is seen in fig 4. The LCL-filter is currently probably the most widely used topology. The reason for the popularity of the LCL filter is that good attenuation is achieved with a relatively small component values .i.e, good power quality is achieved with a reasonable filter costs. To find the desired resonance frequency, the filter parameters must be optimized.

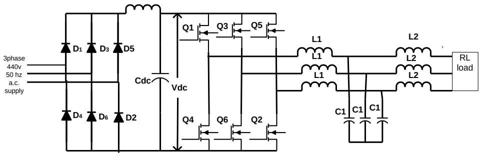


Fig 4. A.C. Inverter Side LCL filter

By taking the resonance frequency f_{res} to be the primary design parameter, we are able to set the resonance frequency without having to iterate it. The resonance frequency of the LCL-filter is defined as

$$fres = \frac{1}{2\pi} .. \sqrt{\frac{L1 + L2}{L1L2C}} \text{..........................(1)}$$

No. of harmonic	without filter	5th arm filter	7th arm filter	high pass filter	5th&7th filter	source side filter
5th	16.49	**0.02**	15.54	13.24	**0.02**	0.01
7th	9.78	6.51	**0.01**	8.61	**0.01**	0.01
11th	6.56	4.51	5.61	**4.86**	3.32	2.31
13th	5.08	3.5	4.38	**2.81**	2.6	1.37
Total THD%	22.23	10.2	18.5	17.50	5.99	3.65

$$fres = \frac{1}{2\pi} .. \sqrt{\frac{1+r}{rL1C}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (2)$$

Then by selecting the desired capacitor values, f_{res} as a function of the inductor ratio $r = L_2/L_1$ can be obtained. The resonance frequency in Eq. (2) can be presented as $\omega_{res}^2 L_1C = 1+ r$ *and* the capacitor value C=1+r/$W_{res}{}^2L_1$.

(iii) L+LC-filter design:

The difference between the LCL-filter and the L+LC-filter is that the L+LC-filter has two resonance frequencies while the LCL-filter has only one. Actually, the LCL-filter has three resonance frequencies, but the one defined by.(2) is the essential from the practical viewpoint. The two resonance frequencies of the L+LC-filter are called the antiresonance frequency f_{ares} and the resonance frequency f_{res} due to the nature of resonances. At the antiresonance frequency the frequency components of the line current are attenuated whereas at the resonance frequency they are amplified.

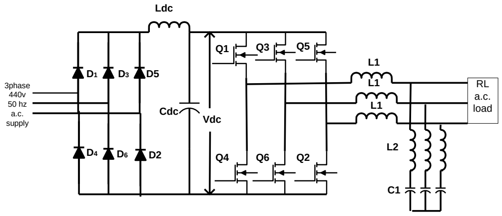


Fig 5. A.C. Inverter Side L+LC filter

The antiresonance frequency is placed on the switching frequency. When placing the resonance frequency of the L+LC-filter, a couple of things should be considered. a considerable loss of attenuation occurs when the ratio between the antiresonance *f*ares and the resonance frequency *f*res $\mathbf{k_{L+LC}=\omega_{ares}/\omega_{res}}$ is diminished.

$$fares = \frac{1}{2\pi} .. \frac{1}{\sqrt{\left(L1+L2\right)C}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

In other words, the higher the resonance frequency is compared to the antiresonance frequency; the lower is the attenuation on the higher frequencies.

When only the L+LC-filter is considered, the resonance frequencies could be characterized as the serial and the parallel resonance of the filter. That is, the antiresonance frequency could be calculated as and the resonance frequency as

Eq(3)

$$fres = \frac{1}{2\pi} .. \frac{1}{\sqrt{L2C}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq (4)}$$

If the capacitor value is fixed and the antiresonance frequency is known, then the inductance L_2 can be calculated as

$$L2 = \frac{1}{2\pi} .. \frac{1}{\omega_{resC}^{2}} .. - L1 \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{Eq(5)}$$

If the value of the inductor $L2$ is chosen instead, then the value of the capacitor could be calculated using Eq.(5) first, by solving C.

Method using resonance frequency as design parameter :

The first step, again, is to choose the value for the capacitance. Then by assuming the parallel connected inductance $L_1||L_2$ to be equal to inductance L_1, the inductance L_2 can be solved from Eq.(4). When L_2 is solved and substituted in Eq. (5), the value for inductance L_1 is obtained. When all parameters are solved, the resonance frequencies could still be inappropriate. To get the frequencies match with the frequencies specified, some iteration has to be done.

Type of filter	Capacitive filter	Inductive filter	L_{dc} & C_{dc} filter
Ripple voltage (volt)	60 (10%)	80 (13%)	3.2 (0.5%)

IV. COMPARATIVE EVALUATION OF PASSIVE FILTERS

A. *D.C Filter:*

Table 1 show the comparison of D.C. filter capacitive filter is used ripple free dc voltage ,inductive filter is used for smooth the supply current ,L_{dc}& C_{dc} filter are used for compensating of voltage as well as current & ripple voltage is also reduce 3.2 volt. Main object of dc obtain ripple free constant DC output voltage & continuous output current.

Table 1 comparison of different type of D.C.filter

B. *A.C. Source Side Filter :*

In shunt source side filter the THD of the supply current is reduced to well below 5% (22% to 3.65%) & the fundamental value of supply current will be increase further by eliminating the ac inductor and increasing dc capacitance of the rectifier, the rectifier current would increase larger, which may result in over current to the rectifier.

Table 2 Comparing of Different Type of A.C. Source Side Filter with Specified nth Order of Harmonic

C. Inverter Side Ac Filter:

Filter parameters of LC, LCL- and L+LC-filters using the component values fulfill the requirement for the line voltage distortion (THD < 5 %) at constant switching frequency.

Types of filter		V_o output voltage(volt)		I_o output current(amp)	
		V_o without filter	V_{of} with filter	I_o without filter	I_{of} with filter
LC filter	Fund. value	573.8	567.4	21.29	22.95
	R.M.S.value	405.7	401.2	15.02	16.23
	THD (%)	44.63	4.71	30.69	0.59
LCL filter	Fund. value	575	565.9	21.04	22.89
	R.M.S.value	406.7	400.2	14.88	16.19
	THD (%)	44.63	3.63	30.21	0.45
L+LC filter	Fund. value	575.2	565.5	22.23	22.88
	R.M.S.value	406.7	400	15.72	16.18
	THD (%)	44.63	4.7	25.19	0.63

Table 3. Comparison of different types of inverter side A.C. filters

V. CONCLUSION

Filter design methods presented, revealed some important issues that should be noticed while designing a filter for PWM voltage source converter. In particular, it was shown that the simulation result when an LCL filter is used for the PWM inverter has a major impact on the performance of the filter.

The performance comparison between LC,LCL ,L+LC filter in the term of component size ,shower very clearly the superior performance of the LCL filter over the other filter .

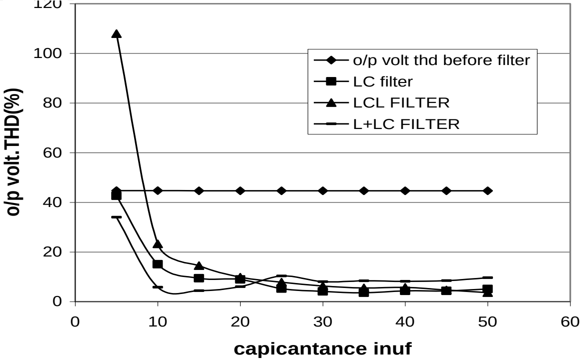
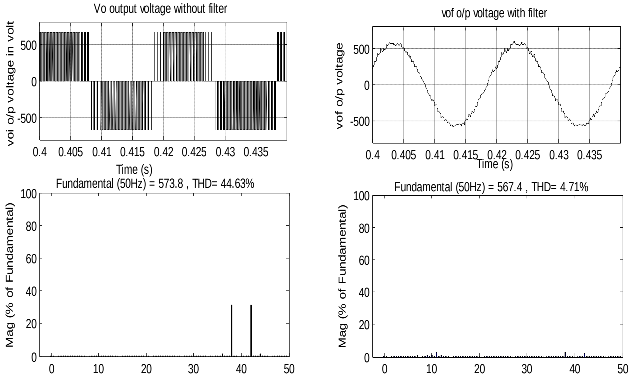
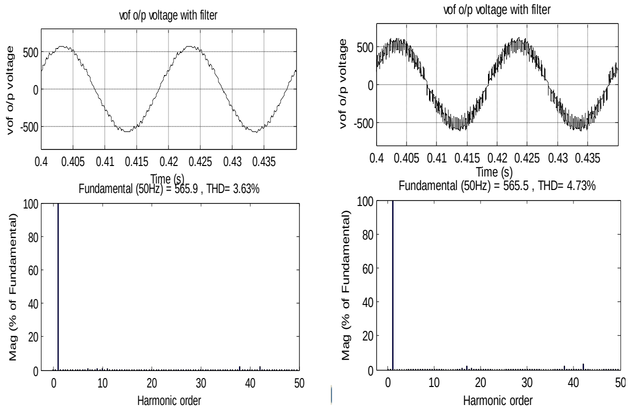


Fig 6.Effect of capacitor value of output voltage THD (%) For different type A.C inverter filter

Simulation result of inverter side A.C. filter:



(a)Without filter (b)with LC filter



(c)With LCL filter (d) With L+LC filter

APPENDIX

Simulation Parameter Of Shunt & Series Filter. A.C. Source Side Shunt Filter.

5th arm	L_5 =1.2 mH ,C_5=337 uf
7th arm	L_7 =1.2 mH , C_7=170uf
High pass	L_h= .26mH ,C_h= 300uf,R_h=3Ω
Lr ll Cr series	Lr=1.2 mH ,Cr=35uf

Simulation t Parameter of Inverter Side A.C .Filter

Type of filter	Resonance frequency . f_{res}	Filter parameter		
		L1	L2	C
LC filter	530	2mH	-	45uf
LCL filter	1047	2mH	0.6mH	50uf
L+LC filter	1677	2mH	0.6mH	15uf

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