**FILTERS**

**Filters:**

* An LC circuit which passes all its frequencies within its pass bands & stop all frequencies in its stop band.
* The electrical circuits with inductor (L) & capacitor(C) of particular values constitutes to form a filter which resonates at one particular frequency.
* The resonant frequency is one at which the filter offers negligible resistance to the particular frequency & allows a path to flow through it.
* Filters are the equipments by which certain frequencies can be allowed to pass & certain frequencies can be blocked from passing through them.
* Filters are used in HVDC system to minimize the harmonics.

**Objectives of filters:**

1. To reduce the harmonic contents in the voltages & current.
2. To supply the required amount of reactive power to the converter.
3. To eliminate the interference with communication system.
4. To reduce the over voltage due to resonance.
5. To avoid the instability of the converter controls due to firing schemes.
6. To avoid interference with ripple control system used in load management.

**Types of filters:**

1. AC passive filters
2. DC active filters
3. High frequency filters
4. **AC passive filters:**
* This is a type of filter designed to reduce the harmonic current flow through the concerned AC system.
* The AC filter are nothing but the circuit consisting of RLC components, eliminating all harmful effects caused by the radio interference, television interference & offering low impedance to harmonic frequencies.
* The single line diagram of AC filters is shown in figure.
* The AC harmonics are calculated by,

 HAC = pq±1

 Where p is the pulse number of rectifier or inverter

 q is the integer

1. **DC Active filters:**
* Filter which is designed to reduce the flow of harmonic voltage to the associated DC system.
* These filters are used to reduce ripple in the DC line & minimization of telephone interference.
* For efficient operation of converter, there is necessity of reactive power, which is supplied by AC filters in AC side, but DC filters don’t supply reactive power in DC lines is not enormous.

Thus there is no difference between AC & DC filters in terms of designing aspect except the difference that the reactive power of DC filter is not significant.

* Depending upon the DC voltage the capacitance required the DC filter capacitor rating are determined & compared to size of AC filter, DC filter has very small size.
* This is due to the effect that a smoothing reactor with high inductance value is responsible for the reduction of harmonic currents in DC side.
* For a converter of pulse number ‘p’ the predominating generated harmonic in the DC voltage are denoted by Hp DC & is given by,

 Hp DC = pq

 Where p is pulse number

 q is the multiple of main frequency or actual frequency.

1. **High frequency filters:**
* A high pass filter is a filter which passes all higher harmonic frequencies & blocks lower harmonic frequencies.
* Whenever these filters are connected across AC bus bars all the higher harmonic frequencies are diverted to through low impedance path, without allowing them to enter the system.
* Using these filters, the higher order (>74) characteristic as well as non-characteristic harmonics are eliminated.
* Instead of using individual tuned branches for each harmonic, it will be more efficient and economic to use just one high pass filter for all higher order harmonics.

Due to this the problem of identifying the characteristic and non-characteristic

* There are two types of high pass filters are presented
1. Second order high pass filter
2. C-type high pass filter

 Both of them consists of a combination of R, L & C parameters.

* From fig(i), the equivalent impedance of second order high pass filter is given by,

 Z=

 Or

* From fig(ii), the equivalent impedance of C-type high pass filter is given by,

 Z=

* So at particular values of L & C the harmonics are eliminated & provided low impedance path to system.
* The impedance characteristic of a high pass filter is shown in figure.

**Quality factor:**

* The quality factor measures the sharpness of the filter.

 Q = ]

QL (Quality factor of inductor):

 QL = ]

 QL =

 QL =

QC (Quality factor of capacitor):

 QC =

 QC = 2πfCR

 QC =

 QC =

**Tuning of filter:**

* To adjust the L & C parameters of the filter to some specific resonant frequency to desired performance of harmonic suppression.

**Frequency deviation (or) D-tuning:**

 In practical a filter is not always tuned exactly to the assigned harmonic frequency which is intended to suppress. The difference between the actual resonance frequency & assigned resonance frequency is called as D-tuning. It is represented by ’δ’.

 )

Where ∆L is the deviation in inductor.

 is the relative deviation in the inductor.

 is the initial deviation in the frequency.

 is the change in frequency.

 is the relative variation in the frequency.

 is the change in the capacitor.

 is the relative variation in the capacitance.

**Single tuned filter:**

* It is a single RLC circuit tuned to the frequency of the particular harmonic.

It offers low impedance to that harmonics.

* The filter configuration that are employed for HVDC converter stations are functions of frequency. Each filter is being designed to trap the characteristic harmonics & blocks them.
* As the name itself indicates, tuned for single frequency, these filters trap the harmonics of particular single frequency from entering the AC side.
* This filter is one of the type of AC filters, providing low impedance for characteristic harmonics at single resonant frequency.
* The single tuned filter configuration is shown in fig (i). The configuration consists of a capacitor, inductor, resistor connected in series.
* The impedance characteristics are shown in fig.

 Where fr is the resonant frequency at which the harmonics are trapped.

**Design of single tuned filter:**

 From fig (i),

 ]

**Harmonic current:**

 Harmonic voltage at the converter bus

**Min.cost:**

 The capital cost of each AC filter tuned to particular harmonic order varies with the size of that filter. The size is expressed in MVAR at fundamental frequency. The cost of AC filter includes the cost of AC filter capacitor, cost of AC filter reactor & resistor. The cost of capacitor varies with proportional MVAR size of the filter. The cost of the inductor varies with inversely proportional to the MVAR size of the filter. The cost of the resistor not related to the MVAR size of the filter.

 KC α S , KL α

 KC = AS , KL =

 Where S is the MVAR size of the filter.

Total cost of the filter K= KC+KL+KR.

 K= AS+ KR

**Double tuned filter:**

* The double tuned filter having two resonance frequencies.
* The impedance of the filter are lowest at this two frequencies.
* The two single tuned filters, can be replaced by a single double tuned filter. With the implementation of this filter there will be reduction in power loss, at fundamental frequency & for fall line impulse voltage only one inductor is enough.
* The configuration of double tuned filter is also a combination of RLC components forming two values of resonant at which the resistance for harmonics is very low & simultaneously allowing them to pass through ground.
* The tripping of two harmonics of discrete frequencies in this filter can be understand by the analysed by impedance characteristics.
* The impedance characteristics are explained by taking X-axis on frequency & Y-axis on impedance.

Where FL & Fh are two frequencies for which the low resistance is allowed to the harmonics by the filter.

**Advantages of double tuned circuit:**

* The losses are considerably reduced at fundamental frequencies.
* The design of insulation for the reactors is simple.
* By using filter the overall cost of equipment is reduced.
* By using double tuned filter in system the usage of circuit breakers can be reduced.
* The double tuned filter eliminates the harmonics of two different frequencies.