Power Quality
Prof. Bhim Singh
Department of Electrical Engineering
Indian Institute of Technology, Delhi

Lecture - 17
Passive Power Filters

Welcome to the course on Power Quality. We will cover today the topic on Passive Power Filter.

In last lecture we covered the non-linear loads and the problems they cause, including increased rms current, increased losses, low system efficiency, and poor power factor.

It causes derating of the distribution system, distortion in voltage waveform at PCC and interference to communication system.

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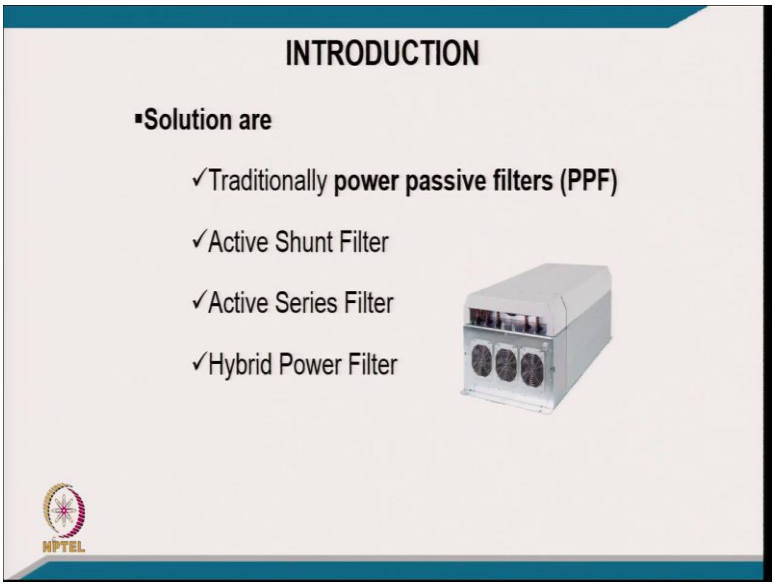

And the solution of course, for these problems which are caused by non-linear load in the distribution system are use of passive power filters, active shunt filter, active series filter and hybrid power filter.

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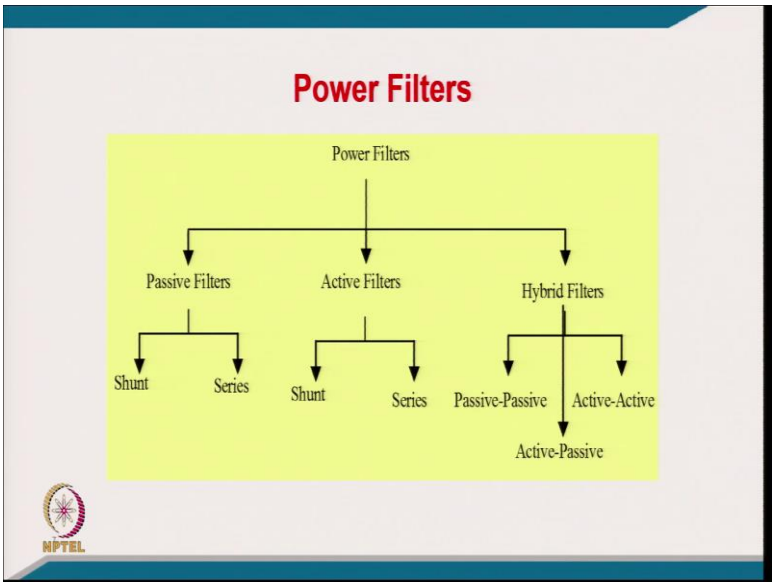

This is the broad classification of the power filter which are used for mitigating the power quality problem in the distribution system or even part of the transmission system like HVDC or other kind of converter where you have a power quality problems caused by harmonics generated by the different converters and non-linear load line.

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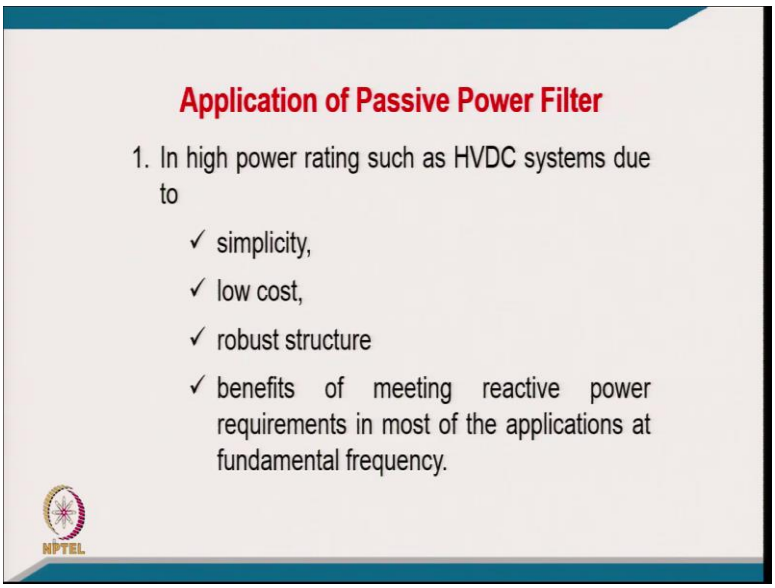

Passive power filter are used in high power rating such as HVDC, due to its simplicity, low cost, robust structure and benefits of meeting reactive power requirements at fundamental frequency in most of the applications.

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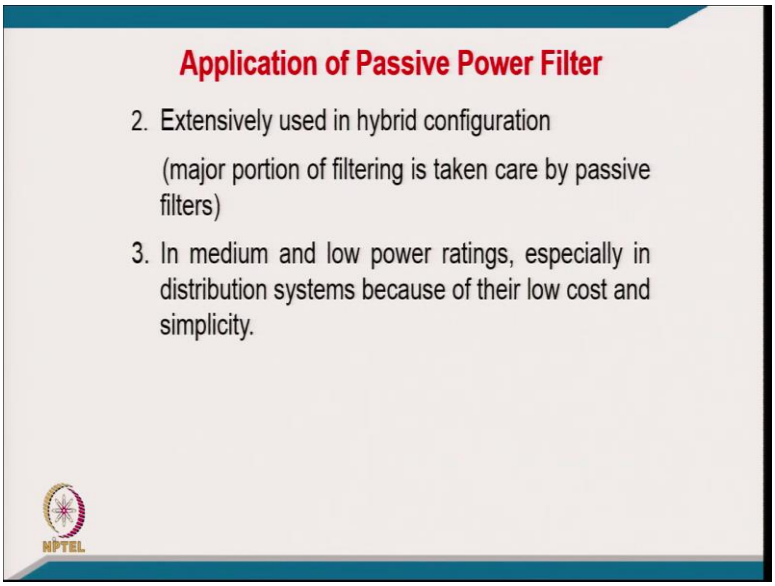

Passive power filters are extensively used in hybrid configuration. Major portion of filtering is taken up by passive filters. Hybridization may be using additional active shunt or active series filter.

These are especially used in medium and low power rating distribution system because of their low cost and simplicity.

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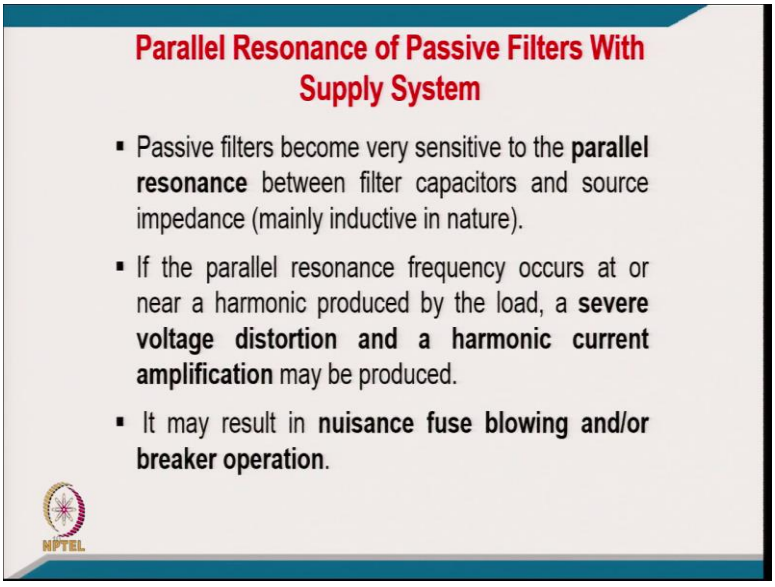

One of the major problem with passive power filters is the parallel resonance with the supply system. The passive filters are very sensitive to the parallel resonance between

the capacitors of passive filter and the source impedance which is highly inductive in nature. And if the parallel resonance frequency occurs at or near a harmonic produced by the load, a severe voltage distortion and harmonic current amplification may be produced and it may result in nuisance fuse blowing and or breaker operation.

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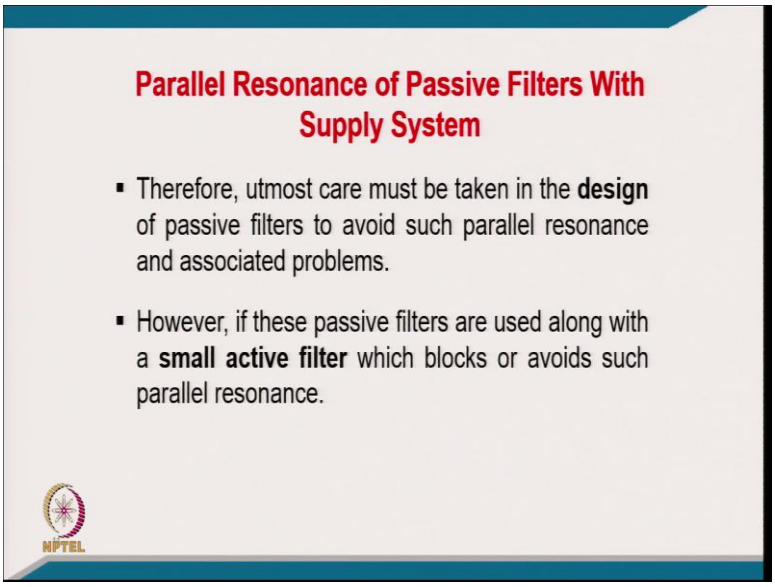

Therefore, utmost care must be taken in the design of passive filters to avoid such as parallel resonance and associated problems.

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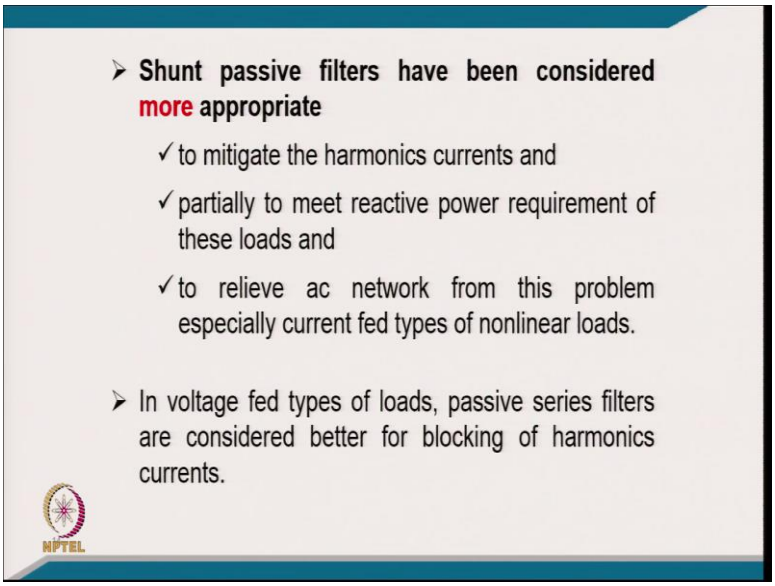

Shunt passive filter have been consider more appropriate to mitigate the harmonic currents and meet the reactive power requirement of loads. In voltage fed type of load passive series filter are considered better for blocking the harmonic.

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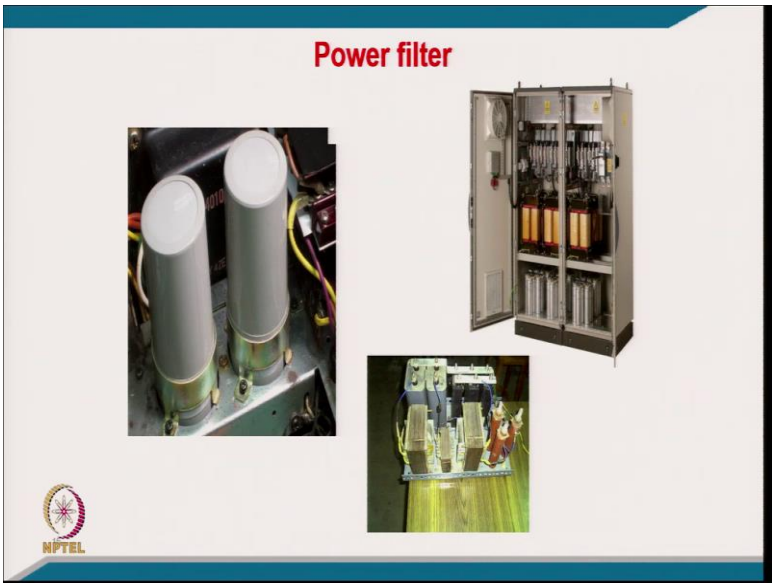

Passive power filters consist of AC capacitors and inductors.

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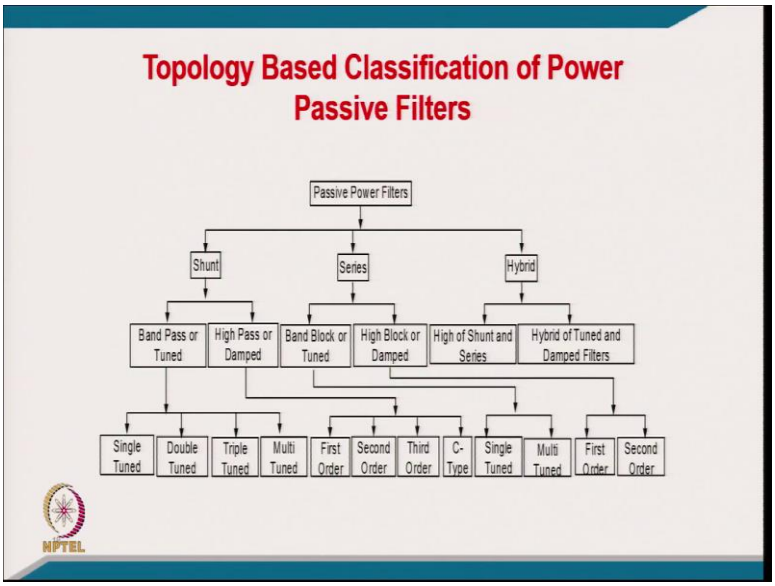

A broad classification of passive power filter is provided here.

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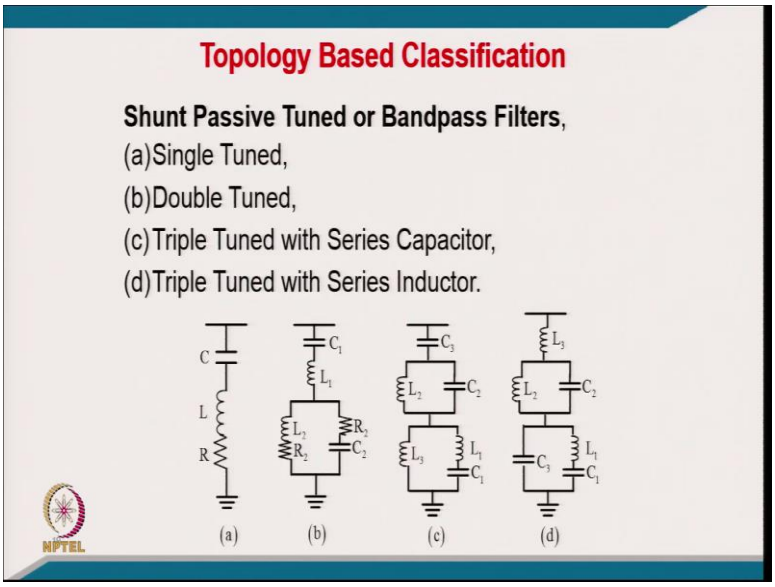

Well coming to each individual category, let us first discuss about shunt passive tuned or band pass filter. It can be like a single tuned, double tuned, triple tuned with series capacitor or triple tuned with a series inductor.

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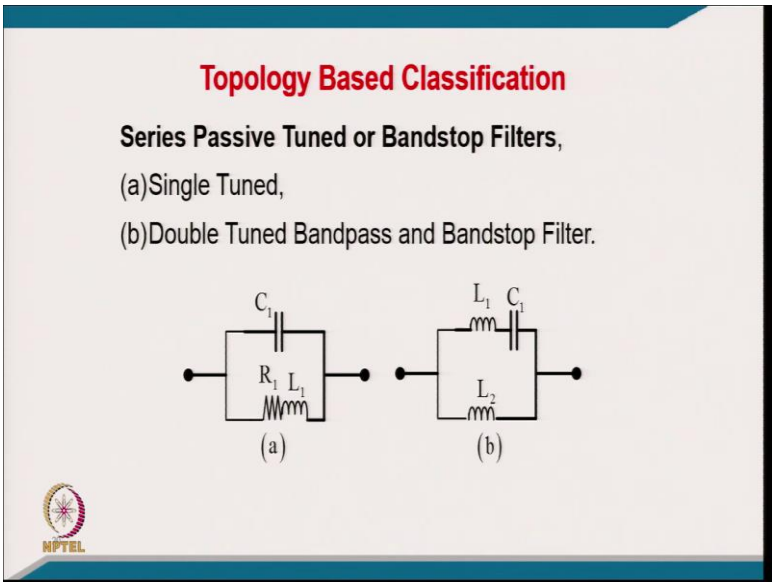

Coming to series passive tuned or bandstop filter. It can be also single tuned or double tuned.

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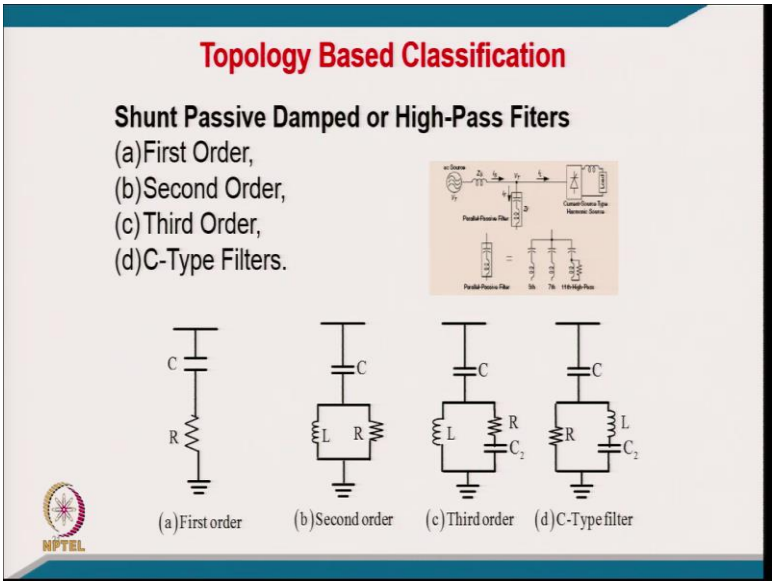

High pass means, all higher order harmonic will pass through and that it can again be first order, second order, third order or C-type filter. C-type filter is normally used in very high rating applications like HVDC also.

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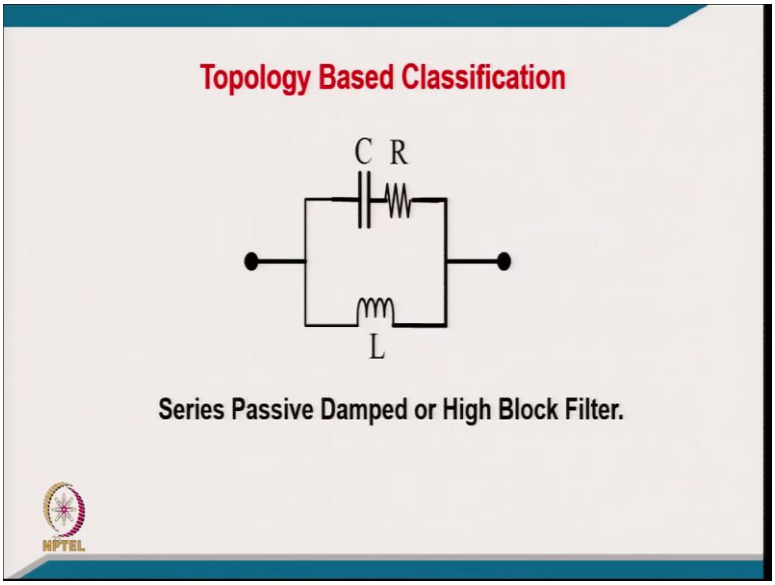

Coming to damped filter for eliminating the higher order harmonics current. The inductor size is small and will take a very small voltage drop at fundamental frequency.

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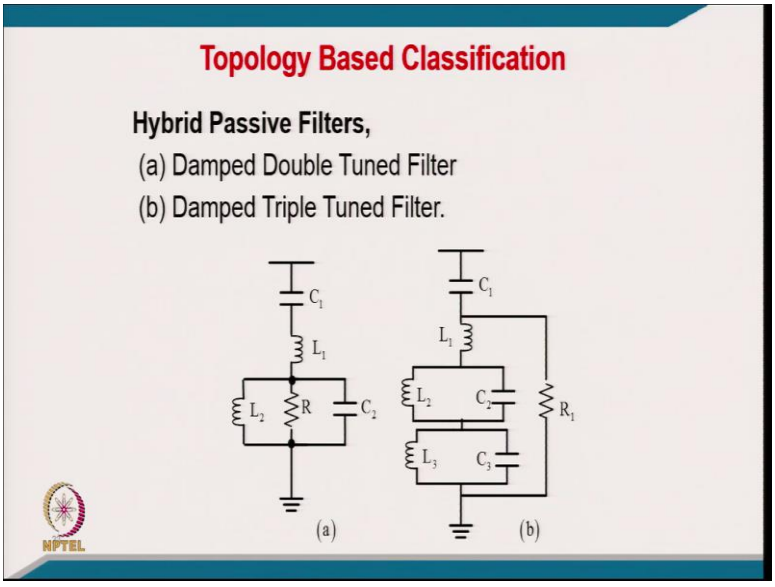

Well coming to the topology-wise classification of the hybrid passive filter. Hybrid passive filters can be damped double tuned filter or damped triple tuned filter.

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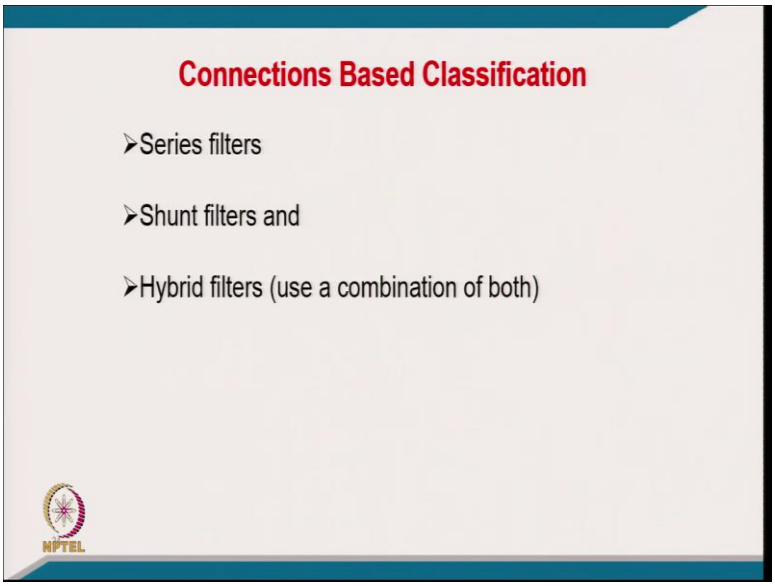

For connection-wise classification, it can be like a series filter, shunt filter and or a combination of both.

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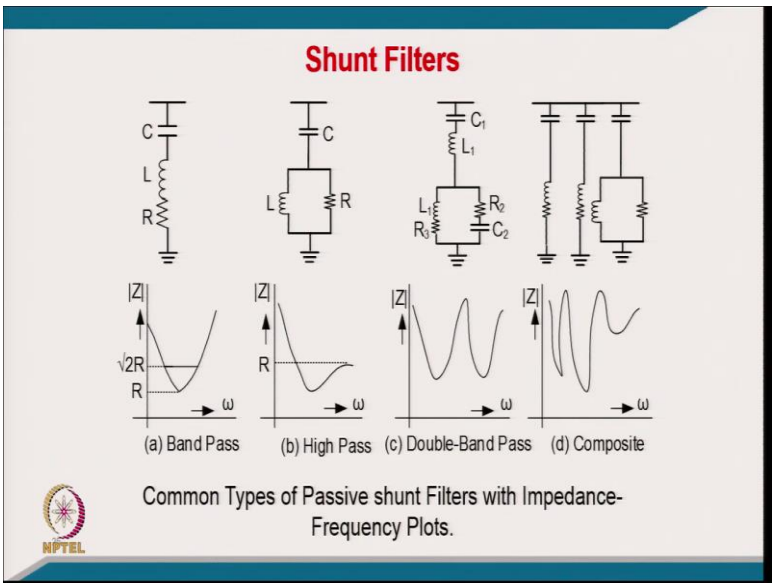

Now coming to classification of shunt filter, it can be band pass, high pass, double band pass and composite filter.

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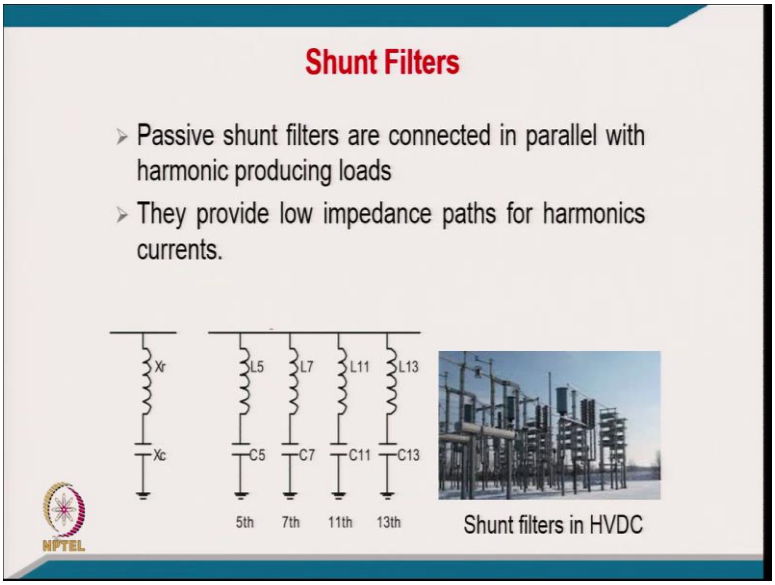

Well coming to the passive shunt filter, they are connected in parallel with the harmonic producing load. And they provide low impedance path for harmonic currents because they are tuned corresponding to that.

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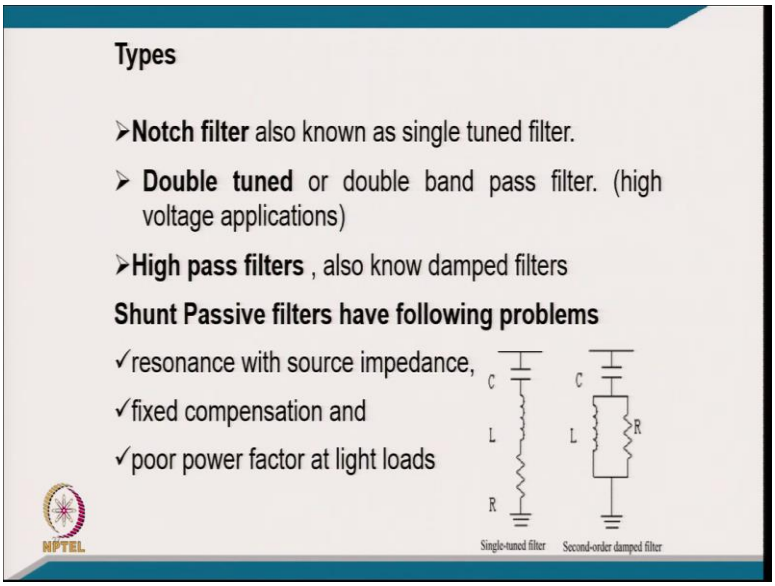

The types of shunt filters are described in the above screenshot.

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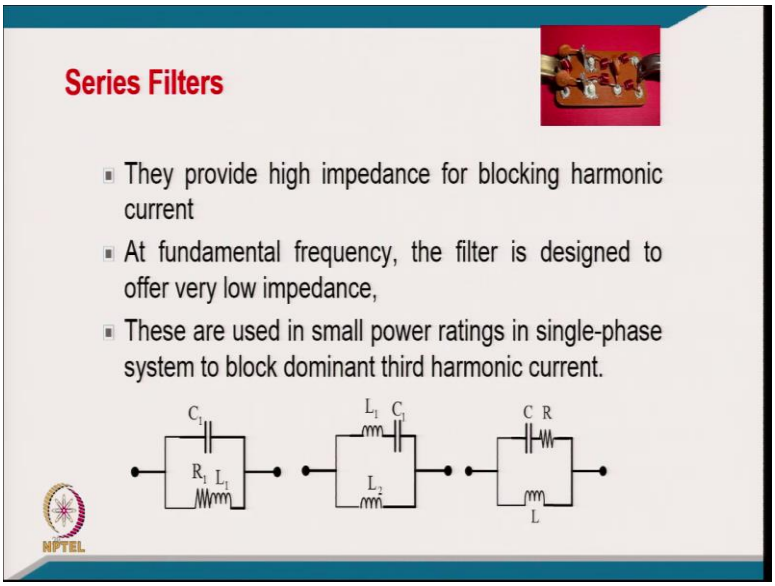

Now, coming to the series filter, they provide the high impedance for blocking harmonic current. At fundamental frequency the filter is designed to offer very low impedance.

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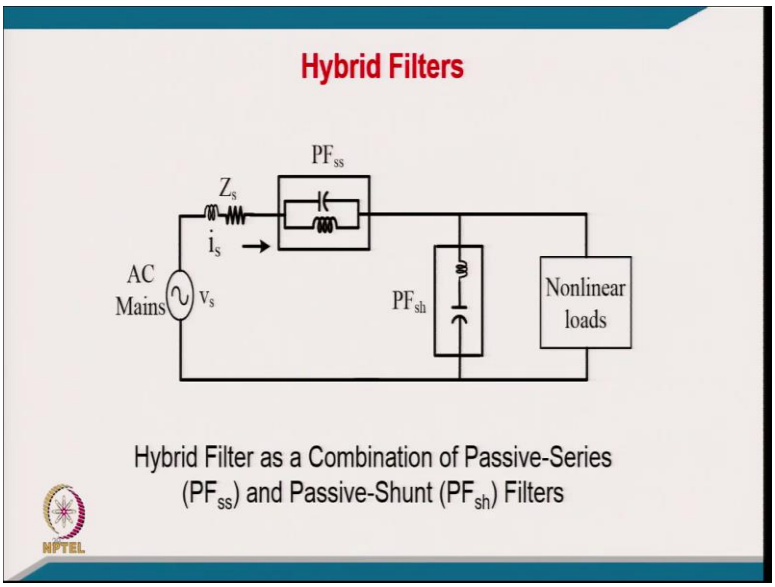

Hybrid filter can be used for single phase two-wire systems, three-phase three-wire systems or three-phase four-wire systems. This is a basic configuration with a passive filter in series and passive filter in shunt with a non-linear load.

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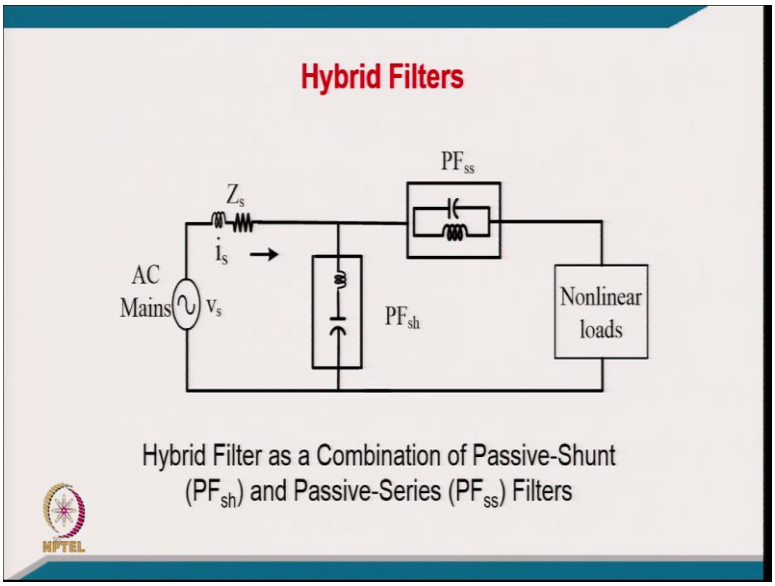

Coming to another configuration, the passive series is put on load side.

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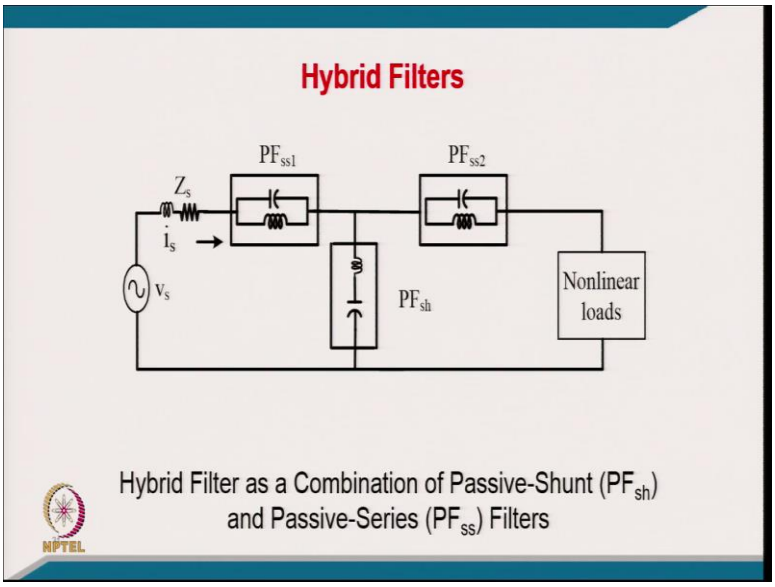

There can even be three passive filters as shown.

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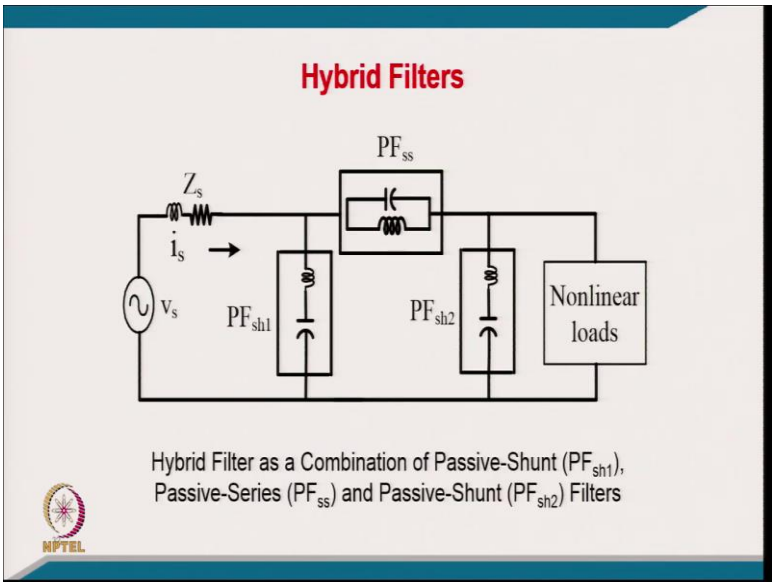

Here there is one passive series and two passive shunt filters.

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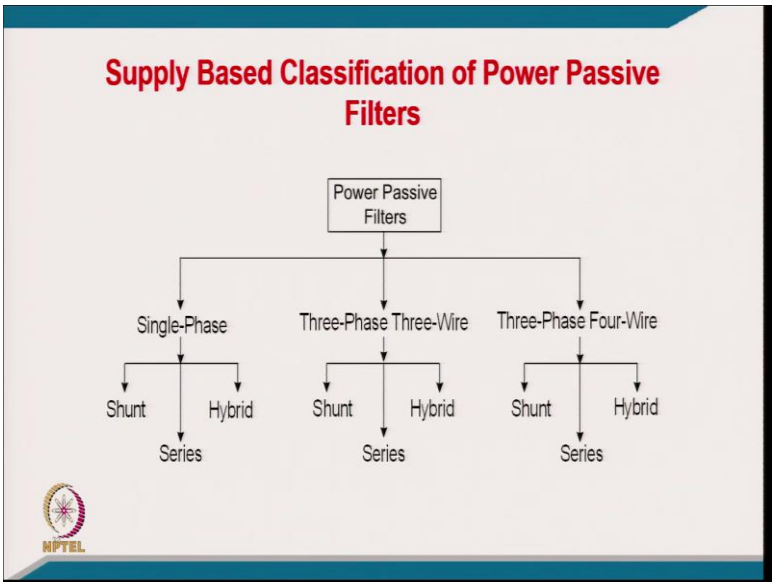

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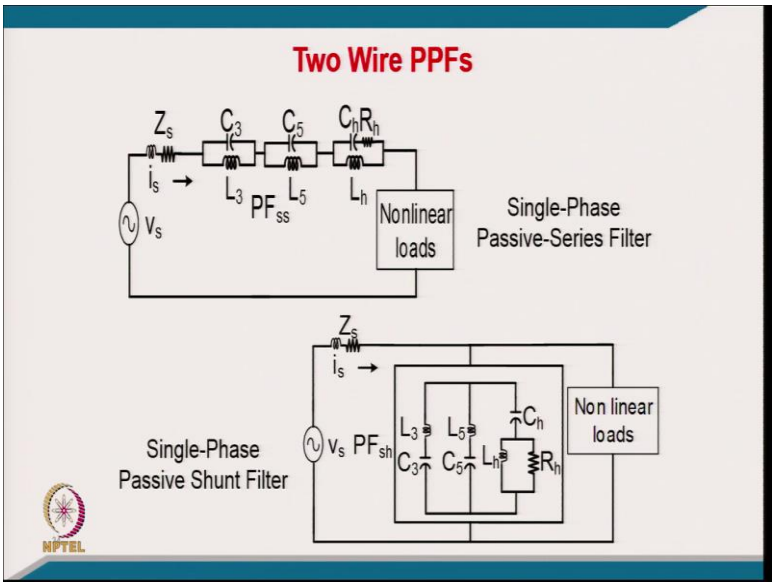

First case of supply based configuration is the two-wire topology.

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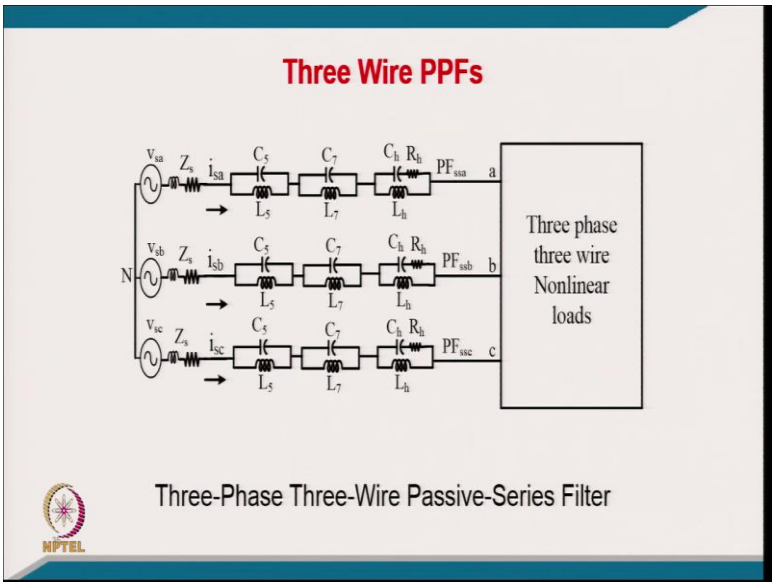

And then we have the three-phase three-wire configuration with series filters.

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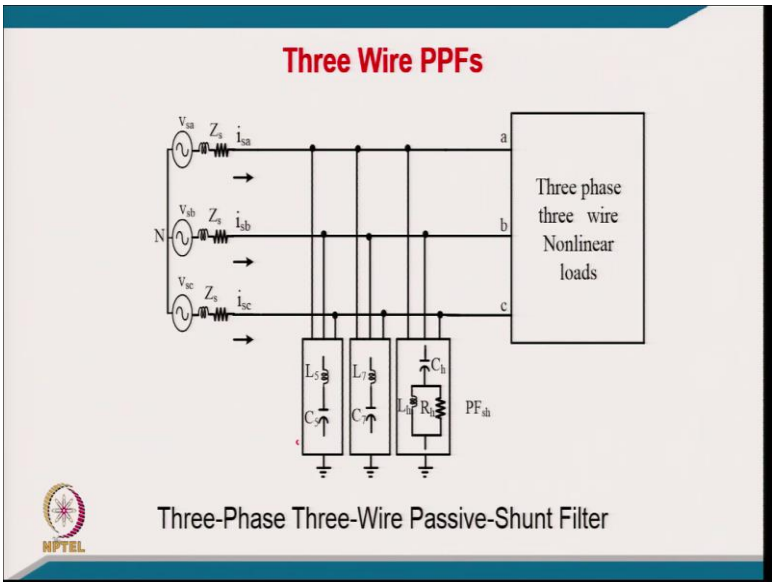

Similarly we have the shunt filter where you have a 5^{th}, 7^{th}, and then high pass. They are normally used with a current fed loads.

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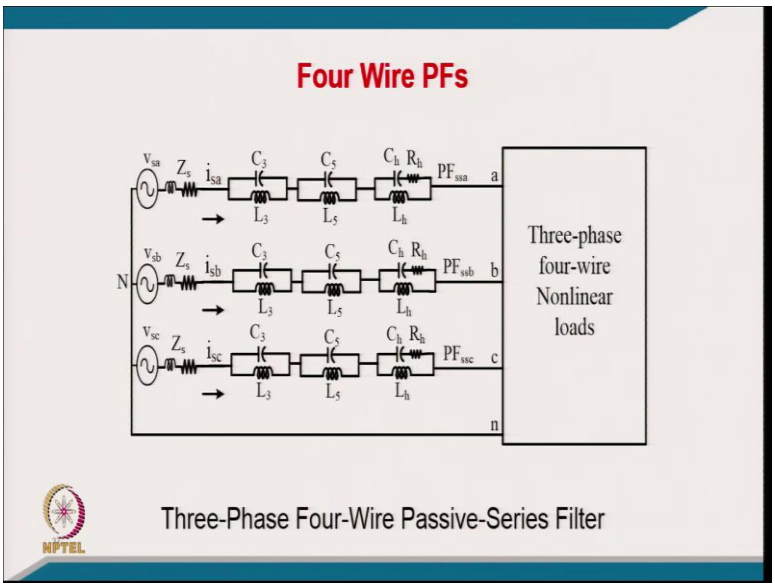

Well this is typically your three-phase four-wire series filter configuration.

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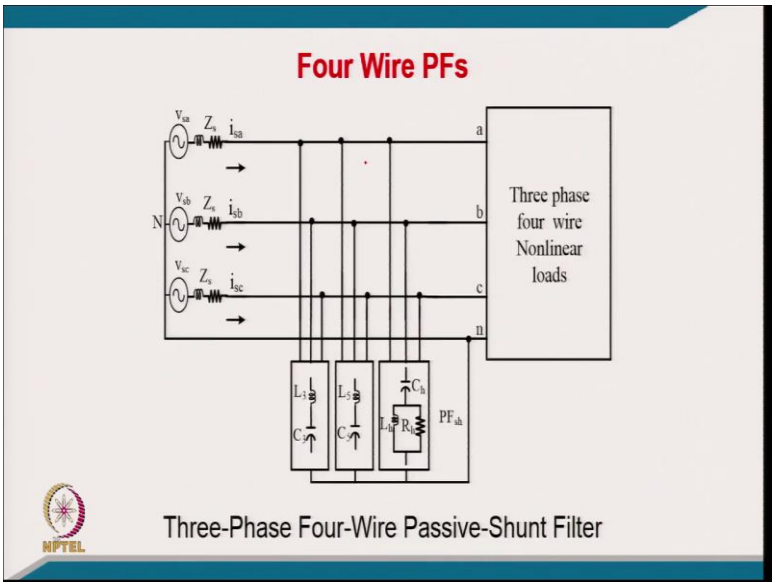

And then here is three-phase four-wire shunt filter configuration.

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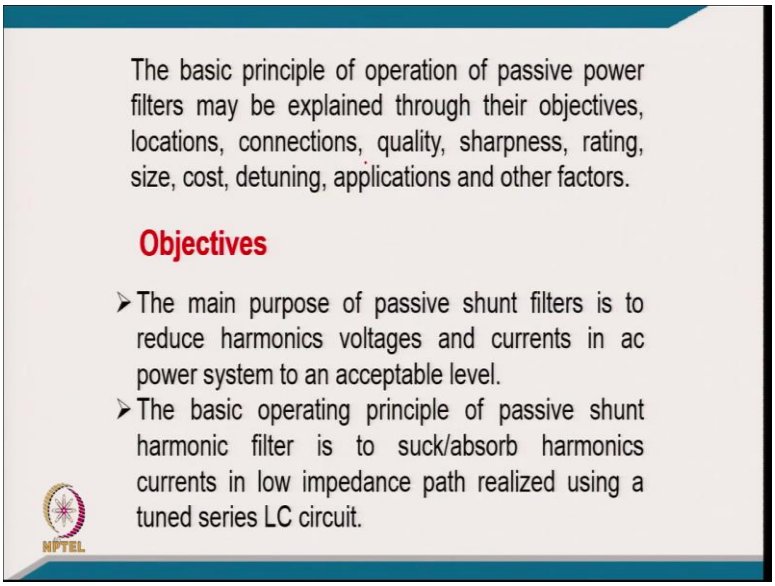

The basic principle of operation of passive power filters may be explained through their objective, location, connections, quality, sharpness, rating, size, cost, detuning, applications and other factors.

[The main purpose of passive shunt filters is to reduce the harmonics voltage and current in the ac power system to an acceptable level. And the basic operating principle of

passive shunt harmonic filter is to absorb harmonic current in low impedance path using a tuned series LC circuit.

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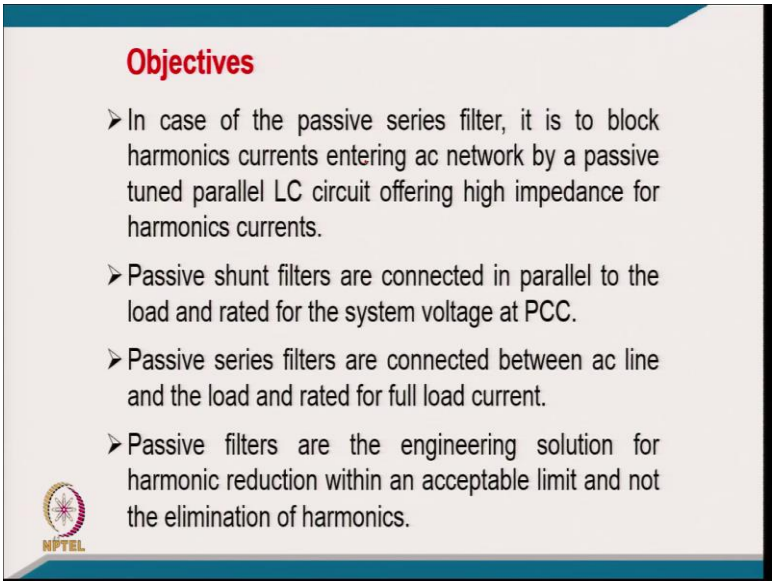

In case of passive series filter, it is to block the harmonic currents entering into ac network by passive tuned LC circuit offering a high impedance for harmonic currents. While, the filter should not draw any fundamental current from the supply as they are put in shunt.

At fundamental frequency they behave as a capacitive network and give the leading reactive power which is required by most of the current fed kind of non-linear load.

Passive shunt filters are connected in parallel to the load and rated for the system voltage at PCC. And passive series filters are connected in between ac line and the load and rated for full load current.

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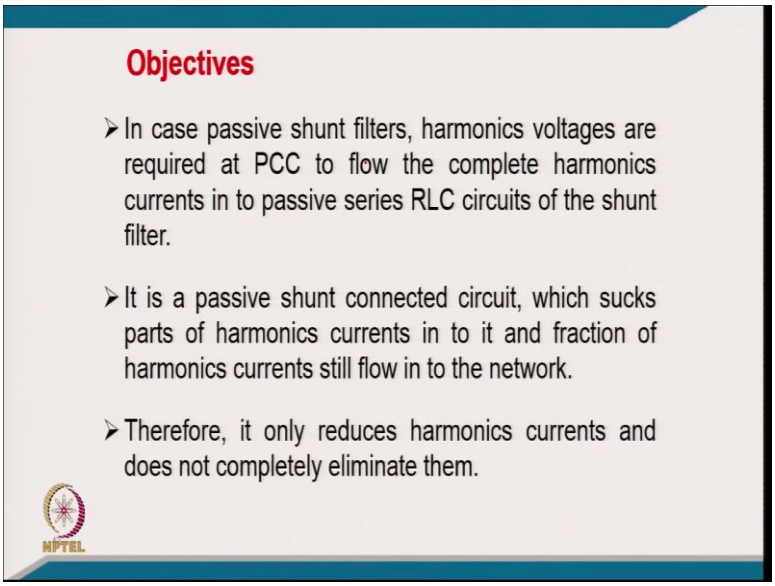

The passive filters are located very close to the load either on ac or dc lines. And most of the time these passive filters are connected at PCC where the loads are connected; however, sometime they are connected in tertiary winding of transformer designed for this purpose at optimum voltage to reduce the cost and to increase the effectiveness because they are popularly designed the leakage reactance of tertiary winding.

Moreover, these passive filters may be used for high voltage harmonic producing loads which require transformers and tertiary winding of the same transformer is designed to use these passive filters like.

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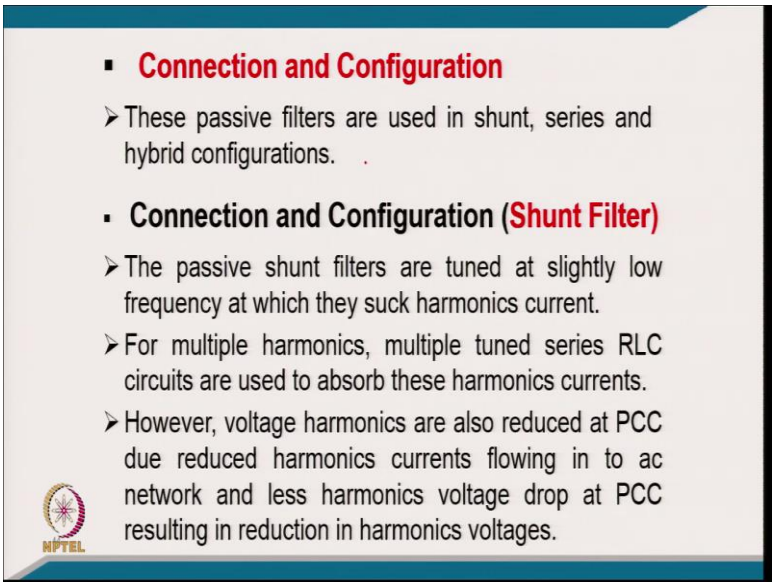

Coming to the type of connection and configuration: these passive filters are used in shunt, series and hybrid configuration.

And the passive shunt filter are tuned at a slightly lower frequency at which they absorb the harmonics.

Like typically, 5th harmonic filter is tuned at 4.7.

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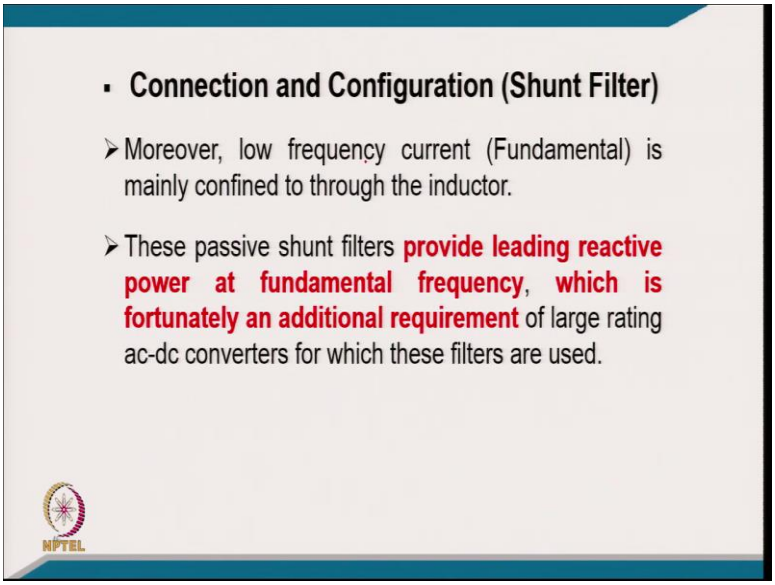

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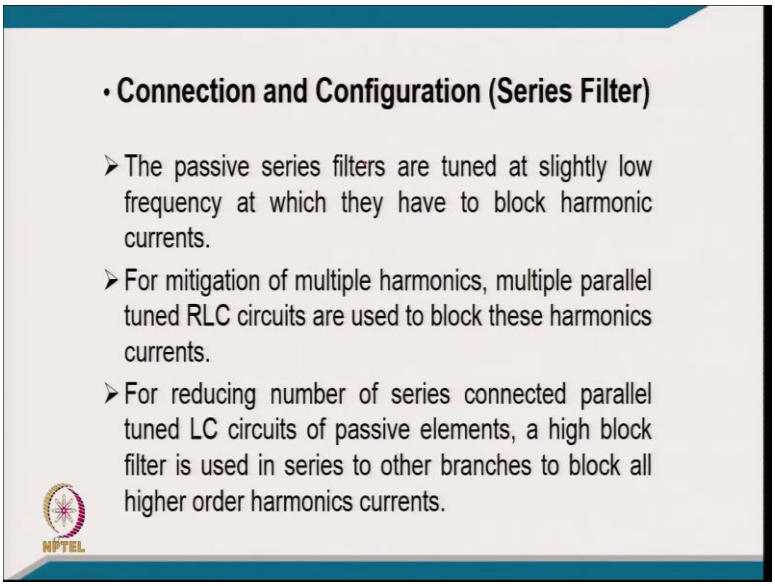

And coming to like a series filter connection: the passive series filters are tuned at slightly low frequency at which they have to block harmonic current. And for mitigation of multiple harmonics multiple parallel tuned RLC circuits are used to block these harmonic current.

And for reducing the number of series connected parallel tune LC circuit of passive element a high block filter is used in series with other branches to block all higher order harmonics current and they are connected all in series.

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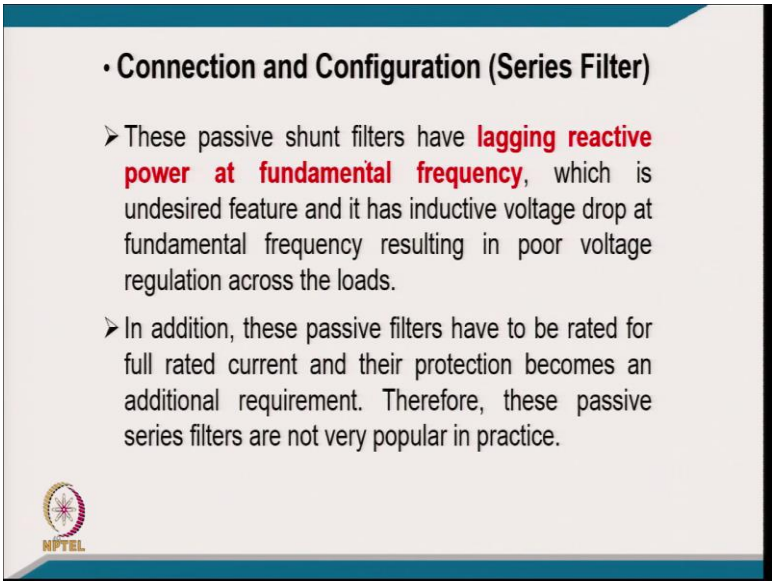

Passive shunt filters having a lagging reactive power at fundamental frequency which is undesired features and it has inductive voltage drop at fundamental frequency resulting in poor voltage regulation across the load. In addition this passive filter have to be rated for full current and their protection becomes an additional requirement. Therefore, these passive series filters are not very popular in practice.

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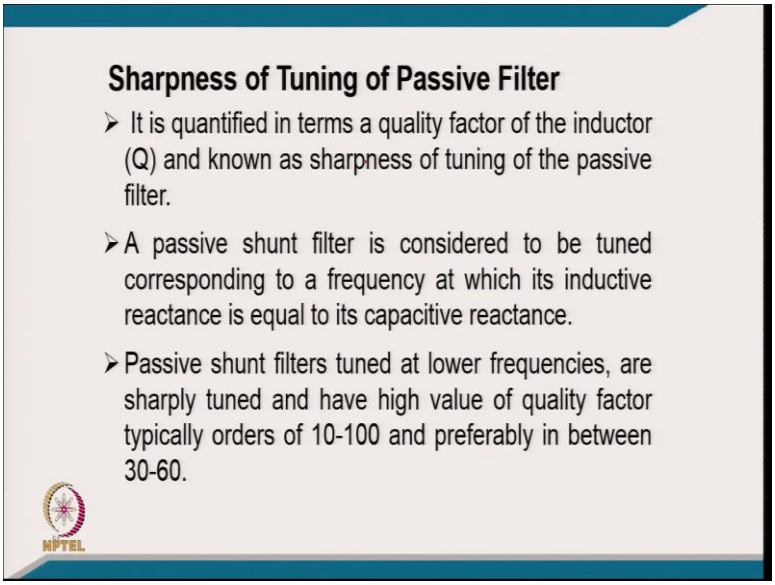

Sharpness we explain with the help of quality factor of the inductor or of the circuit and passive shunt filter it considered to be tuned corresponding to a frequency at which the inductive reactance is equal to capacitive reactance.

And passive shunt filter tuned at lower frequencies are sharply tuned and have higher value of quality factor typically order of 10 to 100 and preferably between 3 and 30, so, that quality factor is quite high. And quality factor is high means the resistance is small and if resistance is small, loss is also small.

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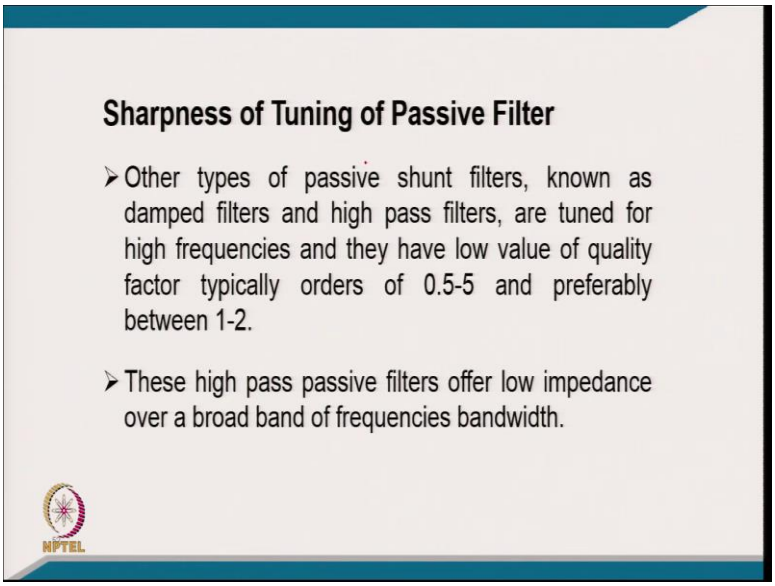

And of course, other type of passive shunt filters known as damped filter with a high pass filter are tuned for a high frequencies and they have low value of quality factor typically order of 0.5 to 2.

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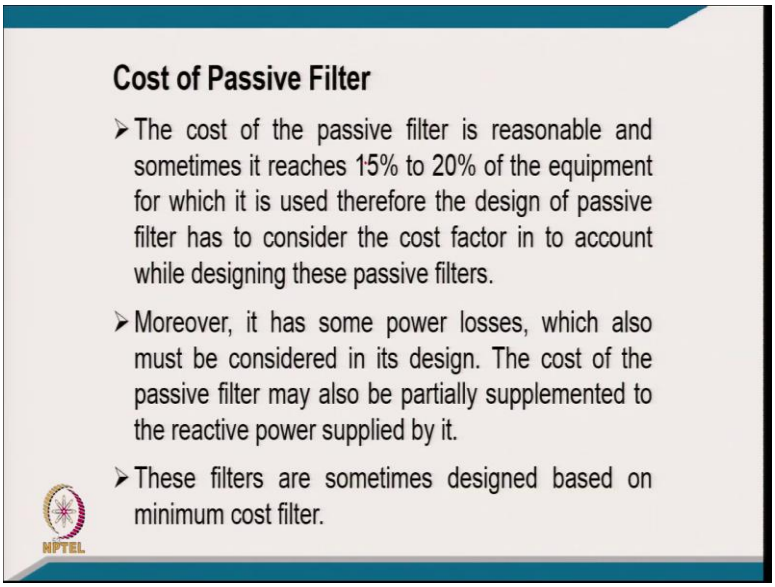

And coming to the cost of this passive filter, cost of this passive filter is the reasonable and sometimes it reaches 15 to 20 percent of the equipment for which it is used.

Therefore, the design of passive filter has to consider the cost in account while designing the passive filter. Moreover, it has some power losses which also must be considered in

its design. The cost of passive filter may also be partly supplemented to the reactive power supplied by it. Well, these filters are sometime designed based on minimum cost filter.