Power Quality
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Analysis and Design of Passive Power Filters
Lecture - 18
Passive Power Filters (contd.)

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Welcome to this course on Power Quality. [FL], we will discuss now the analysis and design of Passive Power Filter.

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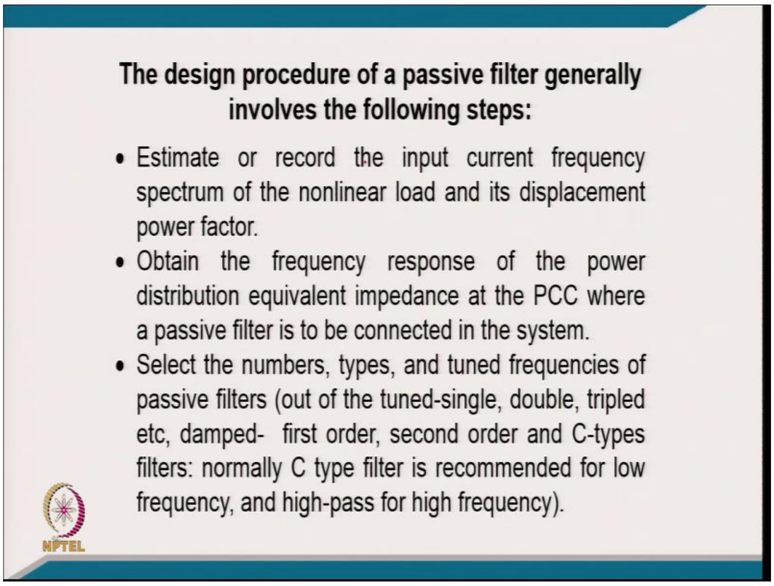

The design procedure for passive shunt filter generally involve the following steps:

- Estimate or record the input current frequency spectrum of non-linear load and its displacement power factor.

- Obtain the frequency response of the power distribution equivalent impedance at PCC where the passive filter is to be connected in the system.

- Select the number types and tuned frequency of passive filters out of tuned single double triple etcetera and damped first order, second order C type filter normally C type filter recommended for low frequency and high pass or high frequency.

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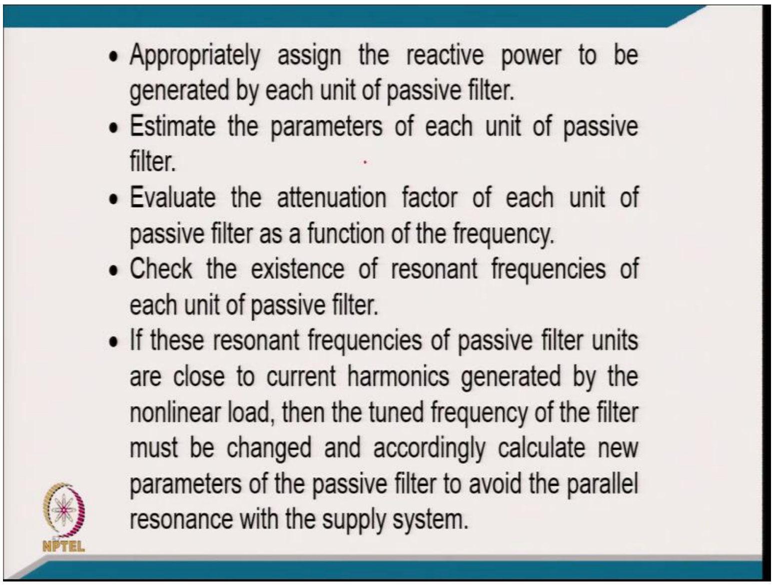

- Appropriately assign the reactive power to generated reactive power to be generated by each unit of passive filter estimate the parameter of each unit of passive filter.

- Evaluate the attenuation factor of each unit of passive filter at the as a function of the frequency.

- Check the existence of resonance frequencies of each unit of passive filter.

- If these resonance frequencies of passive filter units are close to the current harmonics generated by non-linear load then the tune frequency of filter must be changed and accordingly calculate the new parameters of passive filter to avoid the parallel resonance with supply system.

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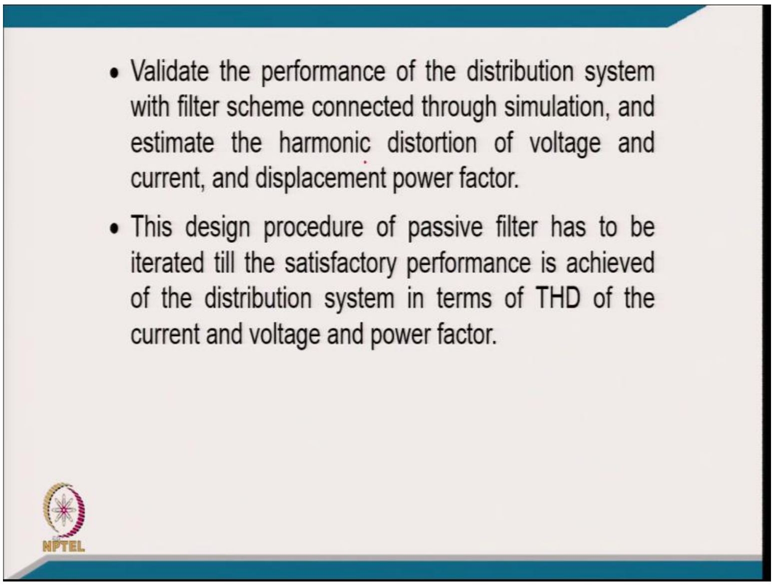

- Validate the performance of distribution system with filter scheme connected through simulation and estimate the harmonic distortion of voltage and current and displacement power factor.

- This design procedure of passive filter has to be iterated till the satisfactory performance is achieved of the distribution system in terms of total harmonic distortion of the current and voltage and power factor.

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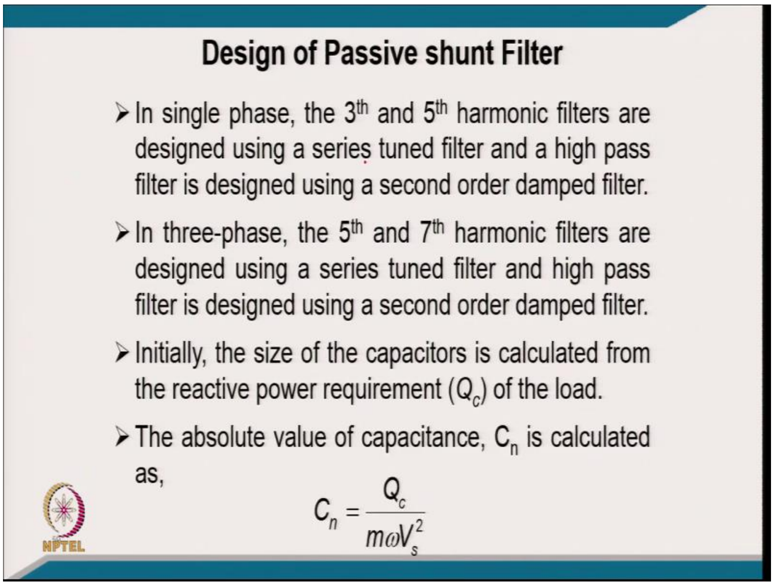

Coming to the design of this passive shunt filter in single phase, the third and 5th harmonic filters are designed using a series tuned filter while the high pass filter is designed using a second order damped filter. In three phase the 5th and 7th harmonic filters are designed using a series of series tuned filter while the high pass filter is designed using a second order damped filter.

Initially, the size of capacitors is calculated from reactive power requirement of the load. The absolute value of capacitance is calculated as presented in figure.

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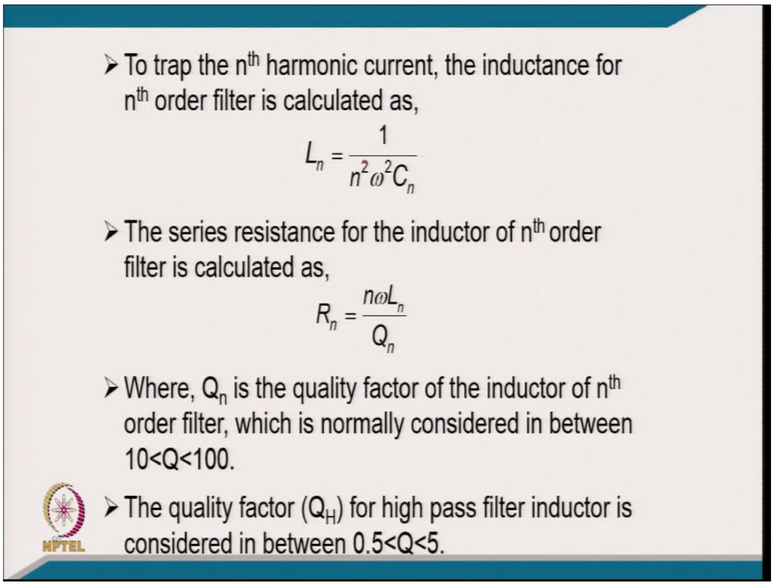

To trap the nth harmonic current the inductance for nth order harmonics and the series resistance of the inductor for nth order filter are calculated. The quality factor relation should be in between 10 to 100.

The quality factor for high pass filter inductor is considered in between 0.5 to 5.

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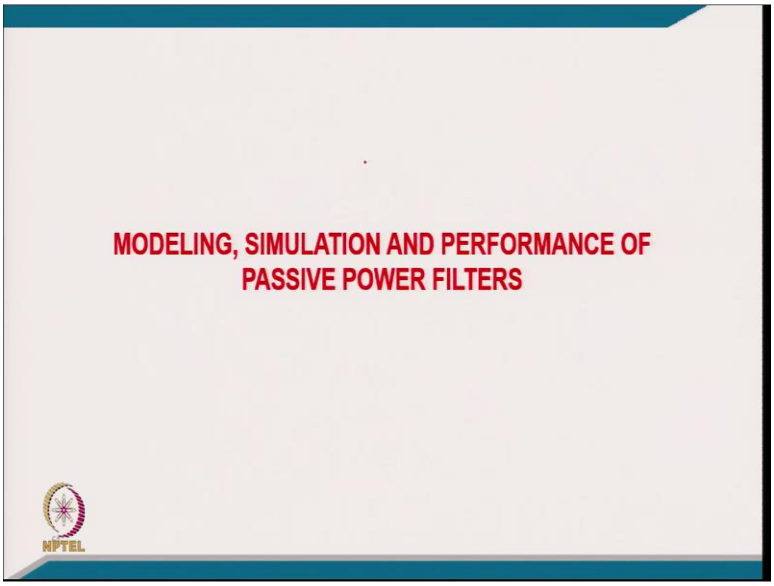

Coming to the modeling simulation and performance of passive power filter.

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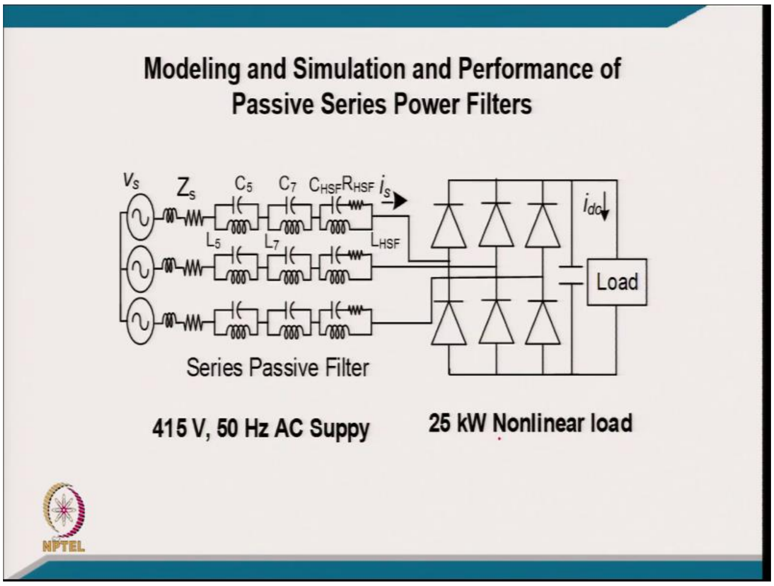

Well, this is one case study which we are taking for 25kW load.

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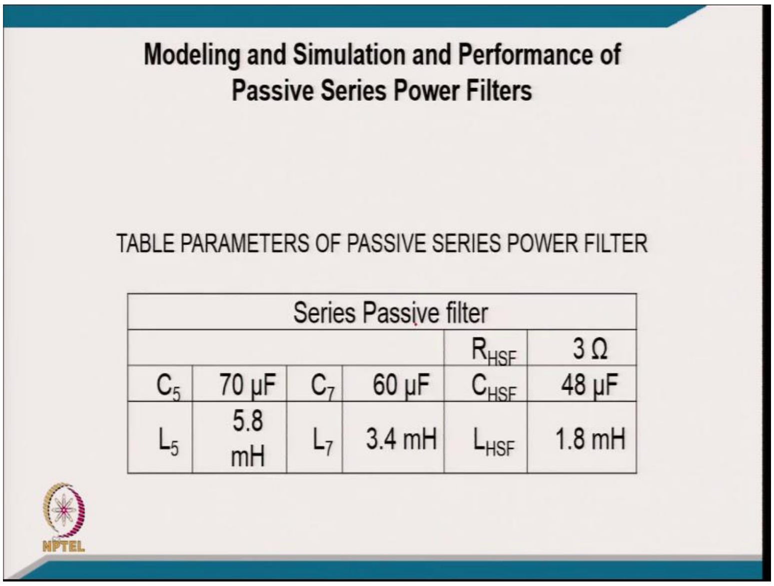

Series Passive filter					
				R_{HSF}	3 Ω
C_5	70 μF	C_7	60 μF	C_{HSF}	48 μF
L_5	5.8 mH	L_7	3.4 mH	L_{HSF}	1.8 mH

The design values of the series passive filter are provided in the screenshot.

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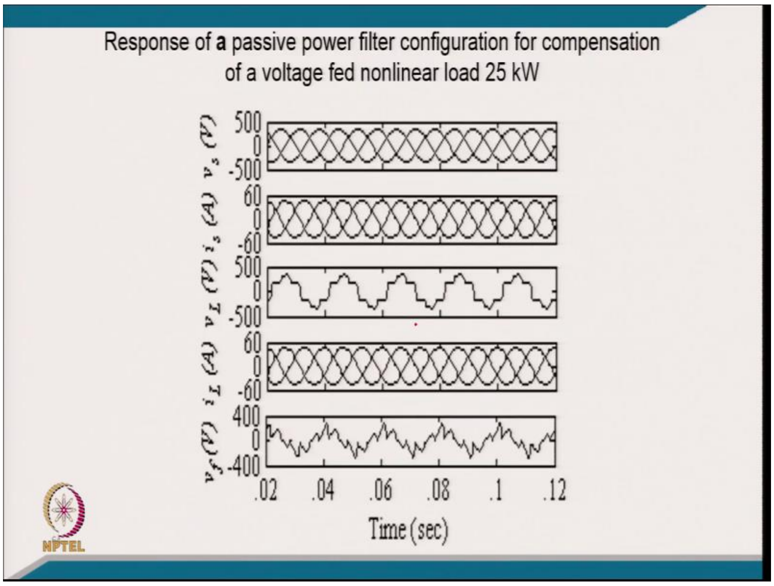

We can see after putting this passive filter with a 25 kW load, the supply currents are very close to the sinusoidal.

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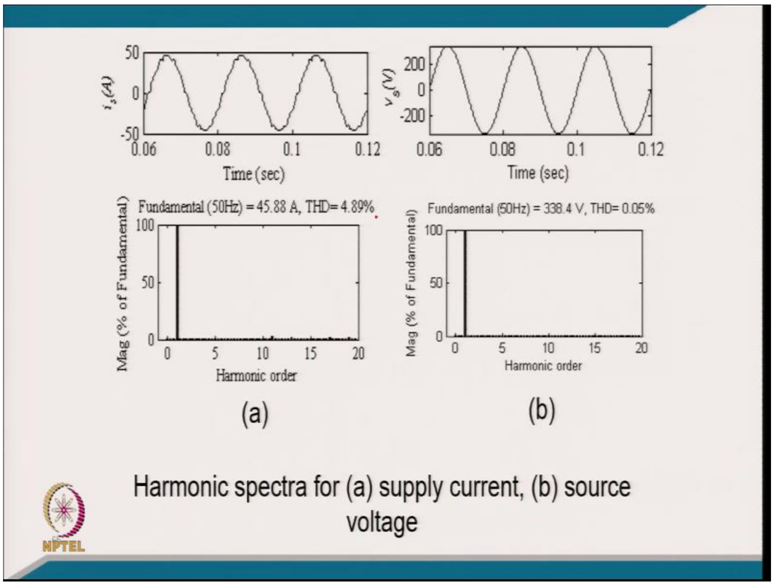

And you can understand now the voltage supply voltage THDs has reduced to 0.05% and THD of supply current is only 4.89% which is less than 5 percent permitted by the IEEE 519 standard.

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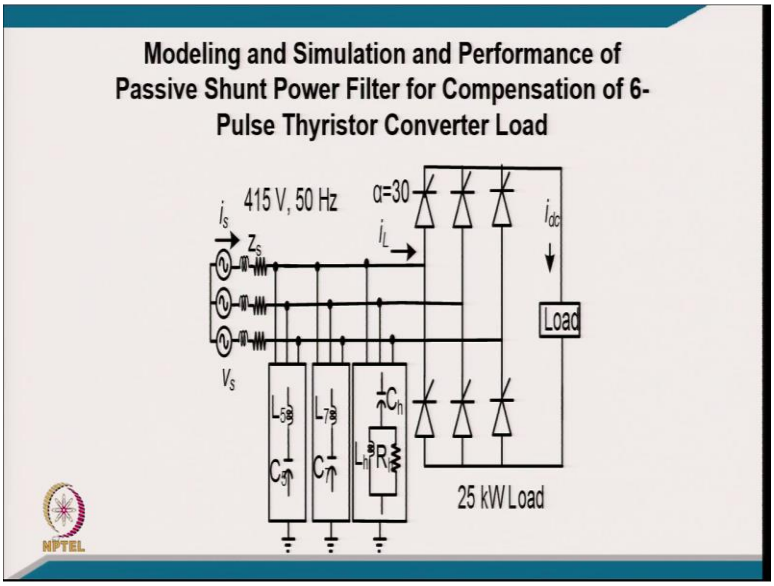

Now that was an example with voltage fed load.

Another example which are going to see is the modeling and simulation of passive shunt filter for compensation of 6 pulse thyristor converter with the constant current on DC side. The below screenshot summarizes the passive shunt filter design.

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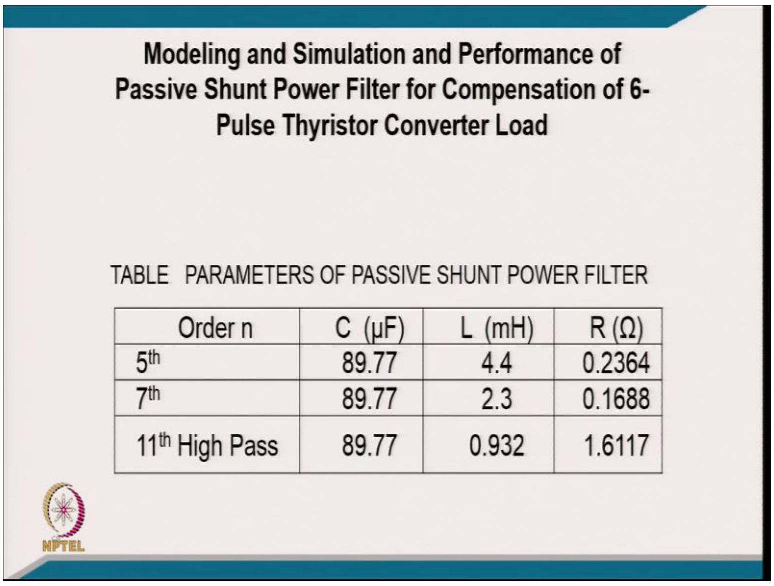

Order n	C (μF)	L (mH)	R (Ω)
5th	89.77	4.4	0.2364
7th	89.77	2.3	0.1688
11th High Pass	89.77	0.932	1.6117

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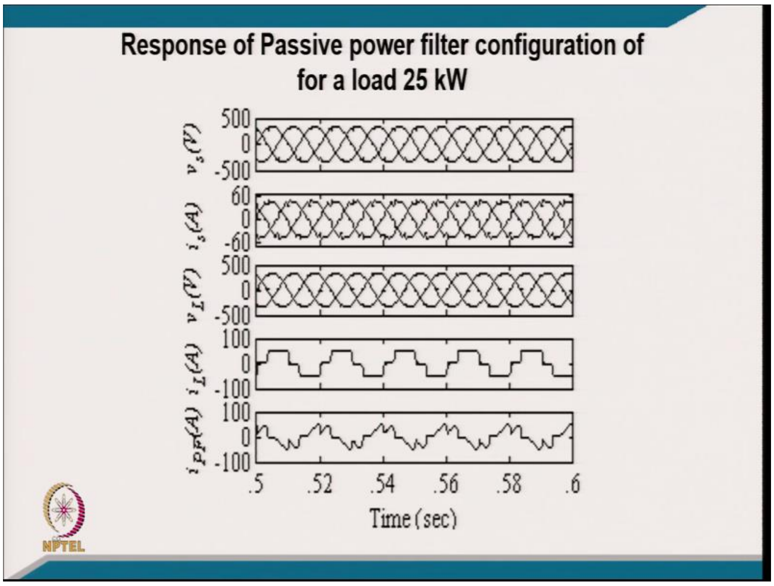

Coming to the simulation, we can see supply current is close to sinusoidal.

The filter current is nothing, but the difference of load current and the supply current. It exchanges reactive power so that the power factor is improved closer to unity. Moreover, harmonics are also reduced.

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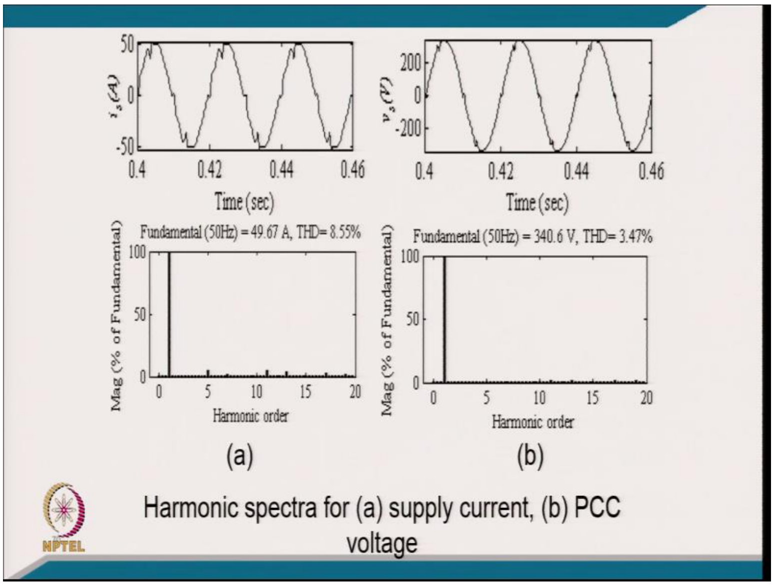

And you can clearly see now THD of voltage comes 3.47% and the THD of current is 8.55%. While the load current THD is 27.81%.

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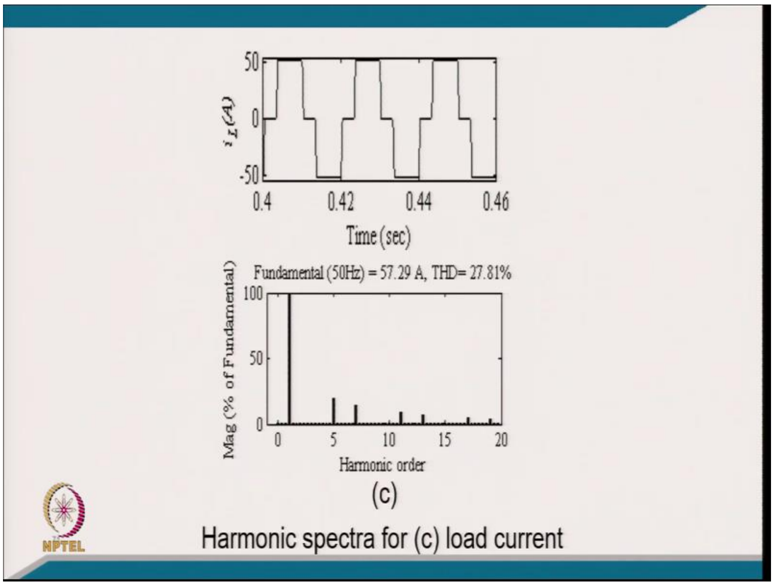

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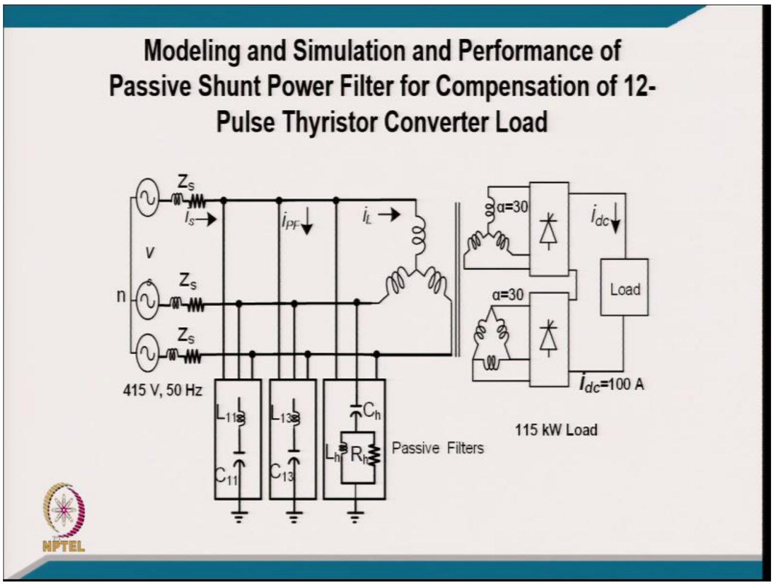

For 12 pulse converter fed load, the configuration, design and simulation results for operation with passive filters are presented herein..

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Modeling and Simulation and Performance of Passive Shunt Power Filter for Compensation of 12-Pulse Thyristor Converter Load

TABLE: PARAMETERS OF PASSIVE SHUNT POWER FILTER

Order n	C (μF)	L (mH)	R (Ω)
11th	345.8	0.242	0.0419
13th	345.8	0.1736	0.0355
23th High Pass	345.8	0.05547	0.204

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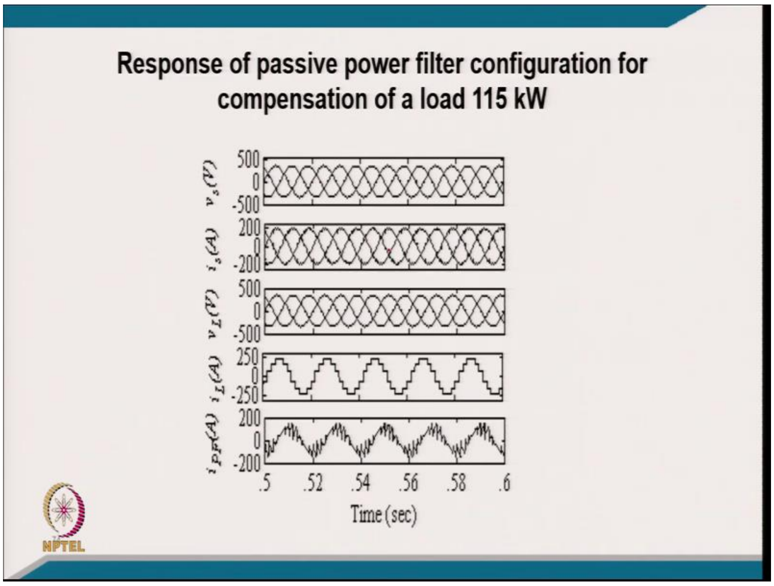

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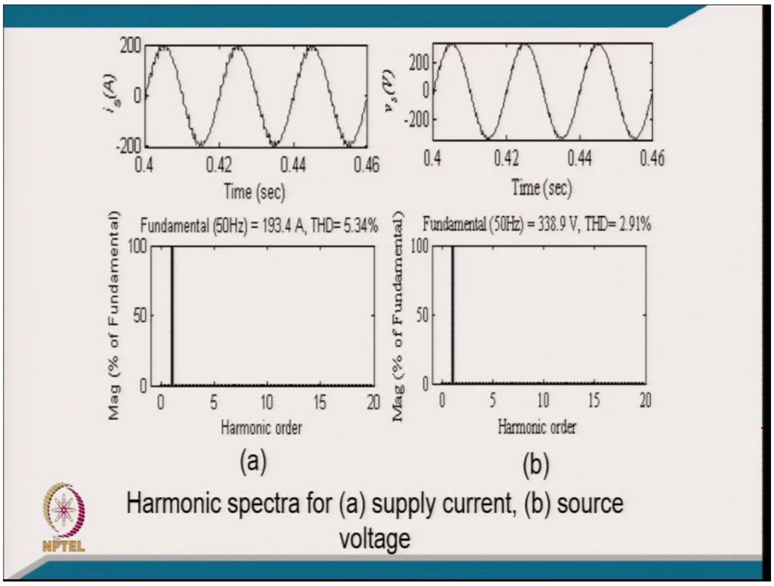

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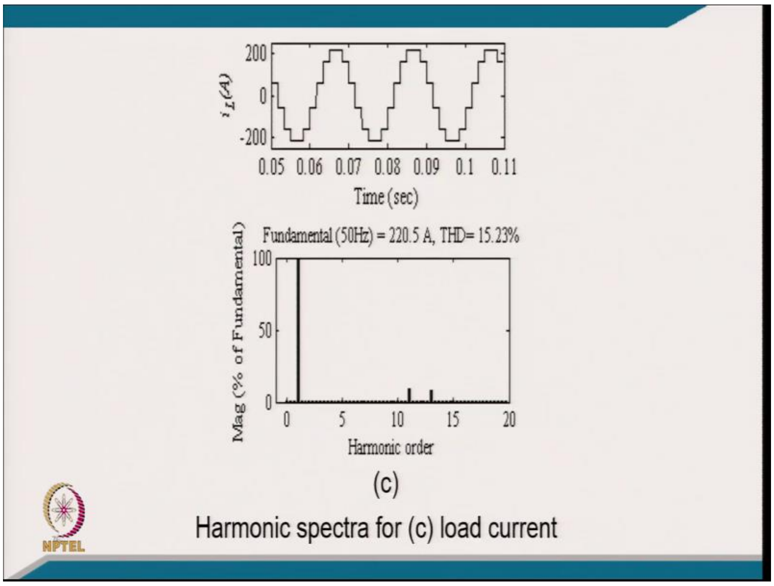

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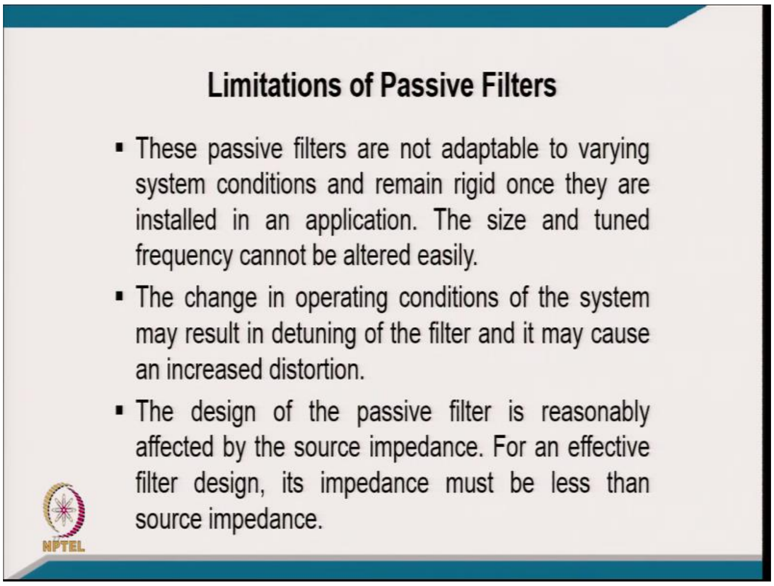

Now, coming to the limitations of passive shunt filter:

- The passive filters are not adaptable for varying system conditions and remain rigid. Once they are installed in an application the size and tuned frequency cannot be altered easily.

- The change in operating conditions of the system may result in detuning of the filter and it may cause at an increased distortion.

- The design of the passive filter is reasonably affected by source impedance for an effective filter design its impedance must be less than source impedance.

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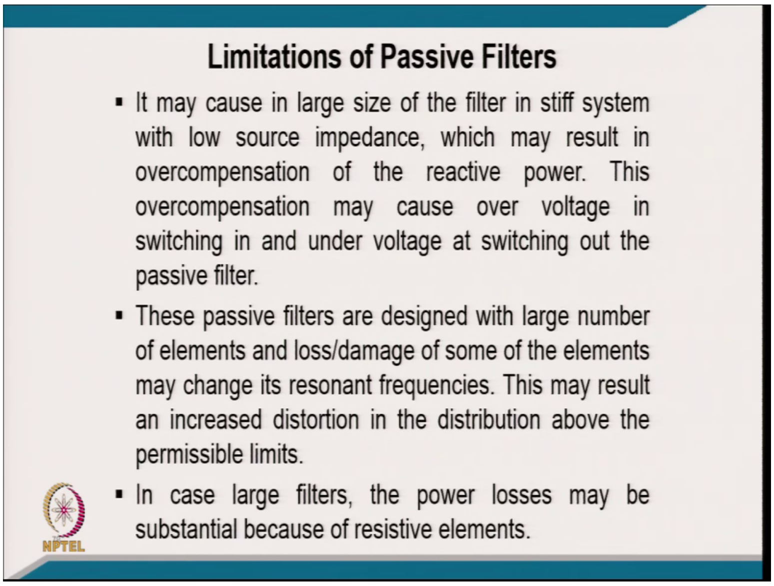

- It may cause in large size of filter in stiff system with low source impedance which may result in overcompensation of the reactive power and this overcompensation may cause over voltage in switching in and under voltage at switching out the passive filter.

- These passive filters are designed with large number of elements and loss damage of some of these elements may change a resonant frequency and this may result in an increase distortion in the distribution of the permissible limit.

- In case of large filters the power losses may substantial and because of resistive elements.

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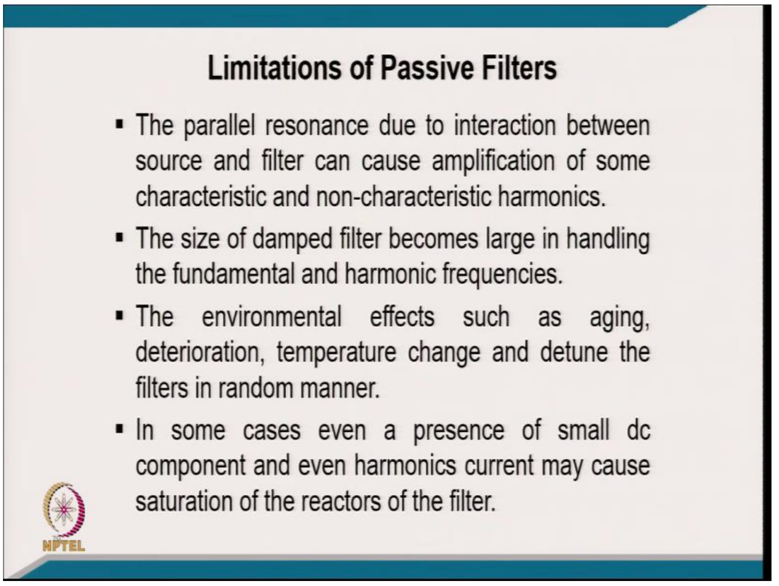

- The parallel resonance due to the interaction between the source and filter can cause amplification of source some characteristic and non-characteristic harmonics.

- Size of damped filter becomes large in handling the fundamental and harmonic frequency.

- The environmental effects such as aging, deterioration, temperature change and detune the filters in random manner.

- In some cases even a presence of a small dc component and even a harmonics current may cause saturation of the reactors of the filter.

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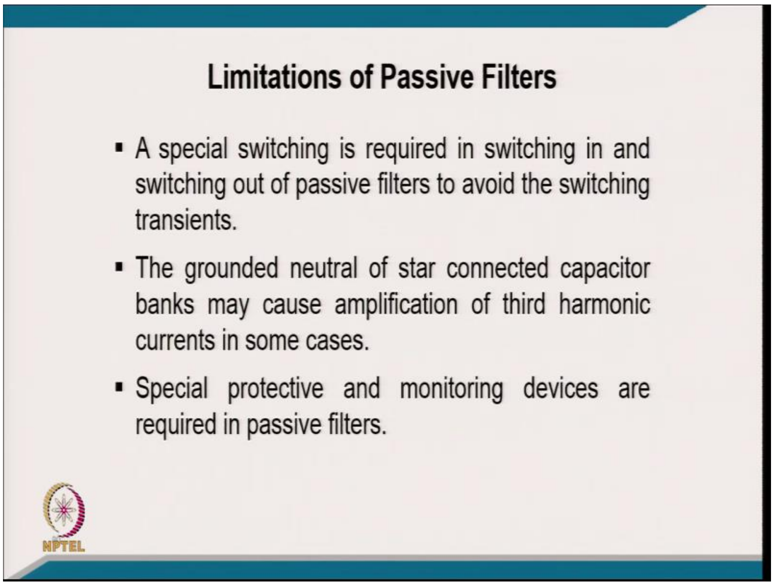

- A special switching is required in switching in and switching out of the passive filter to avoid the switching transients.
- Grounded neutral of a star connected capacitor bank may cause amplification of third harmonic current in some cases.
- Special protective and monitoring devices are required in passive filter.