Power Quality
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Lecture - 26
Hybrid Power Filters

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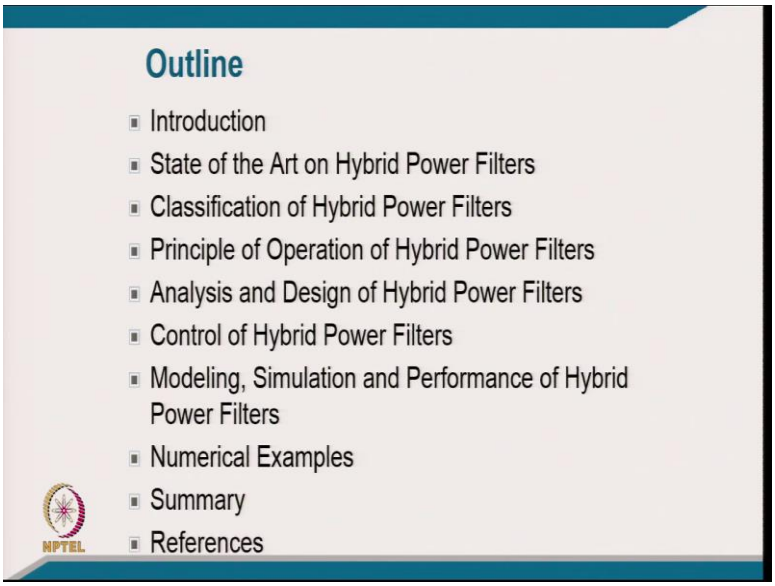

Welcome to the course on Power Quality. Today we will start the Hybrid Power Filters. We will start from introduction. We will talk about the state of art on hybrid power filter. We classify the hybrid power filter, then we will discuss principle of operation of hybrid power filter.

And we will go to analysis and design of hybrid power filter, and we will talk about the control of hybrid power filter then modelling, simulation and performance of hybrid power filter with some case studies. Then, we will discuss numerical examples we will summarize and then the references will be provided.

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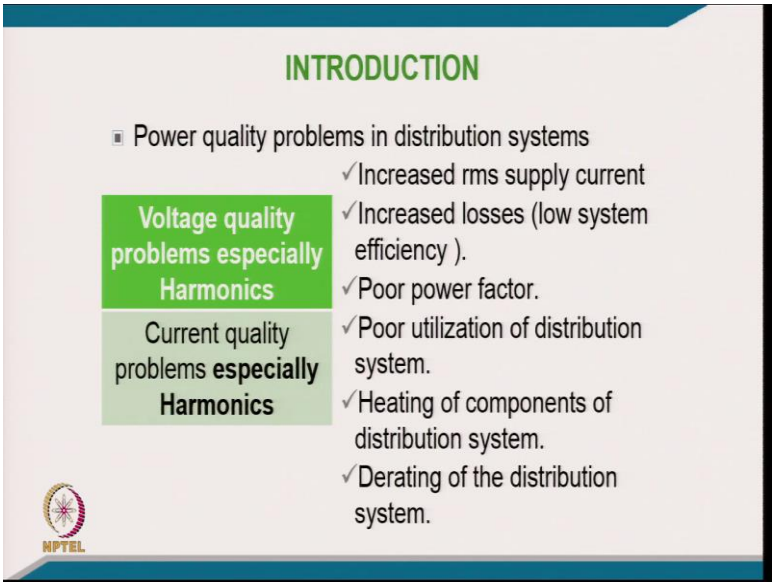

Power quality problem in distribution system, we have both voltage quality problems and the current power quality problems. We have a harmonics in the voltage and in the current and that is the reason we have to use the hybrid filter filters.

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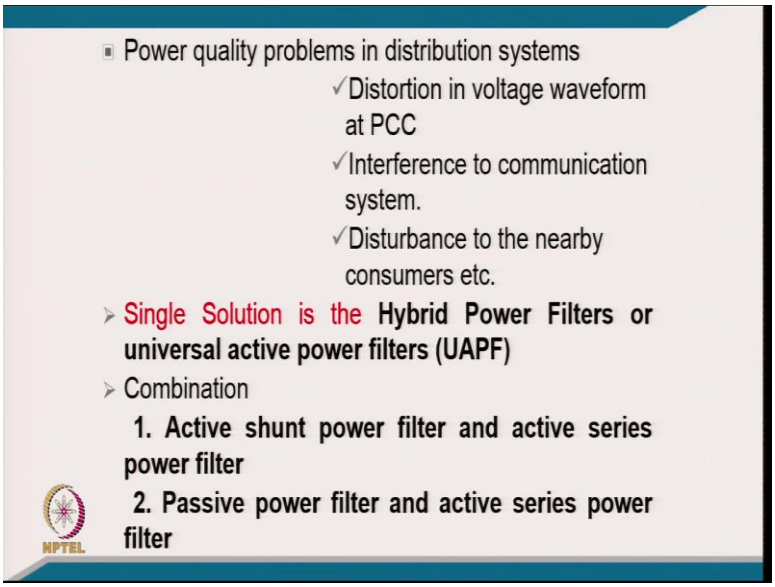

Coming to power quality problem in the distribution system. The distortion in voltage waveform, the interference to communication system, disturbance to nearby consumers. And, the single solution to these problem is the hybrid power filter of or we also call it universal active power filter. It is a combination of active shunt power filter and active

series power filter. Sometimes we also use the passive power filter along with a small rating active series filter.

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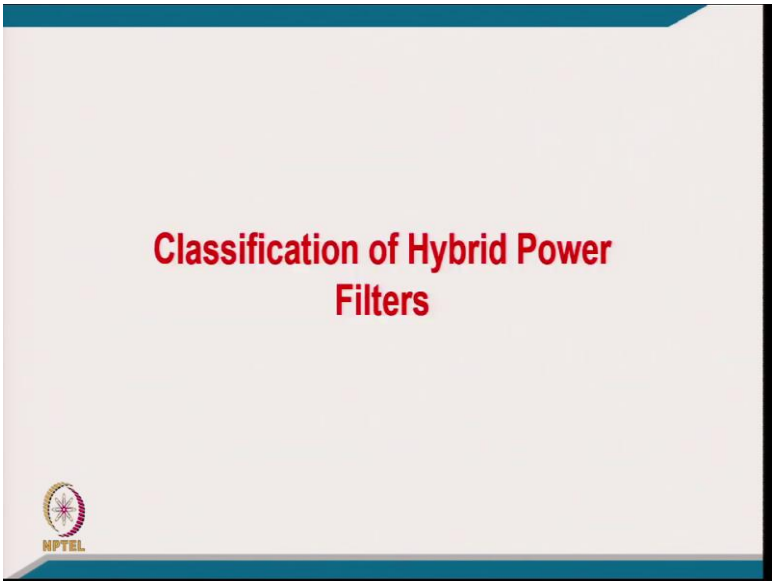

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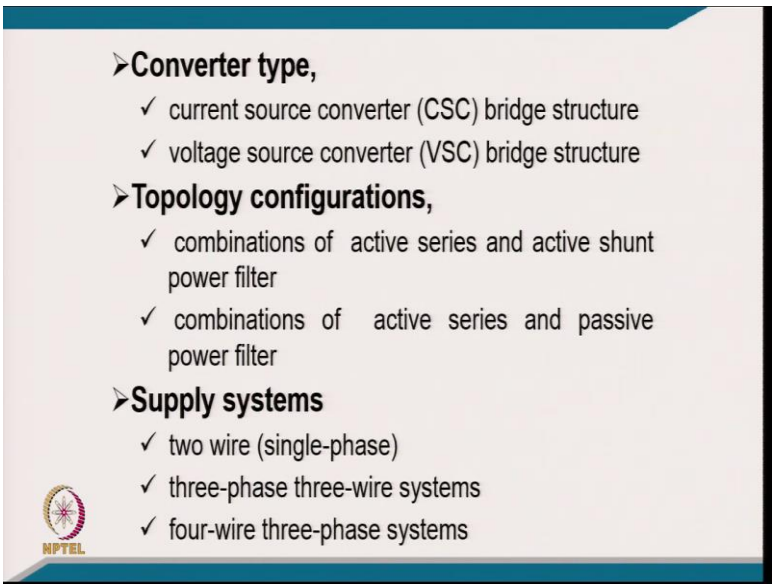

Coming to the classification of hybrid power filter. It can be classified in many categories. First category is the converter type. Whether we are using current source converter bridge structure or we are using voltage source converter bridge structure.

Second is the topology configuration; the combination of active series and active shunt power filter or combination of active series and passive filter.

Another classification is supply based. You might be using this in a two wire system or three-phase three-wire system or four-wire three-phase system.

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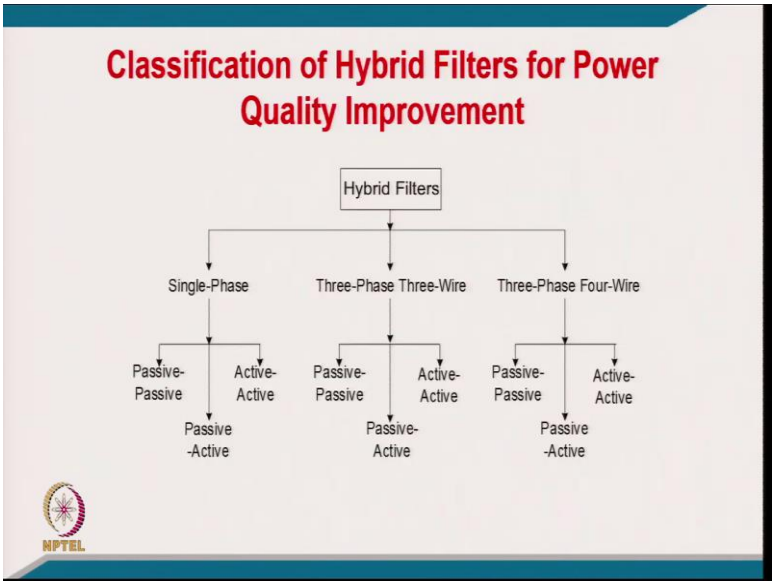

The broad classification is also shown in the screenshot.

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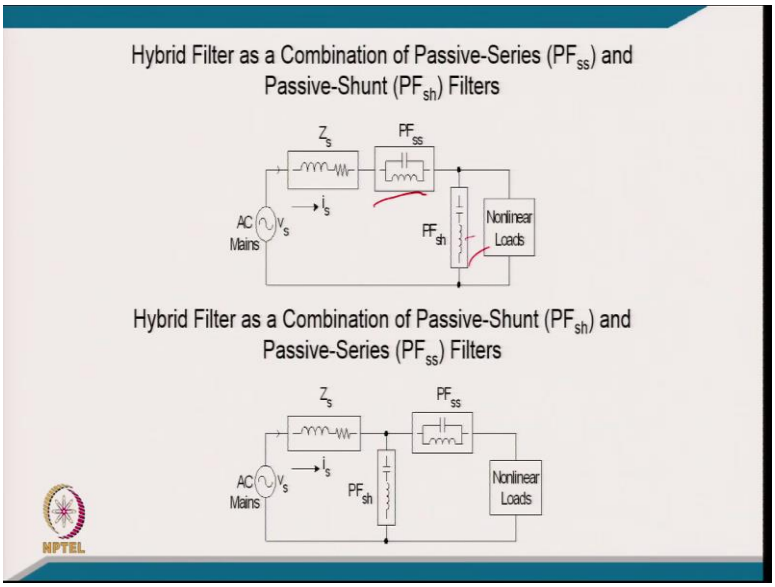

And now, coming to the hybrid filter as a circuit configuration.

Here is a combination of passive series and passive shunt filter.

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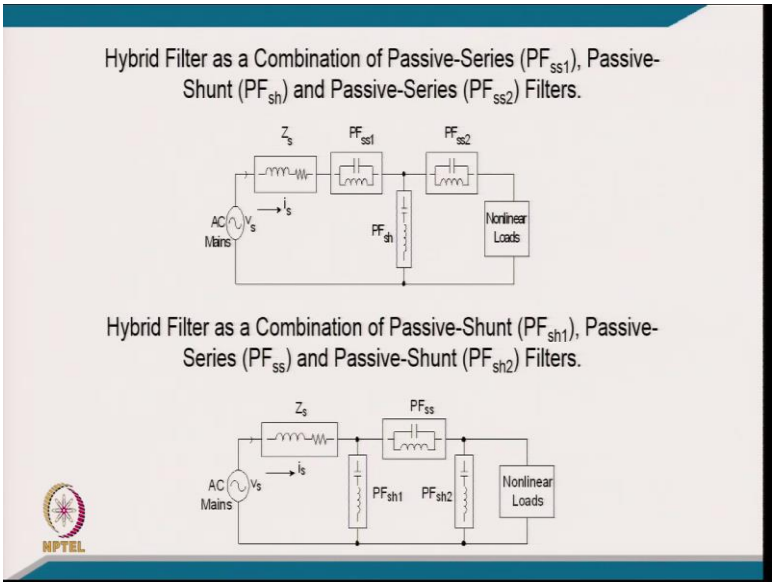

This hybrid filter has two passive series filter one on the load side another on the grid side and then passive shunt in between, like a T network. It can also be present in the form of a pi network.

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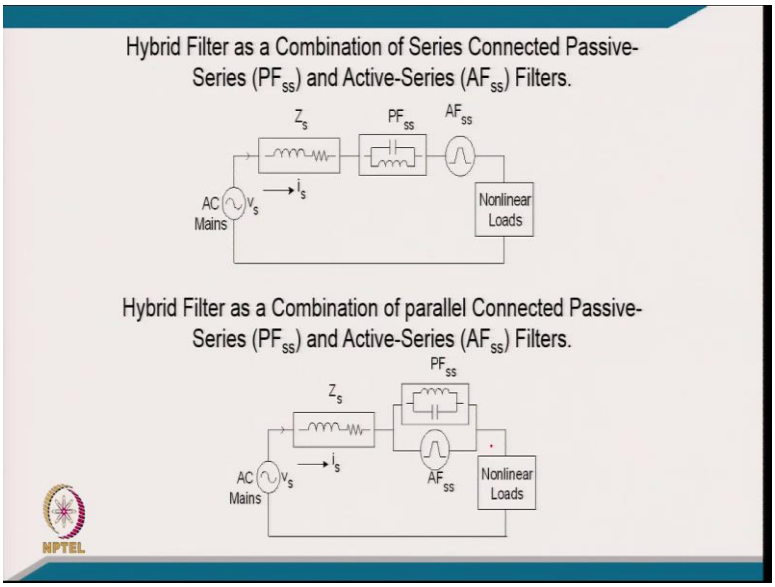

Passive series filter can be used along with the active series filter as shown here.

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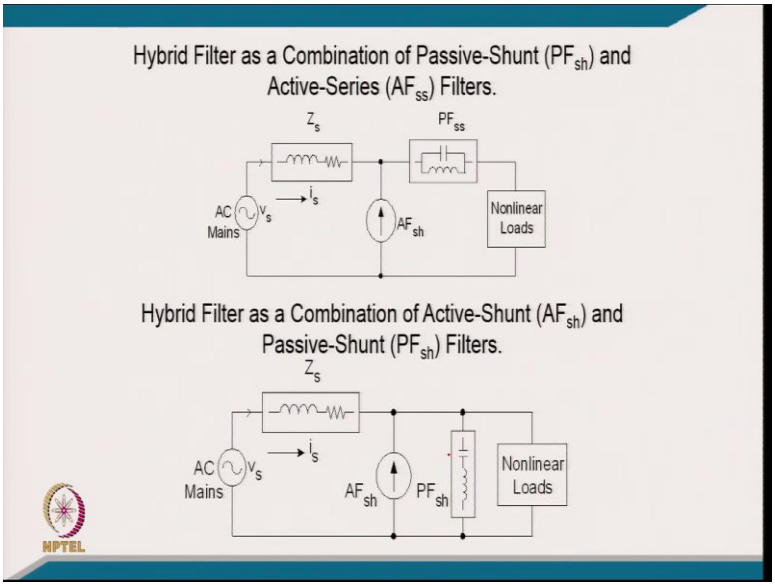

And, there is another hybrid filter with a passive filter in series and then active filter in shunt. Or you can have both passive shunt and active shunt connected in parallel.

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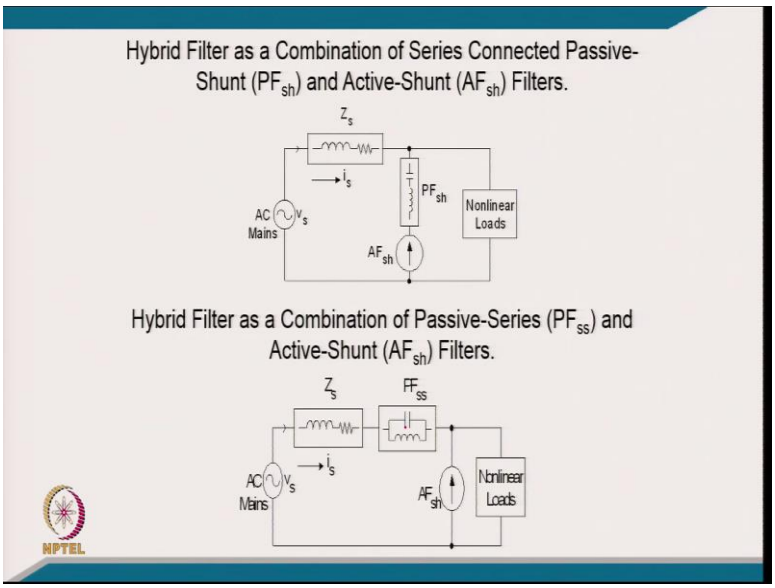

This is another very popular configuration, where a passive filter to make with a small series active filter is present.

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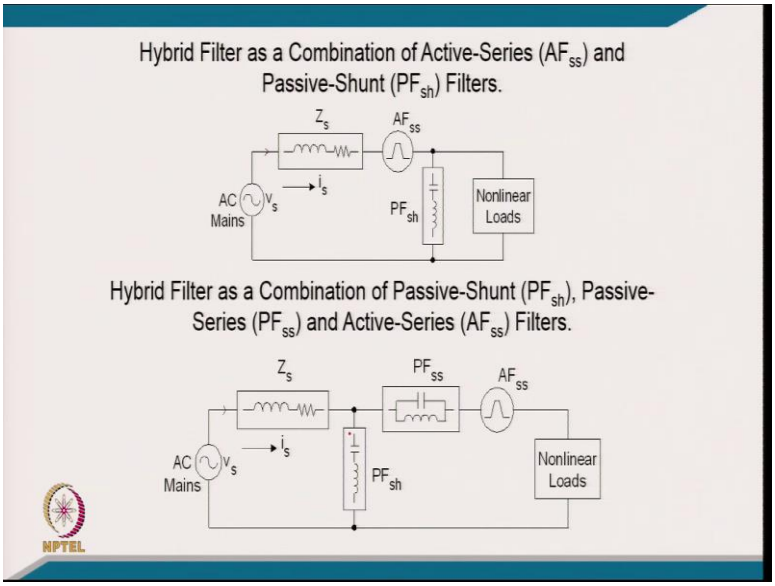

Few more configurations of the hybrid filter are provided in the screenshots herein.

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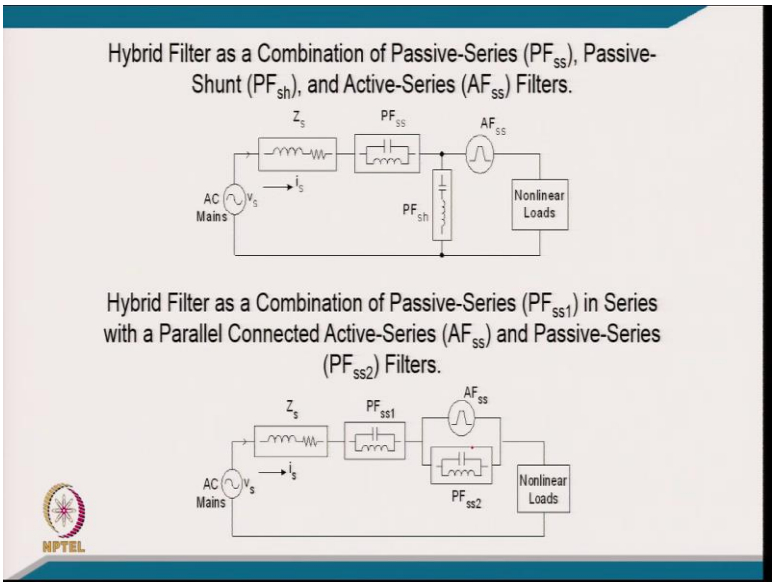

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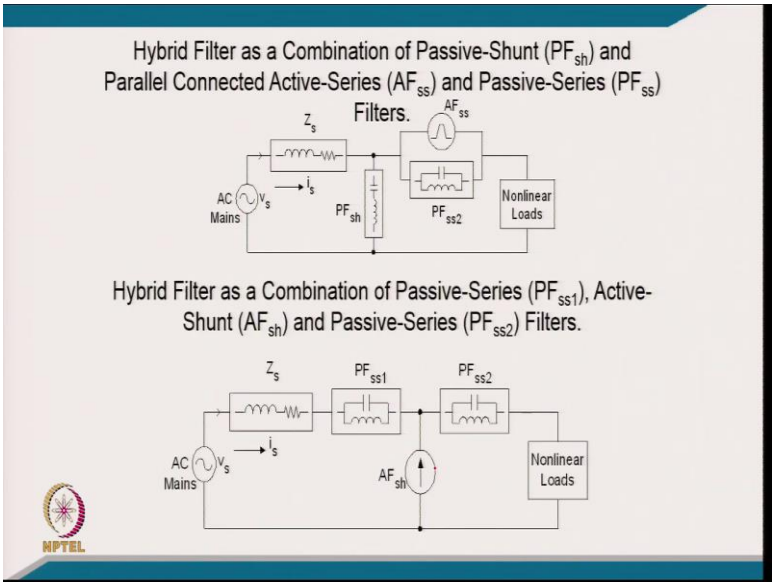

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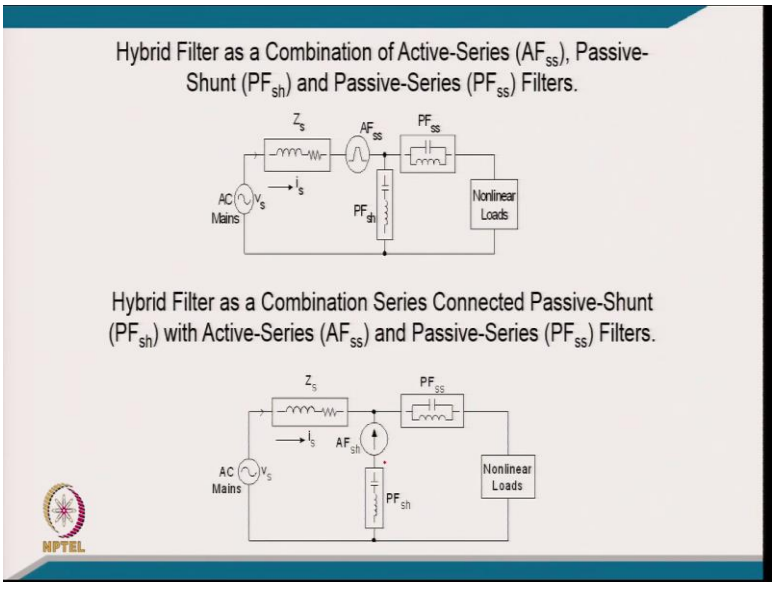

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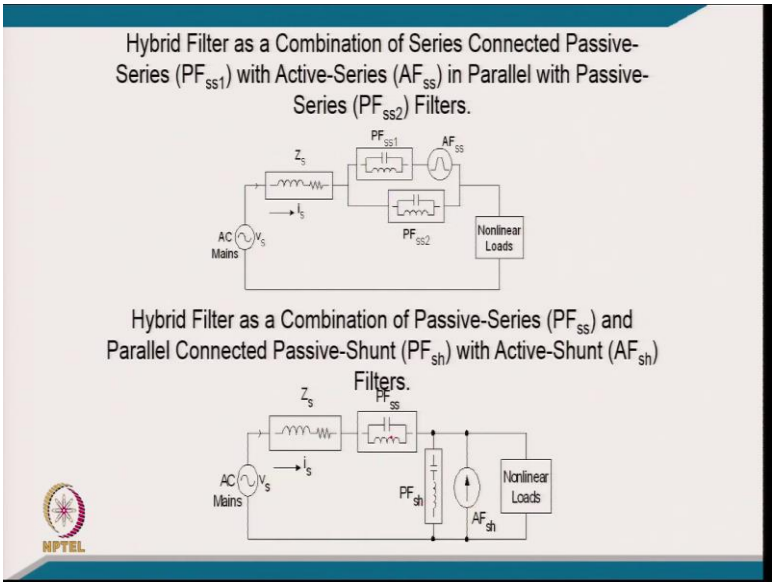

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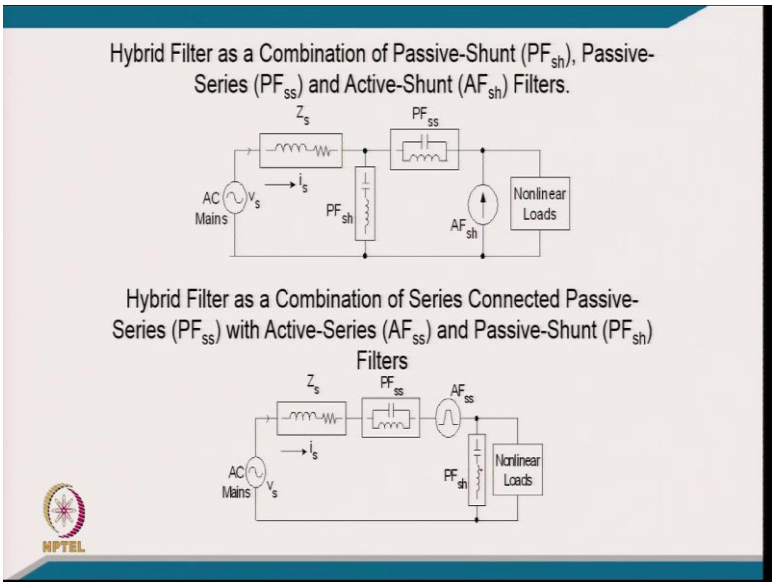

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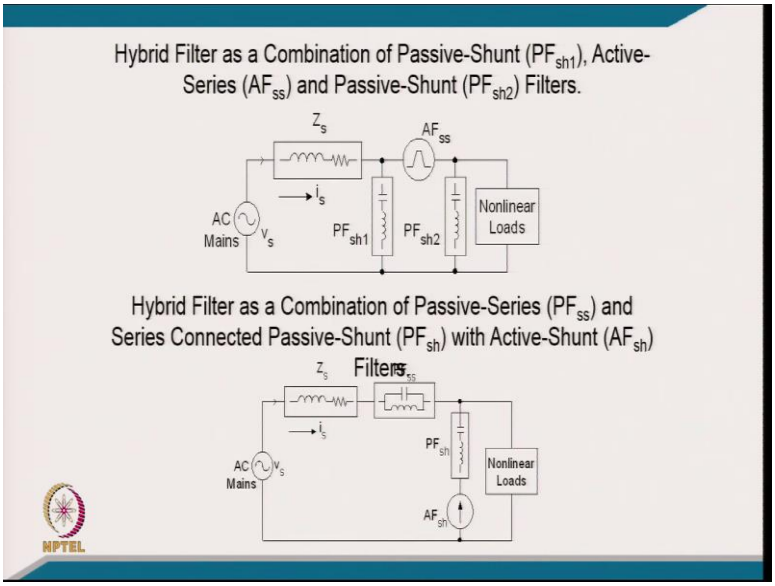

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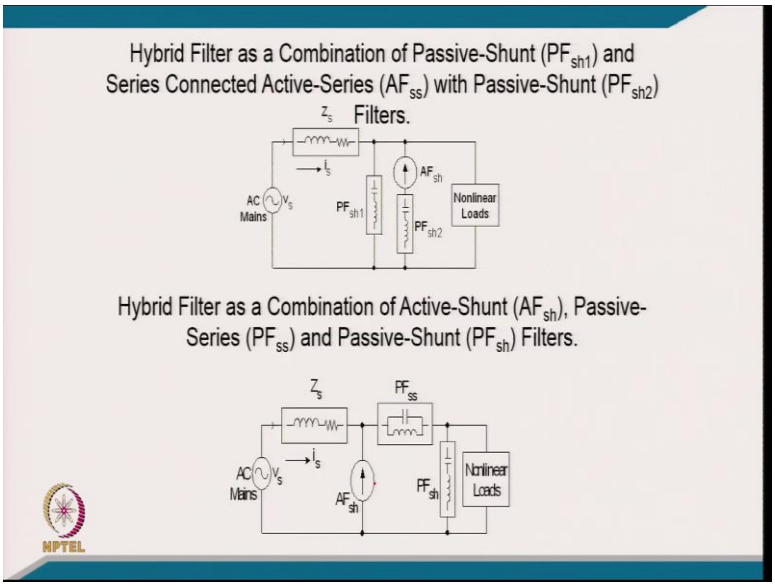

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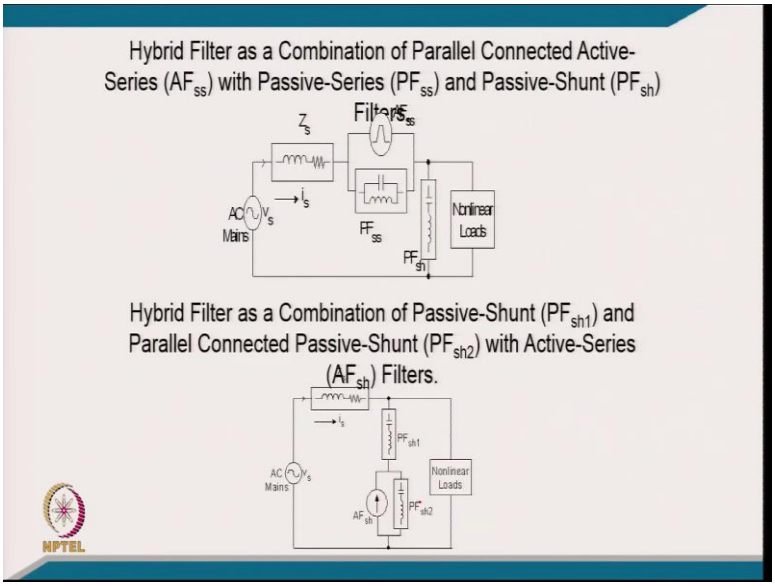

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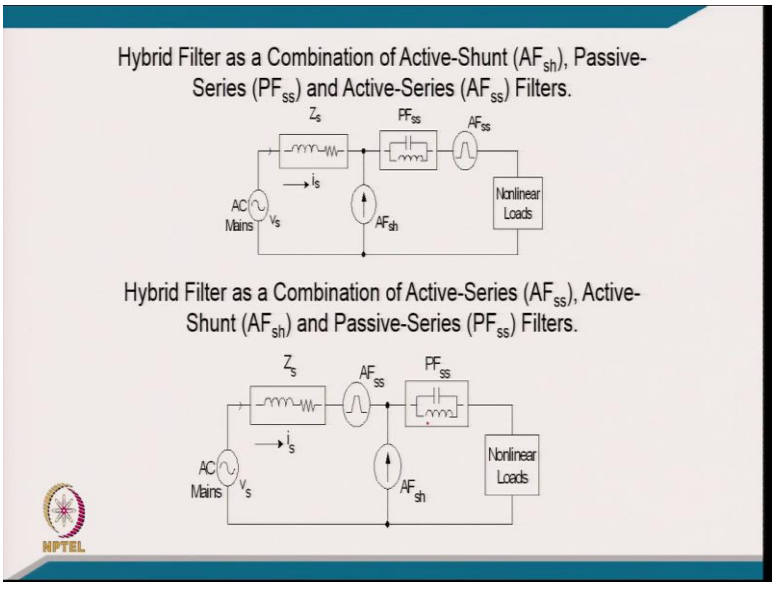

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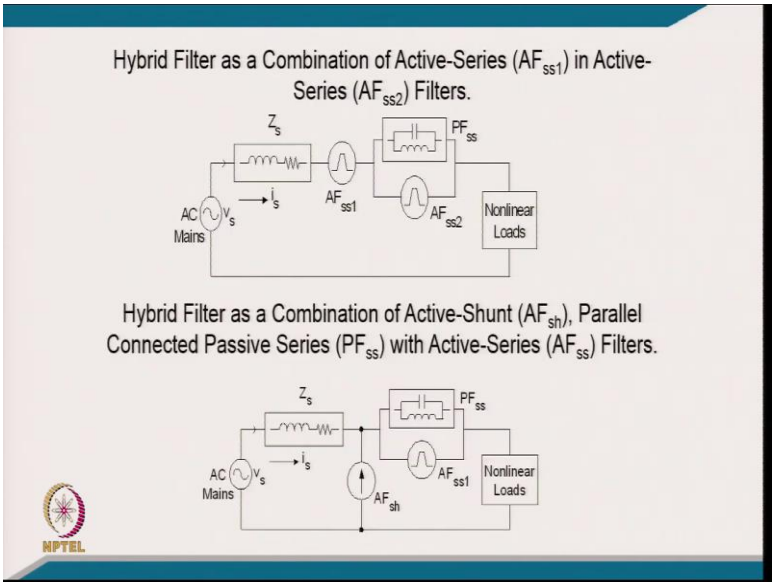

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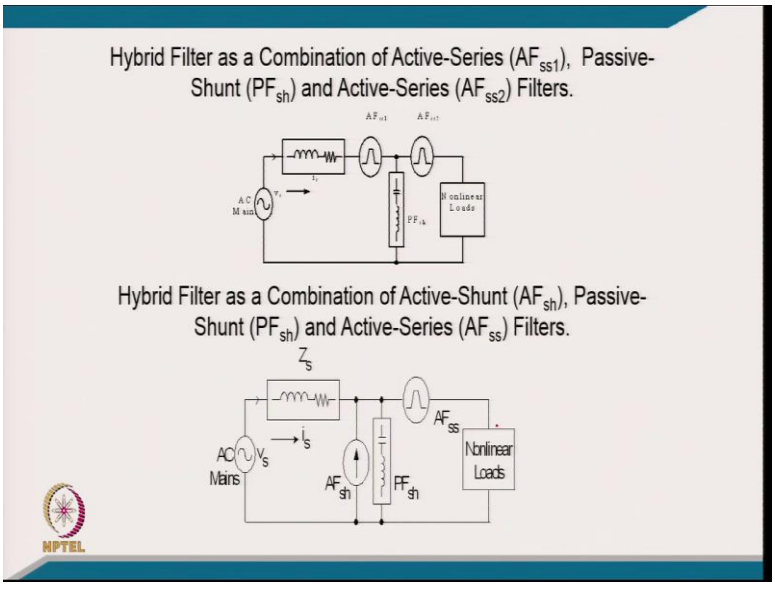

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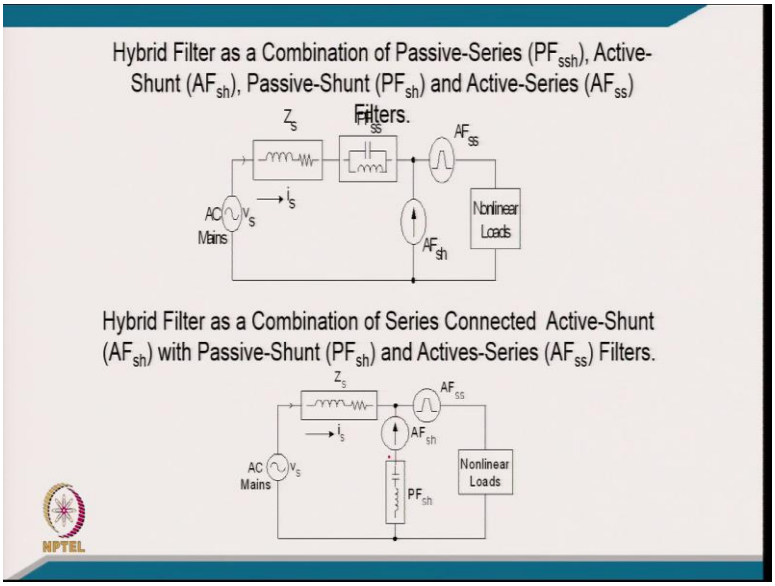

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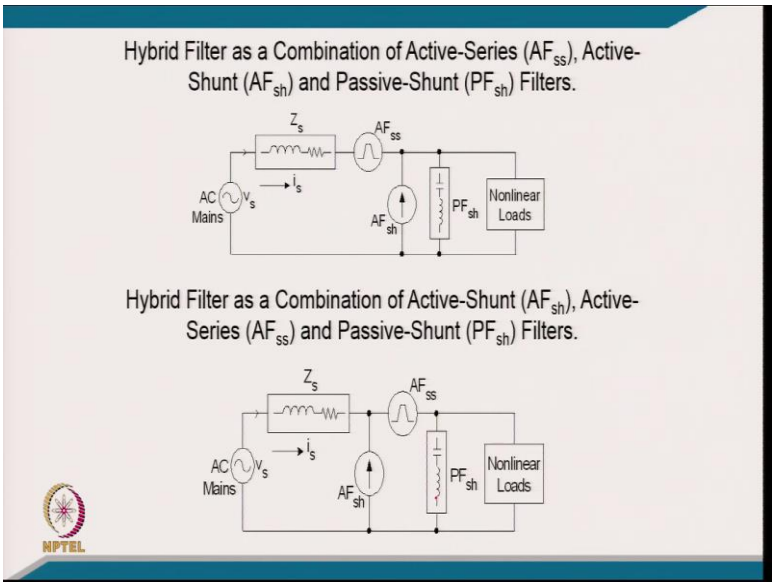

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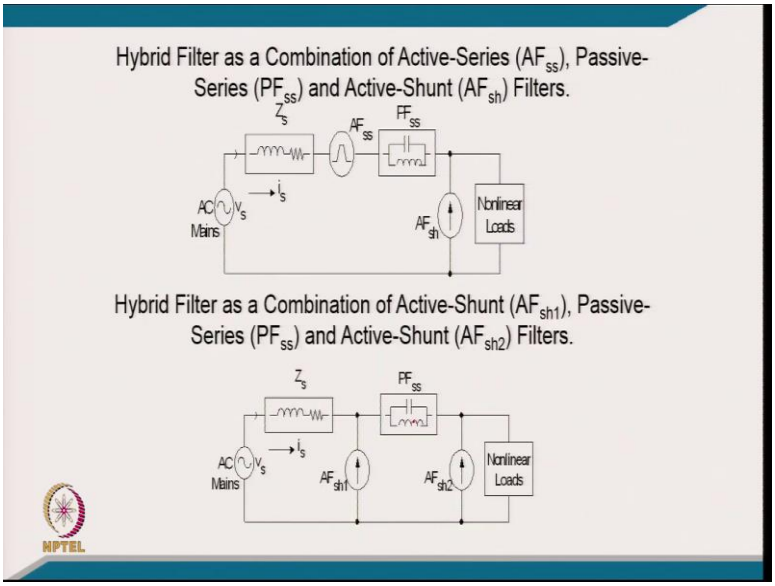

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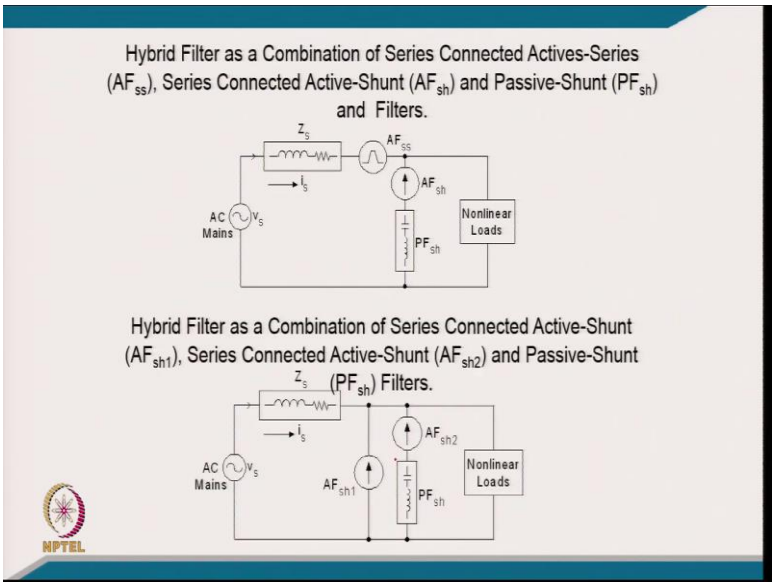

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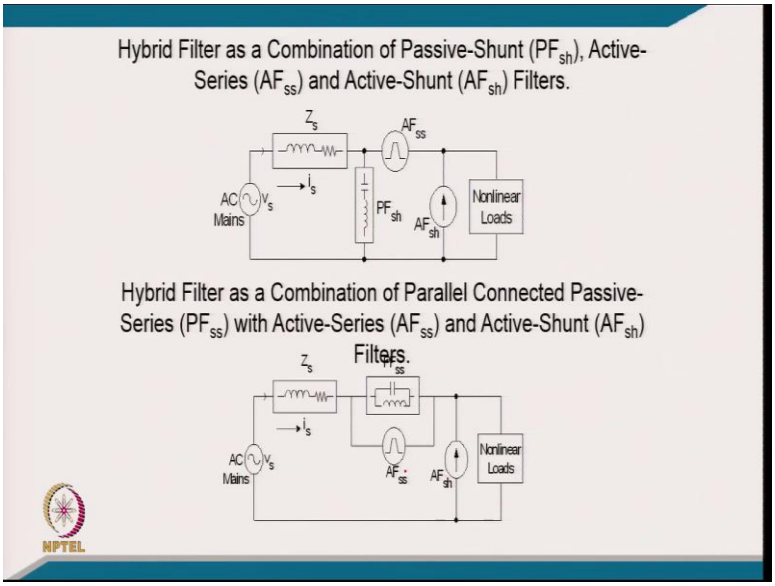

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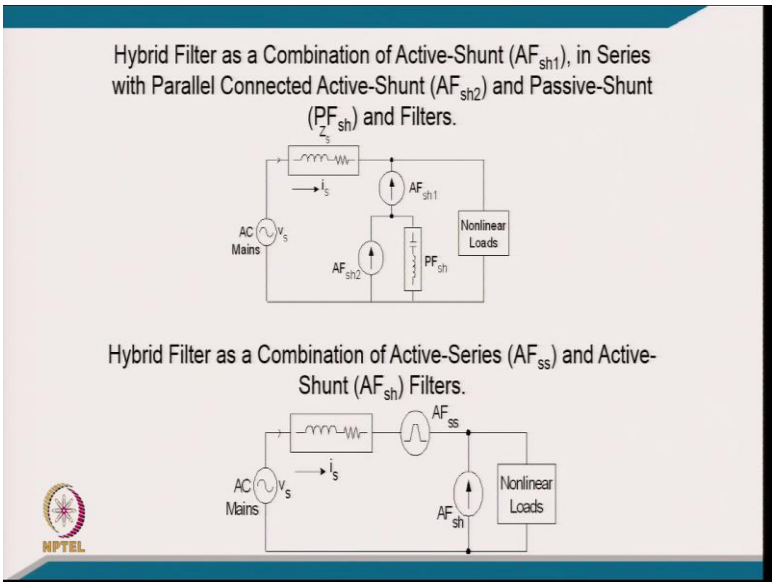

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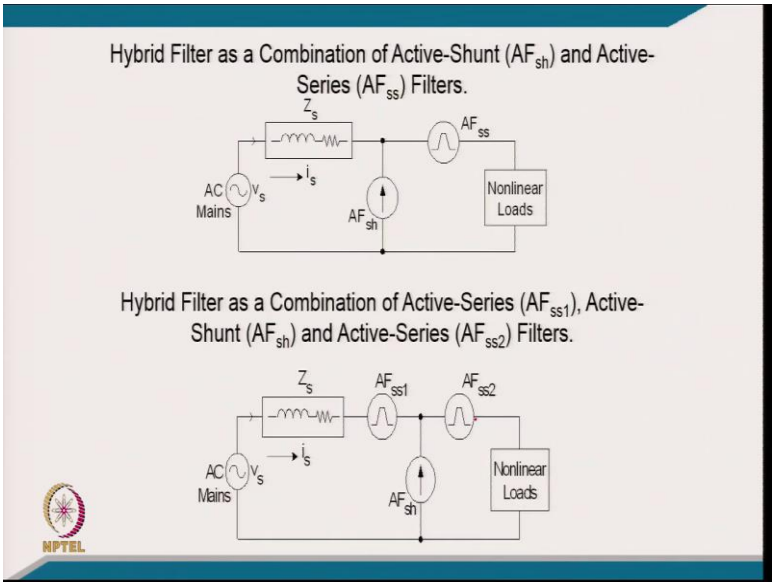

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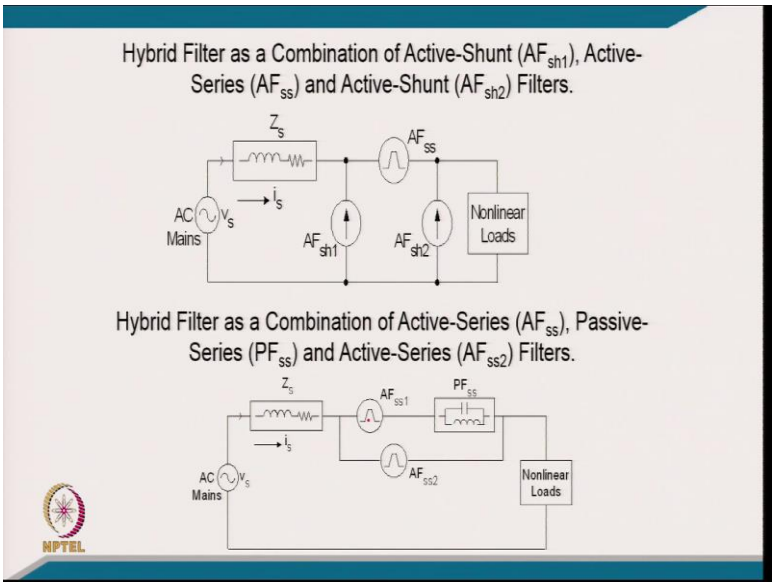

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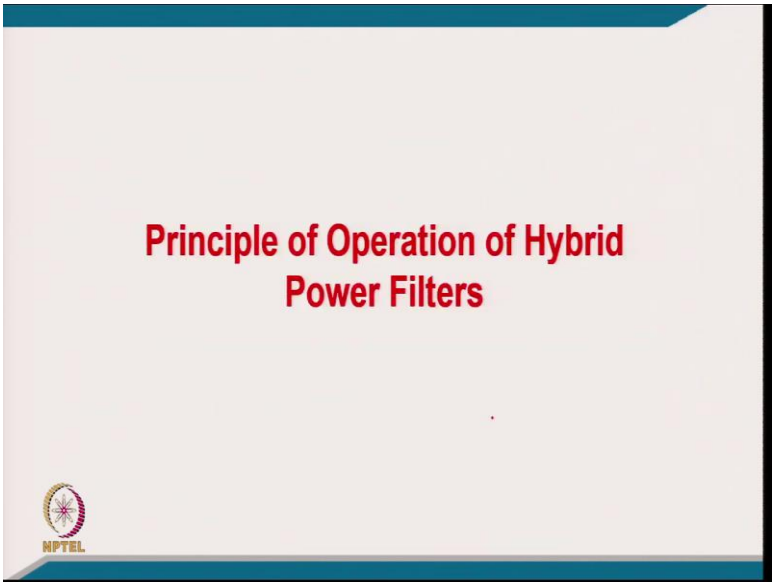

Now coming to principle of operation of this hybrid passive filter.

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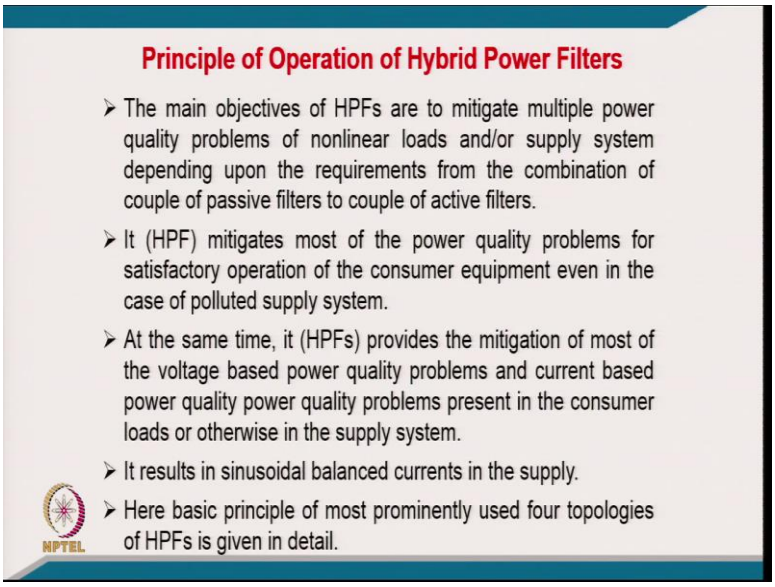

The main objective of hybrid filters are to mitigate the multiple power quality problems of non-linear load and or supply system depending upon the requirement from the combination of couple of passive filter to couple of active filter. And, in hybrids it hybrid filter mitigate most of the power quality problem for satisfactory operation of the consumer equipment even in the cases of polluted supply system.

At the same time, if hybrid filter provides the mitigation of most of the voltage based power quality problem and current based power quality problem present in the consumer loads or otherwise in the supply system. And, it results sinusoidal balance current supply current in the supply. Here the basic principle of most prominently used four wire topology of which given here in detail.

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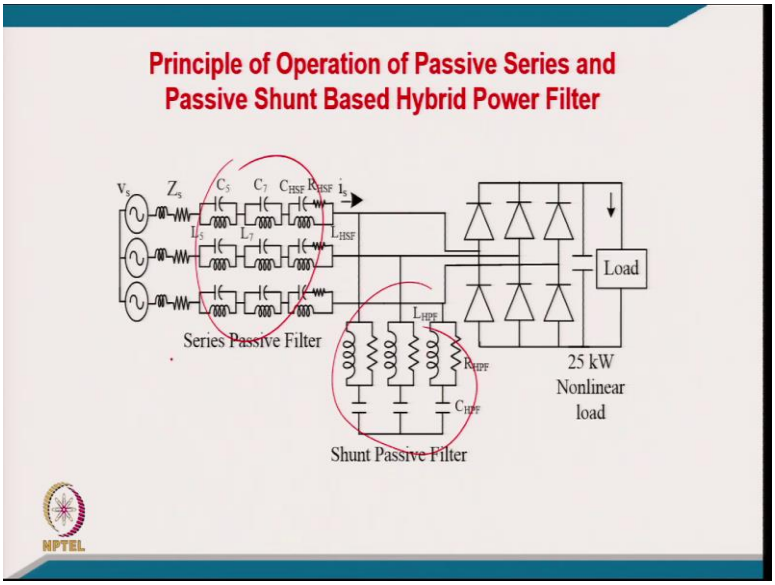

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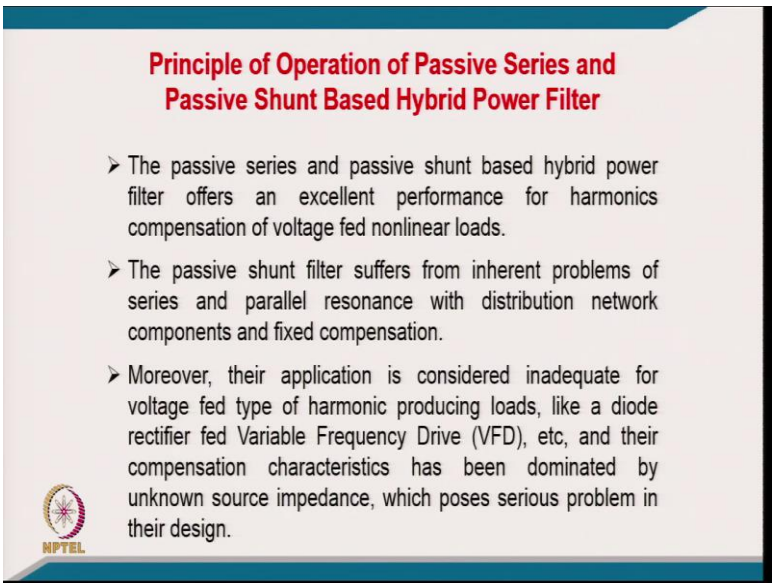

The passive series and passive shunt based hybrid power filter offers excellent performance for harmonic compensation of voltage fed non-linear load. And, the passive

shunt filter suffers from inherent problem of series and parallel resonance with distribution network component and fixed compensation.

Moreover, their application is considered inadequate for the voltage fed kind of harmonic producing load, like a diode rectifier for fed variable frequency drive, and their compensation characteristic has been dominated by unknown source impedance, which pose a serious problem in their design.

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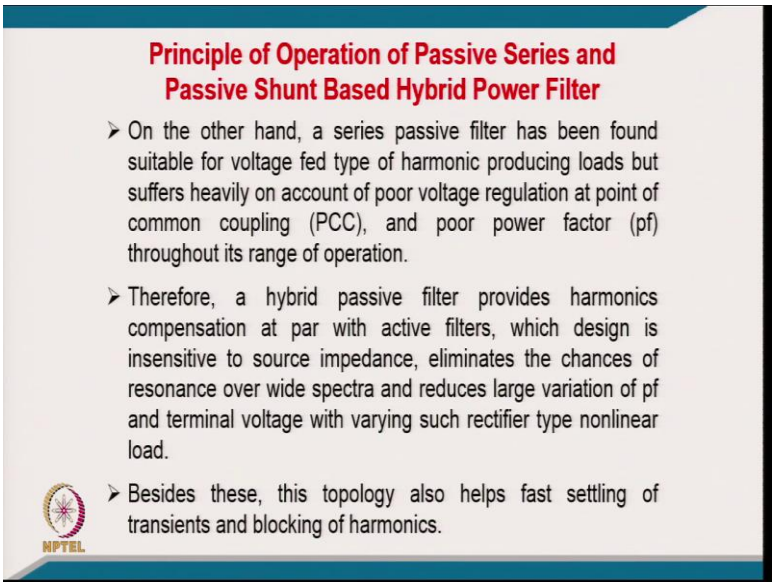

On the other hand, a series passive filter has a been found suitable for voltage fed kind of harmonic producing load, but suffers heavily on account of poor voltage regulation at the point of common coupling, and poor power factor throughout its a range of operation.

Therefore, a hybrid passive filter provides a harmonic compensation at par with a active filter, which design is insensitive to source impedance, eliminate the chances of resonance over the wide spectra and reduces the large variation of power factor and terminal voltage with varying such rectifier type of non-linear load. And beside these, this topology also helps in fast settling of the transient and blocking the harmonics.

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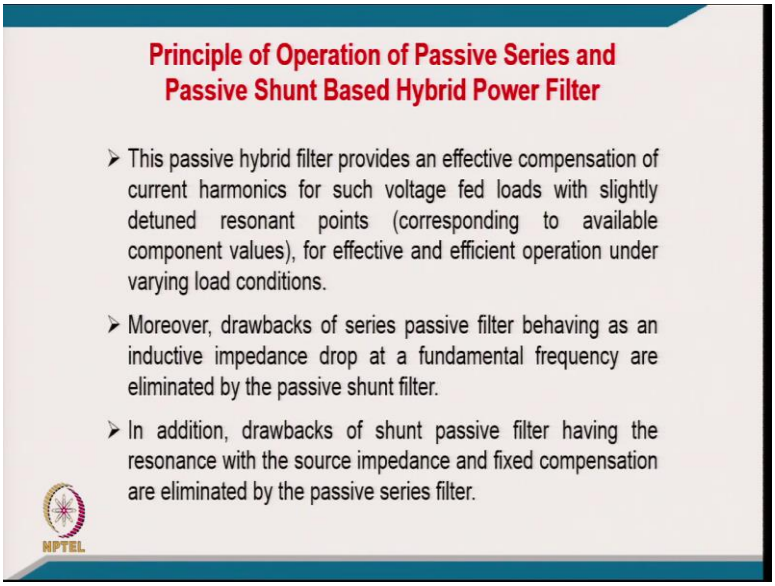

This passive hybrid filter provides an effective compensation of current harmonics for such voltage fed load with slightly detuned resonant points corresponding to available component value, for effective and efficient operation under varying load condition. Moreover, the drawbacks of series passive filter behaving as an inductive impedance drop at a fundamental frequency are eliminated by the passive shunt filter. And, in addition, the drawbacks of shunt passive filter having the resonance with source impedance and fixed compensation are eliminated by passive series filter.

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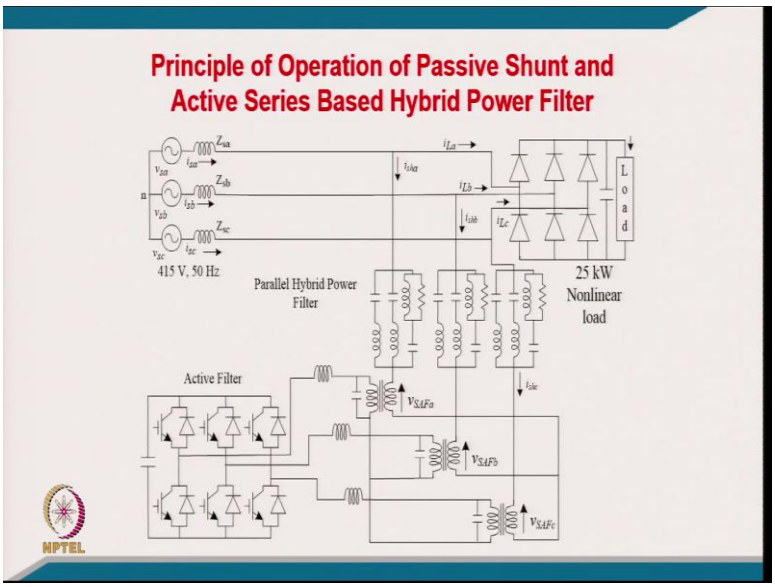

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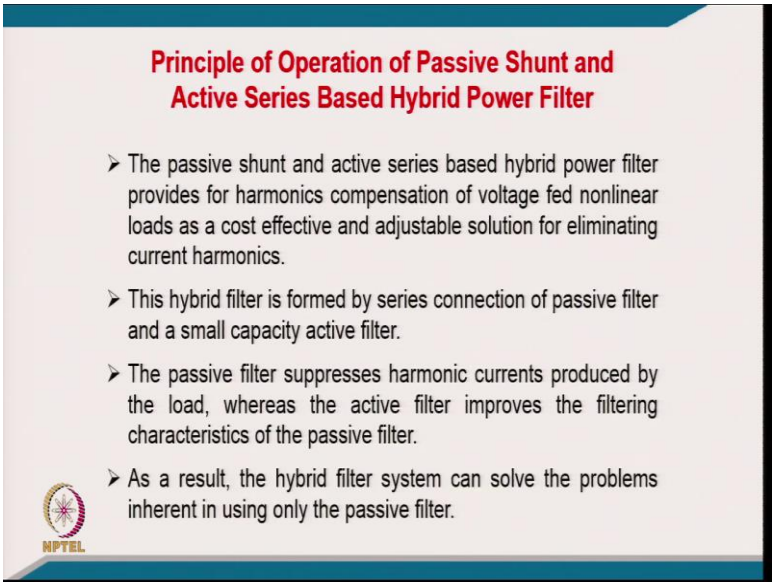

The passive shunt and active series hybrid filter provides the typically for harmonic compensation of voltage fed non-linear load as well as cost effective and adjustable solution for eliminating the current harmonic. This hybrid filter is formed by series connection of passive shunt a small capacity active filter. The passive filter suppresses harmonic current produced by the load, where as the active filter improve the filtering characteristic of passive filter. As a result the hybrid filter system can solve the problem of inherent by using only the passive filter.

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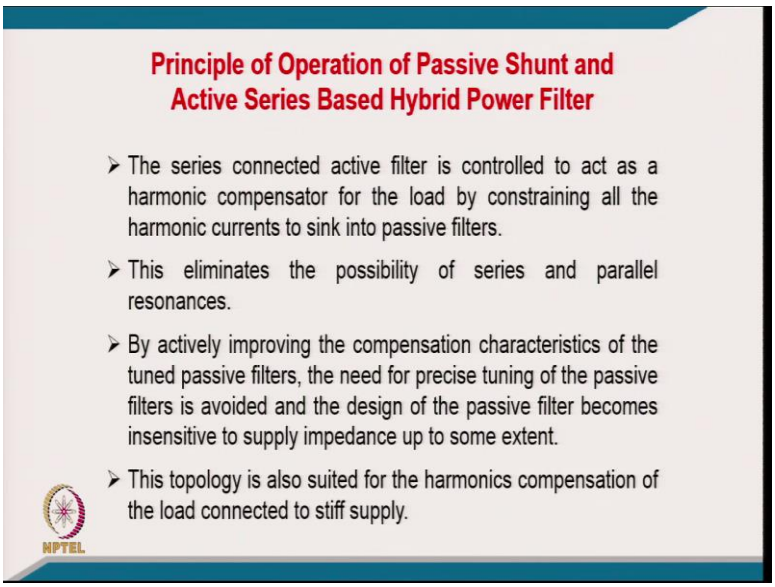

The series connected active filter is controlled to act as a harmonic compensator for the load by constraining all the harmonics current to sink into the passive filter. And this eliminates the possibility of series and parallel resonances. By actively improving the compensation characteristic of the tune passive filter the need for precise tuning of passive filters is avoided and the design of the passive filter becomes insensitive to supply impedance up to some extent. And, this topology is also suited for harmonics compensation of load connected to stiff supply system.

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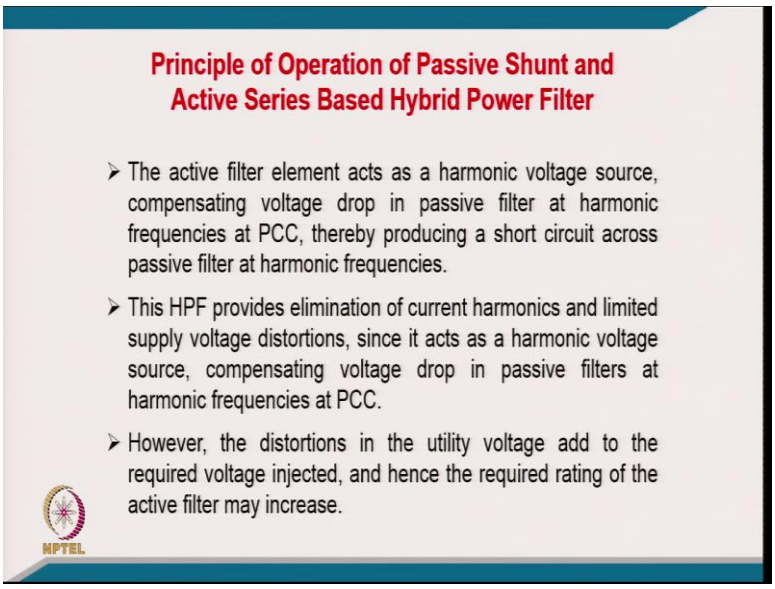

And, the active filter element acts as a harmonic voltage source compensating voltage drop in passive filter at harmonic frequency at PCC, thereby producing a short circuit across the passive filter at harmonic frequency.

This hybrid filter provides the elimination of current harmonics and limited supply voltage distortion, since it acts as a harmonic voltage source, compensating the voltage drop in passive filter at the harmonic frequency at PCC. However, the distortion in the supply voltage adds to the required voltage injected and hence the required rating of active filter may increase.

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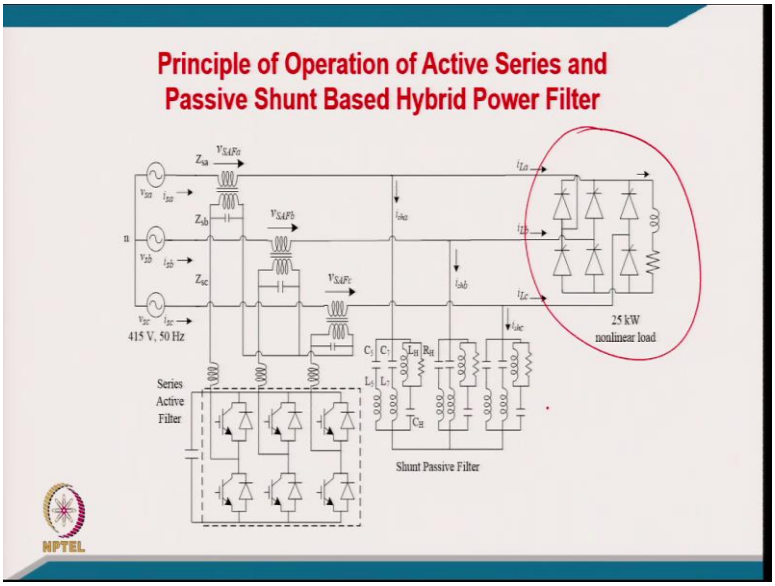

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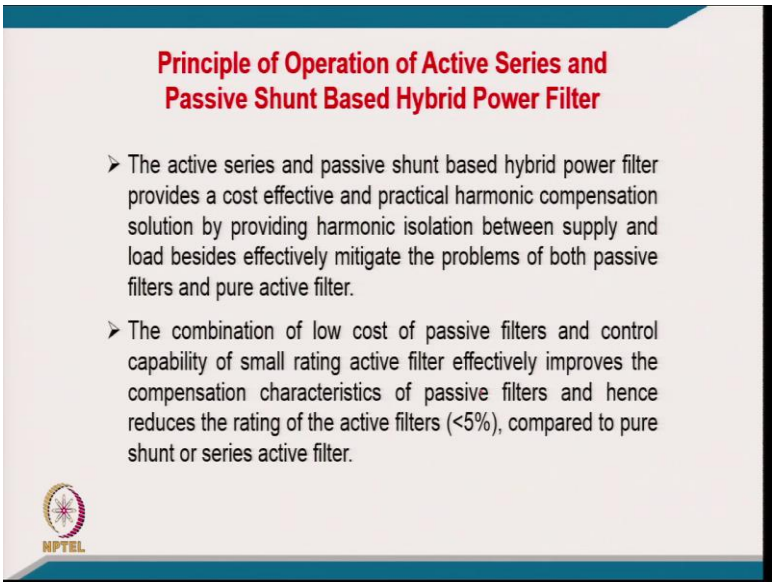

Active series and passive shunt based hybrid filter provides a cost effective and practical harmonic compensation solution by providing harmonic isolation between supply and load, besides the effectively mitigate the problems of both passive filters and pure active filter.

And the combination of low cost of passive filters and control capability of a small rating active filter effectively improve the compensation characteristic of passive filter and

hence reduces the rating of active filters less than 5 percent compared to the pure shunt or series active filter.

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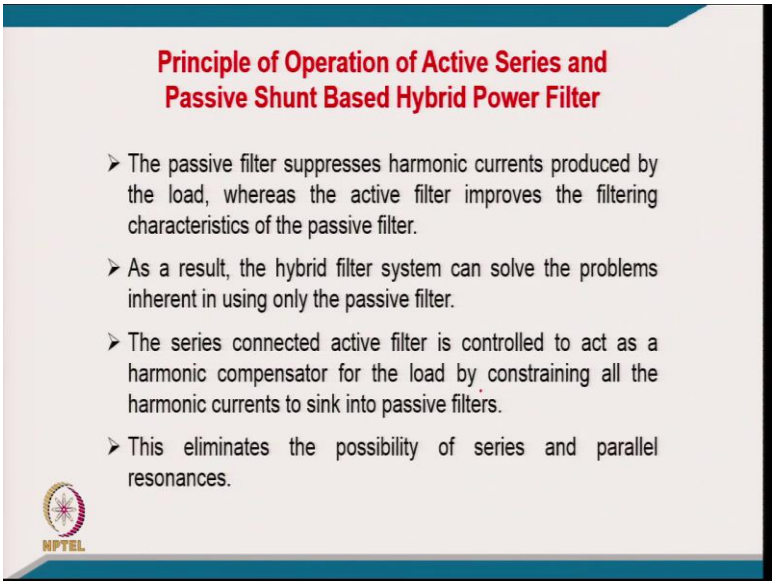

The passive filter suppresses the harmonic currents produced by the load, whereas the active filter improve the filtering characteristic of the passive filter, as a result the hybrid filter system can solve the problem of inherent in using only the passive filter. The series connected active filter is controlled to act as an harmonic compensator for the load by constraining all the harmonics current to sink into the passive filter, and this eliminate the possibility of series and parallel resonances.

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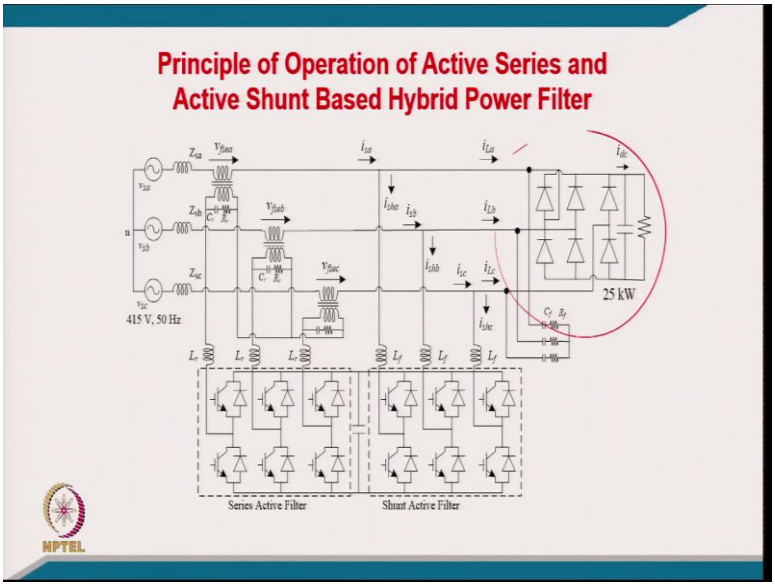

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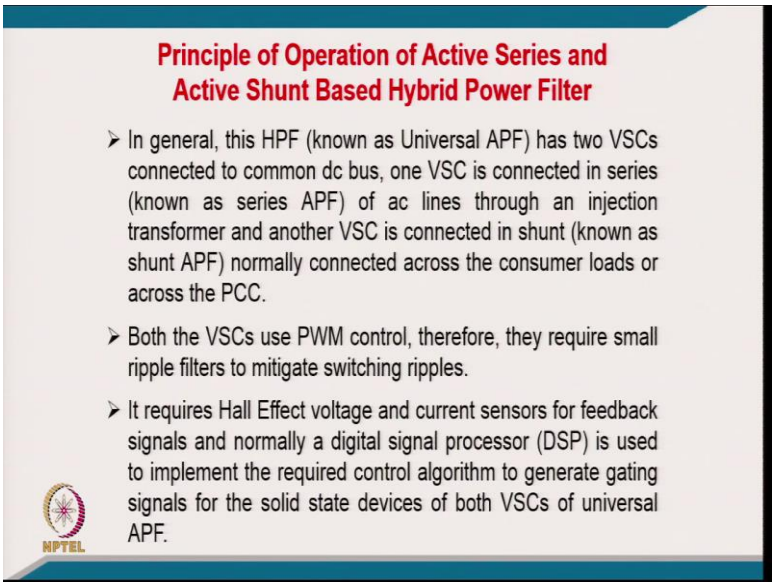

In general this hybrid filter known as universal active filter had two voltage source converter connected to the common dc bus, one voltage source connect converter is connected in series and known as a series active power filter of ac line through an injection transformer another VSC is connected in shunt known as a shunt active power filter normally connected across the consumer load or across the p point of common coupling.

Both the voltage source converter use the PWM control, therefore, they require a small rating ripple filter to mitigate the switching ripple. And, it requires of course, the Hall Effect voltage sensor and current sensor for feedback signal and normally a digital signal processor is used to implement the required control algorithm to generate the gating signal for the solid state devices of both voltage source converter of universal active power filter.

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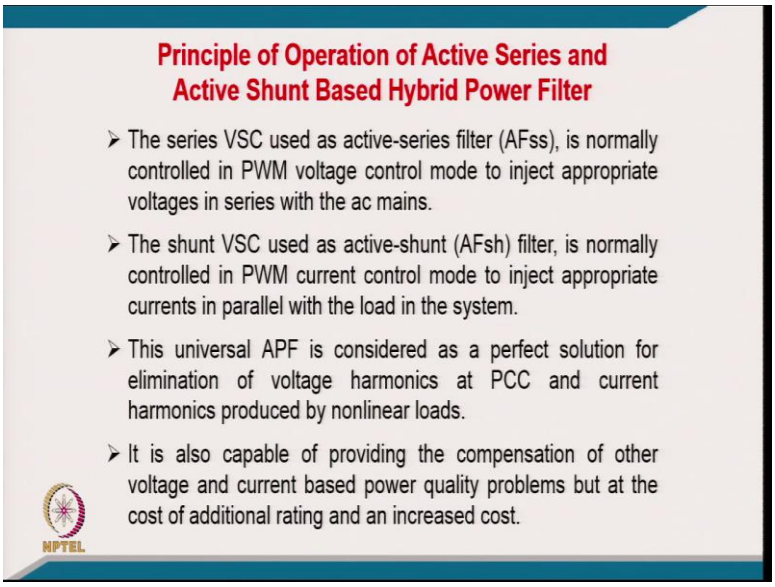

And the series voltage source converter is used as a series; active series filter and normally denoted AFsh, is controlled in PWM voltage control mode to inject the appropriate voltage in series with the ac main. And, the shunt voltage source converter used as a active shunt filter we call it a AFsh filter, is normally controlled in PWM current control mode to inject the appropriate current in parallel with the load in the system.

And this universal active power filter is considered as a perfect solution for elimination of voltage harmonics at the point of common coupling and current harmonics produced by non-linear load. It also capable of providing the compensation of other voltage and current based power quality problem, but at the cost of additional rating and an increased cost.

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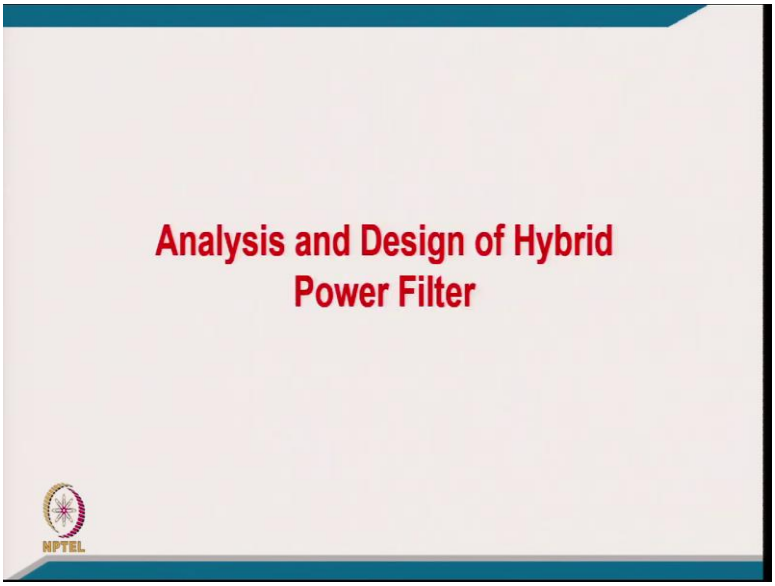

The analysis, design, control scheme and simulation performance of the hybrid power filter is detailed in the following screenshots.

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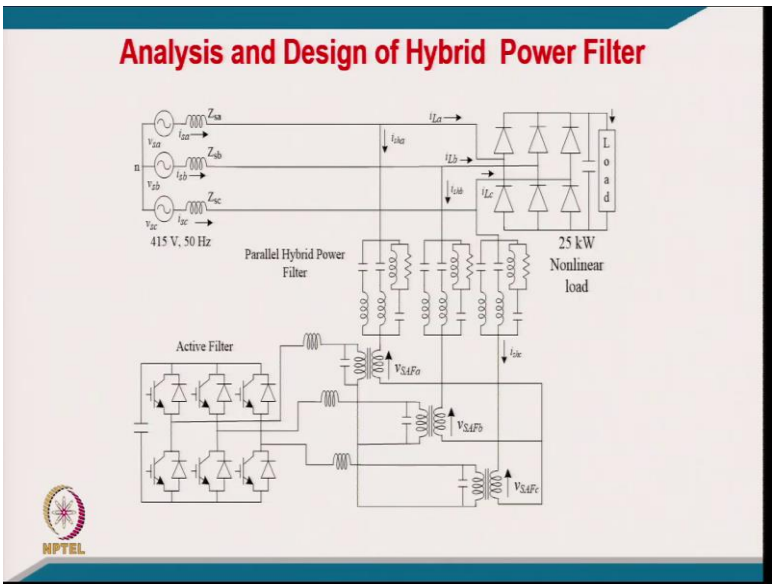

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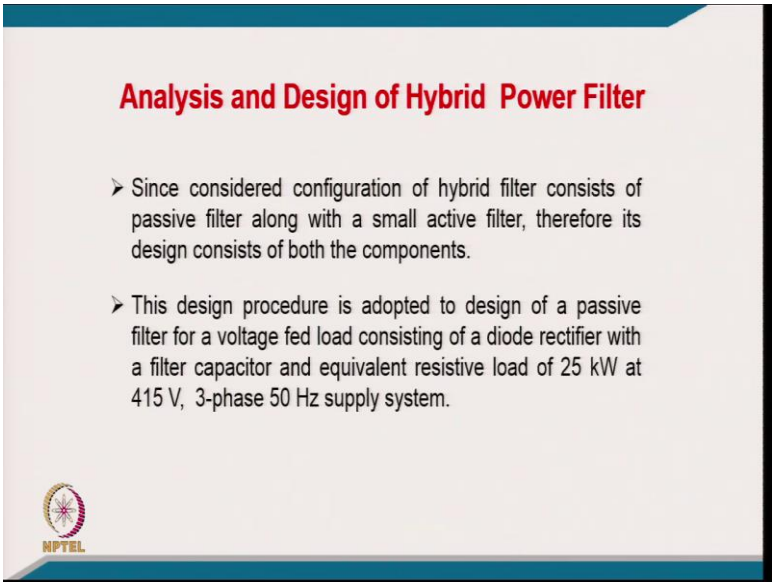

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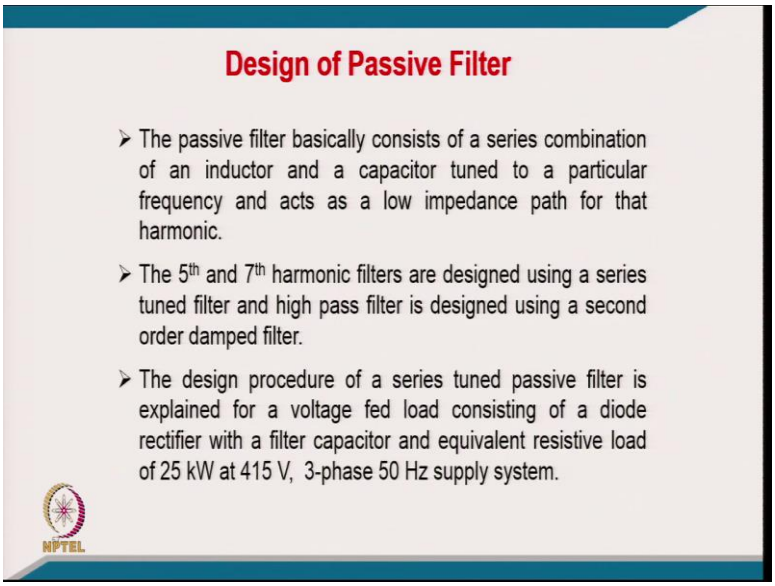

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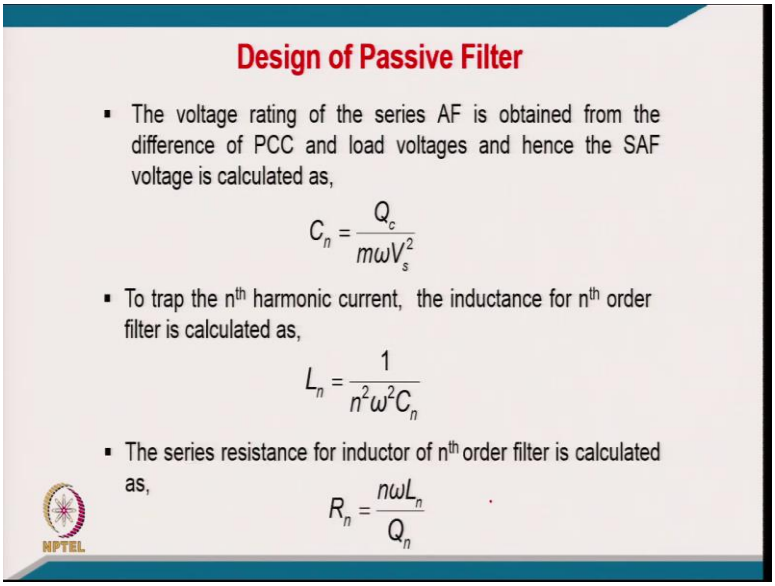

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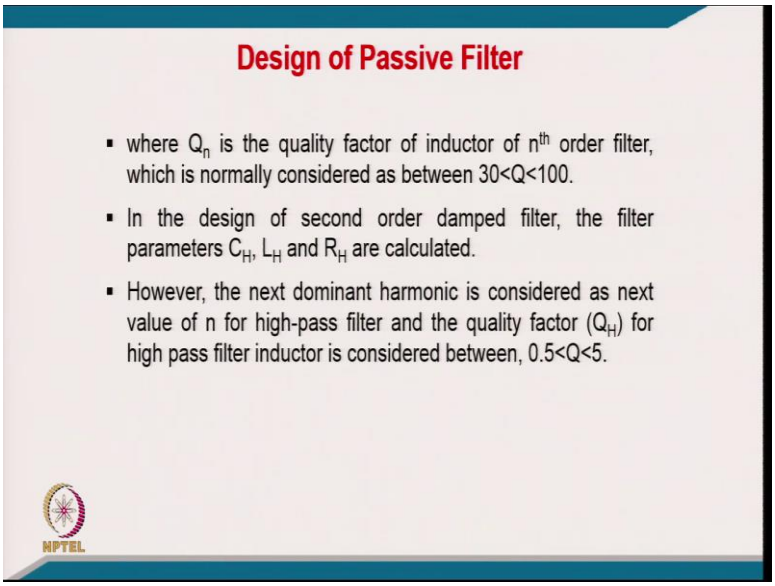

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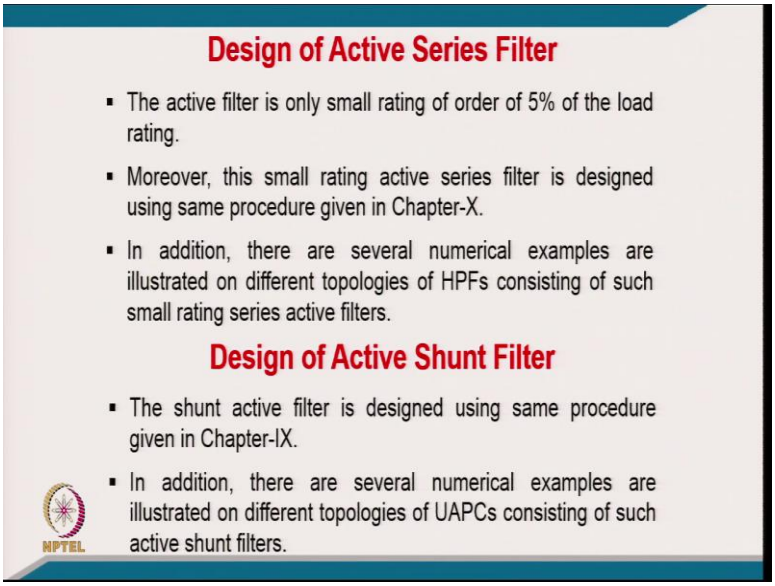

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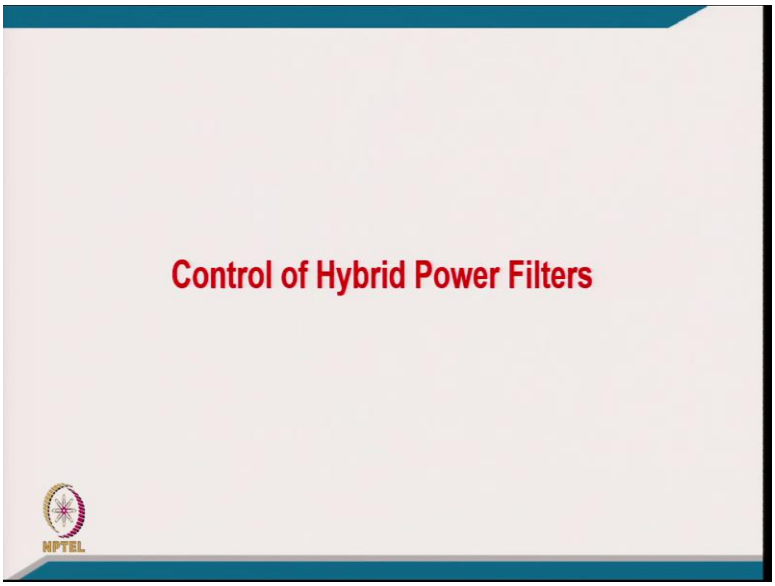

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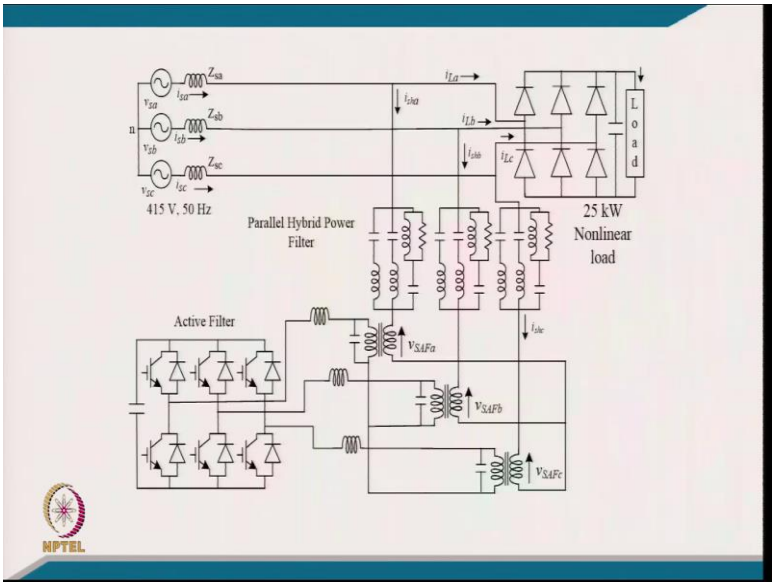

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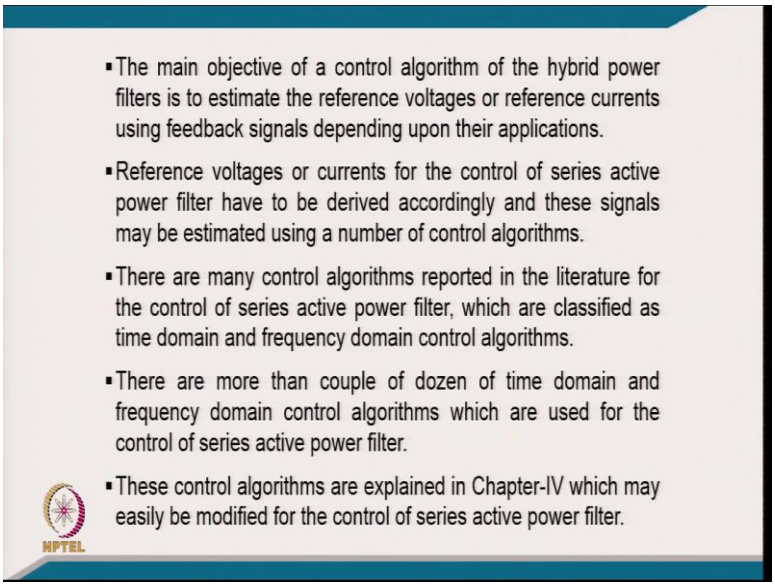

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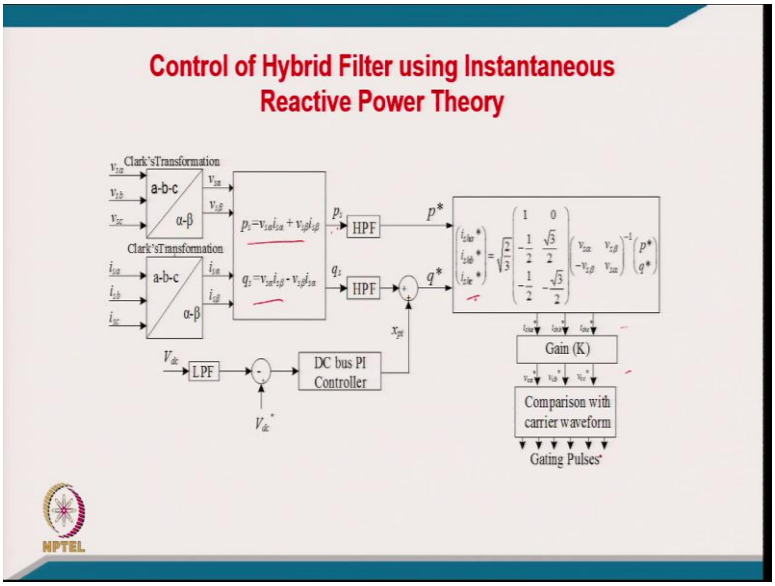

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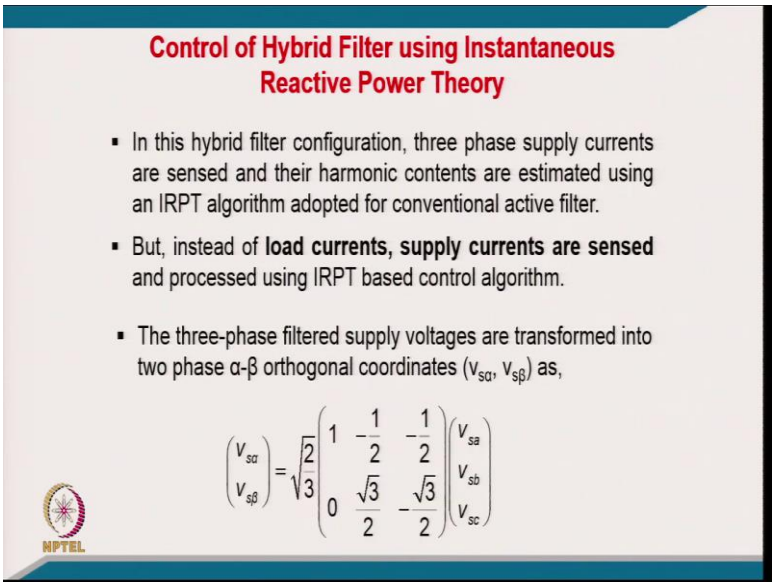

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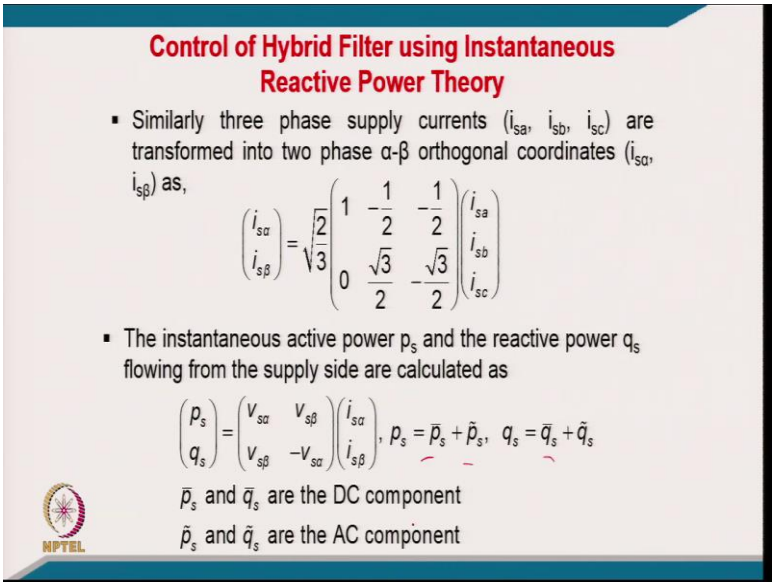

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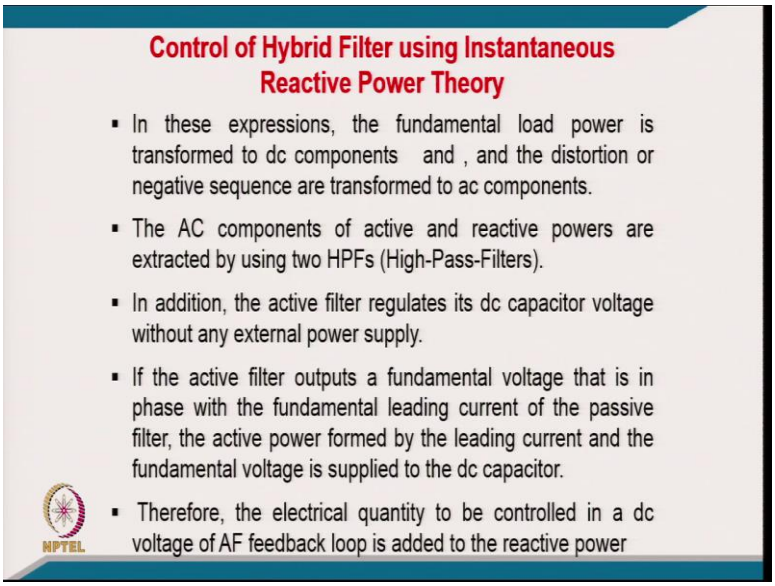

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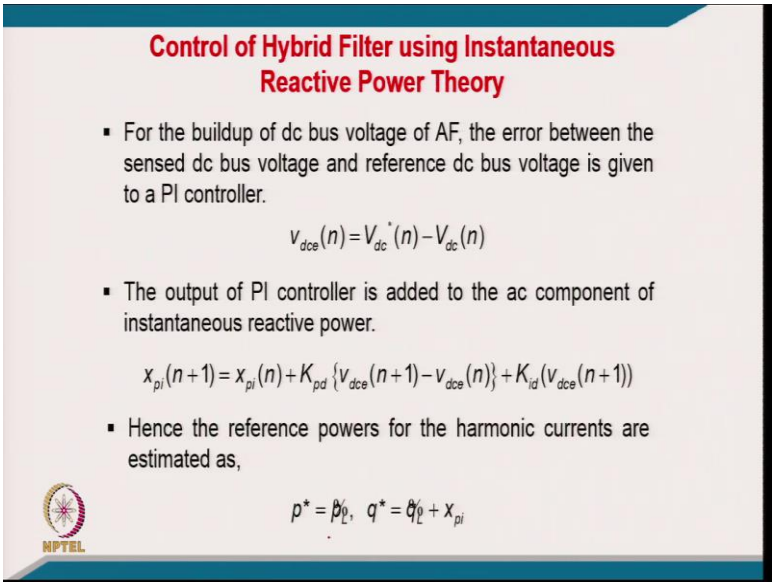

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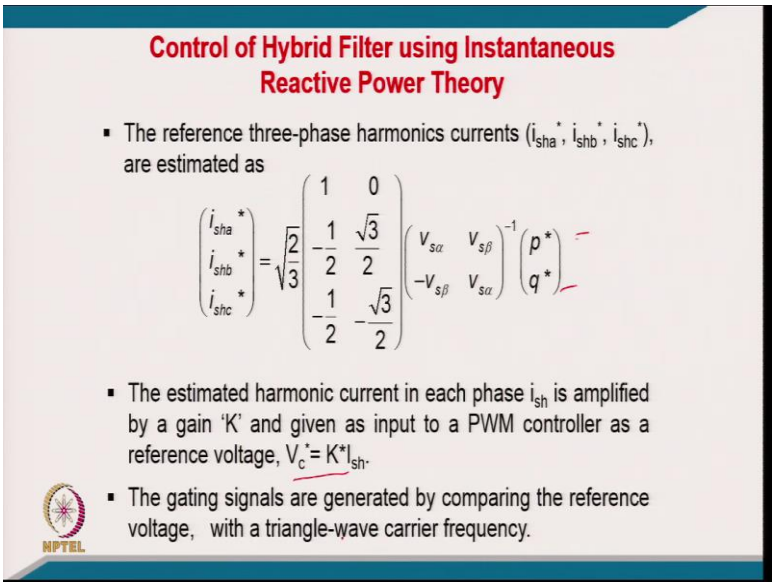

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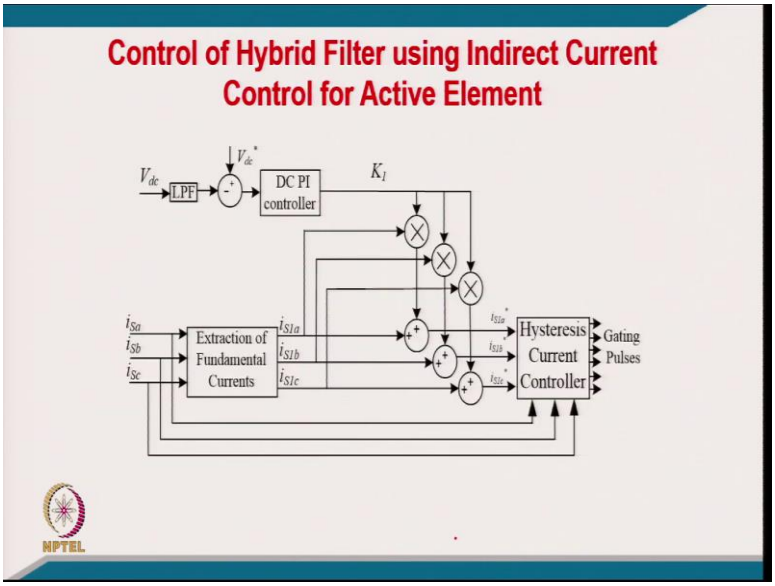

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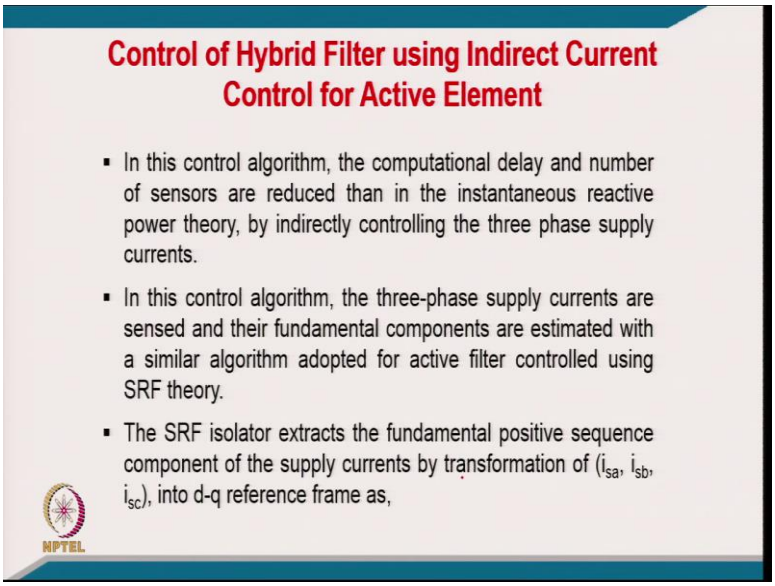

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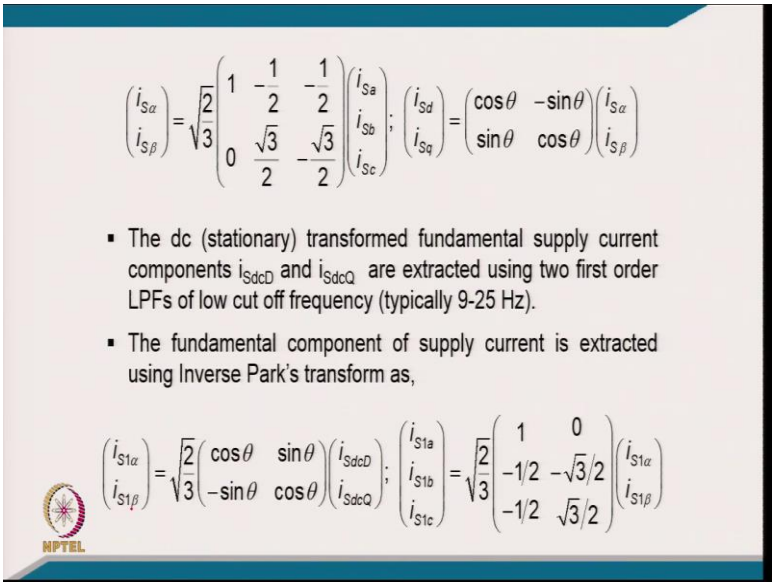

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