Power Quality Improvement Technique
Prof. Avik Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture – 33
Hybrid Active Power Filter

Welcome to our NPTEL lectures on Power Quality Improvement Technique. Today we are going to discuss about the Hybrid Active Filter. We have discussed about the passive filter. We have discussed about the active filter and thus we have seen some topological configuration related to the hybrid filter, but we shall we want a thorough discussions on it.

Essentially, this discussion will be related to the shunt part of the circuit. Thus, UPQC part of it. With the shunt we can have this kind of hybrid filtering and thus, after all we require to reduce the overall costs of the system and the better performance. Both of these can be achieved with the help of this active and the passive filter.

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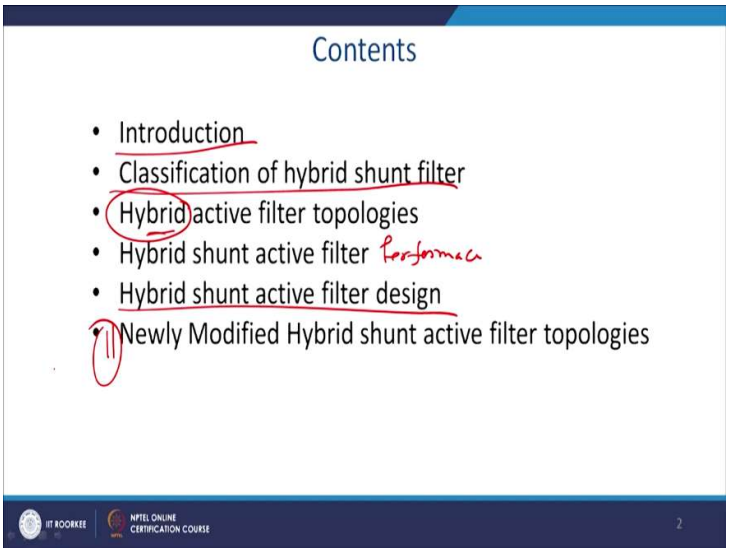

The presentation layout will be today on the introduction. Thereafter, we shall see different kind of hybrid shunt active power filter and, thereafter we will see. I have discussed one topology in a continuation of the shunt active power filter while sharing that topological variations of the hybrid filter. We can have so many topologies there. We shall discuss in detail. Then we will also discuss hybrid shunt active power filter performance.

Thereafter, we will discuss the design of the hybrid shunt active power filter and some newly reported topology and conclude our discussions on the hybrid shunt active power filter.

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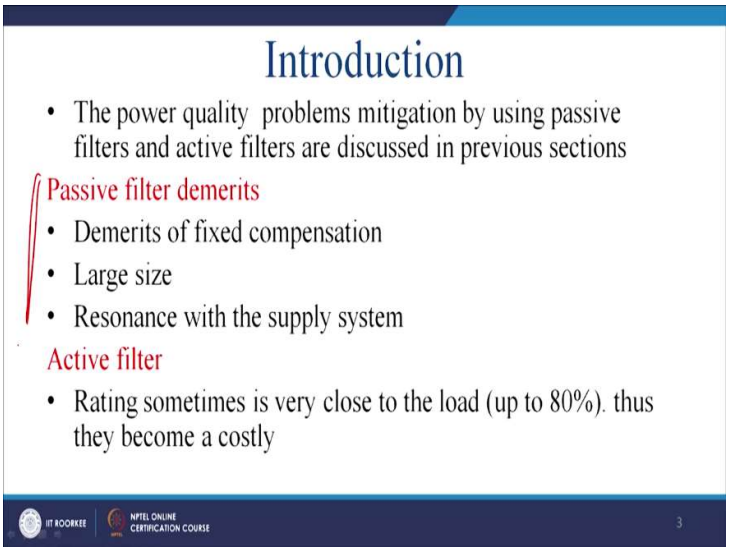

As we know that power quality problem means mitigation by using the passive filters and active power filter has been already discussed. We know the problem of the passive filters, in detail. We have discussed.

Demerits of the fixed compensations: a little bit of change in the frequency. It cannot act properly. Thereafter, large and the bulky size of the capacitor and the high cost of the inductor. Resonance with the power supply and also adjustable speed drive can put the particular resonance. These are the many demerits that we have discussed. I do not want to repeat it. For this reason, we have these demerits of the shunt passive filter.

Same way the active filter sometime it is very close to the load and, thus sometime you want to have the reactive power compensations to be done by this active power filter. If it is at the low power factor then rating becomes higher and thus the solution becomes costly. For this reason, the costly solutions and the bulky nature and other demerits can be removed by coupling them together.

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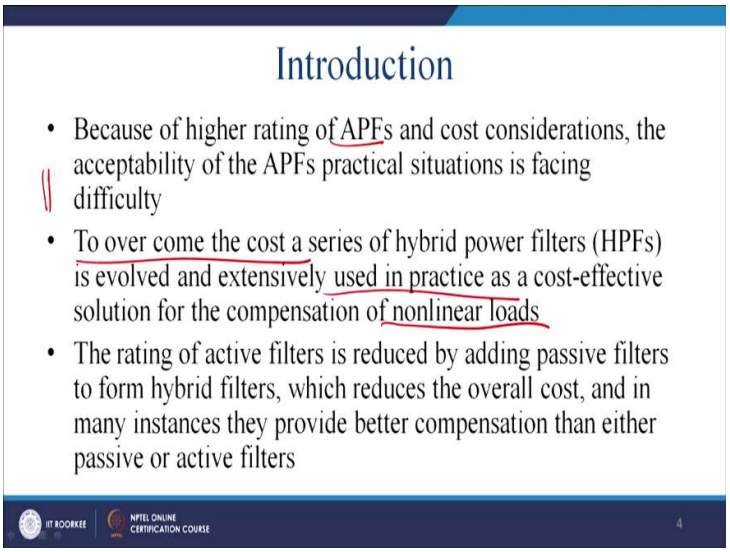

Thus, because of the higher rating active power filter and the cost consideration, the acceptability of this active power filter practical situations is facing difficulty. So, one of the demerits of the active power filter is a higher establishment costs, because you required to put it in a distribution network. If you want to put it into the transmission network, then due to the high cost of the device will come down because of the higher device rating.

But gradually this is all coming down and thus whatever you have optimized, if you are taking a paper of 10 years old whatever the cost you are putting there and if you are doing this analysis today, that will be totally a misnomer. It will be totally a misguided direction. Cost of the copper and the inductor copper goes up hence the cost of inductor goes up, but cost of the silicon devices is coming down.

So, gradually we may totally go for the active solution, but here till now we have a gray way and since, we already using the passive filter, we may require to retrofit some time with that. Thus, we require to understand the feasibility of putting a hybrid filter to.

For this reason, to overcome the costs of the series hybrid power filter, it has evolved and extensively used in practice as a cost-effective solution for the compensation of the non-linear load. So, you have a fifth harmonic, seven harmonic voltages and you can do this series composition.

The rating of the active filter is reduced by adding the passive filter. To form the hybrid filter which reduces the overall costs in many instances, they provide the better compensation in either passive or active filter. Why? Because you please understand it. Let us go back to the whiteboard.

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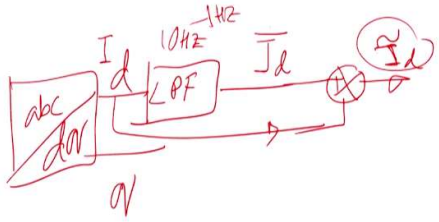

So, let us take a 'dq' solution. So, you have a 'abc' to 'dq', and ultimately you have 'd' component and the 'q' component. You have put a low-pass filter and from there you are estimating that. It may be the I_d and it has $\tilde{I}_d$. Ultimately you got the $\bar{I}_d$. Ok? That you subtract with the $\tilde{I}_d$. Once we get the $\tilde{I}_d$ essentially how accurate it would be it depends on the cutoff frequency of this low pass filter.

Since you know that this will be a dc component $\bar{I}_d$, you can put this cutoff frequency very low. But problem lies that if you put the cutoff frequency of 10 Hertz, there will be some component of $\tilde{I}_d$. Hence, it is not accurately calculated. You may choose 1 Hertz, then you get more accurate result. You choose 0.1 Hertz, you get more accurate results.

But problem is that if you choose 0.1 Hertz then what will happen? Then once the load change occurs to get the steady state value you have to wait for the three four cycles. But what happens? If you have a combination of the active and passive filters? Then you can put this low-pass filter at a very low value, because initially some dominant harmonic will be mitigated with the help of the passive filter. Thus, your dynamic response will also be

better and ultimately your steady state THD also will be better. This is the reasons we want to use both passive and active filter.

So, I have cleared this. While putting them together they will act better. So, active rating of the active filter reduces. That is one of the reasons. Because it is not burdened with the reactive power and also, they are not burdened with the dominating harmonic. By adding the passive filters, with the hybrid filter which reduces the overall cost (these instances I talked about right now) they provide better compensation than the individual active and the passive filter.

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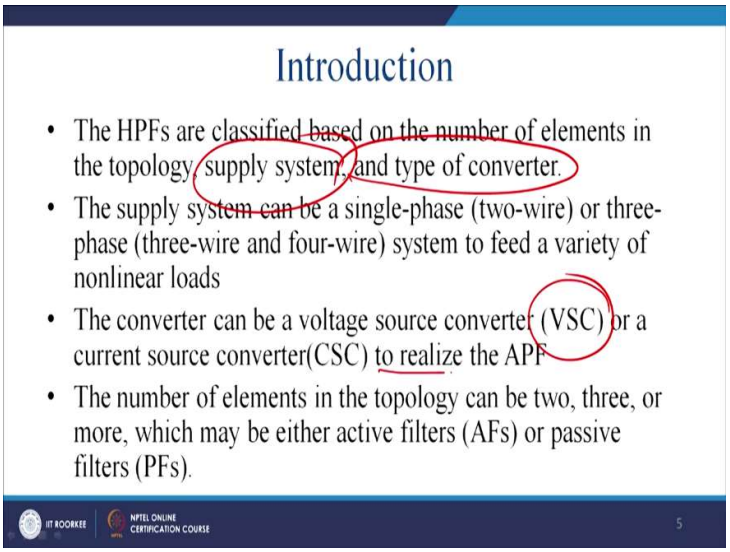

The hybrid power filters are classified based on the number of elements in the topology. Thereafter, it can be based on the supply system. It can be based on the types of the converter. Whether it is a multi level or the two level or you can have a different kind of cascade topology in between. Whether it is even in a multi-level or the diode clamp or the capacitor clamp or the H-bridge or cascade multi-level inverter.

So, these are few variants of the topology that can also come into the picture. as I will discuss in detail about some topological development with the hybrid filter. The supply system can be single-phase, as it is same for the shunt active power filter, there is not much difference or for the three-phase three-wire or four-wire system is also valid with the system feeding a variety of the non-linear loads.

The converter can be voltage source converter that is VSC or a current source converter CSC to realize the active power filter. The number of elements in the topology can be 2-3 or more. Which may be either active filters or the passive filters. You see that this is the overall classifications.

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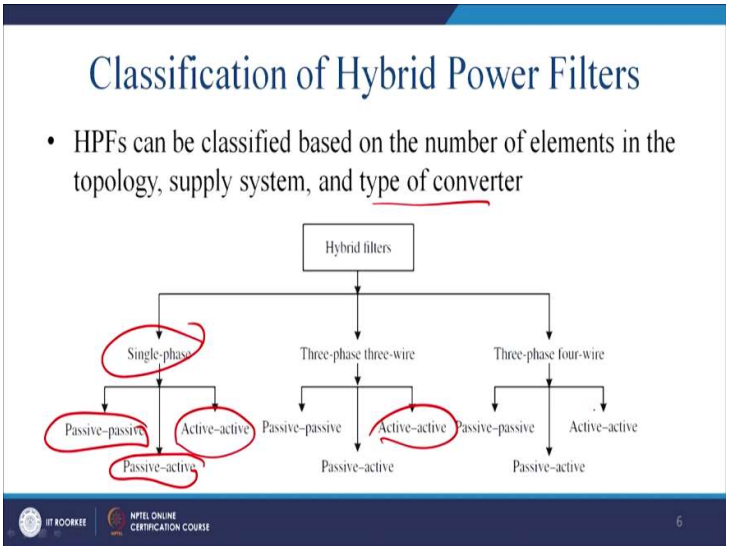

This hybrid power filter can be classified based on the number of elements in the topology. As I discussed earlier, supply system and the types of converter. It can be single-phase and then you can have a single-phase passive-passive. So, this is no longer a power filter. You can have that passive active combination. This is essentially the hybrid entity and also you can have an active-active.

I will show you how does it differ? Same way in three-phases you have a same kind of theme, that is passive-passive, active-active, passive-active and also it is for the three-phase four-wire system.

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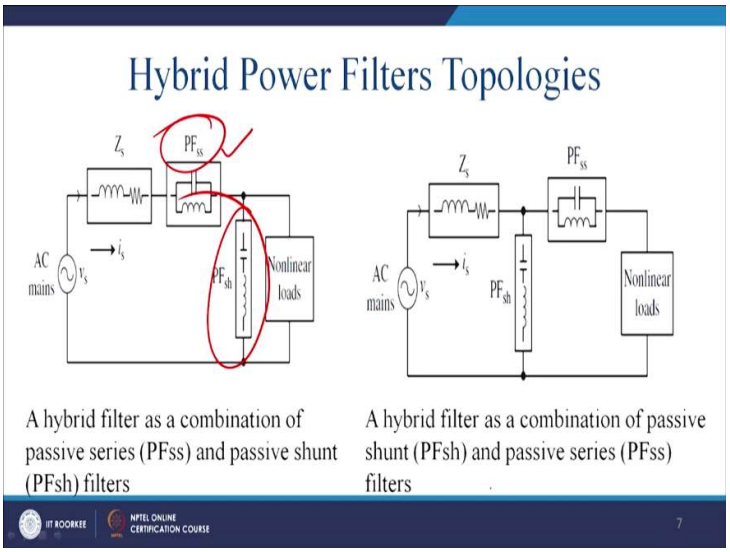

So, let us see that. The hybrid filter is a combination of the passive filter and the passive shunt filter. Then it is called the passive-passive filter. So, you have this one, it is a passive series filter, and this one is your passive shunt filter. This combination, we also call it the hybrid, but it is no longer a power filter though. This combination is called passive-passive filter.

Same way this is the hybrid filter as a combination of the passive shunt and the passive series, then that is also possible and you see that there is a combinational variation. You have first series passive, then the shunt passive. Here, you have first shunt passive if you see from the source side then you have a series passive.

For this reason, this kind of topology is said to be the hybrid power filter. Hybrid filter is a combination of the passive series and the passive shunt filter and this type of topology is considered as a hybrid filter. There is a combination of the passive shunt and the passive series filter.

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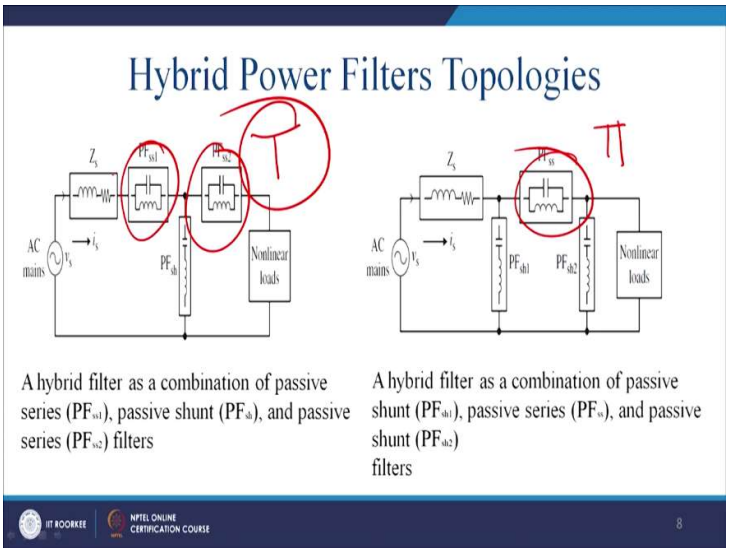

Same way in this case, we can have 'T' network. Ok? We have discussed it in details. But we will later replace one of it. I just revisiting it because for the sake of your understanding only. Some part of it. Because this is a 'T' network with the passive-passive and some portion will be ultimately replaced by the active filter. This is a two passive series filter and one shunt passive filter and here we call it π network, where you have two passive shunt and one passive series network.

This is also called the hybrid filter as a combination of the passive shunt and passive series and the passive shunt. This is called generally the π network and this is generally called the 'T' network.

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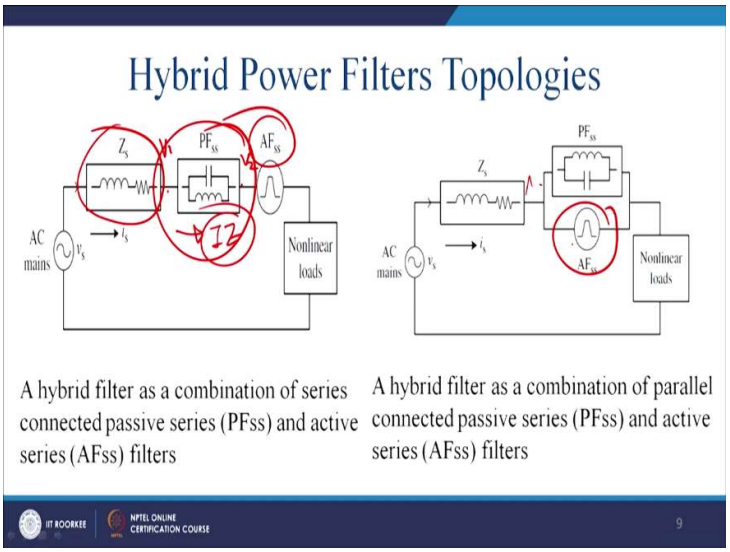

Now, in between you will replace something. Here this is the impedance of the source impedance, that has been coupled or lumped for the short transmission line. Thereafter you have PFss. That is series and now you have active compensation of the series and this is called a hybrid filter, as a combination of the series connection of the passive filters and active series filter.

Again, you know you can modify a little bit. So, here these passive filters are connected in series with the active filter, and here this passive filter is connected with the parallel part of this active series filter. We required to see that which solutions sees a lower power rating. Because it depends on the voltage level. See in this combination, generally the rating of these devices is the series between v_1 and v_2 potential difference between these two entities. But it sees that total current to be flown.

Here in this case it branches out the current. Thus, it does not see the total voltage, but whatever the voltage injection done by the series active filter, due to that the voltage stress will come across it. So, we required to see which topology has a greater merit considering the different values of current is going through it. You have $I \times Z$ is the voltage developed across it.

So, what is the rating? What is a rating here? Which one is less? What is the performance of it? Those are also a consideration. So, we have to have an optimization based on this.

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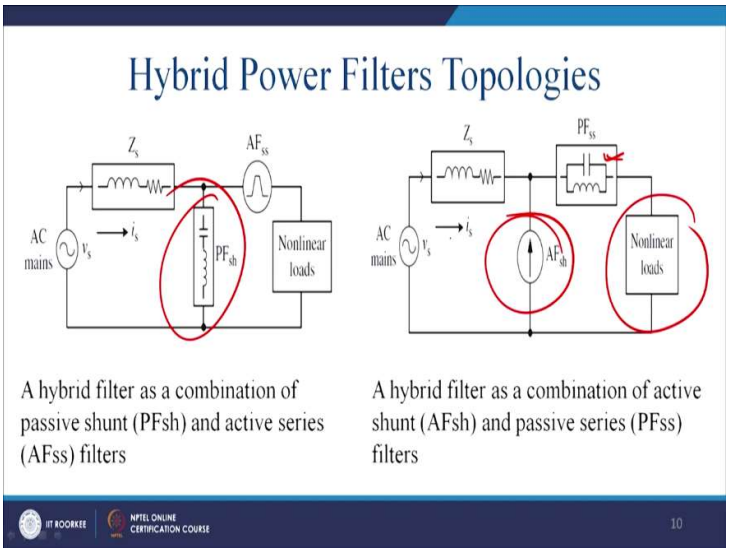

Similarly, we can have a shunt series combination. So, you have a shunt passive filter and series active filter. A hybrid filter is a combination of the passive shunt and the active series combinations. Just reverse and you have a active shunt and the passive series.

So, the hybrid filter combination of the active shunt and the passive series. Here you have a shunt active power filter and you have a series passive power filter and, this is also a combination. All the permutation combinations are possible and you cannot give a unique solution. We have to observe the rating of it and from there you required to find the optimal solution.

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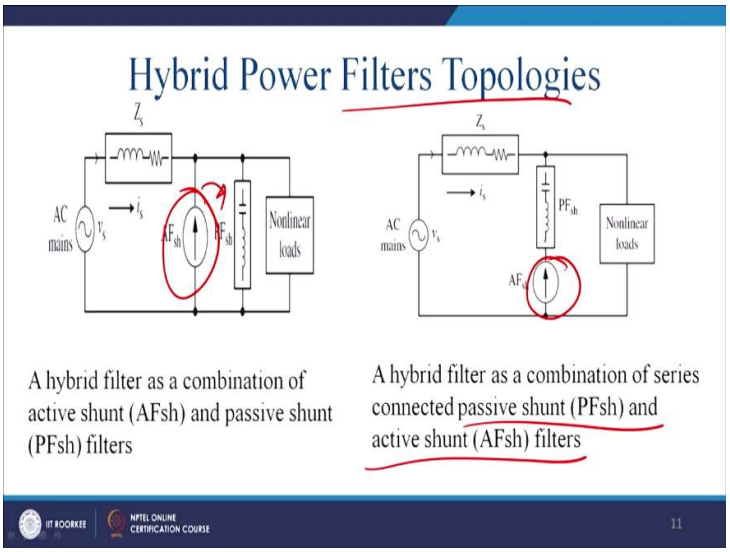

Same way, the hybrid power filter topologies, we can have this shunt parallel. There is another shunt. So, what happened here? This will act in the picture little later maybe. That is what I was trying to discuss in the whiteboard and thus it makes the THD in the steady state quite acceptable and initially it will act and mitigate the harmonic.

The fine tuning can be done by this active power filter and thus rating also will be less and you get a better solution for individual shunt active at the passive filters. This is called a hybrid filter as a combination of active shunt and the efficient. The hybrid filter as a combination of series connected passive shunt and active shunt filter.

Now, what you can do? You can have this passive shunt. It was connected in parallel to it and here you connect in series to it. This is the topology I have shown you while discussing one topological aspect of the shunt active power filter. Then I decided to let us have a thorough discussion on it and this is with the non-linear load.

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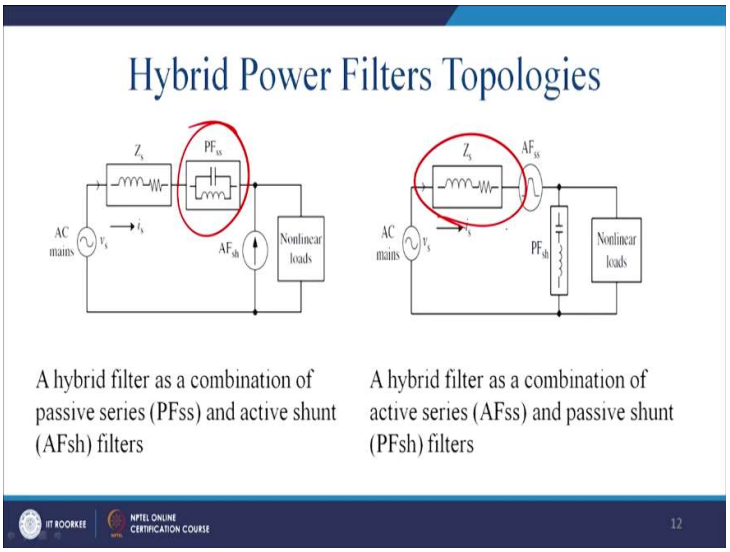

Now, you have AC mains and you can have a series passive filter and shunt active filter. They are connecting like this. This topology is said to be the hybrid filter as a combination of the passive series and the active shunt filter. Similarly, this one is an active series and the passive shunt. This hybrid filter is a combination of the active series and the passive shunt. All the permutation and combinations is possible here.

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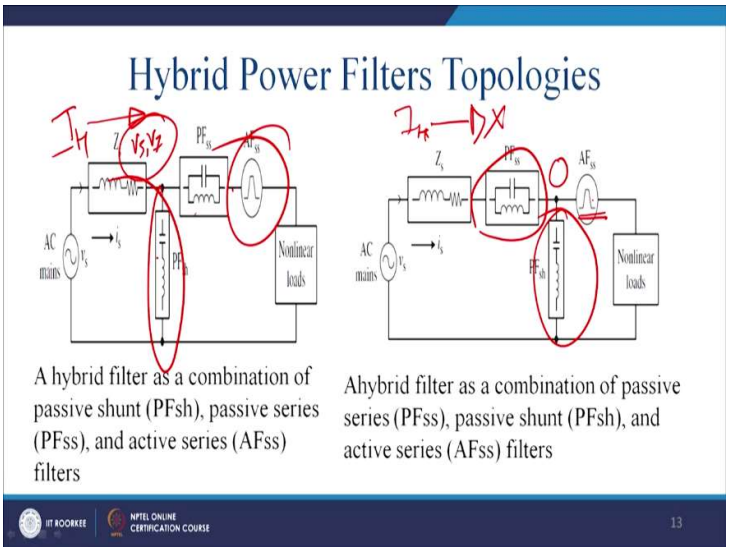

Now, let us see that. Again, in the T network you can add one series passive filter. Sorry. It is not a T network this is a source impedance and you have a combination of the active

and passive. You put the shunt first, thereafter series entity and here difference is that you put the series parts then only you put the shunt. What happens then? Generally, since it will block certain amount of the harmonic its rating required is reduced and here it will see the overall rating.

But what happened? Generally, this performance is superior because you got a harmonic content I_H, you have a drain for the I_H here and it will be blocked here and thus you pass it to the drain. Then what happened here? Here you first blocked I_H, then you have a drain.

So, the harmonic content that handles this passive filter will be low. Here it will be high, but problem lies here the solutions what you get is inferior than this and the cost of the higher power rating is high because, you have to design that and harmonic current will sink to it. Higher power rating here.

Here it will be less, but voltage level will be almost same, because there we are dropping in the voltage that due to the harmonic voltage that does not have a tangible difference between this point and this point. Thereafter what you do? You put whatever you are left with. You inject the active filter and clean out this process. Generally, I have taken the observation from this point. Since source current is flowing and with the Z_s it will have the fifth harmonic voltage and the seventh harmonic voltage.

What does it do? It generally reduces the fifth harmonic current thus the voltage developed here will be less. Similarly, here it will block that fifth harmonic and the seventh harmonic voltages and thus the current available here due to the fifth harmonic will be low and that will be again shunted to the ground. Ultimately whatever the voltage contamination of the fifth and seven or other harmonic you are left with, that will be mitigated by the series filter.

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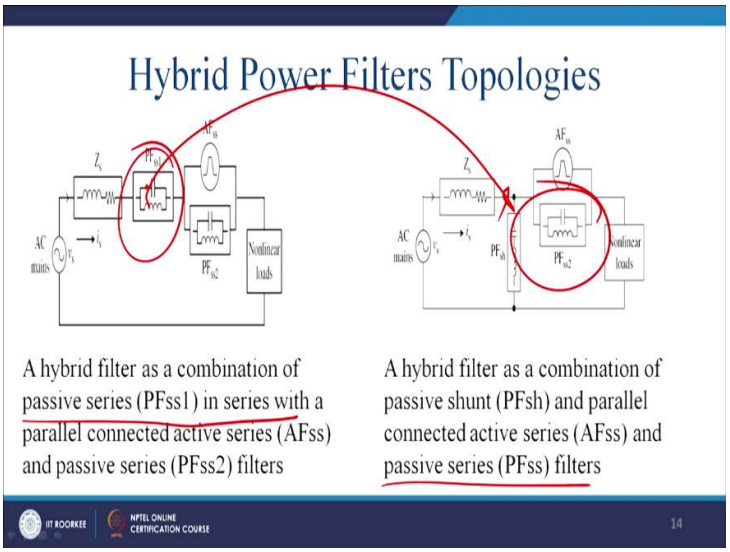

Now, let us see the combinations, that we have already discussed little bit. Thereafter first we have a series compensation for the particular filter. Then we have a series active filter connected parallel to another passive series filter. This is called a hybrid filter, as the combinations of the passive series filter in series with a parallel connected active series.

So, if I tell these things you will get confuse. By understanding the topology, you will understand it better and ultimately once you put this entity here, this becomes the hybrid filter as a combination of the passive shunt (this one) and the parallelly connected active series and this shunt combinations with the non-linear load.

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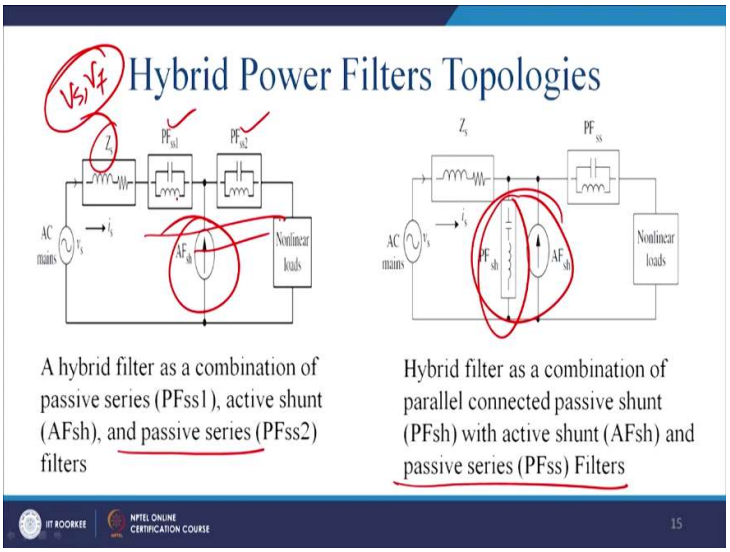

Now, similarly you can have a shunt solution. This is your series passive filter and you have an active shunt solution and that is also possible for the current harmonic mitigations. Hybrid filter as combinations of the passive series and the active shunt, and the passive series combination has been shown. Thereafter you have hybrid filter as a combination of the parallel connected passive shunt with active shunt and the passive series has been shown.

This is something you can see that. This entity here it will be shunted. Both the shunt and one series has been left. Here more importance is given for the series compensation, and here more importance is given for the shunt composition. That depends on essentially your source inductance. If your source inductance is less then fifth harmonic voltage and seven harmonic voltage will be low

But you may have a good quantity of the fifth and the seventh harmonic current. Then you go for this solution. Once you find that fifth and seventh harmonic it is quite high because of the high source inductance, then we may go for this combination.

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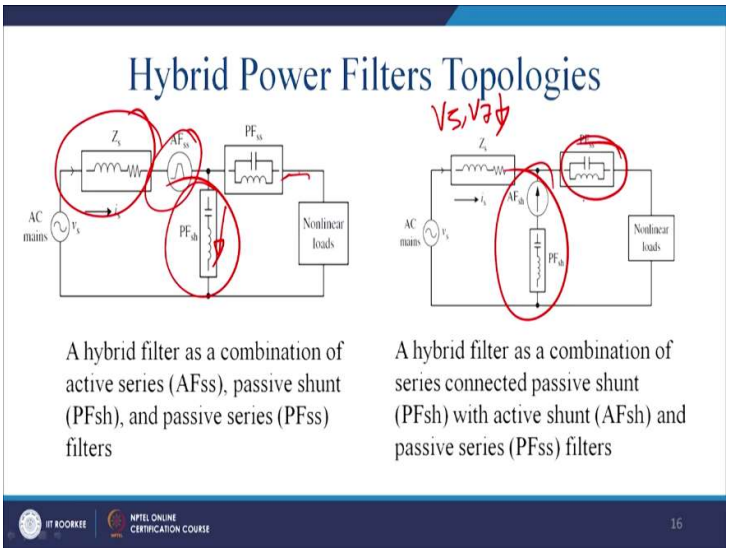

Thus, this is also a possible feature that is your Z_s. Thereafter you will have the active series. It is better because the voltage harmonic is the source inductance due to the non-linear load.

Thus, you mitigate all the harmonics related to that which is coming due to the source inductance. Then this entity will have to sink the current since your fifth harmonic current is less. It does not have a problem. Voltage is less so it does not have a much amount of current left. Also, whatever is been left, it will be blocked. If you see from this side this will be blocked and whatever it is there it will be sink in to this passive filter.

Same combination when your source inductance is quite less and you do not have much problem with the voltage. Harmonic voltage fifth and seventh is quite less then you go for the solutions. You inject the fifth and seventh harmonic. Ultimately sank the direction as such that whatever the non-linear load is having, it will be transform and, there is a small amount of this voltage harmonic that may be there. That can be suppressed by this series filter.

Thank you for your attention. I shall continue our discussion with the hybrid filter topology also in the next class.