Power Quality Improvement Technique
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Lecture – 09
Passive Filter

Welcome to our NPTEL courses on the Power Quality Improvement Technique. Today we are going to discuss about the Passive Filter, that is the one of the element that we are using for a long time. We can use the capacitor but capacitor has lot of problem and for this reason we require to use a passive filter.

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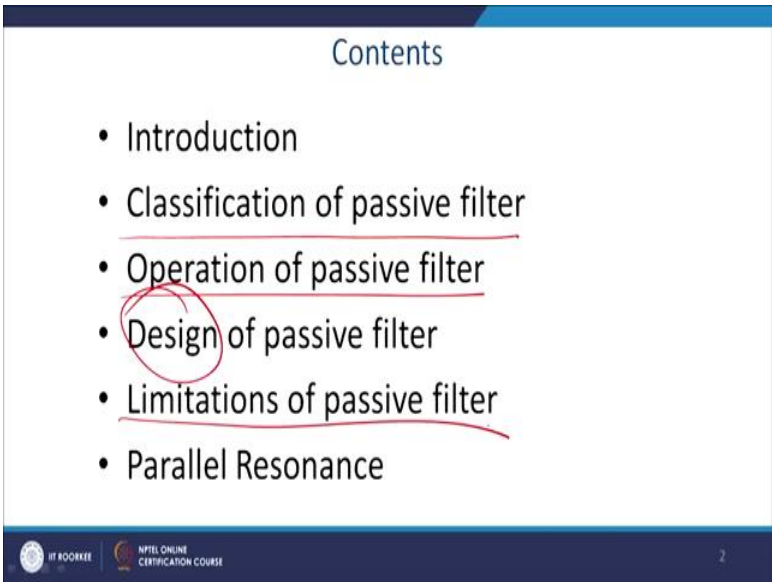

So, passive filter can be tuned to the particular frequency. We shall see that are based on the classification on the filter and ultimately thereafter we will see that how there is operate it is nothing because it is a network theory. So, you are studying for a long time. Thereafter, we shall see how to design the passive filter, that is one of the entities to be considered.

Thereafter limitations of the passive filter. Limitations of the passive filter is something that we required to understood very well. We have talked about those limitations in our introductory overview classes. So, we shall discuss in depth. Thereafter parallel resonance and all this is a one of the limitation of the, this passive filters and the de-

tuning and other problem and the problem associated with the parallel resonance also will be discussed in a subsequent time.

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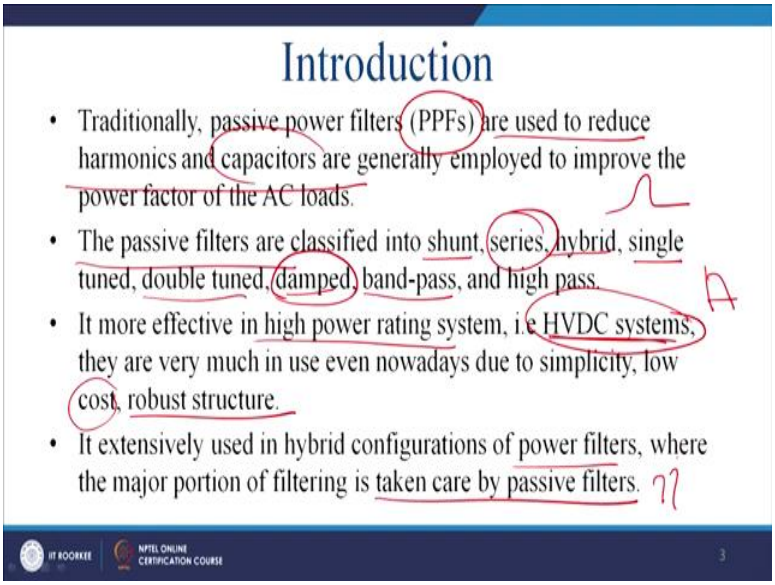

So, traditionally a passive filters we shall abbreviate this one, passive power filter. Please note that there is a signal level filtering and that can be also the active filtering by the op-amp. But, once you are using, once you are using the high power and then it has to be a passive power filters and once you are using the active component of it that will be shunt or the series active power filter that will be also the power filters.

So, it will be persisting of the higher power rating not op-amps. Are used to reduce the harmonics and the capacitance are generally employed used to reduce the harmonics that is what I am saying. The capacitors are generally employed to improve the power factor of the AC loads that we are doing for past 100 years till the AC supply has got the more predominance over the DC supply.

But, these passive filters, but if you use a capacitor then with the advent of or with the power electronics comes into the picture you have adjustable speed drives and HVDC link and these are generally generate a corresponding frequencies that frequency we require to negate it. So, for this reason and also you know there is a problem of the transients in case of the single capacitor and if you tune it properly then also that transient portion can be mitigated and moreover it will responds to a particular frequency.

And it will not it will have, it will have a selectivity and for this reason the passive filters is classified into the shunt. You can put them in parallel path, series that a hybrid you can put them shunt and series thereafter you can have, you can eliminate a single frequency. That is called a single tuned and it can have a let us say it will be eliminating only the fifth harmonic then it is single tuned.

You can have the frequencies eliminate, will be eliminated by it will be the double tuned because it may be eliminating fifth and seventh. Thereafter sometime it required to be damped also otherwise it will have a sustained oscillations. So, you require to damp it out. I shall take a special lectures after that after shunt active power filter the grid connectivity and the control associated with the grid connectivity.

And it will be a general class and not restricted to the and it will would not be restricted to the only the shunt active power filter because with the advent of the micro grid now shunt active power filter also the part of the micro grid sometime and we can put the solar into the system and thus it is gives you a integrated solution. So, we required to have a holistic approach on it and there we can have a active damping as well as the passive damping. That we will discuss in detail in a subsequent class.

Thereafter we can have a band-pass. You allow a particular frequency to be pass and you can have a high pass. So, you have a as well as the low pass. And, it may be more effective in high power rating system. For example, that is the nowadays we have a HVDC transmission line you know that it has been seen that transporting power through the HVDC or the extra high voltage AC line with the facts is a cheaper than if you have a thermal power sources than the coal.

So, transporting coal and land whatever will be there it will take more establishment cost than establishing a high voltage HVDC or extra high voltage AC lines. And, for this reason this is now getting a dominance into our distributions in into our transmission system. And, here also you can see that in HVDC system they are very much in use even nowadays due to the simplicity and low cost and the robust structure.

So, we require to filter out. We want to have a DC from AC to DC. There we can still use a passive filter. The extensive used in hybrid configuration that is the configurations of the AC and DC both. I have seen, I will show some example of the hybrid filter when the topological discussion of the shunt active power filter.

So, configurations of the power active filter, where the major portion of the filtering taken care by the passive filter, but these statement now required to be validated because with the time, the cost of this IGBTs are decreasing because it was high patent cost and unfortunately for this reason the manufacturing all those issues comes into the picture.

Now, since 30 years has been passed more than 30 years the IGBT came. So, price has been decreasing every year and for this reason we, but cost of the once you are putting a passive filter is the cost of the inductor and the capacitor. Inductor comes with the copper and the iron, in general this costs goes high and this statement even if it is validated in a particular rating it may not be so for the other rating.

And also, gradually we may eliminate the passive filter once the cost of the switch goes low and major portion of this, major portion of this filtering can be done by the active filtering and a little bit of portion will be left to the passive portion.

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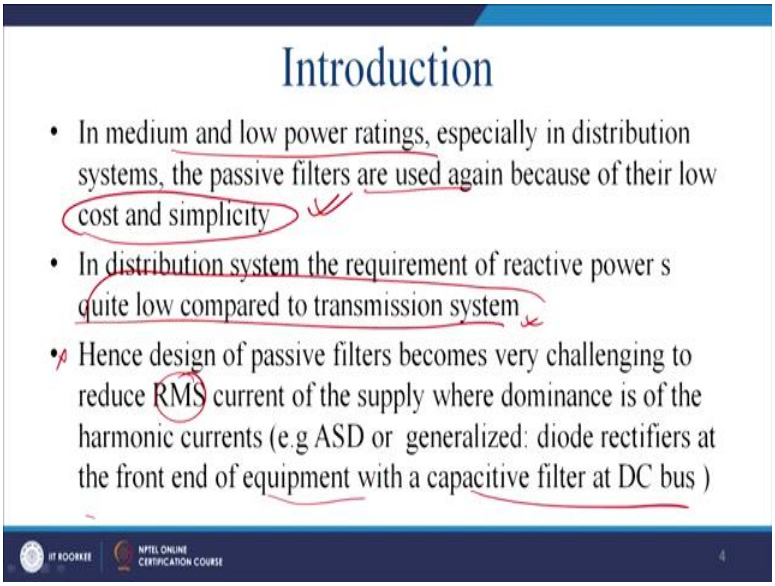

So, in the medium and the low power rating especially in the distribution systems the passive filters are used because of their low cost and simplicity. So, it does not have a much voltage rating. So, thus the and neither you have a big current rating and due to that the, it will be very compact as well as very simple to design and for its simplicity and other cheaper in cost, we prefer the passive filter. In distribution system requires the reactive powers yes, powers quite low compared to the transmission system.

So also, we may have mostly we may have a resistive network for the heating and all and for this reason that small amount of the reactive power can be given by this entity. Hence design of the passive filters become very challenging to the reduced RMS current of the supply where dominance harmonics are due to the adjustable speed drive, generally arises from the rectifications process.

So, there this is a big challenge, this portion. The design of the passive filters become very challenging to the reduce RMS current to supply where dominance is of the harmonic current and this happens once you have, you are feeding the adjustable speed drive. The diode bridge rectifier at the front end of the component and capacitor filtering is the DC bus that is the normal topology you have in the adjustable speed drive configuration. And, what happened in this problem? Why it is complicated? The above applications, the reactive power demand is quite low.

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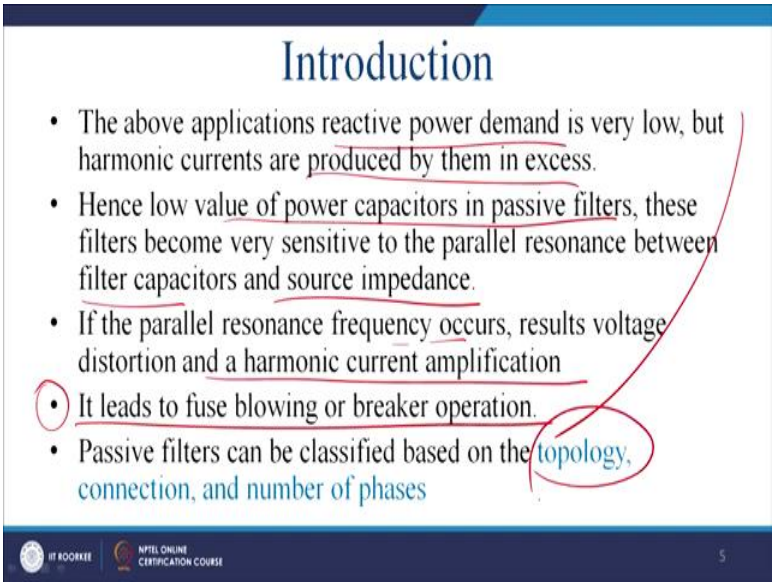

But harmonic current are produced by them quite excessive. Fifth harmonic will be dominating one and it has a huge amount of the fifth harmonic. Hence lower value of the power capacitor in passive filters, these filters become sensitive to the parallel resonance between the filter capacitor and the source impedance and you know that it is anti resonance so, less current flows.

If parallel resonance frequency occurs, this results voltage distortions and harmonic current amplification. So, this is our one of the problem. With an assignment we shall

give this kind of problem. So, this is the one of the major drawback of the passive filters and thus what happened we have explained these issues in a overview, it just introduction of it. It leads to the blowing of the fuse or main operation of the circuit breakers and this is something is challenging. Thus, generally nowadays we use hybrid filter instead of the passive filters.

Passive filter now, this is a classification of the passive filters. Passive filter can be classified based on the topology. Topology means how you can connect it. It can be single tuned, double tuned and all those issues. And the connections, it can be shunt and series.

And the number of phases, it can be a three-phase, it can be a single phase, it can be a star combination for the three-phase, it can be a delta combination in three-phase, there can be a T-connection, there can be a pi-connection. These are the topological aspects of the shunt active power, this is a topological aspect of the pardon me passive filters. So, this is the overall classifications of the passive filter.

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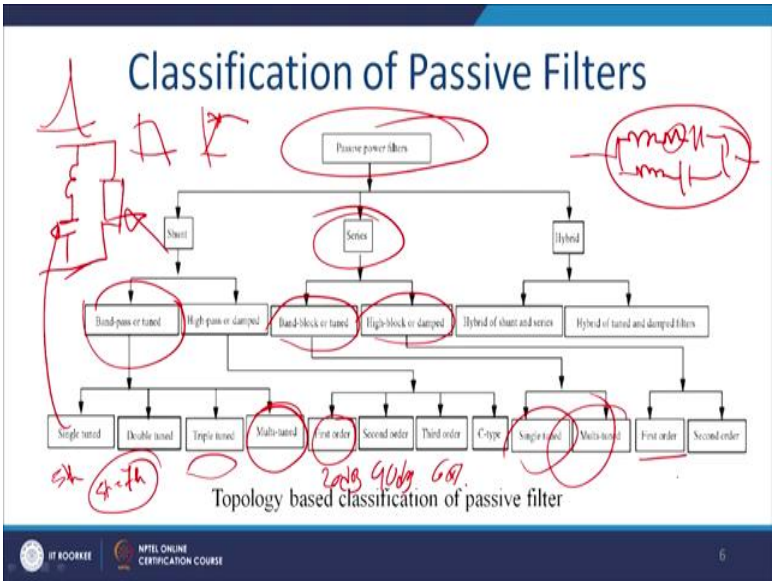

So, passive filters are based on the shunt, series and hybrid. So, shunt: you may have you can connect in parallel to the load then it is shunt and you may have a generally most dominating features of shunt for this reason passive resonance comes. Band pass or tuned: you will pass, you have this kind of filters and there after you have a load then this

is a shunt or passive filter or this parallel filters and there you have a band pass or tune. You may eliminate a particular harmonic, fifth harmonic.

Thereafter it may have a high pass or damped, that mean you will eliminate this kind of frequency response, this is a low pass and rather this will be high pass. So, you can have a high pass kind of entity. It will block everything after some frequency that is low pass and will allow everything after some frequency that will be the high pass. So, this is a 3dB frequency. Same way we can have a series passive filters, start with a band or block or the tuned.

So, you will connect this inductor and the resistance, capacitors and thereafter this capacitor and this is a, this can be connected in series. So, ultimately it can have a band reject. So, if it has a selectivity it only pass a particular harmonics. So, it is band block or tuned. Now, it is high block or damped that is also possible, it is generally we have to provide the damping in the series circuit otherwise series resonance set in and high current will be flowing.

So, for this reason we require to damp. Always damp this passive filters when it is in a series connection and thus it is a loss. Generally, you have to put a resistance in series and we will see later by the control system also you can have active damping. So, high block or damped. Similarly, we can have the combinations of the series and shunt and that is called the hybrid shunt and series. And, in between you have a hybrid tuned damp filter and for the band pass filter it can be further classified into the single tune, this is a this entity.

I just show the pictures after few slides, single tuned that is it may eliminate only the 5th harmonic it may eliminate 7th and 5th and 7th harmonic then it will be double tuned it may be actually tuned to 5^{th}, 7^{th}, 11 triple tuned and it may be 5th 7, 11, 13 then it is multi tuned. Same way we have a, we can have a high pass or damped that is a first order we can.

So, it will have a 20 dB decade we can, second order will have a 40 dB decade, third order will have 60 dB decade and we can have a C-type also that will discuss in subsequent class. Same way this entity you can see that band block will have a single tune as well as a multi tune and for series also high block or damped, it can be 20 dB decade at this first order or 40 dB decade second order. These are the total combinations

of the shunt active power, of the passive filters topologies can be available and the combinations can be available to you.

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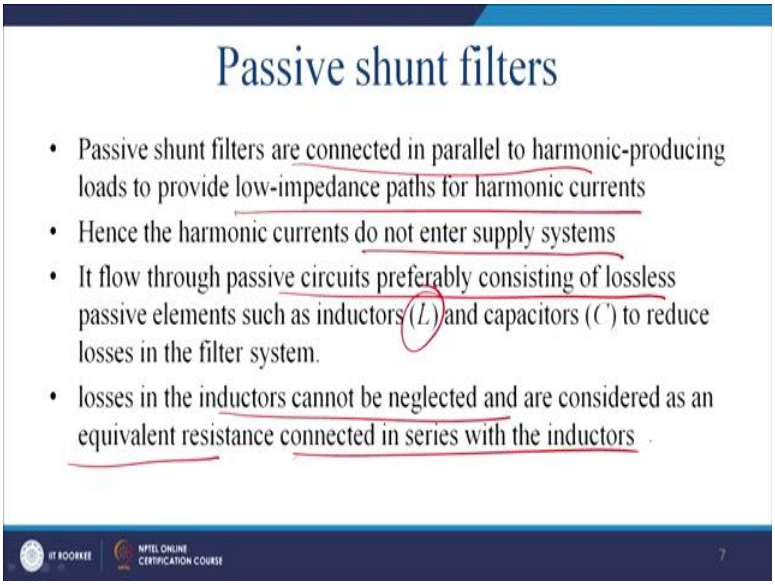

The passive shunt filters are connected in parallel to the harmonic producing loads to provide low impedance path for the harmonic current ultimately it will sink there. Hence the harmonic current do not enter into the supply system or the distribution system. It flows through the passive circuits preferably consisting of the lossless passive elements such as inductor, capacitor to reduce the losses in the filter system.

Losses in inductor cannot be neglected and are considered as an equivalent resistance connected series with the inductor. So, we have to add the resistance to accompany the losses associated with it.

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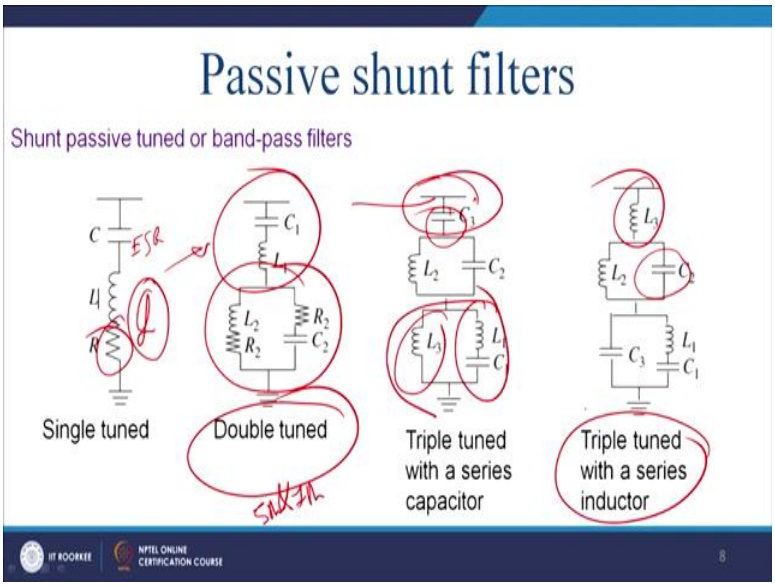

Now, this is as I was telling, this entity is your single tuned. You have a capacitor inductor and though ECR you can have external resistance connected to it and to make it damped. Otherwise the ECR and this ELR can be lumped here as a resistance. So, and you have a particular quality factor, you can design the value of R, based on that you can get the sharpness of the resonance. Similarly, you can have this one, it is same with the this one that may eliminate let us say fifth harmonic.

Ultimately you can have a combination of it that is L and C parallel. These combinations is said to be the double tuned and can eliminate the dominating harmonic let us say 5th and 7th harmonic. So, you have to design the 5th harmonic the same value will come there and for a 7th harmonic that will be a parallel filters. So, then you have to design like this.

Now, you can go to the another level. So, these combinations you can see that there is a, this combination L_1 and C this comes here. Similarly, L_2 and C_2 comes here. And effectively there will be a L_3 and C_3, that has to be calculated. These calculations will be given in your assignments. So, you can make it to operate to eliminate the three harmonics.

Similarly, if you have this one. This will eliminate the multiple frequencies and this one is been preferred because of the series capacitor, it is cheaper in the size but problem lies it has its the voltage has to match. So, switching on and switching off has to be very

proper because this line subjected to the first charging through the capacitor is charging first, but in this combination capacitor this charging through the inductor, that is something like the spring.

So, for this reason the damping effect can be smoother here and transient will be sustained more here if there is a state of, if there is a little bit change of voltage and current and otherwise this one will have a less sustained oscillation and ultimately we do not want that sustained oscillation to be carry forward and we require to damp all those passive and the active entity.

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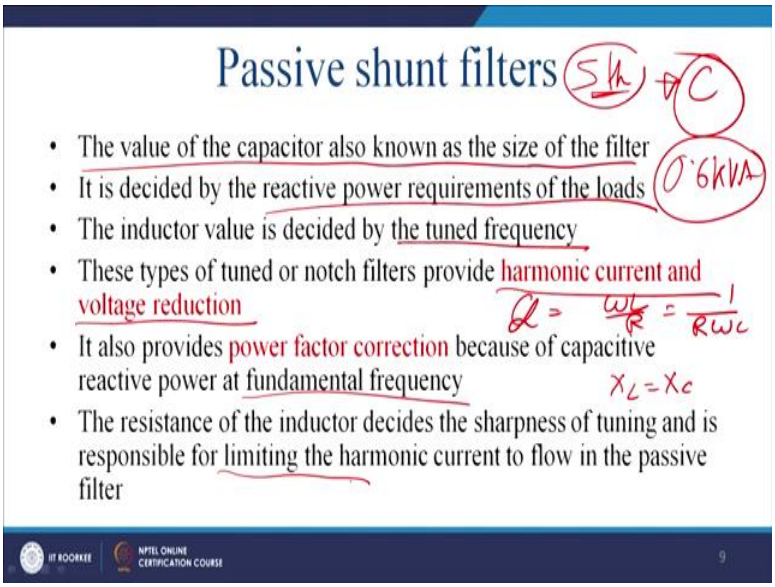

So, the value of the capacitor is also known as the, as the size of the filter. Value of the capacitor is also known as the size of the filter. Generally, you have to talk about the capacitors that will occupy a huge amount of space. So, ultimately this value will because if it is a distribution system voltage level is not very high, but the value of the capacitor will be quite bulky, will be high and thus size will be bulky.

It is decided by the reactive power requirement by the loads generally. It is already been placed so, you know that what is the worst reactive power comes into the picture based on that this compensation has been provided. The inductor value is decided by the tuned frequency and you require to tune the 5th harmonic. You already know this value of the C. This comes into the picture from your reactive power demand because you know that it is 0.6 kVAR (say some value).

So, from there this value of the C is fixed and if you wish to eliminate the 5th harmonic then value of the inductor it has to be calculated from that. This type of tuned or the notch filter provides harmonic current and the voltage reduction. This is the one of the disadvantage of this kind of filter. Though you can retrofit it and, but it has the notch filter provide harmonic currents and the voltage reduction also. It also provides power factor correction because capacitive reactive power at fundamental frequency. You know it is providing resonance to the 5th harmonic.

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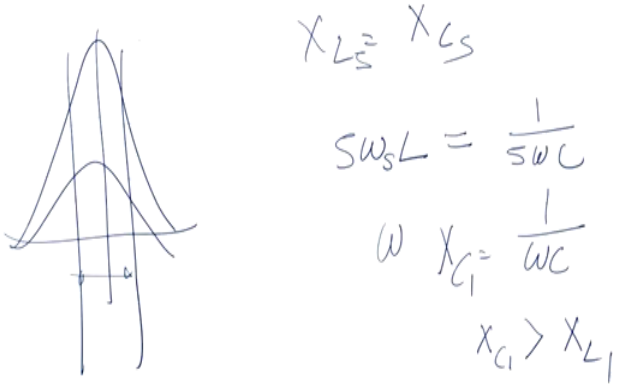

So, you know at resonance X_L is equal to X_C. So, let us understand why. X_L equal to X_C at 5th let us say at the 5th harmonic. So, 5 omega S into L that is basically, essentially you know 1 by 5 omega C. So, essentially what happen? So, when you have, at fundamental value of X_C is 1 by omega C. So, of course, you can see that X_{C1} is more than X_{L1}. Thus, what happen? At fundamental frequency since this capacity VAR is more it will be correcting the power factor.

The Q factor, that is called sharpness of resonance. Another factor is Q that is omega L by R or R omega C whatever may be. So, that because at the resonance omega L equal to omega C. The resistance of the inductor (generally you connect small inductor with it, it is not that the parasitic inductor that comes into this with the copper wire that is not enough) decide the sharpness of the tuning and it is responsible for limiting the harmonic current to flow in the passive filter.

So, how much current it will flow that you can. So, you can have a flattened response. You can have a different value of the Q. So, sharpness of response for sake of you have studied it. So, some values of the Q can be there. So, this can be there. So, how much current will flow at the resonance. This is your bandwidth. How much current will flow at the resonance? You can check it by putting the value of the resistance.

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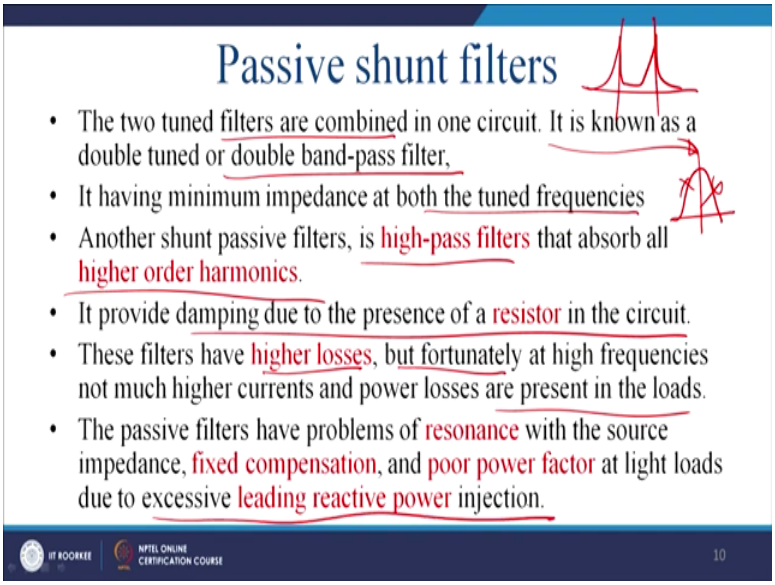

Now, let us come to the double tuned filter or the double tuned filters are combined in one circuit and it is that is two tuned filters combined in one circuit is called a double tuned or the double band pass filter. So, it will allow or eliminate. It may eliminate 5th and 7th. So, it can have this peak as well as this peak or it can have 5th and 7th both.

So, here 5th and there is a 7th, but if there is a, sometime we managed with this if these frequencies are quite close, but we some time required to do it like this. For example, if you are eliminating let us say 5th and 11th so, you have to do this way. It having minimum impedance at both the tuned frequencies, since it is a we are talking about the shunt. So, that will, those current will sink through it.

Another shunt passive filter is a high pass filters. It also absorbs all the higher order harmonic. Generally, put a very small capacitor and this will take out all the switching harmonic and all those harmonics and thus you may, we will have a smooth wave form. It provide damping due to the presence of the resistors into the circuit generally you have

to have a RC network and RC network time constant will be the same the close to your switching frequency.

These filters have higher losses, but fortunately at higher frequencies not much higher current and power losses are present in the load. So, for this reason their rating, power rating is quite low. The passive filters have a problem of resonance with the source impedance (that is one of the greatest limitations of the passive filters and for this reason gradually our shift is on active filter), fixed compensation, poor power factor at a light load due to the excess leading operating power injection. This is the one of the major drawback of this passive filter, shunt passive filter.

Thank you for your attention. I continue our discussions with the passive filter in our next class.