Machinery Fault Diagnosis and Signal Processing
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Lecture - 47
Faults in Electrical Machines

Yeah, in this lecture, we are going to discuss about faults in the electrical machines per say, in the last lecture, we discussed that how one electrical motor current can be used to find out the defect in a gearbox or a submersible pump or for that matter in many mechanical unit, but what if the electrical machine per say has a fault; how do you detect using MCSA something which you want to talk and then towards the end.

I will also talk about how the condition of an transformer or a switch gear can be used; can be found out

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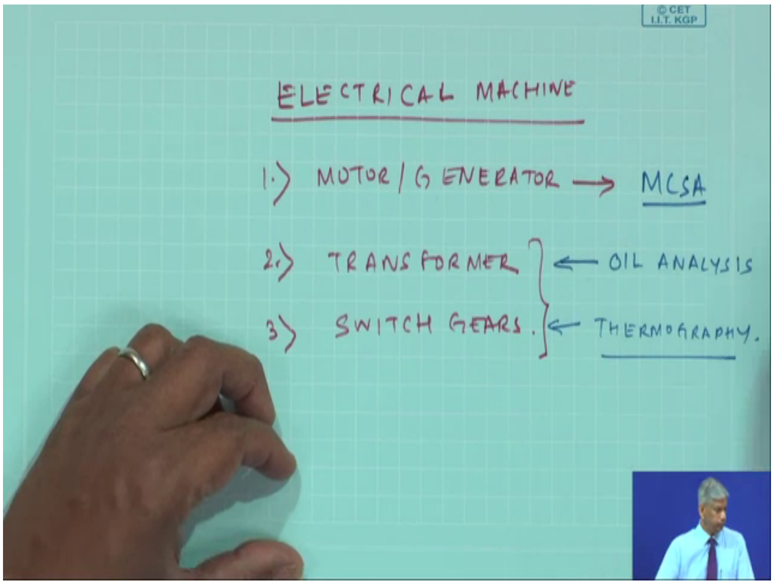

So, when I talk about electrical machine, I will broadly classify them as the motor generator, then we have the transformer and of course, the switch gears ok. So, we will focus primarily on motor current signature and passing, I will tell about transformer and switch gear actually transformer when you talk about oil analysis, we will discuss about them and this is very easily done by a technique called thermography which is nothing, but infrared imaging.

But, let us focus on the motor current signature analysis for MCSA for motor and generator set.

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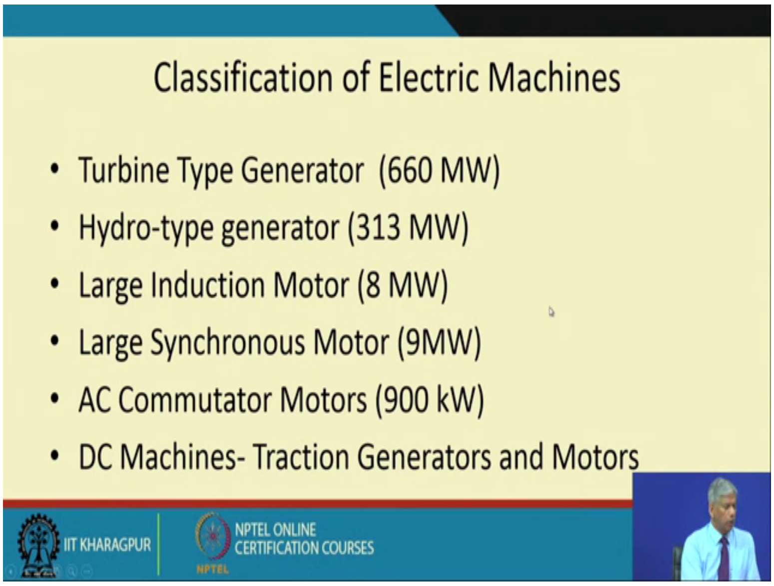

So, if you look at the electrical machines which are generator or motor, you know, they can be very very big; 660 megawatt hydro type generator, 313 megawatt large induction motor, 8 megawatt large synchronous motor, 9 megawatt AC commutator motor, DC motors and traction generators and motors and railroad locomotives etcetera, ok.

So, motors or generators are there almost everywhere and we will see; how we can find out the faults in such systems.

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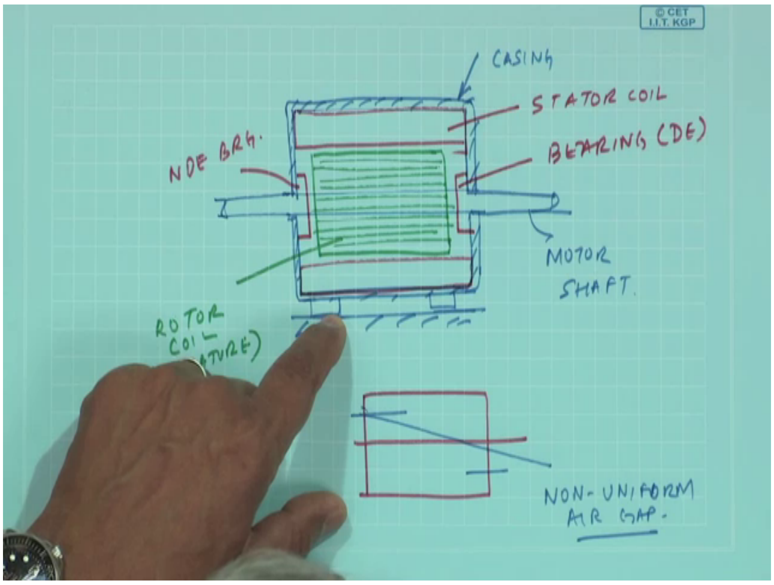

Now if you look at a motor, essentially, they have such a unit, this is the rotor which is supported on bearings and this is put in a casing where there is a stator coil and this is carrying a rotor coil and everything is there in casing.

So, this is my casing and this could be on a foundation. So, this is the stator coil this is the rotor coil or the armature this is the bearing one could be driven another could be NDE; non driven bearing and this is the motor shaft, as you all know the purpose of the stator coil is to give a magnetic field and in this rotor, there are coil and because of the magnetic induction torque producing current will be produced and this is this torque is responsible for rotating the rotor which is there in the supported on the bearing and these are all very nicely held in a casing ok.

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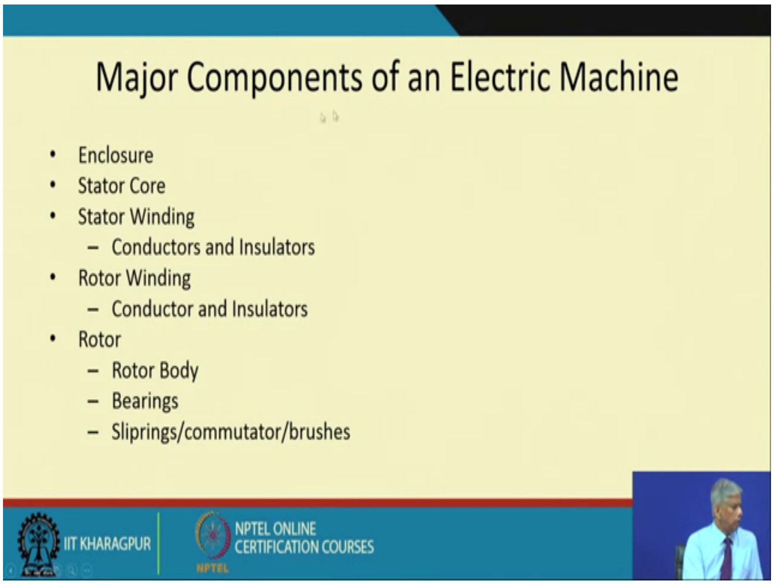

So, the major components of an electrical machine is the enclosure of the casing the stator core, the stator winding, it has conductors and insulators the rotor winding which has conductors and insulators the rotor itself the rotor body bearings slip rings commutators or brushes. So, that the current actually comes out of the motor or we supply them or and so on.

Now, the problem is you know this magnetic field or current is very much dependent on many things what if they are not concentric with these end plates. So, what happens; the motor and the stator, it has to be concentric if they are not concentric, they are like this I am exaggerating this drawing. So, this air gap is going to change non uniform air gap ok, uneven uniform air gap, there is an unbalance and apart from it, there are uneven coil windings in terms of one has shorted the resistances in the three phases or not same the bearings are having defects the foundation is soft in the sense one is the casing is very not rigid it is flimsy ok.

So, these things may happen lead to a fault, this is just to give you an view if you open up an electrical motor.

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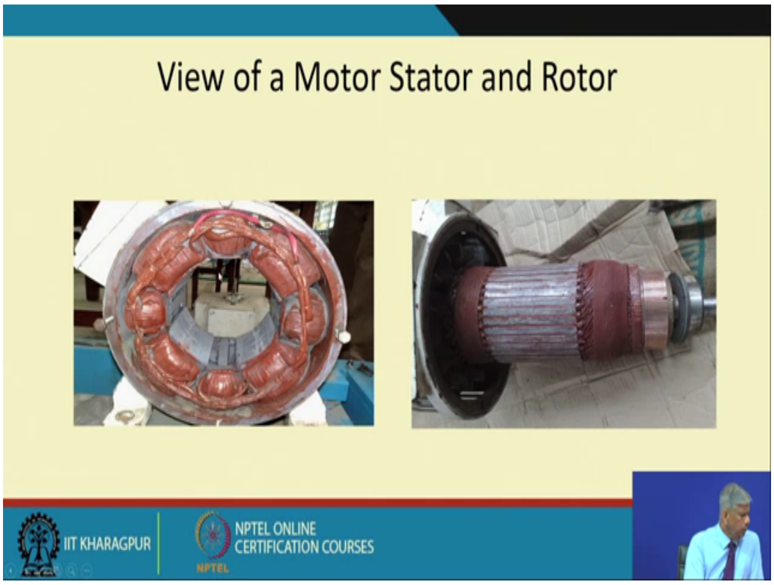

This is the view of the stator coils because there are pole pairs and then this is the casing and this is the armature ok, where there are the rotor bars and this is the bearing and this for generator this is the slip rings where we put the carbon brushes to take in the voltage output and these are all rigid.

So, imagine this rotor has to be concentric in this unit here. So, if it is not concentric the air gaps would vary and if air gaps vary the torque should vary and so on. So, there will be pulse setting motion and before we go into the details, you see this motors can be of different capacities and sizes look at this electrical motor driving a gear coupling and a gearbox.

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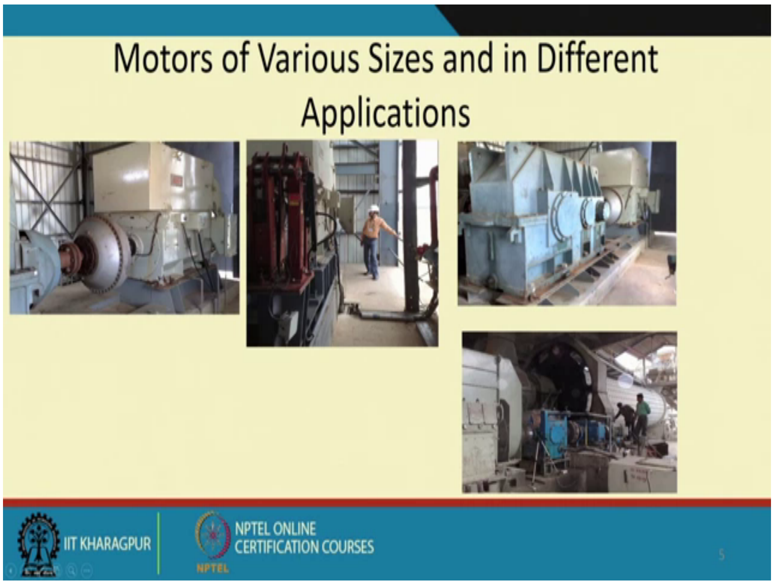

So, big blower there because as you know these motor bearings I had told you before should not be overheated. So, they need to be cooled and this is a person standing here. So, you can understand the height of the gear of the motor box and this is another motor which is driving a helical gear box bevel gear arrangement is there, this is a another motor which is driving the kiln of a cement plant.

So, motors are almost used in all applications. In fact, about more than 90 percent of the prime mover in the world today are electric motors.

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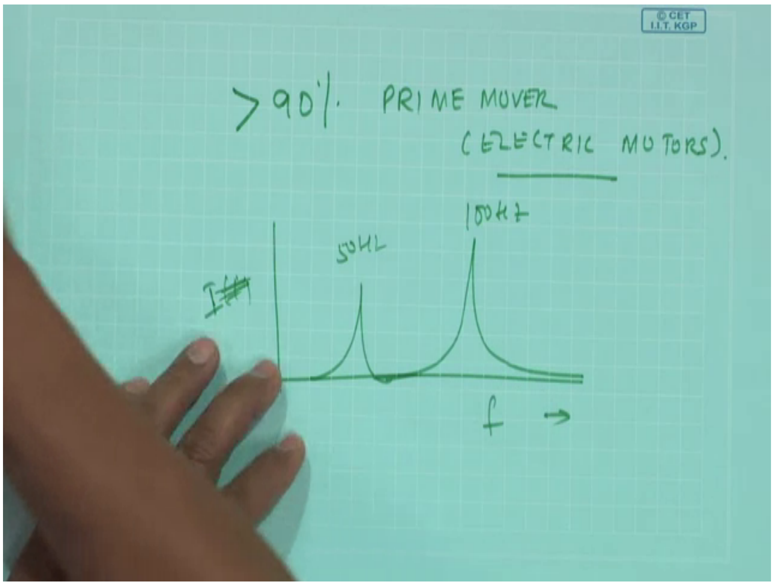

So, any defect in this electric motor is going to have a problem with your unit, I mean you think of any plants rolling mills cement plants paper mills motor is the lifeline, I mean if a motor has a defect the mechanical unit which has been driven may not be running at uniform speed, if it is not running at a uniform speed, the product output of the plant would get affected in terms of varying thicknesses you know and so on and so forth.

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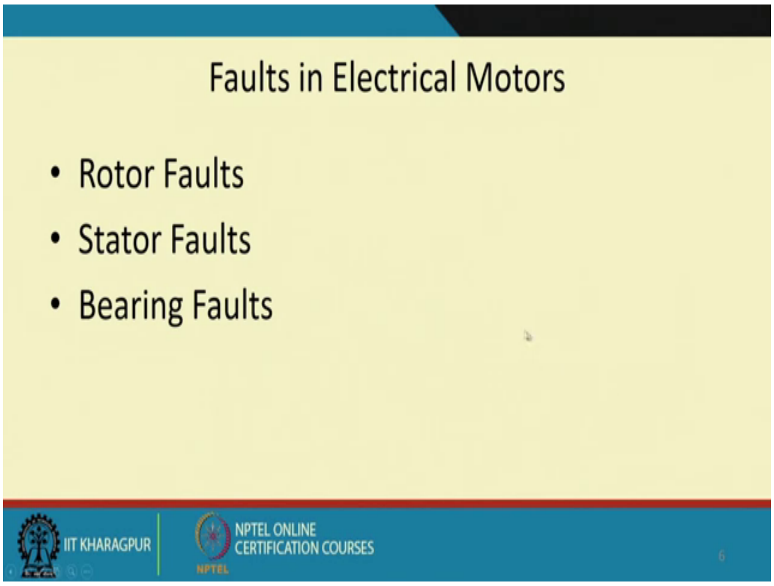

So, faults in electric motor could be rotor faults stator faults and bearing faults rotor faults means the rotor bars could be broken. The stator shots; stator bars could be broken, stator could be eccentricity, the rotor could be eccentric bearing could have a mechanical fault. So, all these scenarios happen.

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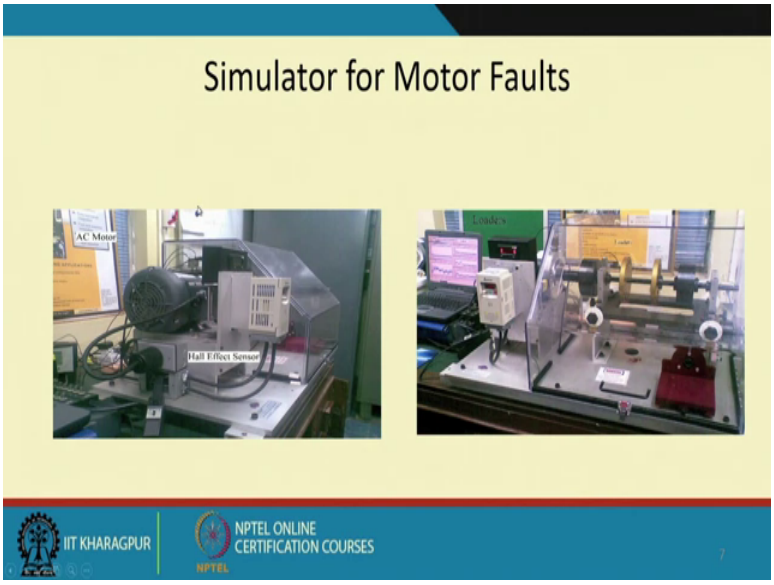

So, to understand the effect of motor faults, we have a simulator in our lab the same simulator which we use for wires and analysis actually if you see here this has been driven by a motor ok.

So, I remove the panel cover here and put a hall effect sensor to measure the motor current and then they have; we have in the setup electrical motors with seeded defects and then they could be used to find out the motor current be used to find out the faults in this motor.

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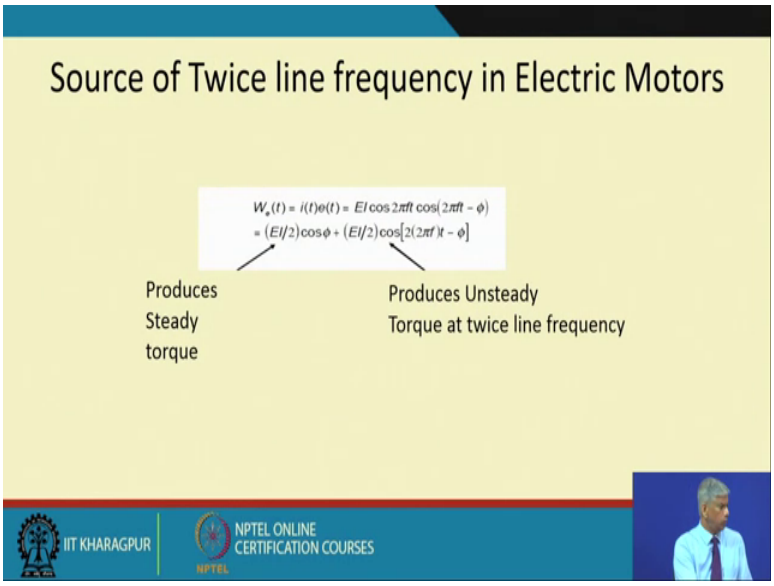

But another thing also we must see in the; in a line electrical motor, I had earlier told you that if the supply frequency is 50 hertz, I will see sometimes peaks at 100 hertz, this is because of the reason that if the supply frequency is a cosine function EMF is produces a phase difference. So, if I multiply them, the power will be have a cosine phi term and also this is a steady torque and produces an unsteady torque at twice line frequency.

So, this is possible and that is why mini systems, you will see quite twice the supply frequency being shown in the current spectrum sometimes, this also will be used to excite the mechanical unit. So, you will see frequencies of twice the supply frequency also have a mechanical vibration.

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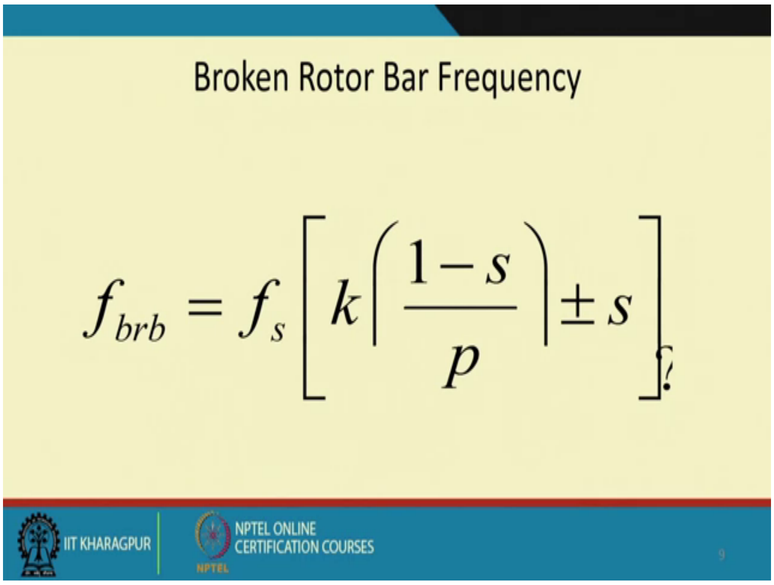

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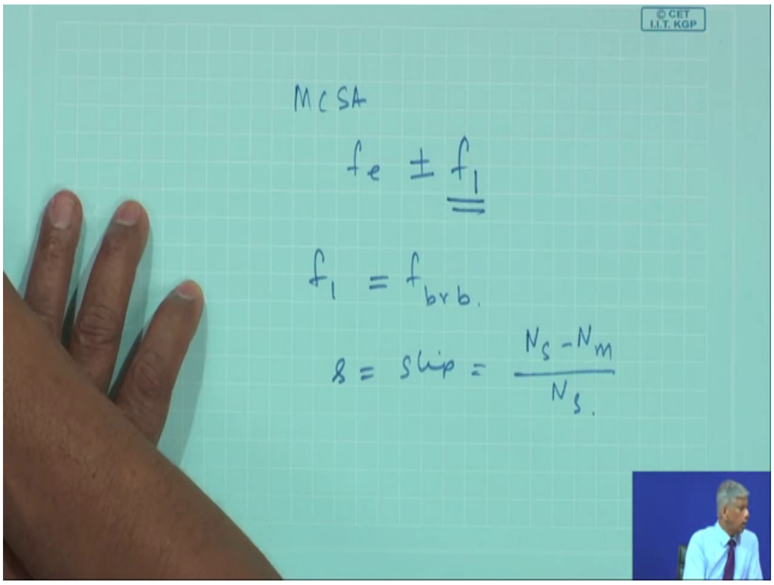

Now, if there is a broken rotor bar, if you think of the motor current signature analysis, we had told you that there will be supply frequency plus minus or defective frequency f 1. So, this f 1 is because of a defect and this could be because of the broken rotor bar ok. So, this is the supply frequency fs and s is the slip ok, slip is nothing, but the difference between the ratio the synchronous speed minus the mechanical speed by the synchronous speed ok. So, and k is an integer and p is the number of pole pair.

So, these frequencies can be calculated beforehand and you will see them in the frequency spectrum and which I am going to show them in just a while just a little bit.

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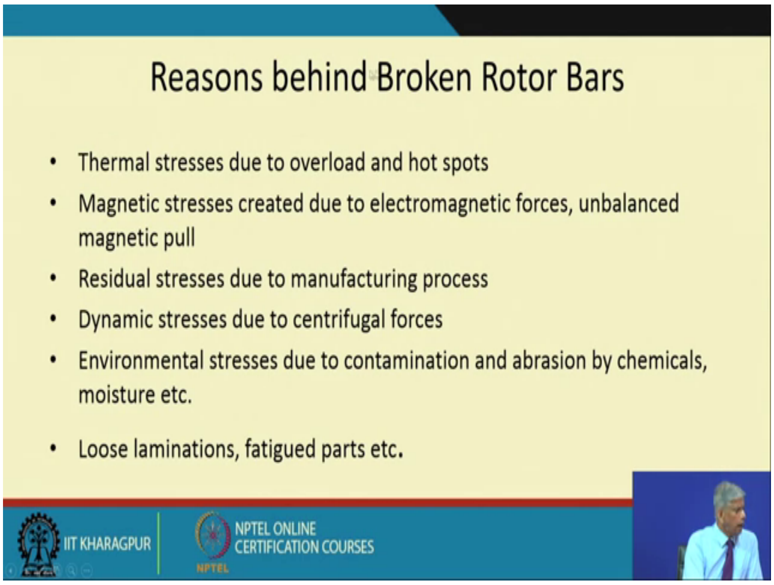

So, reasons behind broken rotor bars is thermal stresses due to overloads and hot spots magnetic stresses created due to electromagnetic forces unbalanced magnetic pull residual stresses due to the manufacturing process dynamic stresses, due to centrifugal forces environmental stresses, due to contamination and abrasion by chemicals moisture, etcetera, loose laminations fatigue parts.

So, the just if I have a coil, put in a stator, it may work, but this may not be good enough. So, basically you see the same electrical motor the residual stresses because of the manufacturing process could influence and so on.

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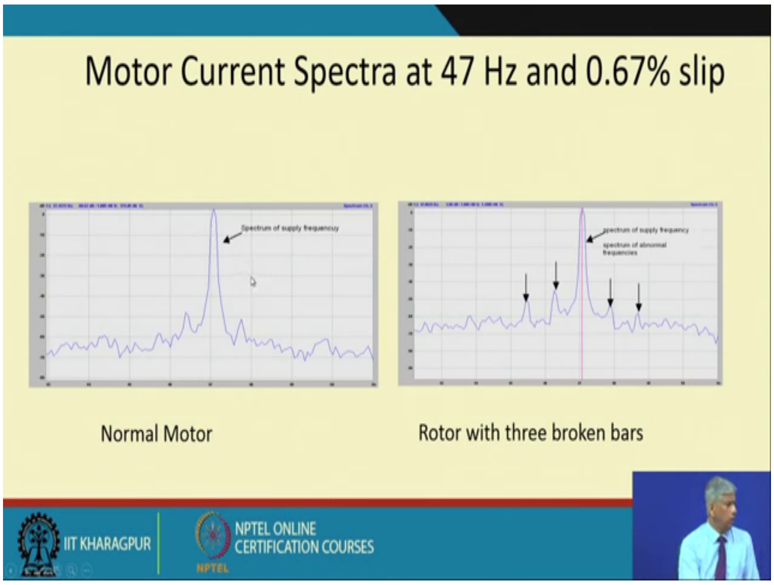

So, here in a motor being driven at 47 hertz with 0.67 percent slip, this is the normal motor and if you look at the current spectrum ok, though, there are few sidebands happening because the normal to begin with there could be some defect in the broken bar.

But as soon as there are three broken bars and this was the motor where the rotor bars were actually specifically broken. So, you can see around supply frequency, how the sidebands come up and these are very powerful indicators as to that a fault has occurred in an electrical motor. So, you all can realize the power of MCSA and let me tell you, if an electrical motor when it is running it is also vibrating and when there is a defect of this sense just has occurred there may not be a significant change in the vibration.

So, vibration becomes very difficult by vibration to measure this to find out these faults, but very easily monitoring the motor current and of course, you know you have to do the sideband identification or you can demodulate the signal ok.

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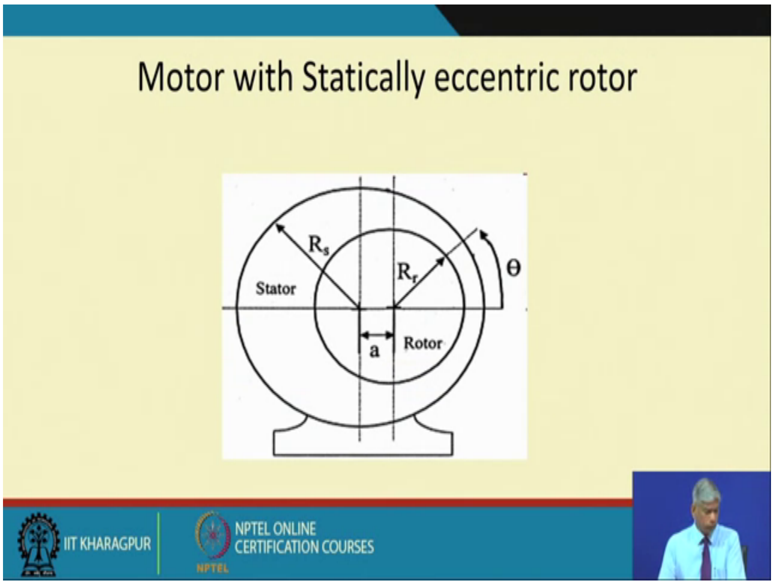

Now, similarly when we have motor with static eccentric rotor you see the centres of the stator and the rotor are not as the same point. So, there will be an ovality ok. So, this hobbling of the rotor in the stator and this creates an uneven gap.

So, this would give a different change in the magnetic field every in every rotation. So, this is also going to affect the magnetic producing torque this is going to produce a torque and then we will have a current.

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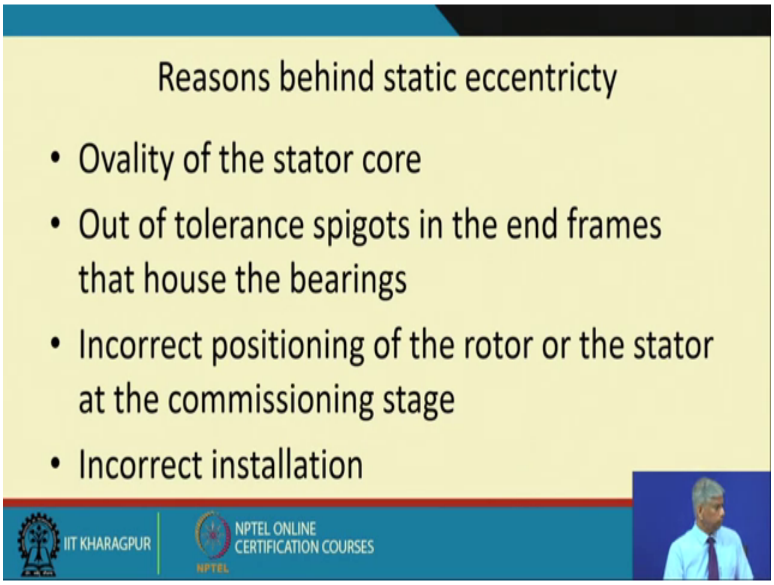

So, reasons behind static eccentricity ovality of the stator core ok.

Somebody has manufactured the core where the casting was not perfect and there is a inherent ovality ok, it could be the in the end frames, you know you would have seen the end frames of the motor.

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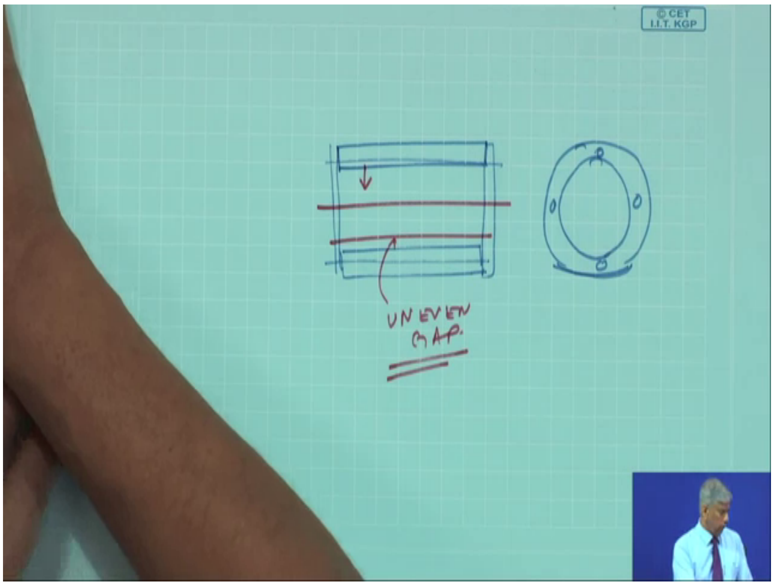

So, maybe, we have fault 4 bolt holes ok, suppose the end frames and both of them both these directions both the planes are not the same. So, there could be a eccentricity incorrect position of the rotor or the stator determine in current installation.

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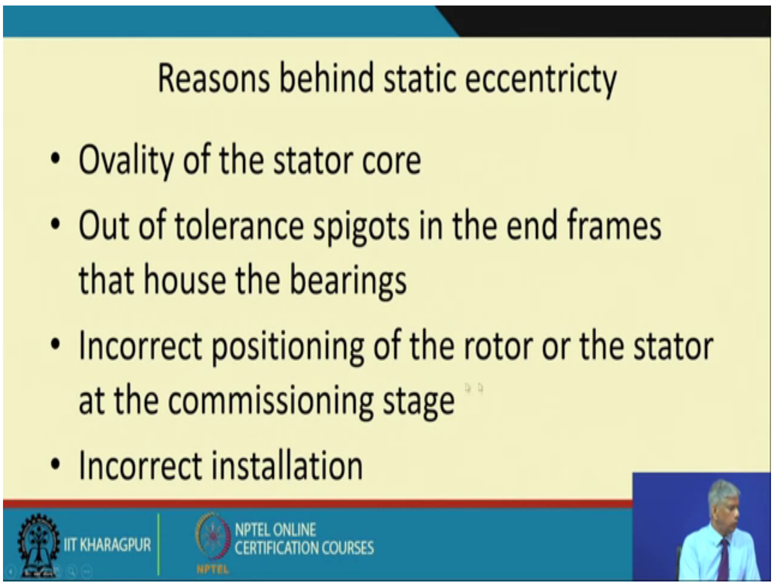

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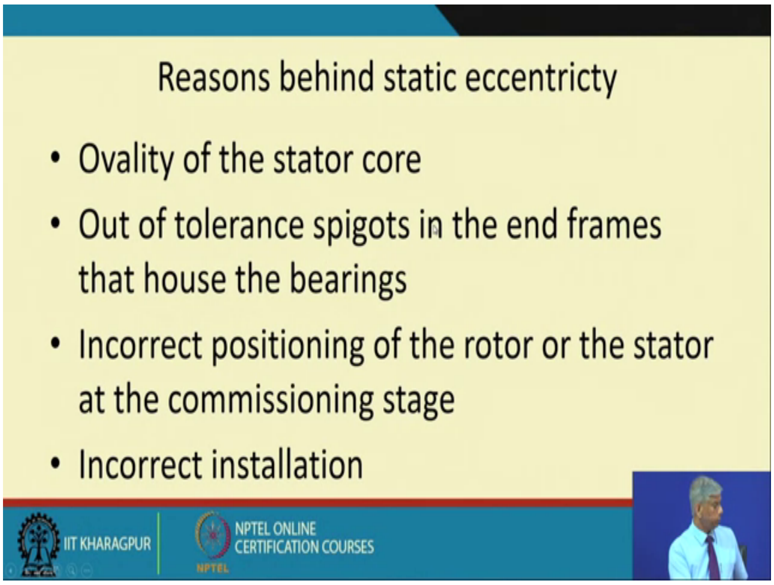

So, all these could leave rise to a gap uneven gap. So, this will relieve two problem.

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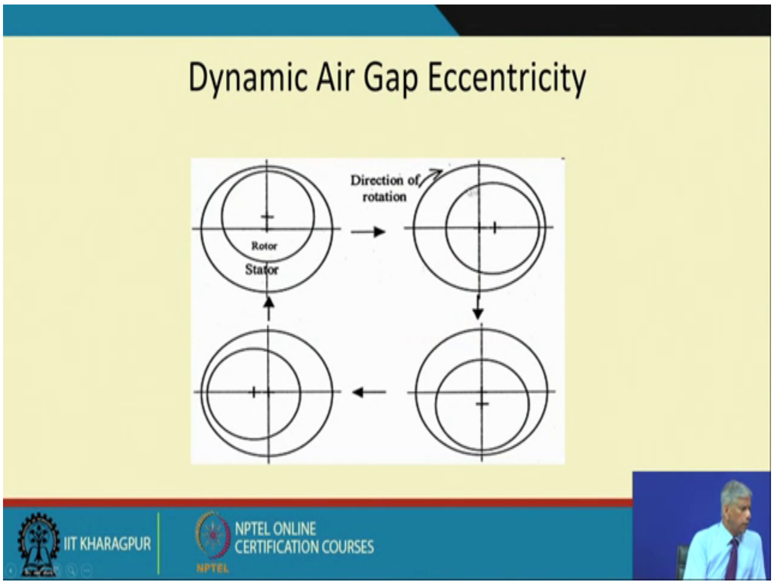

So, dynamic air gap eccentricity, you see, if it is rotating this gap is going to change, right so; obviously, the magnetic torque would change and then bent rotor shaft bearing has worn out misalignment mechanical resonance at critical speed.

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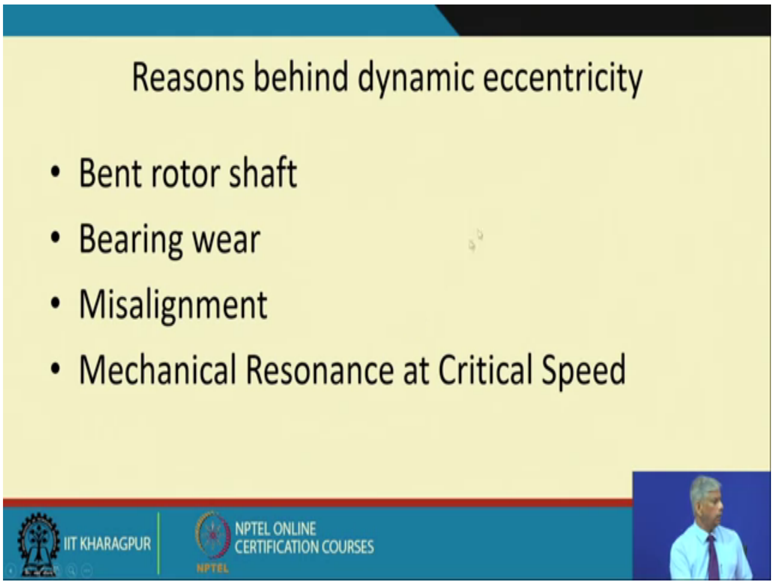

So, in motion, this can happen all these are possible. So, these are all not perfect conditions in electrical motor sometimes, again from experience, I am telling you in by vibration monitoring, we may not be able to sense all these defects and particularly when the power of the motor increases the vibrations are so high that the dynamic range is so poor that, we may not be able to the resolution is so poor that we may not be able to differentiate the difference between a broken rotor bar or whether a stator defect has occurred or whether a motor bearing defect has occurred.

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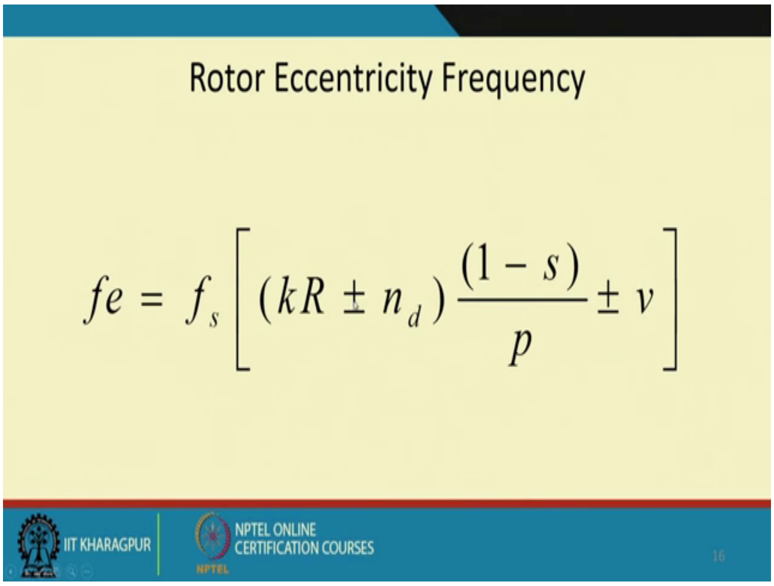

So, in such a case; the candidate for motor current signature analysis is this ok. So, these are again the same frequencies for the rotor eccentricity frequencies.

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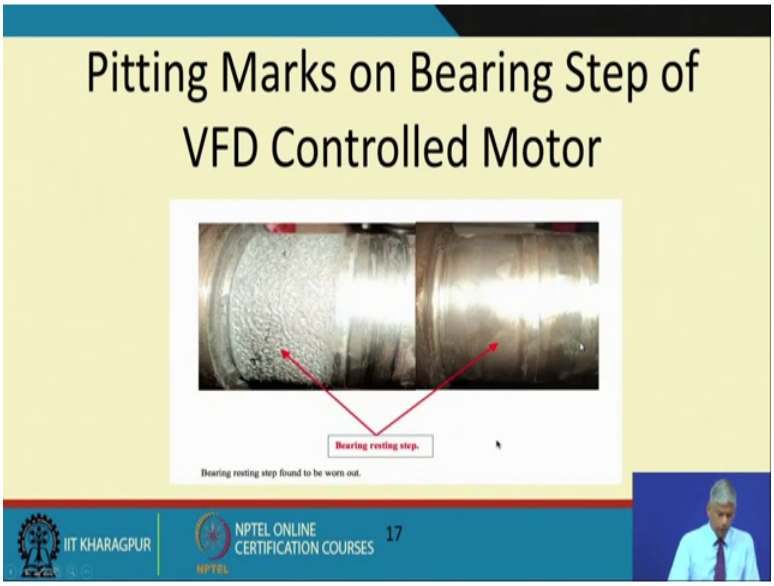

Now, in many scenarios, we will come to the VFD drive in a little later on, suppose there is a bearing fault again in the supply frequency.

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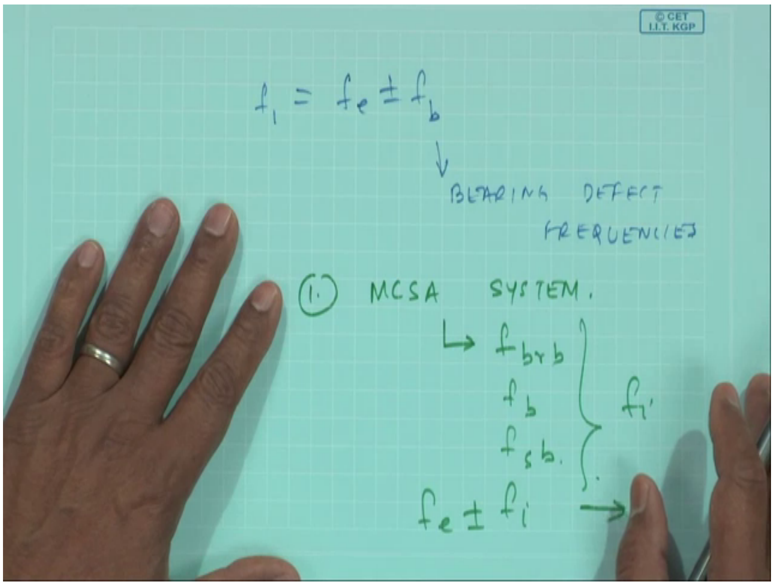

There will be some these are the bearing defect frequencies. So, just to monitor the defects in an electrical motor, if we have a MCSA system and if you know the rotational speed or the supply frequency, you can calculate the frequency because of broken bar because of bearing because of stator eccentricity and look out for these frequencies, all these defect frequencies and then very easily you can find out faults in electrical motor and the most important part is you do not have to go near the electrical motor to put your wires and transducers these all without measuring vibrations ok.

Now, another defect which has occurring in electrical motor is I must tell you, I had told this in on the when we discussed about bearings, but today many of these motors are actually being driven by variable frequency drives why are they driven this is the ease of speed control.

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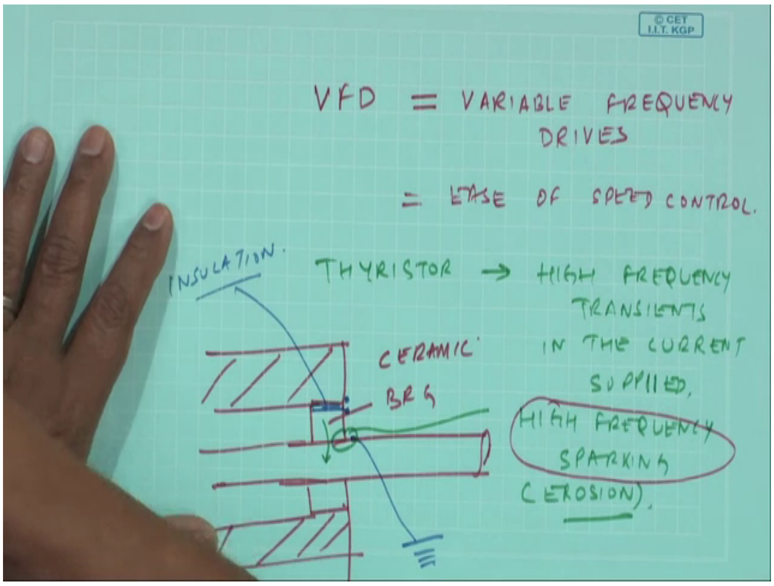

Now, in VFD drive because of the Thyristors involved, there is lot of high frequency transients in the current supplied. So, look at this because of this high frequency transients and if there is a conducting path between the motor, the motor shaft disappearing, there is a current which flows through the stator to the bearing and at this part, there is high frequency sparking which creates an erosion ok, you see a normal shaft of a motor and wherever the bearing was resting you see this, this has sparked out ok.

So, this gives a problem as to if this sparking has occurred this will damage the shaft and you know and there will be lot of play in the bearing. So, bearing will start to vibrate. So, such VFD drives has a problem only because of this high frequency sparking ok. Now to avoid that couple of things, I have discussed regarding, I can have ceramic bearings where because of this ceramic there is a good amount of insulation. So, there is no direct path of the current to flow through the bearings or else I attach or ground the shaft to a good potential.

So, just by grounding the shaft I can give a alternate path for the highest frequency current to flow through and not spark the bearings. So, particularly you know, we have I had seen in many textile mills driven by VFD drive, this kind of problem occur and they can only be prevented by grounding, we demonstrated this in the laboratory by having a VFD drive driven electrical motor.

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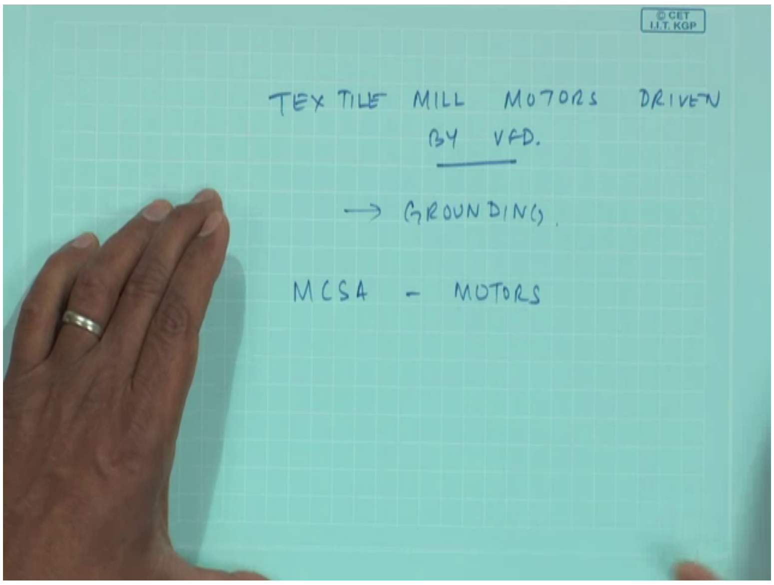

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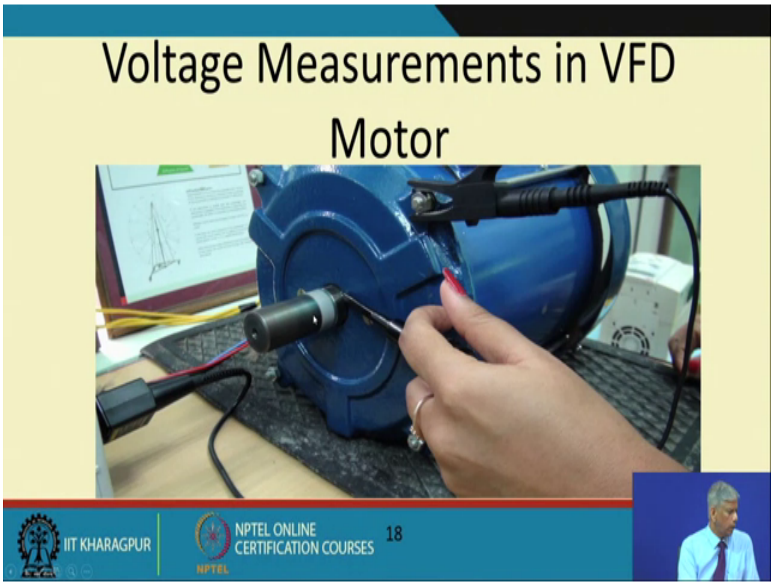

How does the VFD drive driving this motor just by grounding it, we could remove the transients which were occurring.

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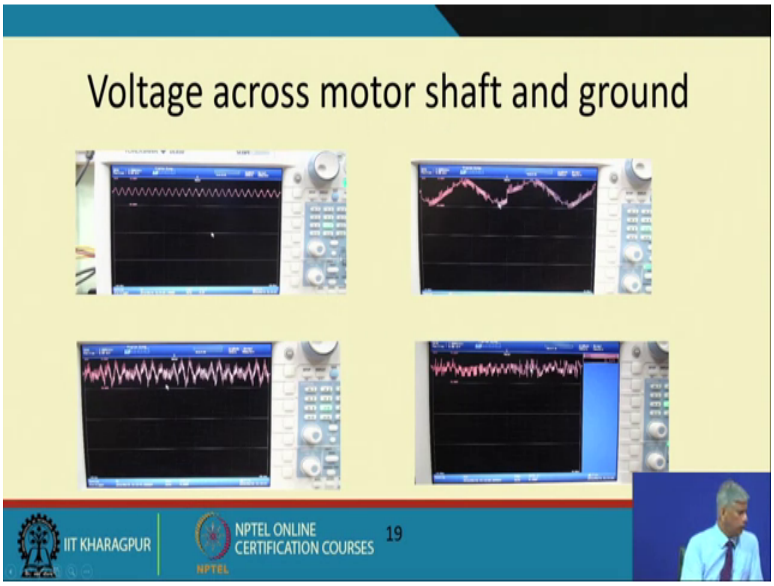

And I do not know if you can see these are very high frequency transients which could be removed and this is the normal motor very low voltage single frequency.

But these high frequencies transients are actually the dirty ones which will creates sparking. So, this has to be avoided. So, just to summarize the fault detection techniques in MCSA for motors, we can find out faults in because of broken rotor bars because of stator eccentricity because of bearing faults and of course, now because of bearing damage due to or bearing seed damage due to a high frequency sparking because of the transients given by the current which is produced by a VFD drive in an electrical motor ok.

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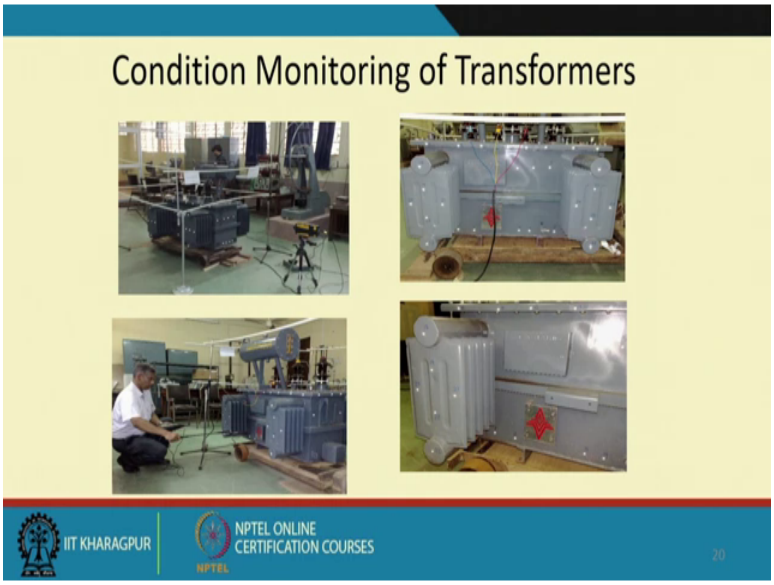

But then there are few other machines which I have told in the beginning in this transformer ok. So, in transformers what happens this is in a laboratory which I am trying to explain to you this transformer there is a we are measuring through laser based vibrations. Here if you can see here, this is a laser vibrometer and these are the spots wherein we are measuring the vibrations, but this is not humanly possible to always measure the vibrations.

In fact, I am also measuring the sound radiated by a transformer ok.

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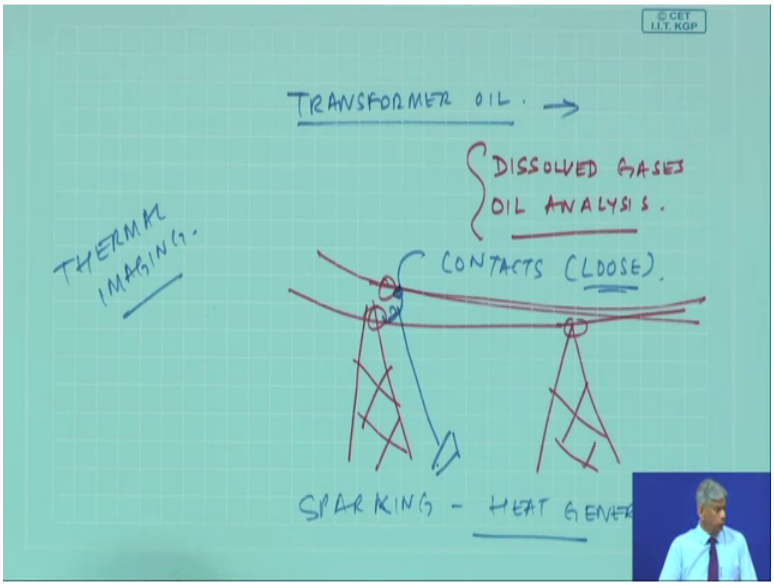

But if you look at this wire here the transformer oil is required to keep to transfer the heat because of the magno to resistive forces which is generated to be exchanged with the atmosphere these are the fins. So, what happens the oil quality would change with time? So, just oil quality has to be monitored we have a routine as to and of course, some dissolved gases which are there in the soil.

So, dissolved gases and oil analysis can be used and we will discuss about oil analysis in one of the subsequent lectures this week and then you will see certain tests are there done on the transformer oil or for that matter any oil to find out whether the oil is of a good conditions.

And most important is many of the damages which occur, you would have heard of transformer burst because the oil had come down to a level which was never replenished and there was not enough oil. So, there is lot of heat and then the things the coils seed because of heat they burst or they broke and then this is the prism.

So, monitoring the oil of a transformer is very important as opposed to switch gears which carry your current carrying conductor. So, if some connections have to be made ok. So, some contact points are there some switch, gear liver, etcetera. So, these contacts could become loose, if contacts are loose, they will create sparking and there will be heat generation.

So, to thermal imaging such lose contacts can be determined and we will discuss this when I talk about thermography perhaps in the next lecture and so on ok. So, more of this regarding MCSA, you can find in my book and you can refer to our website ok.

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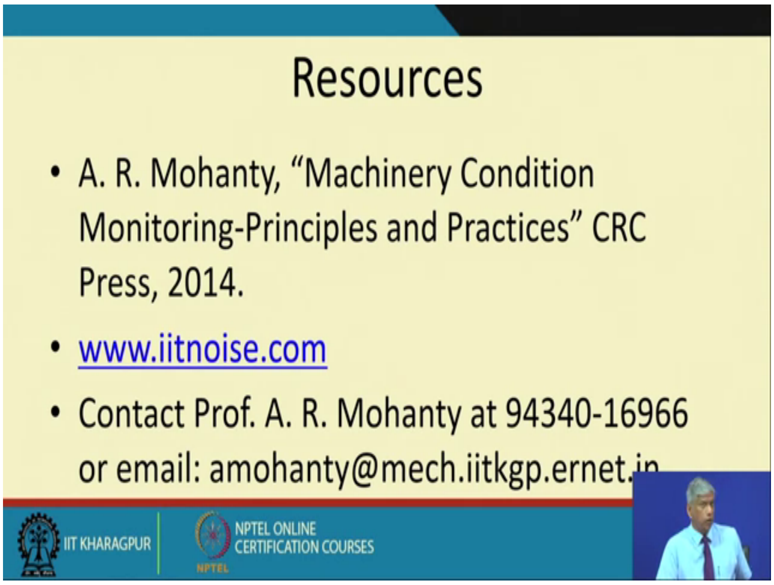

Thank you.