Machinery fault diagnosis and signal processing
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Module No # 07
Lecture No # 31
Pumps and Turbines

In this lecture we are going to discuss on another topic of interest it is in pumps and turbines this is another class of machinery one will come across in major chemical process plants steel plants, power plants, ships, air crafts. So we are going to see how we can find out the major faults in such pumps and turbines through vibration signature analysis through motor signature analysis maybe sometimes through AW analysis as well.

And many times of course NTD inspection are done on such critical machine components like air craft turbines and so on.

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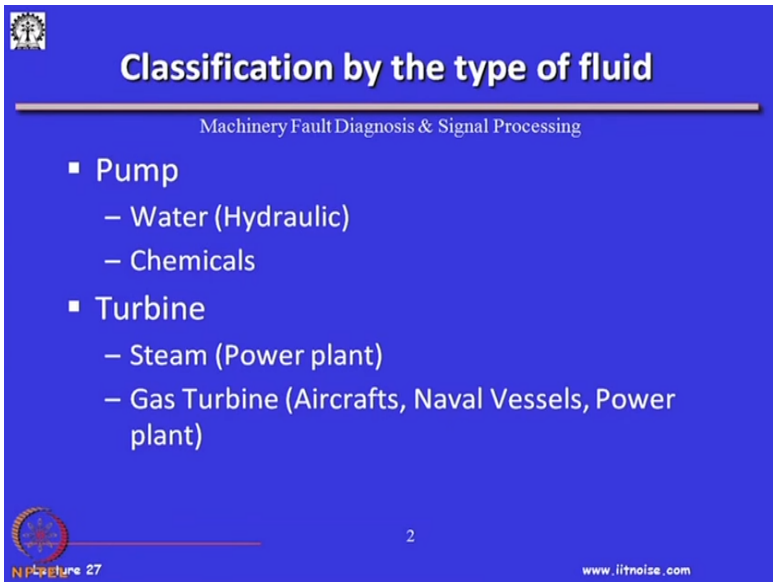

So I will classifies these pumps and turbines based not on the principle of the operations but rather on the type of fluid they pump one type of fluid they use okay as you know pump is a mechanical device where when we give some sort of an energy in the form of an external energy to give certain output energy to pump in terms of pressurizing the fluid.

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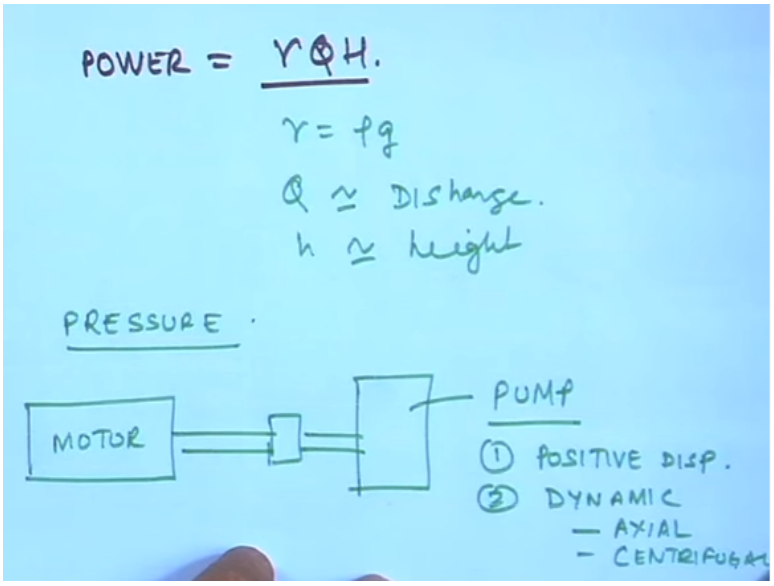

So that it can gain much potential so in such pump capacity the power of the pump gamma QH okay. Wherein gamma is nothing but Rho G, Q is discharge rate and H is the height through with this fluid is to be pumped okay and this is a requirement because I need to develop a certain pressure head in a pump because they can flow. A pressure head is required in the pump so these pumps are usually driven by a motor through a coupling and then we have a pump.

So this pump can again be positive displacement or could be dynamic so in dynamics they could be axial they could be centrifugal and so on.

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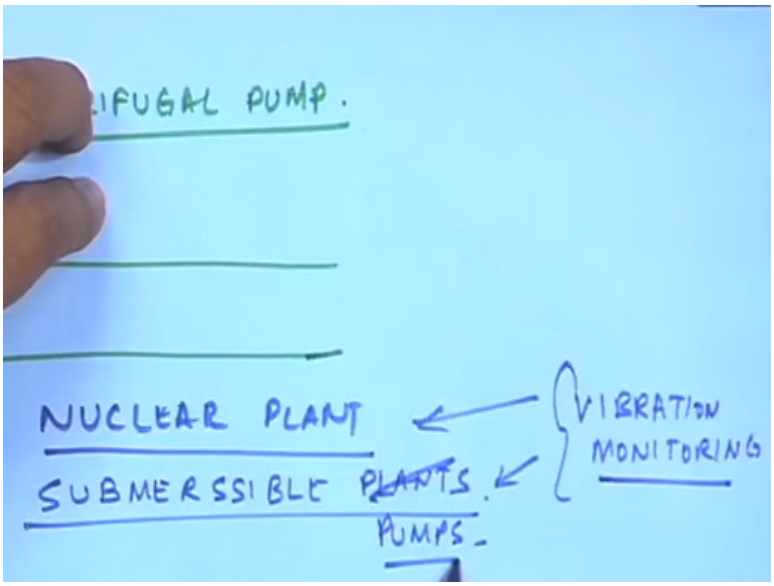

And the most common pump which you will see is the centrifugal pump and many would have seen this centrifugal pump this or pumping water in the fields in they produce a certain water at a particular flow rate and a pressure. So that we can indicate the land lot of chemical process plants you know if you talk about distillery refinery there are lot of pumps okay.

And imagine the pumps which we were putting it under the ground okay to pump out crude oil from the bed of the ocean okay underneath the bed of the ocean crude oil pumping, pumping of water domestic supplies, pumping of water fire fighting etc., chemicals and refineries. So they all requires pumps and this pumps have to be powered another pump is the pump which is submerged in liquid. The sewage pump inside pipelines large pipe lines wherein we have self-loop pumps okay.

Pumping of crude oil etc., so these pumps can have defects okay and then how do we rectify them another important application is nuclear plants. Think of a nuclear plants okay how do I monitor the health of such machines or such pumps. So these candidates so this is what we are going are going to focus on nuclear plants and then submersible pumps. I will impose a challenge to everybody right now.

The fact that we have studied about vibration monitoring in details in the course okay but can they be applied in nuclear plants and submersible pumps because to install a transducer I cannot go inside a nuclear plant. I cannot go underground unmounts the transducer in submersible pump so these are issued okay. When we will see how this can be done the pump diagnosis in nuclear plant and submersible soil pump.

Another important machinery which we will study in this course are turbines usually this turbines again by the type of fluid will have two types one is the steam turbines which is there in almost in all the land based power plants thermal power plants in our country. Of course we have the hydro power plants we have hydro turbines like the coupland or francis turbine or even sometimes the peltal wheels.

So we will briefly talk about the hardy turbines as well and then of course gas turbines in air craft. Gas turbines used to power naval vessels and even some time small gas turbines you know

20 megawatt capacity are used in capti power industries run by gas turbines to for generating electrical power.

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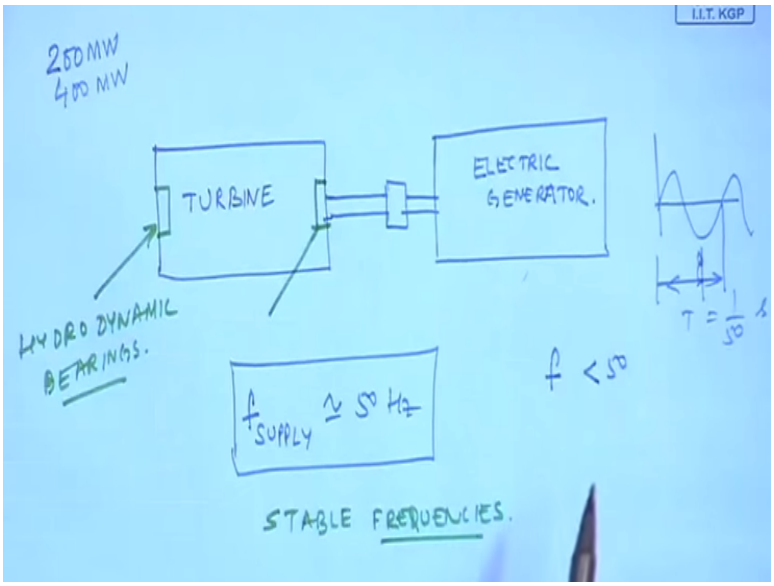

So wherever the turbines are used to generate power what happens the turbines rotate in they are coupled to an electric generator. And I you talk about large power plant and steam power plant as 200 megawatt or 400 megawatt super thermal power plants etc., they generate you they have turbines running on steams and this turbines are rotate and rotor of the electric generator and then basic current is produced by the way I should tell you they when we talk about the frequency of the current which is been generated.

In our country this is you know this time period corresponds to 1/50 seconds because out supply is 50 hertz so the speed of the rotation of the rotor of the electric generator is governed by the turbines. So there are lot of control over the mechanism as to show there I do not produce a currently supply frequencies less than 50 hertz or greater than 50 hertz. So I have to reproduce the electrical supply frequency have supplied at 50 hertz and that is my primary requirement of a power plant okay.

With of course continuously so on but this turbines you know when we talk about 200 or 400 megawatts they are very very large in size and this rotors are so heavy they are supported on hydro dynamic bearings okay and there are lot of mechanism so that we operate them stable

frequencies rotating speed and so if I give in more steam it is going to generate at a rotate at a high speed and then suspect to be govern.

So I will not going to controlling mechanism of such system it is pretty complicated we have to discuss about the individual machine components like rotating shafts on the bearings carrying a gears shaft carrying pulley, shaft have been misalignment but when I talk about a turbine or a pump okay g maybe a how do we monitor the condition of a turbine. So this is not a single component so think of a turbine I will talk about the turbine first and then I will come to the pump later on.

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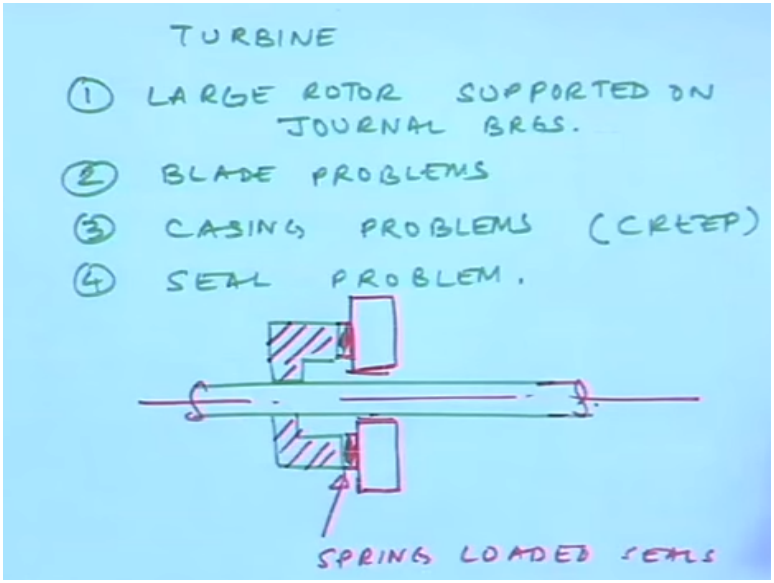

So in a turbine what are the important characteristics large rotor supported on journal bearings okay. And usually all the phenomena of course in the turbine the there could be blade vibration there could be blade problems there could be casing problem casing defects there could be high heat could be creep etc. There could be seal problem because we do not like seals to leak and so that the steams you know pass out through the shafts.

So in fact the seals or something like this as a rotating component to take it tightly and the seals and here they are spring and then they can have another component here okay. This is the shaft which can be which will be having the shaft rotating and then can be carrying. And of course as I was telling you in the beginning if I go back here this. So turbine the first place would be to put

vibration signals at all the locations a whole locations would be I mean plus all the bearing locations all the foundations locations okay.

These are all the locations where you can monitor transducers and so on but the problem with nuclear plant is that this is not same problem in submersible pump is the pump is not submersible so that something will discuss later on and the normal method of vibrations monitoring is the well understood by now. So whenever we have machine we just installed a transducer and find out the characteristics first of all in time domain itself based on the higher system we see whether the levels are within the allowable limits.

This could be the standards and the power of the machine that is number one and if you want to diagnose faults in the turbine. What we do through vibration monitoring is installed the sensors all the bearing locations or the foundation locations and then do a signature analysis to find out unbalance misalignment gear defects blade machine blade etc. The technique of FFT analysis analog decision can be used.

But I was telling for a case when this turbine itself is not accessible say for example a nuclear plant.

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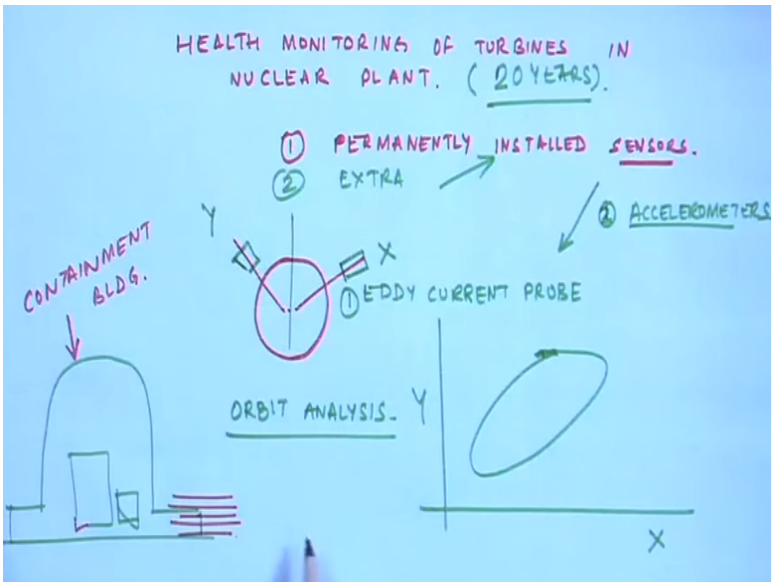

So how is the health monitoring in turbines in nuclear plant first of all because of high radio activity are not allowed to go inside the plant. So they are permanently installed sensors by

sensors I mean usually in such turbines at the journal bearings and usual bearings is to put some sort of an on contacting type eddy current probe at this actually at 45 degrees X , Y and you can do lot of orbit analysis.

To defect we discuss about orbits in one of our earlier analysis to find out the defects in the but in this sensors can be eddy current can also be vibration transducers is like accelerometer. A question is suppose a nuclear plant is made and you are not supposed to go inside the life of about 20 years. So what do we do they put lot of extra transducers extra or redundant transducers are installed.

Suppose and then all they have is a because we if we look good the nuclear plant there actually the containment build in and then all the machines are there. So all you can have is sensors signals coming out all the plants and then you can do the vibration analysis.

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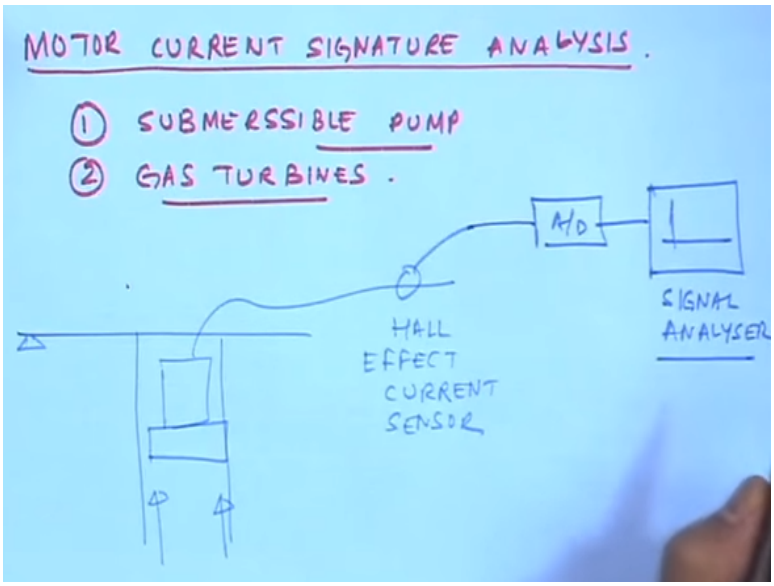

But another important technique to find out faults in turbines is what is known as motor current signature analysis and this is very helpful from fault detection in submersible pump. And then in even in gas turbines I will give an example I mean believe we have about motor current signature analysis this in submersible pumps for the fact that. In a submersible pump which is under the ground which is rotate it by motor.

All we require is on HALL effect current sensor and then we can have an A to D process and then we can have an signature analysis. And this could be under the ground and we do not worry about and same is to for a turbines.

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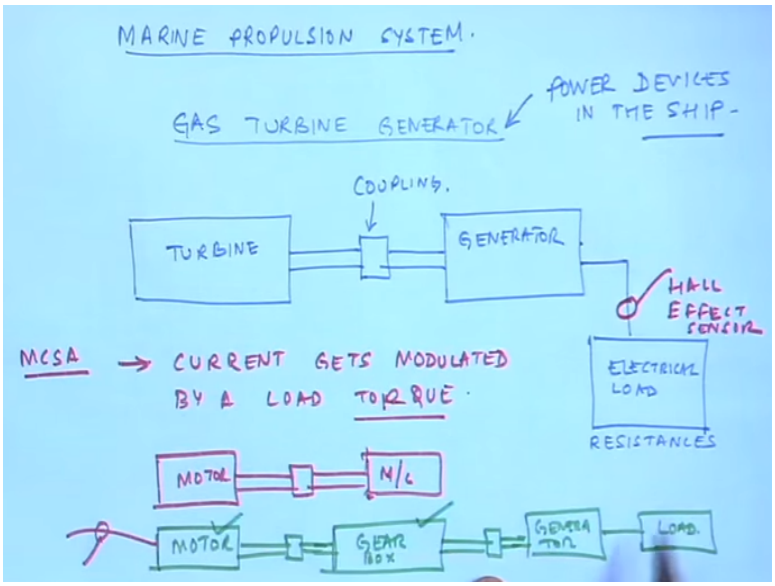

In fact if you think of the marine propulsion system we have what is known as the gas turbine generator. So the turbine which is a gas turbine driving a generator. And this generator which is used to power devices in the ship and this is the generator and this is the coupler.

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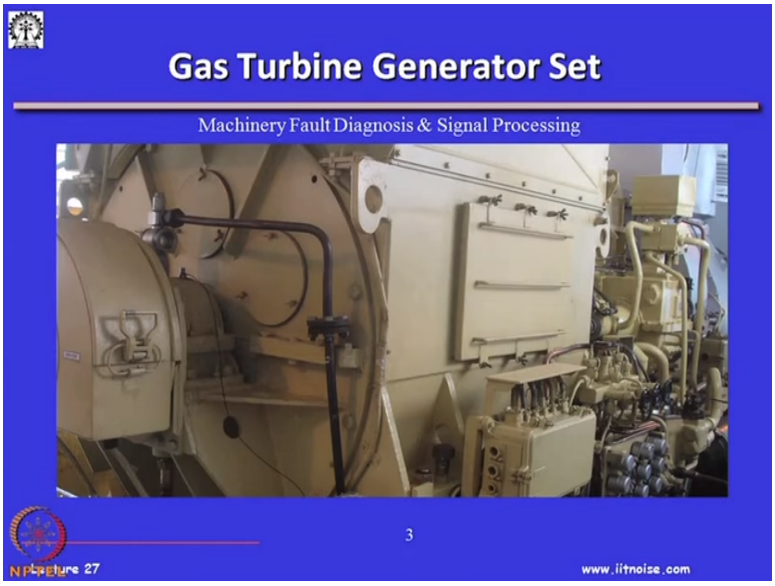

And I will show you some pictures of a did a condition monitoring on a gas turbine which is a gas turbine and this is coupled to a generator okay am sorry this is the gas turbine and here we

can see the heavy exhaust here and this is generated and if you see here we have put a accelerometer and the bearing housing of the generator and this is replied and then this is the case study which we have been for the one of our sponsor project by the DRDO for the Indian navy.

Wherein we are trying to see the visibility of the using motor current signature analysis for monitoring a health gas turbines. Small gas turbines test establishment and this is the replica of the actual gas turbine this one of the actual gas turbine which is use in an marine propulsion unit and we have put an accelerometer here to measure the vibrations. So that we would like to see whether the defect characteristics of the generator can be picked up by the transducers.

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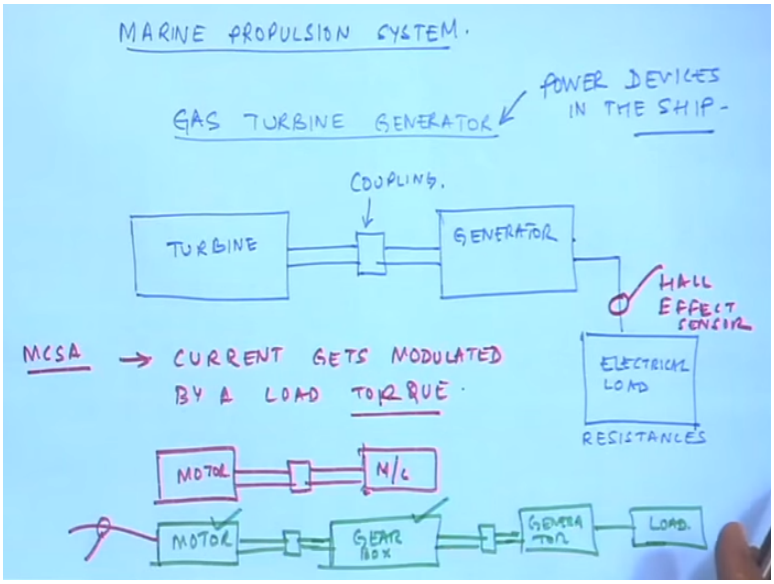

And then i will come to associated problem another view of this will be driven we are monitoring the accelerometer by linear acceleration another view of it is pretty noisy. So that we have are put an ear noise here it is very noisy test environment and you will see these are the shoots of the gas turbines because this is a stationary limit otherwise this should have normally used to power the shift and then we have only coupled to drive the generator for own generation of power in the ship they have what is known as the gas turbines okay.

The small gas turbines has how power to be ratio and convenient and shift and this was being used to drive a generator okay.

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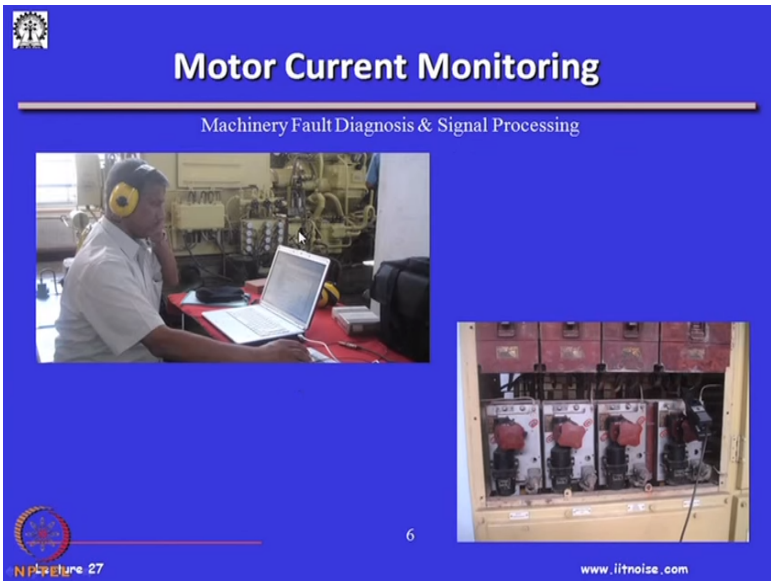

Now what happens in another view in the naval is we measure because this generator was delivering power okay. To our resistance back whatever we generated power here it went to a electrical load this is a decorative load and resistances. So on to this we put a hall effect sensor okay and this is the tectonics all of extendedness out on one of the field cases of the load output load and then we can correlate what is defect in the generator and then in the turbine.

Because the principle idea behind MCSA is the current gets modulated by a load torque okay so in the case of the motor driving in a mechanical unit if this mechanical unit as a defect it is going to load the motor and the motor current drawn will be weld up but same is to here if the like we had done in the case of a in the laboratory I have shown you earlier we had a motor driving a gear box which was in coupled driving a generator okay.

And then there was a load okay so we had established there is defect in the gear box motor currents gets modulated and then measure it this way. So all of its sensor okay we have demonstrated this earlier.

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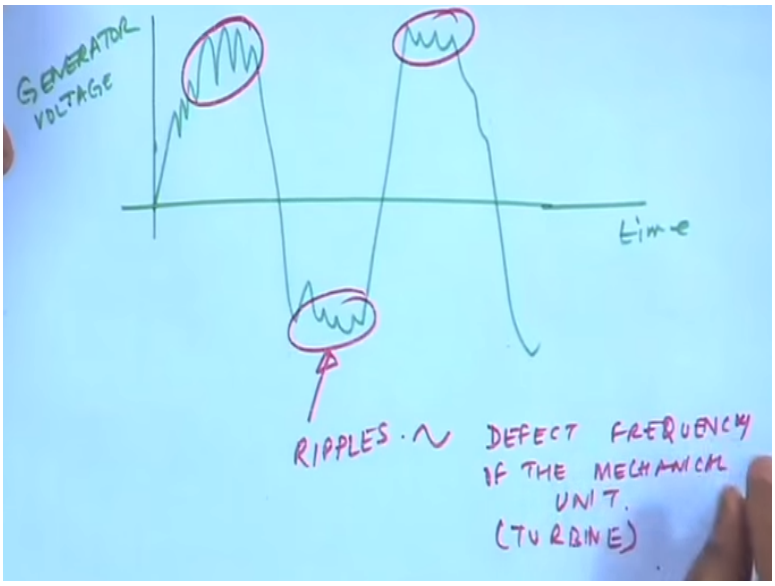

Now the other way also happens is this a load defects in the gear box the generator voltage which is generated by the generator we have repels this is the time generator, voltage and these ripples are at a frequencies at a defect frequency of the mechanical unit and that is the turbine in our case.

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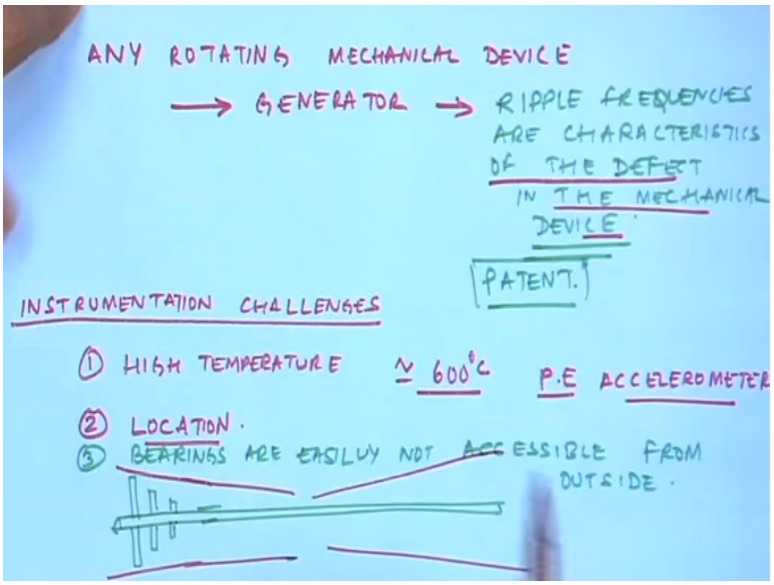

In fact this is a powerful technique that any rotating machines I just showed you for the case of a turbine. So any rotating mechanical device if it is coupled with an generator the ripple frequencies are characteristics of the defect in the mechanical device. So this is one of the important observation and infact our group IIT at Kharaghpur as a patent on the same for the fact that any mechanical device which is powering a generator.

Generator is going to generate and this voltage will not be clean the voltage will have a ripples somebody can understand and measure capture the ripples and understand the frequency we will see that they will or characteristics of the defects in mechanical device. So this becomes a very powerful technique to find out defects in gas turbines powering aircrafts power in systems. So these are very powerful technique okay.

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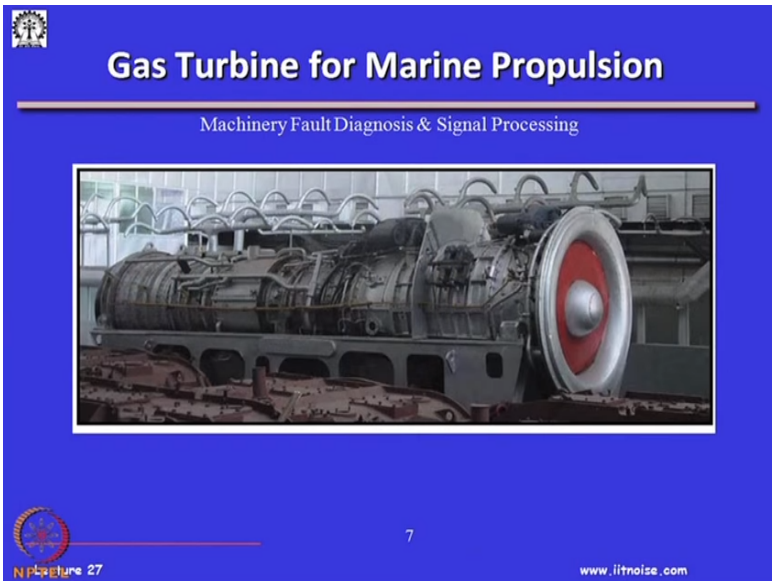

This is one of the examples view of the one of the gas turbines which is used for the marine propulsion system. This the compressor the low pressure compressor on the front of the gas turbine this red cover is just a cover this are just come to the bay and this one of the naval establishment units where we are measurements for our projects and a this has a low pressure compressors high pressure compressors and the combustion and then the significant turbines.

And each one of them as sets of blades okay and how do you the health monitoring of such gas turbines okay. So the best pace would be to keep vibration transducer align the rings okay we see lot of the rings and these are there because you obviously cannot access them the challenges instrumentation challenges are monitoring gas turbines as such because of high temperature and there is a few you have studied that we mount accelerometer using magnets.

But these magnets are very very soft they loose their properties and crack I myself have lost lot of magnets mounting accelerometer locations which were at high temperatures late once I had

the cracked magnets. So they have to be with stand the high temperatures and nowadays we have transducers we go up to 600 degrees transducers accelerometer piezoelectric accelerometers and they can be mounted accelerometer.

Again the problem here is one of this temperatures could be even harden suction so certain that is one issue the temperature and then the self is how do you clear the cable and the locations. Locations become a problem okay because I cannot look close to the bearings because if you look at the bearings the okay these shafts okay these bearings are somewhere close and these bearings are not accessible from outside.

So this is again I challenge and as you know in all these machines the vibration reflects pretty well at the bearing locations and if I cannot access the bearings how do I measure it.

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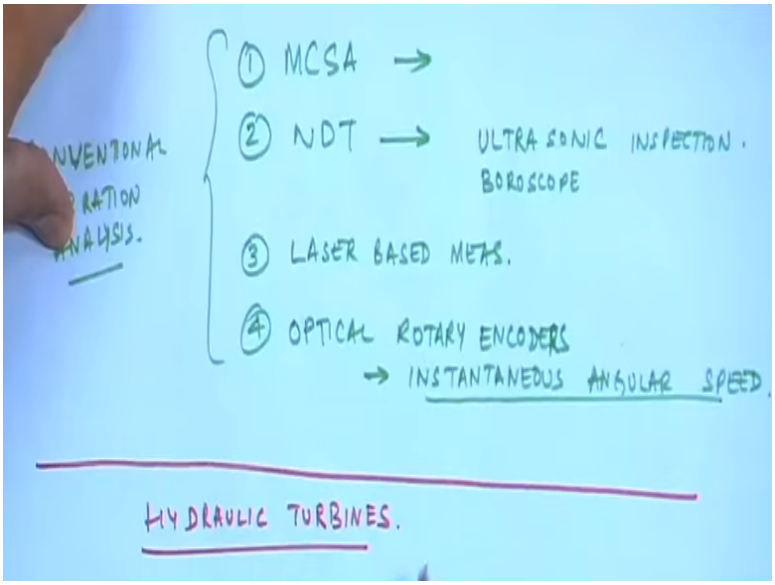

So to some of the and that is why MCSA has become a good candidate next is when you use along the NDT technique of course NDT technics cannot be real time but it is a good practice particularly for the gas turbines are turbines we can do an quick ultrasonic inspection the internals of the turbines can be looked through visible inspection Baroscopic okay. And of course another technic we will note is a on laser based measurements and the optical rotatory encoders for what is known as detecting the instantaneous anglers speed.

These techniques are over the conventional vibration analysis we will study about MCSA and NTD in the later classes but these are techniques wherein this can be used to measure a understand more about such gas turbines.

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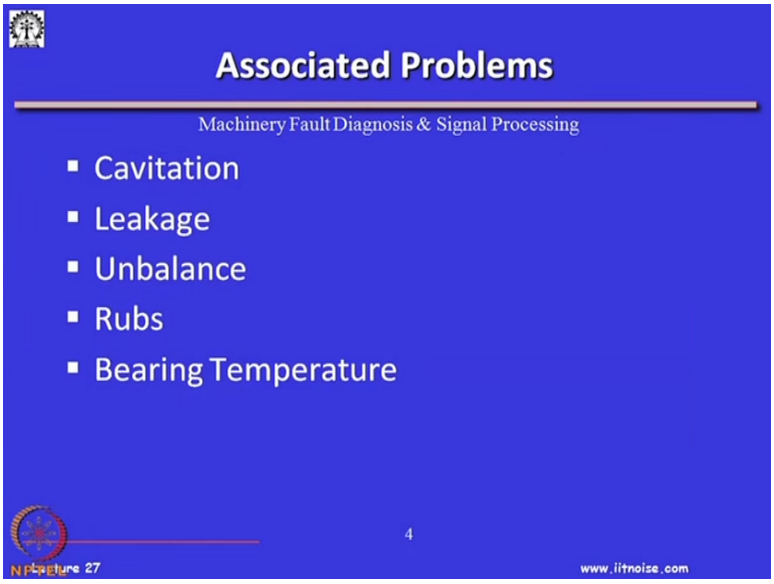

But there are few other associated problems like in such turbines did the particularly in hydraulic turbines there is a limit to the maximum flow rate okay because if the flow rate increases the velocity become so high. Because to conserve energy the pressures of the liquid if the fall below the vapor pressure so what is going to happen is this vapors will form a bubbles will be formed in the pipeline.

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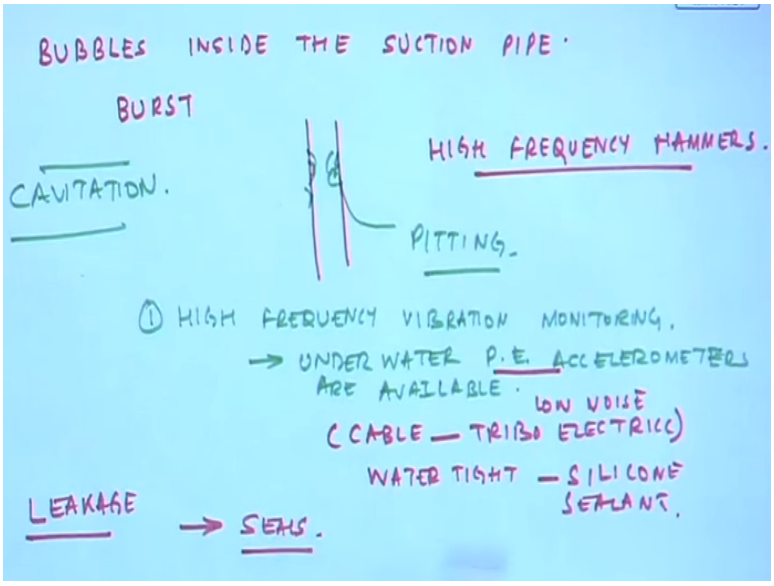

Inside the suction pipe okay and when this bubbles come up its time come up to the surface to air pocket they will burst. So they are like hammers high frequency hammers and this what is known as the cavitation. So cavitation limits the operational pressure or flow rate or turbines and there has to be this is the cavitation goes undetected in inner walls will get pitting will be there and this bubbles when they burst they raise energy and they are hitting this goes unnoticed they will weakened the structure and then of the surface will become week and eventually break.

So to monitor the cavitation's because they are high frequencies we can always have the high frequency it could be vibrations monitoring. Nowadays under water piezoelectric accelerometers available okay the most important and this can be put one the pipeline and the most important is the cable tribo electric low noise travel electric cable they have to water type with good silicon sealant.

Sometimes you know cables are more costlier than the piezoelectric accelerometer okay so we can monitor the vibrations of because of cavitation on the pipeline because this go unnoticed they will damage the will affect the internals of the pipelines of the casing and then they will become week and then the start to leak and then. Another important aspect which will go is the leakage.

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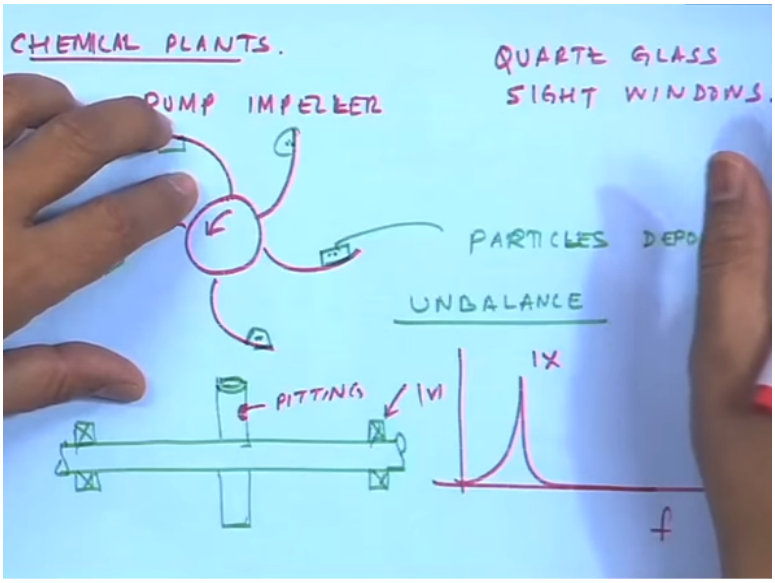

So leakage as to be provided with good seals so this many things happen in chemical plants in the pump impeller if I have lets draw the blades there could be particles which get struck

sometimes not uniformly this is are particles which will get deposited okay. Because of this deposited particle they will be unbalance okay and this unbalance will again get detected at the bearing locations.

So if I have shaft and then either it can be unbalance and with it can be because of pitting so all these will give rise to again the same problem which you see in the frequency in the vibrations signal are strong 1X component. So this can be one will lead to other and many times again in process plants they go for resonant inspections. There are lot of particularly in process plant there are lot of site windows glass the high pressure glass.

Sigh windows are provided which equipment to visually see from the outside what is the condition and associated with these impeller getting defected in bearings there will be load on the bearings.

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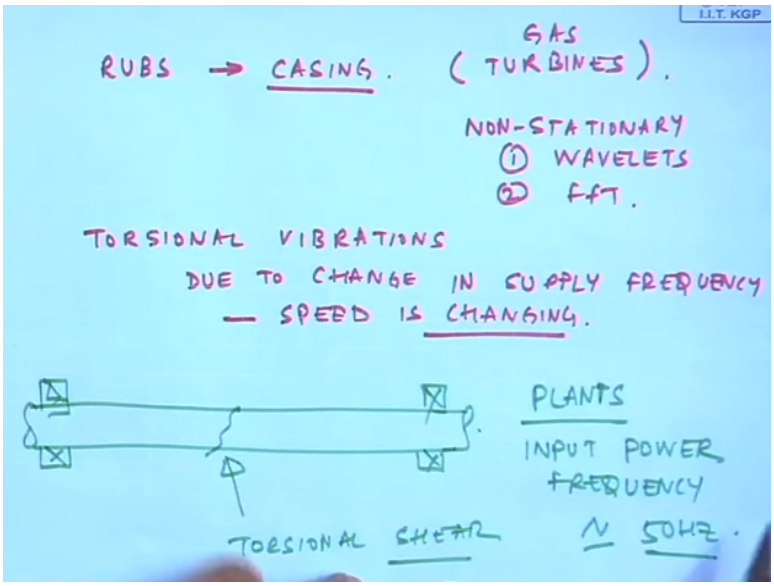

And then misalignments eventually again they will rub on the casing this rub I told you in the case of the pumps this also severe in the case of turbines particularly gas turbines oaky. And then this will give rise to lot of problem and we discussed in few of the classes earlier how this rubs can be detected by what is known as the non-stationary signal analysis like wavelets or FFT okay.

And particularly associated not with high level turbines but with steam turbines and gas turbines as series problem is the bearing temperature and there are lot of control measure circuits available so that the gas turbines the bearing temperatures are below related temperature of usually 75 degree Celsius. And many of you those who have gone to power plant there are certain very important parameters which are monitored and one of them is generator output speed.

Because that output speed is would correspond to the frequency of electrical power compression and that has to be strictly at this internal speed of 50 hertz and you know the effect if the speed falls below that there are lot of circuits lot of protection circuits and equipment which will shut them up of the supply frequencies less than 50 hertz. Because of the fact that many devices are synchronic many timings circuits are dependent on the supply frequency.

Then and you would have heard of the grid failure. Because suddenly the load the machine shut down automatically the would again decrease and again that would lead to again high speed increase there will be lot of frequency fluctuation that is known as the hunting of the machines and hat has to be provided okay.

And because of this speed fluctuation because of the change in frequencies there will be lot of torsional vibrations associated due to change in supply frequencies because of the speed is changing okay. And I have seen many times particularly crack shaft of machines structures failing because of such speed fluctuations. So many times in many plants input power frequency plants in India as to be maintained constant and 50 hertz.

Because of the load poor power generation sometimes this fall but then again if they increase decrease this will give rise to speed fluctuations.

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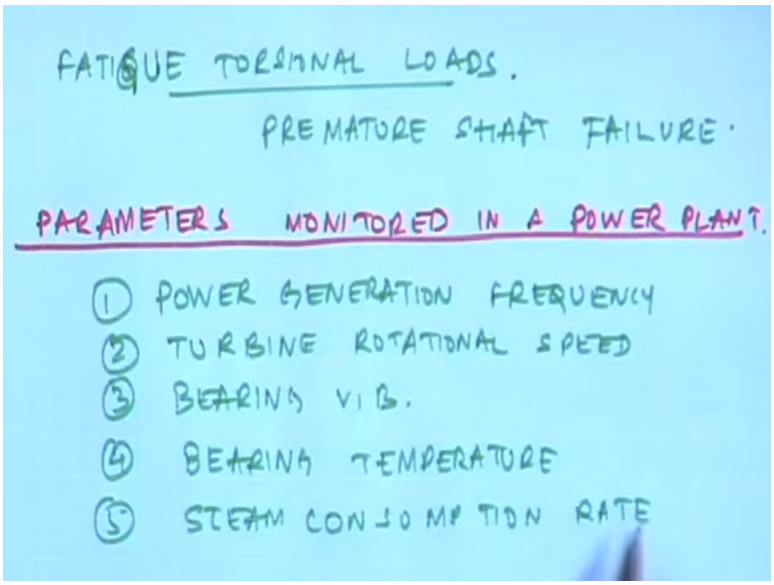

And the speed fluctuations would be introduce fatigue torsional loads and lead to premature shaft failure. So in a power plant parameters monitored in a power plant from a machinery health point of you is of course the power generation frequency then the turbine rotational speed bearing vibration, bearing temperature of course the steam consumption rate okay.

And of course the voltages etc., is there these are the parameters which have to be monitored so that we will know where the turbines is stable or not and so on. So in conclusion pumps and turbines are important machinery which are there in all power plants and all nuclear power plants gas turbines for say as used for propulsion for captive power plants for aircraft propulsion so they have their online condition monitoring techniques by vibrations.

Motor signature Analysis is another new candidate which can be used for analyzing and one monitoring system you know bearing temperature can be monitored as well and particularly if are gas turbines which are used in aircrafts lot of entity inspection have done in the maintenance workshop lot of onsite internal inspection through technique of visual inspection in (()) (52:30) etc., have done.

Some of the entity techniques we will discuss in the next class few classes down the row and all including MCSA but there is just to introduce you the techniques are other than vibration monitoring like motor signature analysis and NTD techniques which can be used to find out defects in machinery okay thank you