Power Plant Engineering
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Lecture - 36
Direct Energy Conversion

Hello, I welcome you all in this course on Power Plant Engineering; and today we will discuss the Direct Energy Conversion. The direct energy conversion means the conversion of available energy into the electricity by not having any intermediary stage of energy. For example, when we dull up energy using Rankine cycle, so what we do? We available energy is coal or we burn the coal heat is generated and that heat is converted into the useful work by using Rankine cycle.

Output of Rankine cycle is covered with generator electricity is generated. So, this is a conventional type of or indirect type of energy conversion of energy in the coal to the electricity. So, it is passing through various stages; in direct energy conversion the available energy is directly converted to electricity. For example, photovoltaic cell it is the best example of direct energy conversion.

The moment to the sun rays fall, this available energy will be very thin it does not matter. So, where the rays of the sun are falling on the this photovoltaic cell immediately the due to photovoltaic effect the energy is converted into the electricity or we get the electrical output. So, this type of conversion their other methods also for converting direct energy from source to the electricity we will discuss them one by one. So, in those I mean photovoltaic we have already discussed.

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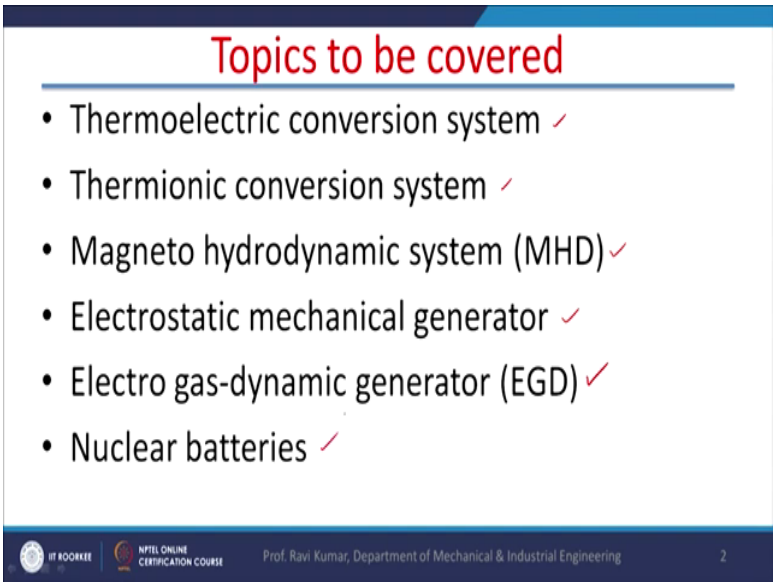

In addition to that it is thermoelectric conversion system which is known as the direct energy conversion system, thermionic conversion system, MHD Magneto Hydro Dynamic system, electrostatic mechanical generator. Though it generates very small amount of a energy, but it is also direct energy conversion; Electro gas Dynamic Generator EGD and nuclear batteries.

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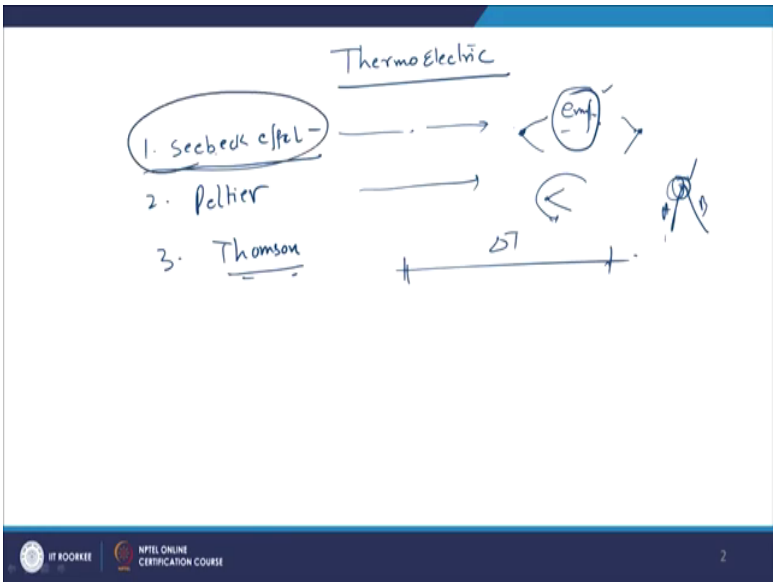

So, we will start with the thermoelectric conversion system thermoelectric, as it implies for the name itself thermo electric means heat into the electricity. Now, they are three effects one is Seebeck effect, another is Peltier effect and the third one is Thomson effect. Now, Seebeck effect says if there is a junction of the similar materials if there is junction of the similar materials right. And this junction these junctions are kept at different temperatures emf will be generated right.

So, this is Seebeck effect, Peltier effect is reverse of the Seebeck effect. If your junction of different materials and the current is passed either junction will become hot and will become cold. So, if you have junction of any two materials A and B and if you pass the current, so either it will become hot or it will become cold. So, this effect is used in thermo electric

refrigeration systems. So, we have a junction, so when the electricity is passed through the junction it becomes cold, so that is known as thermoelectric refrigeration system.

But here our requirement is different, here our requirement is we have to convert heat into the emf, so for this will go for the Seebeck effect right. So, the junctions would be kept at different temperature and we will generate the emf, so this is a sort of direct energy conversion there is a Thomson effect also. Suppose there is a no junction there is a wall of wire of the same material and there is a temperature difference between these two ends emf will also generated along the wire as well, so em for our concern is only Seebeck effect.

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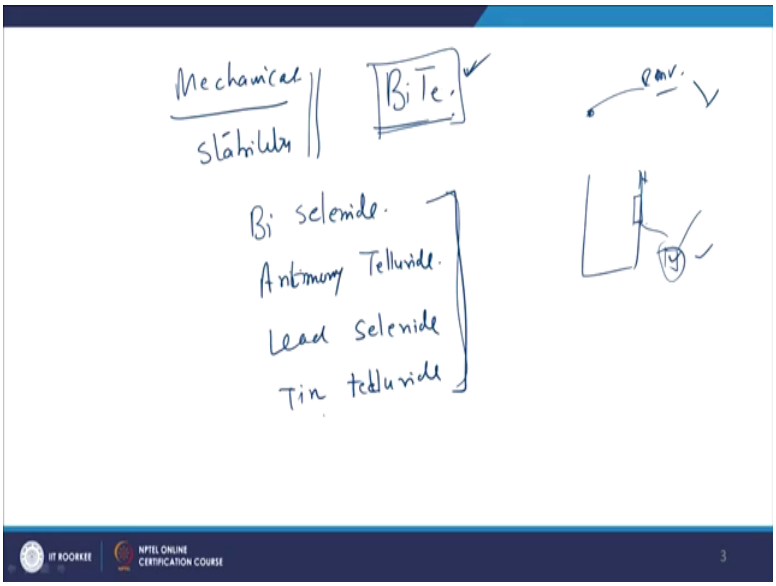

Now, for Seebeck effect we have to choose the material, when we choose the material we should do its mechanical characteristics, stability, the material should remain stable and material should be mechanically sound. Under operating condition it should remain a stable

and under fabrication also it should remain a stable in the both the cases it should remain a stable.

So, for this bismuth tellurium sorry bismuth telluride bismuth telluride is considered to be the best suited. So, bismuth telluride is has a it as a normal application as for as thermoelectric conversion of or direct energy conversion is required.

So, this appears to be the most suitable material if we consider all these constraints. Second thing is for the bismuth tellurium is that it can produce alloy with bismuth Selenide, Antymony Telluride, Lead Selenide, and Tin. So, it can make the alloys also and the properties of thermo electric of properties of alloy. Thus thermo electric properties of this bismuth telluride can further be improved by making alloys right.

Thermo electricity can also be produced there is an option by taking heat from the nuclear core. The nuclear, if you go for the nuclear power plant the core temperature is very high. So, if we take core as a hot junction room as a cold junction there also you can generate the emf. Nowadays, research is also going on to generate this mobile charger with the help of stoves.

So, this stove can be the stove can be stove surface can be hot junction, room can be cold junction, emf can be generated. And then emf can with the help of this we can develop a mobile charger can be developed. So, in those area where electricity is not there people can further use the mobile. So, there are several application for thermoelectric conversion.

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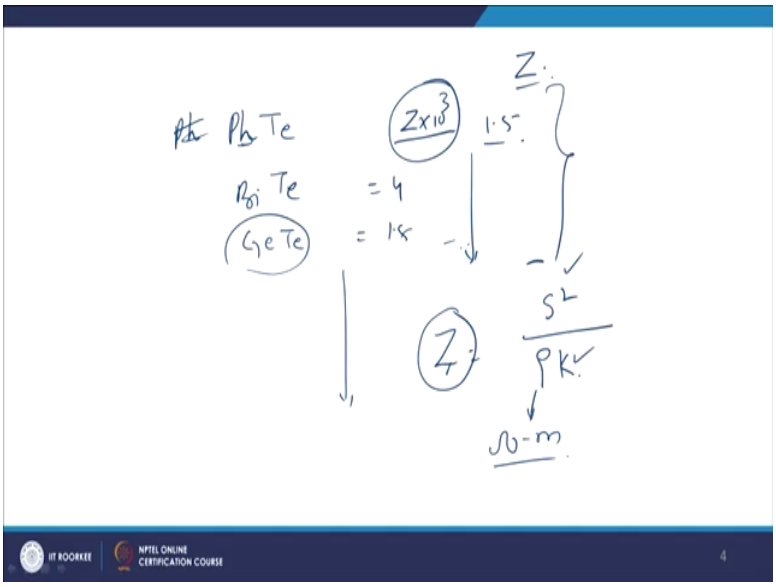

So, there is a factor figure of merit Z. So, far any we cannot go for any (Refer Time: 07:10) or any material. So, Z has to be seen we have to look in to the Z for example, lead telluride sorry lead Pb Pb lead telluride. The value of Z is Z into 10 to power 3 is equal to 1.5 lead telluride. For bismuth telluride it is equal to 4, for germanium telluride is equal to 1.5, for many compounds are the alloys it is given compounds and alloys it is give.

And we have go for we have to go for the best value of Z that is the one of the criteria of choosing a material for thermoelectric purpose. Now, Z is figure of merit is S square divide by rho k, S is Seebeck coefficient. So, it differs from material to material, rho is specific resistance specific resistance is expressed in terms of ohmmeter and k is nothing but thermal conductivity right. From this we get the value of Z and the best the alloy or the compound

which is giving the best value of Z should be use for thermoelectric refrigeration system sorry thermo electric energy generation.

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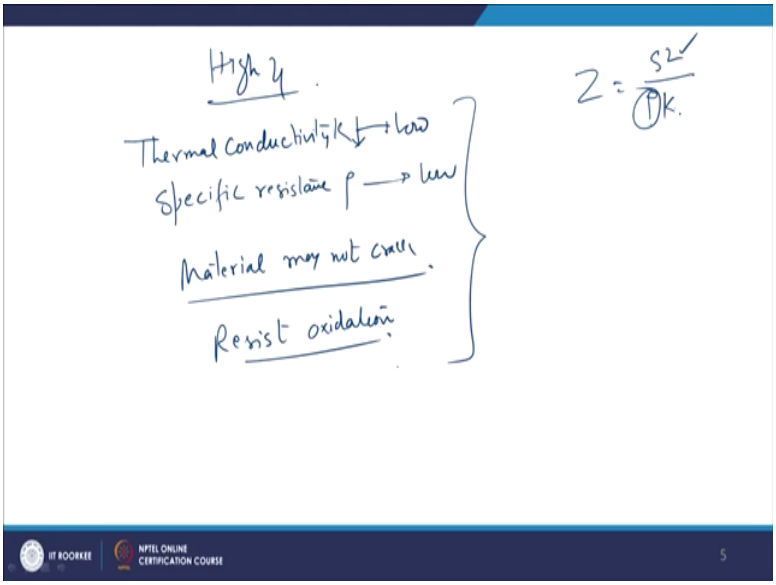

Now, how to achieve high efficiency? This is always a concern for any machine to achieve high efficiency. In I wrote achieve high efficiency as I said Z is equal to S square by rho k, we have to have high value of Z. So, thermal conductivity has to be low, specific resistance that is rho is k that is rho has to be low. Specific electrical resistance a specific electrical resistance has to be low, thermal conductivity has to be low and Seebeck co co-efficient has to be high.

Mobility of the current carrier it should be high mobility of the current career it should be high. And second thing is for high efficiency the material should not crack the material which is used for this purpose should not crack while manufacturing while use. And it should resist oxidation, because at high temperature there is the possibility the metal get oxidize.

So, it should resist the oxidation it should have good material strength and it should be empirically elastic. So, these are the requirement for thermoelectric conversion system which can convert heat into the heat directly heat into the current.

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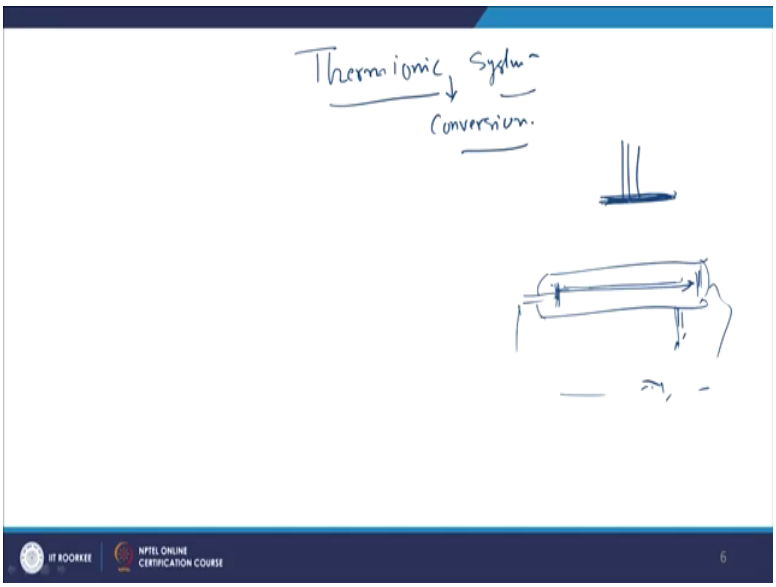

Next is thermionic, system this is conversion system. Thermionic conversion system, it means where heating a plate simply when you are heating a plate at high temperature the electrons will be emitted right. Especially when you do it in the vacuum when you do it in the vacuum when you do it in the vacuum the electrons will be emitted.

And you must have heard about the cathode ray experiment where there was a tube right this side plate was heated and this is cathode. Actually this experiment was done not to, so this experiment was not conducted to find this experiment was not conducted to find the nuclear

structure. Though this experiment has a significant contribution in establishing the structure of an atom.

This experiment was conducted to simply to find the conductivity of gases under low pressure. So, when this experiment was conducted the t was put under vacuum close to the perfect vacuum this side was heated. Then the phenomenon was seen there was a sudden blow on this side and the electrons move from this plate to this plate and the current was flown. So, that is how the electrons were discovered and similar on the similar principle the electricity is also generated in thermionic systems, the plate is heated under vacuum.

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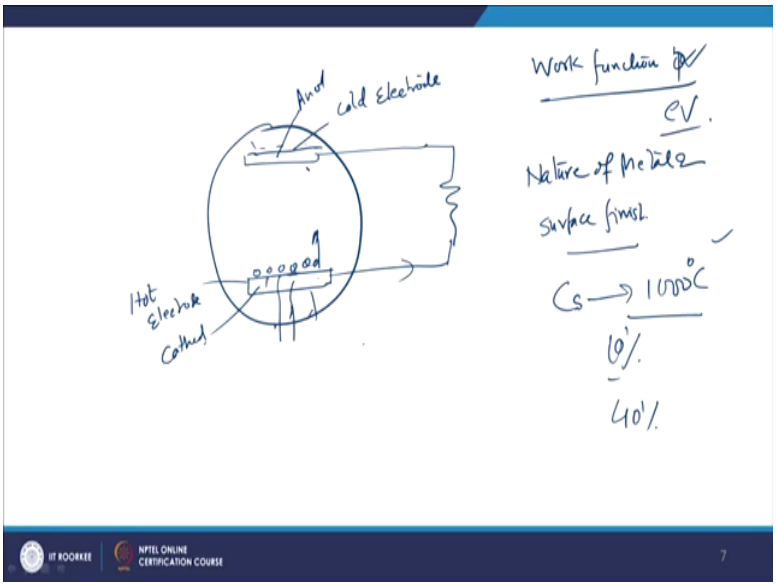

So, in a thermionic system, suppose we take a cylinder and there is a plate is a evacuated tube and this is cathode and cathode as coolant also. Because, due course of time this will get heated or its known as cold electrode right and this is hot electrode. So in fact, this is a

cathode and this is this side is anode and this under vacuum this cathode is heated and electrons are liberated on from the surface.

There is a term which is known as work function phi it is a amount of energy which is required to bring the electrons just at the stage of releasing from the surface. Or they are brought to the work required to bring the electrons to the surface zero energy level any edition of energy will liberate the electrons. So, this is known as work function because metals have free electrons. So, when these free electrons are excited by energy can be thermal energy also they leave the material right.

So, for this phenomena or this concept of work function has coming to the picture it is expressed in terms of electron volts and it depends upon the nature of material of metal and surface finish right. For example, you take cesium, if you take cesium and cesium is heated up to 1000 degree centigrade.

So, in this case 10 percent of energy can be converted into the electricity. If you go for the higher temperature 40 percent thermal energy can be converted into electrical energy right. So, let us go back to this construction, so from here the electrons flow to the dc load and from dc load to, so the currents flows in this direction in the opposite direction.

Because, electrons will be coming here and entering here right; this is cold junction, hot junction, cathode and anode rest. So, this part when is heated when heat input is given electrons are liberated, because vacuum is here the immediately travel to the anode, so a circuit is the circuit is completed.

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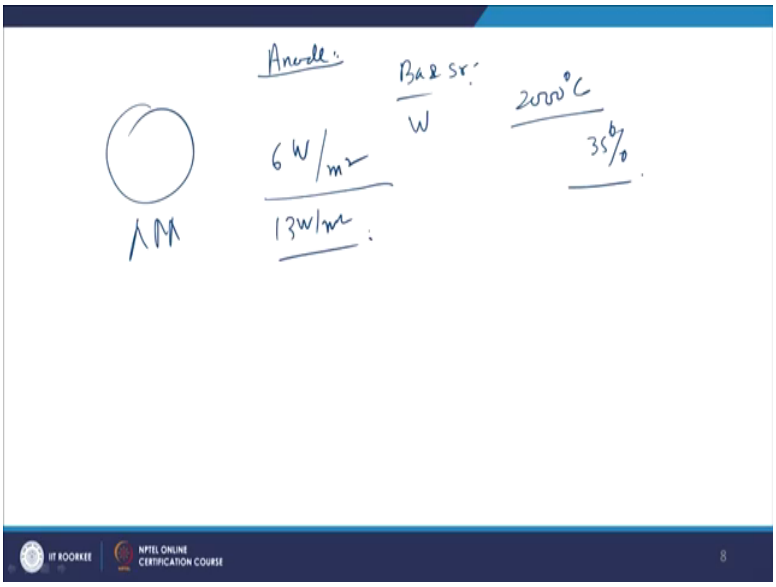

Now, so the anode should have a low for work function it should be like, so that, so barium or its strontium is used for this purpose. Cathode should have high, so tungsten is used for this tungsten is used for this. So, if we go temperature around 2000 degree centigrade as I said earlier in this case of cesium in other material also the efficiency is approximately 35 percent. Now, this system can be use of any fuel because we need heat only.

So, how heat is generated we are not concerned, so any type of fossil fuel can be used right. And this electric output is of the order of I mean it is few Watts I mean few watts say the density is approximately let us says typical density 6 Watts per meter square. It can go up two 13 Watts per meter square the energy density is of this order in this case.

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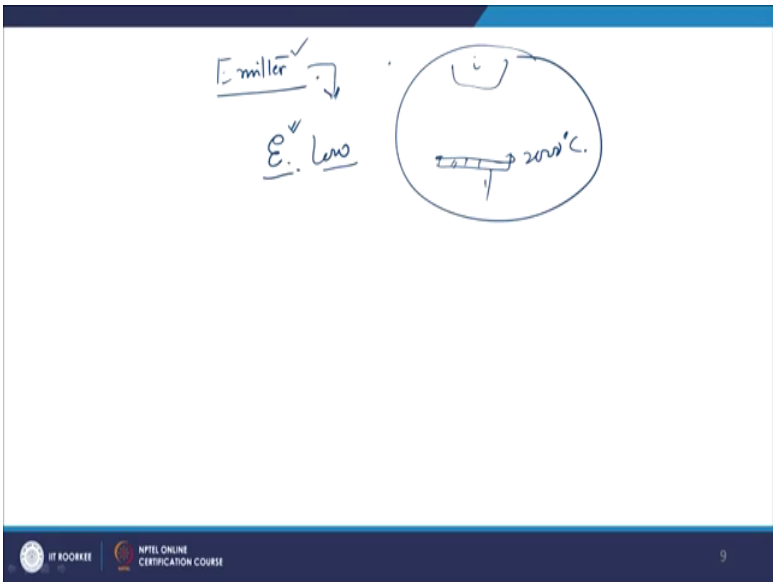

Now, for emitter now properties of emitter which emits the electrons. So, emitter should have sufficient electrons free electrons right, and it should have low rate of deterioration because it will be put at the heat. So, the low heat of the rate of the deterioration has to be there for the emitter. Emissivity has to be low for emitter emissivity has to be low, so heat low is not lost through by radiation from the emitter. Second thing is because when we heat emitter to a temperature of to a 2000 degree centigrade.

So, part of the emitter may get also vaporized, so this metal vapor should not deposit on anode. The metal vapor which is generated cathode, because cathode is very high temperature may be at 2000 degree centigrade, so some part of the cathode we get vaporized. So, it should not deposit on anode otherwise it will efficiency of the system will go down. So, these are the; these are the required property of an emitter in a thermionic system.

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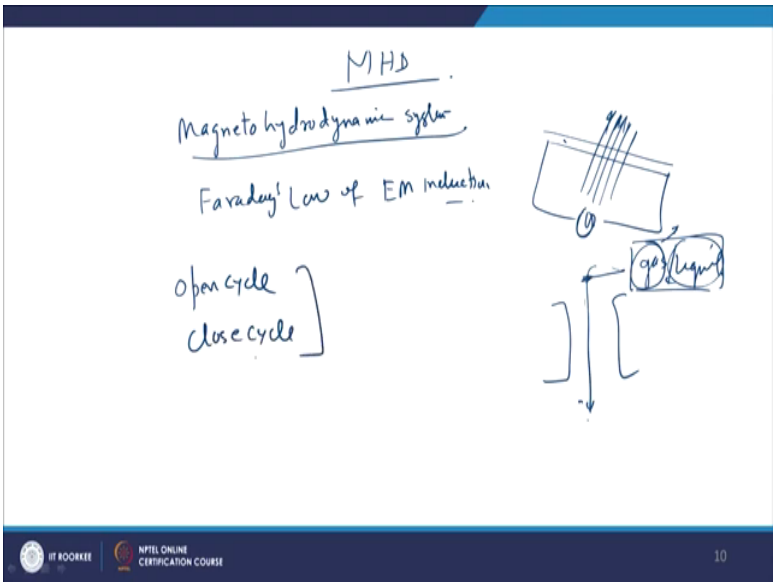

Now, let us come to the MHD, MHD is known as Magneto Hydro Dynamic system MHD. And it works on the Faradays principle and it is name from the it is clear for the name itself right. The electromagnetic effect is used is in the principle of electromagnetic effect is also used here.

So, there if there is a conductor, and there is a perpendicular electric field. It is a conductor is crossing the; conductor is crossing the magnetic field and it is moving with a certain velocity emf will be generated across the edge of the conductor right.

And this principle is also used in many of the application; for example, your ceiling fan. In ceiling fan there is a conductor there is a magnet electro magnet and when the conductor

rotates it does the rotation motion or the linear motion. When the rotation motion is done then it is reverse of this.

When emf is supplied in electromagnetic field rotation motion is rotation motion results in a fan. So, it work on the reverse principle of this another is when a conductor moves in a like electricity generator electric power generator. In electric power generator the armature which rotates in a magnetic field electromagnetic field and that is how the voltage across the armature is develop and we get the output from the motor right.

So, here also here because it is magneto hydrodynamic system here ionized gas is used instead of a conductor ionized gas is used right. It works as a conductor, but it is not visible I mean it is in a gases form. So, high very high magnets and through this magnets high velocity of this ionized gas is passed right, when it is passed the emf is generated. Now, this is this fluid this working fluid may be a gas or it may be a liquid also, it is also possible to pass the liquid to have this effect.

So, the temperature of the gas or the liquid is very high. So, MH device MHD does MHD converts high temperature in to the electricity. High temperature is attained by hit these gases this gases are at very temperatures some separate arrangement is made for hitting the gases. They are now they go to the ionic ionized form. And these ionized gases when they pass through this magnet emf is generated across the ends of the gases ends of the; ends of the conductor.

So, this MHD works on Faraday law of electromagnetic induction right. The system can used high temperature and high pressure gases also right. So, the MHD have there are two types of MHD; open cycle, and close cycle the two types of MHDs.

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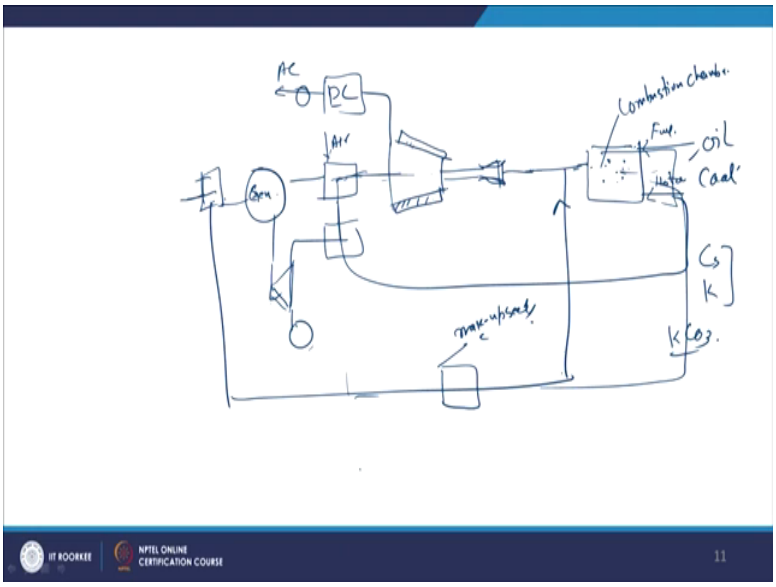

In open cycle MHD there is a MHD we can have an a schematic diagram there is a MHD it has magnets right. Just before MHD there is a nozzle, the function of the nozzle is it is a convergent divergent nozzle. The function of the nozzle is to provide the kinetic energy to the gases at the expense of pressure drop right.

So, there is a combustion chamber here where combustion takes place fuel come from this side hot air goes from this side right. Fuel and hot air they burn, high temperature gases are generated, high temperature gases are pass through this MH [laughter] this magnetized field, and power is generated. And this gets the DC supply DC supply is the output and then it can be converted into the AC by a convertor.

Now, what happens to the gases which are coming here? Now, gases which are coming out in order to save the energy, air can be preheated air can be preheated it can be sent to the

combustion chamber. So, that is how the energy can be utilized, but still after preheating air a lot of energy remains right. That substation energy which is remaining can generate the steam generator the steam generator is there a stream boiler a stream generator is there.

Where a steam is generated when the stream is generated then power further power can be gen. So, it is additional power we are getting from MHD. So, exit at the exit of the MHD exit of the means first of all air is pre heated. Remaining energy goes to the generator where a steam is generated and that steam is used for power generation. Seeding is done some solid particles are mixed here that is known as seeding, like potassium, potassium carbonate, potassium sodium they are mixed here in order to increase the efficiency of the system.

Now, when the steam is generated now here the seed recovery takes place seed recovery takes place here again it is sent to the combustion chamber right. Now, this seeds the seeds they are again sent to the combustion chamber or they can be mixed off with the combustion chamber as well. There is no need to send them directly which combustion chamber and it is known as an some seeds are lost in the process right.

So, some makeup arrangement can be made makeup seeds. So, this is the; this is the general schematic arrangement of a MHD open cycle of MHD. So, in open cycle MHD you can fuel, you can use oil, coal or any fuel you can use. And there is a small amount of alkaline material like cesium and potassium they are used as a seed material.

Normally, potassium carbonate is used as a seed material in this type of system. There is another arrangement which is known as a close cycle, in the close cycle the this hot air which is coming out from here directly goes to the chamber it is a close cycle. And during this course of course, through a heat exchanger heat is extracted to run the turbine. So, that is a arrangement of a, but the benefit of the closed cycle is it can operate on high pressures it can operate on high pressures right.

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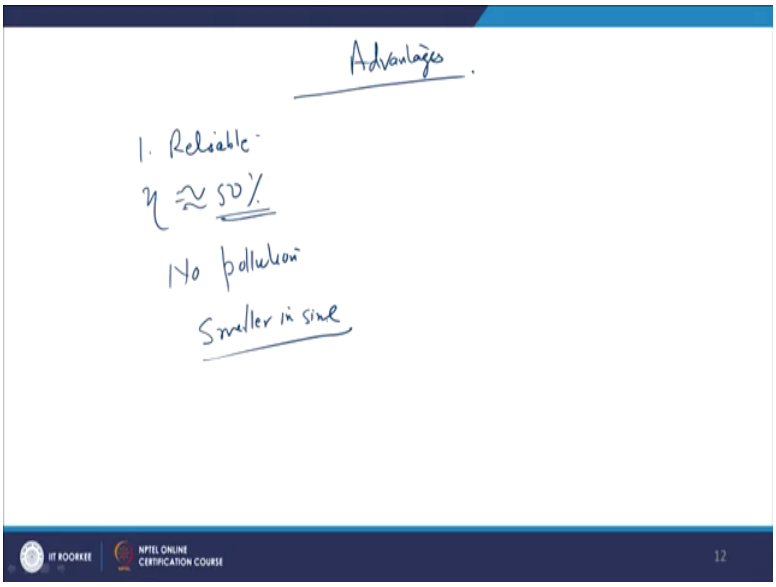

So, the advantages of this type of system, first of all it is reliable it is reliable because there is no moving part. So, in those systems any system which does not have any moving part is more reliable than a system which has a moving part, so this is more reliable. Efficiency is also approximately 50 percent, if you look at the normal thermal energy to mechanical work system.

The converse for example, in IC then the efficiency is 33, 35 percent right. Turbine efficiency is also low, overall efficiency if you look at the thermal power plant it is also very low. So, this efficiency is quite high efficiency, we get no pollution or power is free from pollution right. And the best thing is the moment you switch it on you get the full power in other system it takes time to come to the full power warning up time is there, but for this warning time is minimum right.

So, the moment you switch it switch on the system you get the full power, it is smaller in size and operation cost because there are no moving parts. So, operation cost is also less in MHDs, it gives better utilization of fuel and if you go for the high I mean high capacity production the cost is comparable with a convention power plant the cost is also not very high. But, it is still recommended for the peak power plant as not as base power plant. There are certain disadvantages also because when there are advantages there are disadvantages also.

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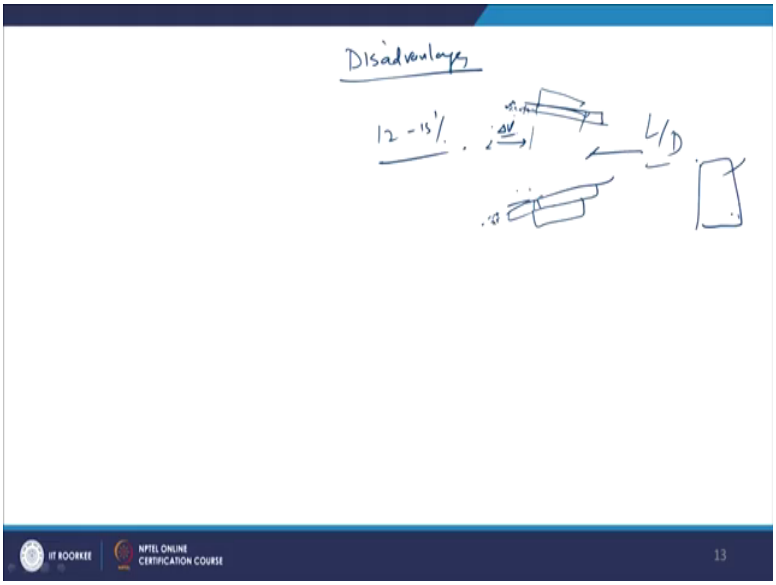

Disadvantages is when there is a flow of electron in MHD it is observed that this side becomes cooler and there is a reverse flow of electrons. Now, for in order to overcome this losses the L by D can be increased, or magnetic the length of the magnetic field is increased more than the required that is one thing. Or beyond the end of the MHD it can be extended. Friction losses

are very high because the fluid is moving with the very high velocity, so energy losses in friction go up to 12 to 15 percent.

So, they are the major disadvantage. Now, what happens the gas is the very high temperature right and the flaming side of the electron they are temperature is relatively low, because this side the temperature is relatively low. When the temperature is lower resistivity increases and when the resistivity is increased there is a large voltage drop in the trailing side of this MHD generator. Because, there is a delta voltage drop is high that is also a form of loss energy loss.

The next word is that we are using magnets of high capacity the magnets are costly they are expensive. So, magnets we are using here for MHD power generation they are expensive, so that also exceeds the cost of the system. Third thing is when we burn the fuel here there is a molten carbon ash molten, the ash is also get comes into the molten form. So, there is a molten carbon in the gas and the molten carbon this sometimes it leads to a short circuit.

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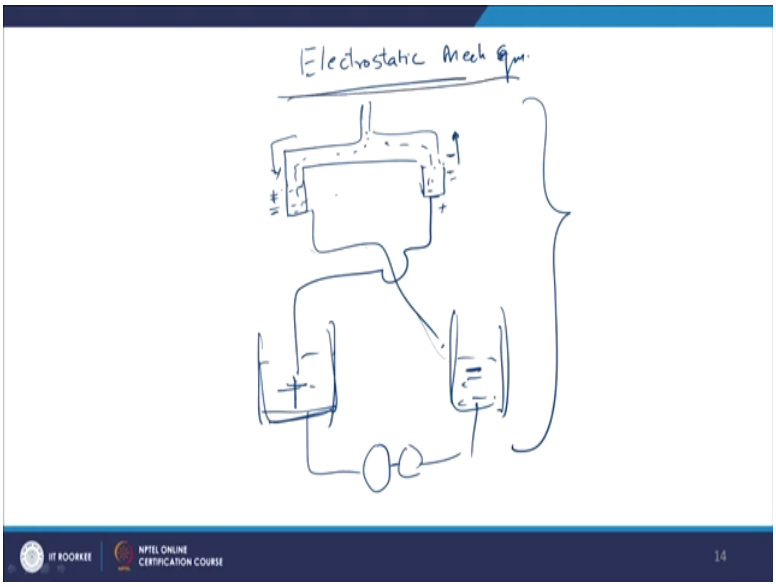

So, this is also one of the disadvantage of this type of system. Now, we will come to the electrostatic mechanical generation generator. This device is not for high level of power generation it is simply if you have two containers. And it is simply conversion of potential energy water to the electricity right. And the mechanism is very interesting that water is coming from here there two vessels positive negative positive it is neutral vessels. And their two ponds, there is a cross connection to this ponds right and this is as positive charge and this is negative charge.

Now, initially suppose this is this side is positively charged let us say some by external means. When this side is positively charged then this side will become negative charge right. And when this become negative charge it will repel the electrons in this direction, the electron will

flow here they will come here right. When the electron come here this side will become positive this will become negative.

The water which is coming through these vessels right it would be collected in two different vessels down the line one vessel has positive charge another has negative charge. If you connect to this any main which charge basic device or any let us say short circuit device you can find a spark here. So, this is a very small scale experiment which depicts the electrostatic the potential energy of water can also be converted into the electricity.

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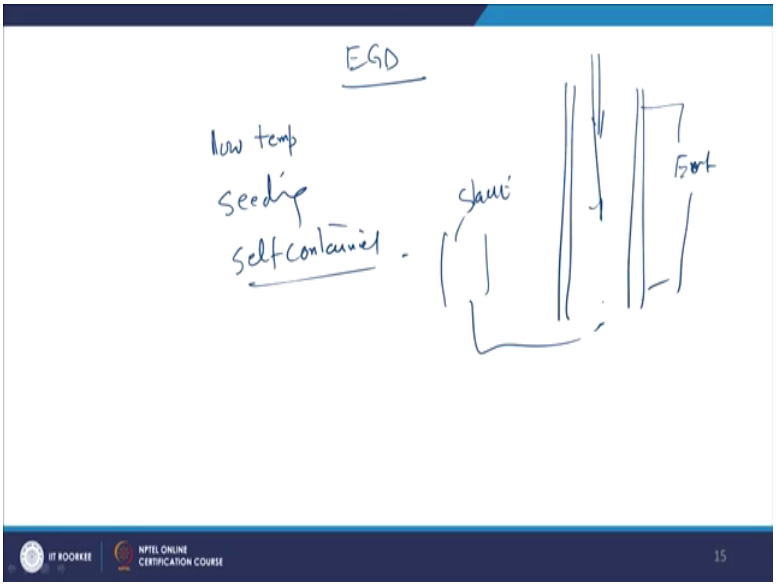

Now, next is electro gas dynamics system, in electro gas dynamic system there two magnets, and electrons are high velocity electrons are forced to this magnets between these magnets. When high velocity electrons they are force through this magnets then emf is generated. It is quite similar to the magneto hydrodynamic system, but in magneto hydro dynamic system it is

a they are ionized gases. Here it is only electrons which are moving in this and they are on very high pressure and very high velocity right.

So, this is the working principle of this EGD, Electro Hydrodynamic Generator. So, it works at a relatively low temperature the benefit of this, this MHD works on relatively high pressures. Seeding is not required, their seeding is required to have efficient energy transmission transfer.

Self contained there is no need of steam generation in the system because it is a close roof type of system. And you can continuously extract energy till the gas reaches the stack temperature. Continuously the energy can be extracted and the condensers and the cooling towers are not required, so there are certain differences between EGD and MHD.

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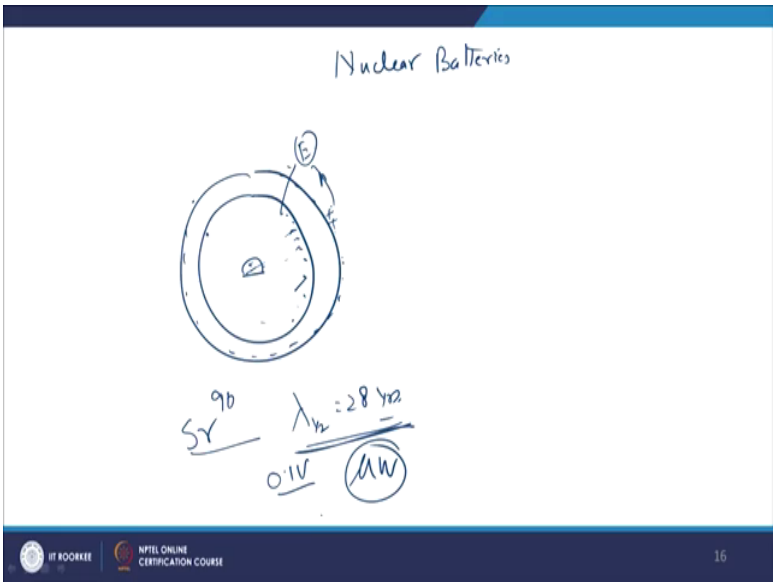

The last one is nuclear batteries the concept of nuclear batteries is that you take one shell and surrounded by another shell. And this shell is kept at low temperature by circulating a coolant right. Now, in the centre of this shell if you put some radioactive material the best suit age is strontium 90. The half life of strontium 90 is 28 years right.

If you put it here it will emit electrons beta particles and these electrons will break this surface negatively charged. Outer surface will become automatically positively charged and you can extract energy from this. This is very good concept of extracting energy from the nuclear power that is not direct extraction of energy. Normally, extraction of energy of nuclear power is by utilizing heat of nuclear fission to the for converting water into the steam.

But here the fission is used is used the emission of the beta particle is used for charging these two spheres. When the spheres are this is sphere is charged negatively and this is positively emf will be generated. Emf for a normal size the emf it is of the order of 0.1 volt and it gives microwatts right. But if the design improvement is done and further research is done in this area we can also develop substation power by this concept ok. So, this is also a sort of direct energy conversion that is all for today.

Thank you very much.