Non-conventional Energy Resources
Prof. Prathap Haridoss
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture - 40
Magnetohydrodynamic Power Generation

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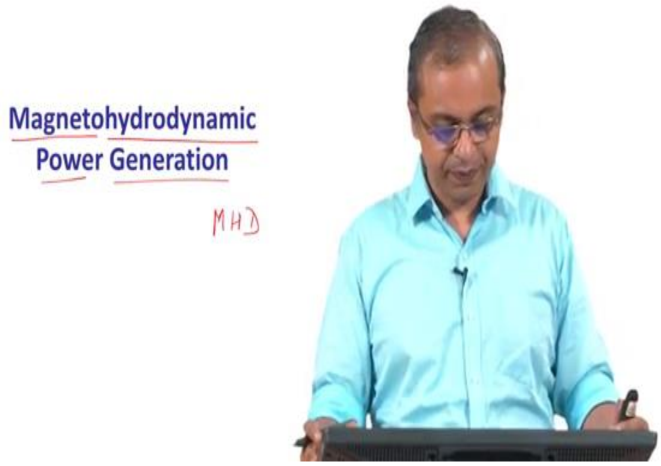

Hello. There today we look at Magnetohydrodynamic Power Generation. So, that's the topic for today's class, well let's look at some of the terms right at the title slide. So, we do have this term hydrodynamic. So, if you are a mechanical engineering background student or even otherwise you may have encountered this term, essentially it has got to do with the fluid flow with you know the movement of say some mass in the in the presence of a fluid, relative movement of the mass with or some object, in the presence of moving fluid, and that is what we that study is then referred to as the hydrodynamic you know study of that a combination of some movement of this liquid and this mass.

So, that is hydrodynamics relative moment study of the relative moment of solid in some fluid flow. So, that's what we are looking at hydrodynamic behavior. Now we are additionally adding something here, magneto hydrodynamics. So, there is some fluid flow here. So, as you can imagine from this terminology there is some fluid flow here, there is some magnetic field here, and there is some relative motion. So, all these things are going to be there in the concept that we are going to discuss through this class. And it is associated with power generation. So, and that's the relevance of this topic to our course.

ah Now I will also point out that people have studied this, and there is still some work that goes on it; however, it is not still that commonplace, and there are competing technologies, there are issues with this technology etcetera. So, it is not something that and that's the reason why most of us are unlikely to have heard about this. So, it is you know for example, this is yeah. So, this is abbreviated as MHD, but chances are most of us have not really heard about it or you know heard about it as something significant you don't really read too many articles about it, and in the general public parlance. Unlike say lithium ion batteries or any other such technology which you are hearing about all the time.

So, that's something to keep in the background so, although we will look at this for a sort of a sake of completeness kind of activity, and it does have some relevance in the in the grand scheme of you know what impact it is making it may not be as significant as of it's of today ok.

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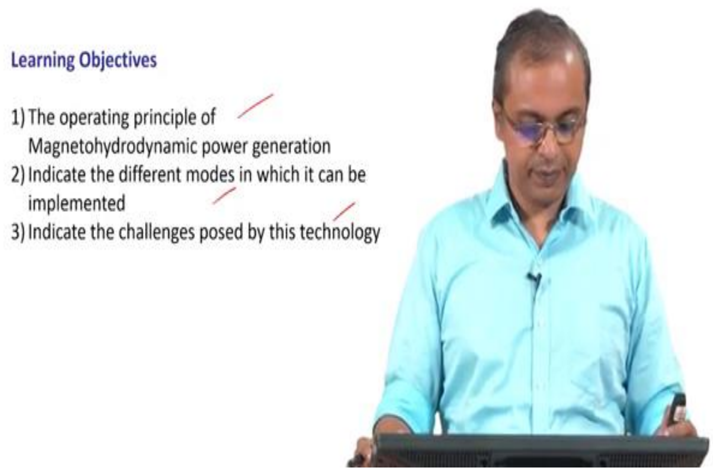

So, we will learn objectives for this class are to look at the operating principle of magneto hydrodynamic power generation, and we will also see that there are different modes in which it can be implemented.

So, we will briefly look at those different modes in which this magnet magnetohydrodynamic power generation can be implemented and of course, in the context of this discussion we look at the challenges posed by this technology, and try to get a sense of what is possible here ok. So, those are our learning objectives the operating principle the different modes, in which the magnetohydrodynamic operation happens, and what are the challenges supposed to wait.

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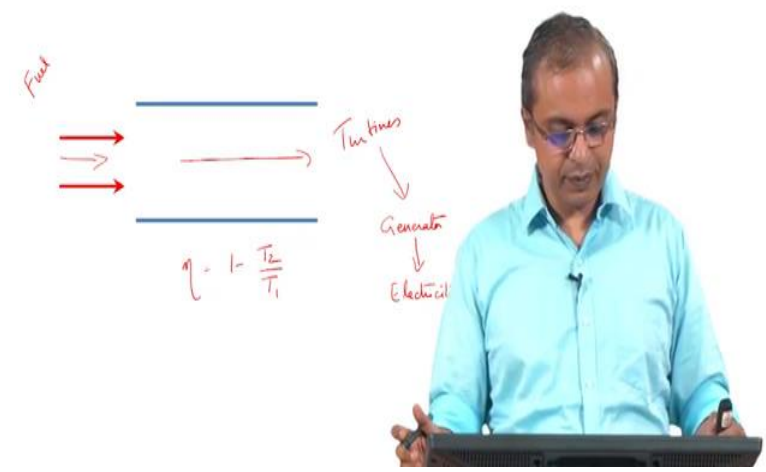

So, if you see what do we normally do in terms of a large scale power generation plant. In a large scale power generation plant, you have some fuel and that fuel is burnt ok. So, it is burnt to release that energy, and so that energy then moves this way ok. So, some from fuel some energy is coming out that energy moves this way, and then it heads off towards some generator. So, maybe let’s say turbines that rotate, and that is connected to a generator, and then we get electricity right.

So, our output is electricity; input is some fuel which is then burnt, then moves through this process and generates electricity. So, when you do this as we are aware since it’s like a heat engine kind of a process you have this thermal energy that is coming and you are converting that to electricity after discarding some amount of heat, the efficiency is given by 1 minus T 2 by T 1.

So, we are sort of limited to this efficiency and therefore, it is in the scope of this efficiency that we pick up energy from the fuel. So, there is some energy in the fuel we pick up that energy. So, there is always interest to see if there is some little extra energy that we can squeeze out of the fuel over and above this you know this limitation. This limitation is there, but is there a way to work around it is there a way to do something before we reach this hit this limitation etcetera, and so that is something that we are interested in always looking at.

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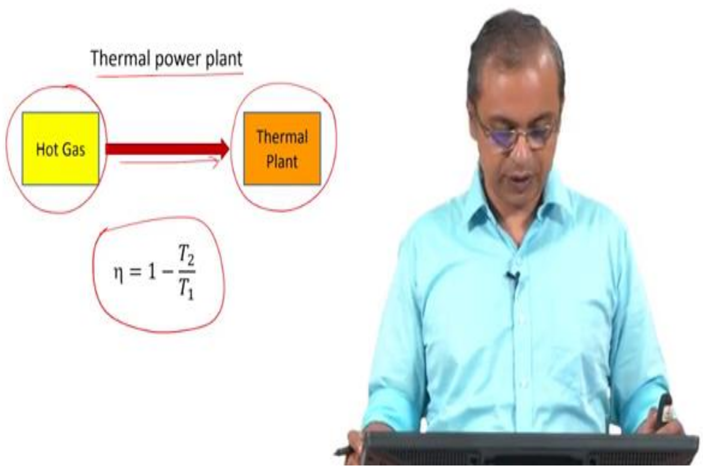

So, as I suggest said you know in a typical thermal power plant that’s our scheme of operation. So, we have some hot gas that is coming in, and that’s essentially sent towards the thermal plant, and in the thermal plant we are generating electricity. So, that is the general scheme of operation that we have, and as I just mentioned this is our efficiency limit ok. So, that is basically what we are trying to do.

So, as I said our intention is to see if there is something extra we can do in this circumstance to get a little bit more energy out of this fuel, and any extra energy that we get out of the fuel essentially increases our overall efficiency, overall process efficiency relative to the energy that is available in the fuel is only going to go up if there is some way, we can squeeze out some more energy from this process right.

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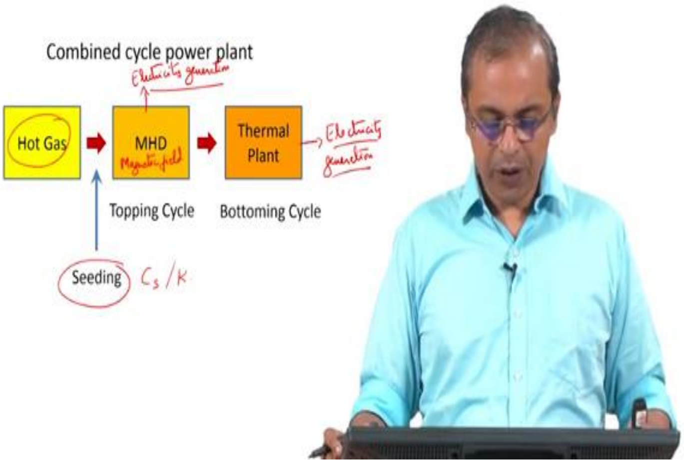

So, this is where we create this we utilize this magneto hydrodynamic generation process ok. So, this MHD process is utilized in this context it's the magnetohydrodynamic energy generation process is used, in this context of utilizing the process flow that's already happening in a thermal plant, and sort of introducing this into that process flow to see if you can extract some more energy out of that fuel.

So, basically now what we do instead of going from the hot gas directly to the thermal plant which is the turbines essentially, and where you know you generate electricity, and then you get the electricity out of it, instead of doing that the hot gas first goes to this magnetohydrodynamic generator, and from there it goes to the thermal plant. So, in this is the pathway it takes right.

So, first to the MHD and then to the thermal plant so in fact, they call this as the topping cycle and sort of the bottoming cycle. So, at the top end of this cycle of you know the movement of this fuel, we pick up some energy that's the MHD cycle, and then the thermal plant comes right after that and that's the bottom half of this cycle. So, usually the MHD is operated in this mode, in a combined cycle power plant ok. So, typically it's not really operated separately of course, for study purposes you can operate it separately I mean that may be the best way for it to operate it even.

But generally you are looking at a combined cycle power plant, which is where we generate this energy. So, it is in this context that it is utilized ok.

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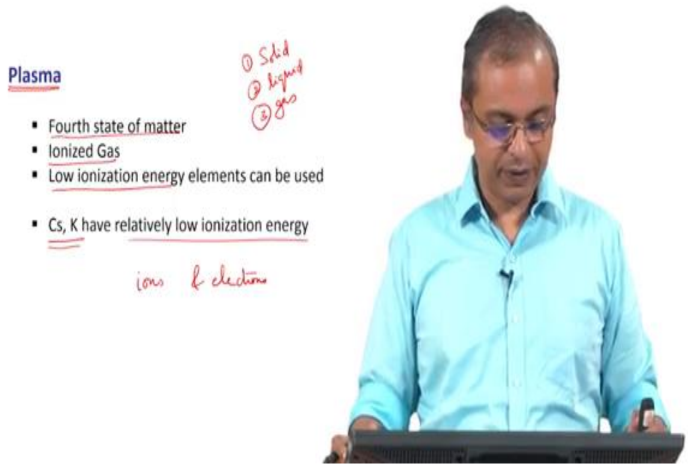

So, to do this process to you know operate this magneto hydrodynamic generator, we actually need to create a plasma ok. So, we need to create a plasma. So, what is plasma? Plasma is actually it is considered as the fourth state of matter ok. So, we are we are more familiar with solid liquid and gas.

So, these are the 3 that we are more familiar with plasma is the fourth state of matter ok. So, it is basically you can think of it as an ionized form of gas it is gas, in an ionized form it is only in the form of ions that it is present, and it has it is own behavior associated with it and it is actually the fourth state of matter. So, interestingly I mean the reason again; we don’t hear about it much we do not talk about plasma much, because for the most part on the on our planet we are not really dealing with plasma ok.

So, you have to go to fairly high temperatures or fields high electric fields etcetera to create this plasma kind of a situation, normally in the you know commonplace activities that we deal with for the most part on the planet; we don’t see plasma for the most part, we are not really encountering it on a daily basis in any of the activities that we do typically we don’t see plasma. Interestingly though if you take the universe as a whole if you take the universe as a whole even, if you take the solar system and you take the universe as a whole, plasma is the most common form of matter ok.

So, it’s the easily we are considered as the most common form of matter, it is there across the universe there is a lot of ionized material around the universe. So, for example in all the stars in the in the sun for example, the temperature is so high that the material stays in the ionized state. So, in the sun we have plasma, and if you look at the mass of the sun, mass or volume of the sun, well over 99.5 percent of the mass of the solar system is the sun right.

So, 99 point whatever more than 99.5 maybe 99.9 percent of the mass of the solar system is the sun rest of all it is all very small relatively speaking. So, if you look at it that way in terms of mass or volume even with respect to just our solar system, if most of the sun has this plasma in it, clearly plasma is the most common form of matter in our solar system ok. So, that is something that is unusual to most of us because we don't see it on our daily basis, and so something that we do not see on earth that much is what is most common in the universe.

So, across all stars wherever you know you associate matter with stars essentially and all that stars have plasma. So, that sense it's a very common state of matter so actually the solid liquid gas that we are talking of is the most uncommon state of matter. So, actually we should call plasma as the number 1 state of matter everything else should be less common so, but that's a uniquely with respect to our experience it is the other way round.

So, it basically consists of ionized gas. So, that is what plasma is and, so if you want to create plasma. So, you need to get to high temperatures as I said you can put high fields etcetera to create plasma, but if you want to create plasma easily, you need to have elements in your stream which have low ionization energy ok. So, generally I mean given the various options, if you are trying to create plasma, if you have a material that has a low ionization energy you have atoms of a particular kind which have low ionization energy, then those atoms can be converted into plasma much more easily, than other atoms which have high ionization energy.

So, where you have to put in a lot of energy to get those electrons off, and in that context cesium and potassium have relatively low ionization energy, if you look at the periodic table, and you look at all the elements, and see what all ionization they have cesium, and potassium have relatively low ionization energy, and the I mean there are some other elements in between which also have low ionization energy, but they may be rarer to find.

So, these are relatively you know I mean in comparison to atleast some of the other elements these are much more available and they are more easily ionizable. So, incidentally we do have you know plasma is also of different kinds in different depends on you know; the when I say high temperature the temperature doesn’t even have to be uniform across the plasma, you can have a situation when you talk of plasma you are talking of ions and you are talking of electrons so ok.

So, you have ions and electrons; so, once you create plasma where you have this ions separated from the electron and the electrons are moving around, the ions are moving around; they don’t necessarily have to have the same energy ok. So, you can have electrons having much higher energy, the ions having much lower energy you will have some average energy, but in general you can have a situation where much more of the energy is being held by the electrons much less is being held by the ions and so on.

So, in that case. So, you can have plasma that is somewhat cold, you can have plasma that is hot lot of different options are available here when you talk of plasma. So, we do have you know plasma related electronic devices that we utilize. So, some of these you know lamps which have some vapor in them, and then they are giving you the light they all have this ionized form of matter plasma. So, you do have some of the lighting systems that we use are based on plasma, some of the display systems that we use are based on plasma.

So so plasma is there in some of the devices that we are using, although we may not have consciously understood what exactly we are referring to when we are talking of a plasma ok. So so, it is available it is the fourth state of matter it is ionized gas, and if you if you are trying to ionize cesium or potassium it may be easier. So, you can get plasma out of it much more easily. So, what is that relevance of plasma with respect to magnetic hydro hydrodynamic power generation ok?

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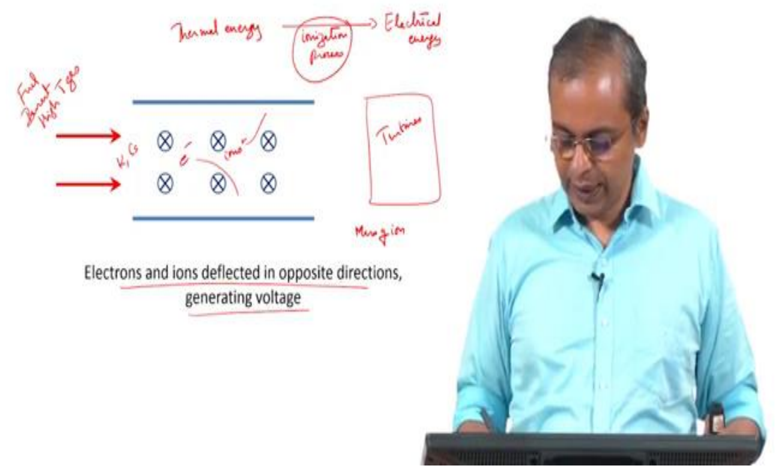

So, what we are trying to do is essentially create a situation, where we have this fuel that is burnt, and so you get high temperature high temperature gas that has been generated. So, that’s the first part of our energy generation process, that we sent through some passageway and then eventually we arrive at this power turbines, and generate power turbines etcetera.

And we generate power. So, there’s another process that are that is there later on where we are generating power. Now there is you have the option that before this hot gas goes to the regular thermal plant cycle, where you have this turbine, and you are doing some various activities associated with that, before you get there you can see if you can get some energy out of this hot gas, because it is already hot, and we spoke about plasma where basically you can ionize some material.

So, we idea in tension in this or the principle behind this magneto hydro dynamic power generation is to take this hot gas, and introduce into it the atoms such as potassium and cesium, these will then ionize okay so they will ionize, and then so now, in that gas stream why do they ionize the ionized? Because the gas is at high temperature ok. So, because the gas is at high temperature the electrons, and ions will separate out. And so, you have an ionized gas and, so this ionized gas is now moving in a stream.

If now you apply a magnetic field perpendicular to the direction of movement of this ionized gas, you can get the ions and electrons to deflect ok. So, that’s the basic principle you get the ions, and electrons to deflect; they deflect in different directions because of the charge that they have, and in that process you generate a voltage that voltage you can tap ok. So, this process these individual steps that I put together here, this entire process is then referred to as the magneto of hydrodynamic power regeneration process.

So, you ionize a gas you get it to go through an area where there is a magnetic field, and because of that magnetic field the ions and the electrons move in different directions and you generate a potential difference. So, that's the basic idea. So, the burnt high temperature gas is there, and you have introduced say potassium or cesium, and then you have this magnetic field here. So, the magnetic field now is in to the plane of the display that you see.

So, and so then the electrons and ions so, you will have e minus and you will have ions, which are positively charged they will get deflected. So, you can get them deflected in different directions. So, you will have them deflecting, and you will have them deflecting like that. So, you will have some deflection occurring and in that process you get the you get a potential difference which you can capture. So, this is energy that is available in the stream which we are now capturing in a different way.

So, what have we done here? We have basically created a situation where the thermal energy that is available in the incoming stream has been used to do some ionization ok. So, some amount of thermal energy has been used for that ionization process. So, that created ions, now that ions and electronic ion pair that you had, you use that to generate a potential difference, and using that potential difference you generate electricity ok.

So, so you have picked up some electricity from. So, some electrical energy has come out of the thermal energy that was available in the gas stream using, an ionization step in the middle ok. So, you had thermal energy, and that gave from there itself directly you got electrical energy. So, from thermal energy, you went to electrical energy by simply including an ionization process in the middle ok. So, that's the idea so that is in this process. So, that is why this process is explored and investigated.

Because it gives you a pathway to pick up energy from because your original energy is only in thermal forms so, the you have burnt fuel. So, you have fuel the energy is available in thermal energy form from that only you are trying to generate electricity. So, you could do that by doing all those turbine related activities all the heat exchange related activities that occur with a normal power thermal power plant.

And that is that would be another legitimate way in which you could generate your electricity, except that that would be subject to all those limitations of the you know 1 minus T 2 by T 1 kind of a limitation efficiency. So, even before you do that, you add 1 ionization process in the middle, and in that process you change the form of energy, from thermal energy to something that is now in the electric form and then you tap that energy. So, you get electrical energy; so, ions and electrons will get deflected in opposite directions generating voltage, we will come back to this in in just a moment.

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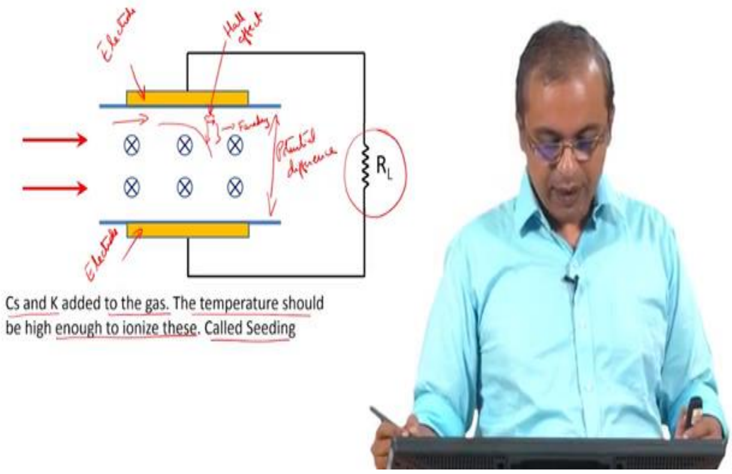

So, this is the basic idea. So, you get voltage potential difference, now you will get a potential difference here, and so you put an electrode here this is an electrode, and this is another electrode or a current collector ok. So, you put 2 electrodes, and you generate a you it’s the system is already generated a potential the potential difference.

So, then you can tap the electricity, and so you have a load resistor which are which is your external circuit and in that process you tapped electricity. So, this is the basic idea and as I said cesium and potassium can be added to the gas, the temperature should be high enough to ionize these right. So, it should be high enough to ionize these cesium and potassium, and this idea of adding cesium and potassium to it is referred to as seeding not to get rain you add seeds to the clouds right. So, cloud seeding that is that is different here, you are adding potassium and cesium as seeds to generate the ionization process to enable ionization process, because the ion is very easily. So, that is the basic idea.

So, if you want to look at relative to what we saw a little while earlier. So, you have the hot gas coming in, but before the hot gas goes to the MHD, if you just send it directly into a region and you call that the you just put 2 electrodes and you send this hot gas in there that is not really going to help you in a big way. So, you have to do the seeding so cesium or potassium, and here you are going to have a magnetic field, and then you have the thermal power plant.

So, you get some electricity out of this. So, you have some electricity generation out of this, and then you have further electricity generation out of this. So, you have you know you are generating electricity in a 2 step process as opposed to a single step process, you have 2 steps of electricity generation that is happening here, and therefore, this is interesting I mean we are getting 1 additional amount of electricity over and above what you would have otherwise got and therefore, your overall efficiency is going up.

Now, I must point out that if you look at this situation here that you know you have these electrons, and ions that are moving in the in response to the magnetic field that you have put, you must keep in mind and it is not as simple as it as it is shown in this figure, although in principle this is what is happening in principle this is what is happening the electron is moving in 1 direction, the ions are moving in another direction, and then you have a potential difference. But there are lot of other aspects that we have to keep in mind so for example, the mass so mass of ion right. So mass of ion.

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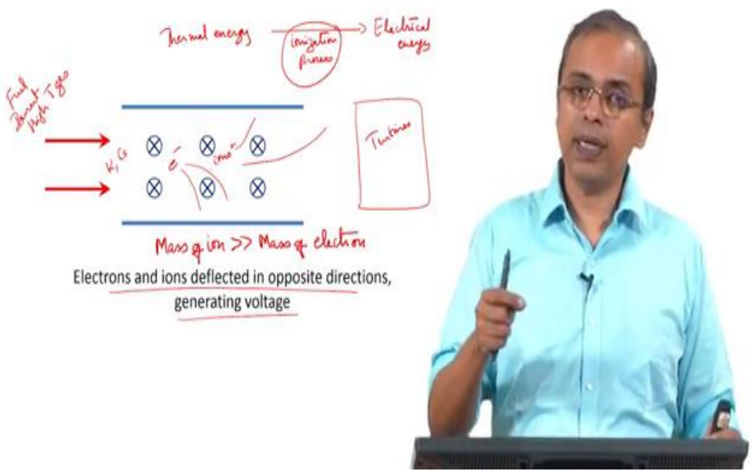

So let me put it here, mass of ion is much much greater than mass of electron, right mass of ion is much much greater than the mass of the electron. So, therefore, given the same amount of magnetic field, and the fact that it is all coming in the plasma to together, the extent to which the ion will deflect it will be lot less than the extent to which the electron will deflect.

The electron will deflect much faster much more steeply than the ion. So, you may have the ions much more gradually deflecting whereas, you may have the electron deflecting much faster, relatively speaking right. So, you may have that kind of a situation the electron will may deflect much faster, the ion may deflect much more slowly. So, you may even have some of the ions leaving this region without even reaching the electrodes. So, that’s a concept that you have to keep in mind.

Also we have to understand that as the electron begins to deflect, it is not it is not sitting in vacuum right. So, it is electron that is going along with a plasma that is moving right. So, when that happens you may have velocity of the electron in different directions, and based on which direction it is in the magnetic field can impact it or may not impact it. So, to the extent that there is a component of the velocity perpendicular to the magnetic field, it will start doing this deflection the way we have shown it I have shown you.

So, and as it deflects it doesn’t just deflect once and just go straight into the electrode, it will continue to deflect it will continue to deflect. So, in principle it can actually get into a loop. So, it in principle this can start traveling in a loop, over and above that if there is a component of the velocity in the direction of the magnetic field ok. So, if it is already in the direction of the magnetic field, then it is not getting affected by the magnetic field, it will simply spiral along that direction ok.

So, if there is a component of the magnetic field in that direction. So, a velocity electron velocity in that direction, because of the magnetic field also in that direction the deflection is happening like this due to the component of the velocity in this direction, but the component of the velocity in that direction simply pushes the electron further that way. So, it will spiral that way. So, it will just spiral that way and go both.

So, you are having that is itself 1 no motion that is happening over, and above that it is going to interact with the ions that are moving there, it is going to interact with the plasma that is moving there, some probability of interaction will be there. So, it is all statistical you have to see what the probability of interaction is and so on. So, it will have some interaction. So, the movement can be quite complicated it is not going to be quite simple it is going to be relatively complicated.

Because there are many factors here which are impacting the movement of that electron over and above that if you generate a potential also right. So, you have a you end up generating a potential like we saw here. So, we have a potential difference. So, now over and above the magnetic field you also have an electrostatic field right. So, because the so this means this potential has been generated due to let’s say the first set of electrons that underwent this process.

So, the fresh and the next set of electrons that are arriving will see this potential already existing, against I mean which will impact the may which will also influence the way they move. So, now they are moving in the presence of a magnetic field, as well as an electrostatic field. So, number of things are happening here, in addition you will also have a situation that if the electron is deflecting right, there is a relative to the plasma, there is some you know movement of the electron this way, and there is also a movement a relative velocity, if this deflection had not been there it would have moved further right.

So, there is some relative movement this if this way also. So, there is a movement this way there is a movement vertically down, and there is a relative movement a horizontally as well relative to the plasma. So, what happens is if you actually want to step back and see there is electricity in both the direction perpendicular to this movement original movement of the electron, and also in the direction against the direction of the movement of the electron.

So, this is referred to as the Faraday effect Faraday based effect which is causing this movement perpendicular to the original direction of flow of electron. And this movement which is happening you know due to this curvature as it happens in the presence of the magnetic field, and as a result it is moving actually slower than the plasma this is due to the Hall Effect ok, on the movement of the electron.

So, you can sort of see that there can be a potential difference in the vertical direction, there can also be a potential difference in the horizontal direction, generating if you just look at this region if you look at this region and you go from left to right there can be a potential difference due to this Hall Effect, if you go from top to bottom you can have a potential difference due to the Faraday effect.

So, it’s it’s a fairly complex situation that we are dealing with when you are talking of this kind of a situation where you have a hot gas going, you added something to it created a plasma, and that plasma is now interacting with this magnetic field it is generating an electric field, and then both of them are present, and then subsequent you know atoms, and I mean atoms that come there which become ions, and the electrons have to deal with all of this or are interacting with all of this. So, it’s a fairly complex situation that we have here, but still at the end of it we have a potential which is the potential that we tap, and then we get the load resistor to function.

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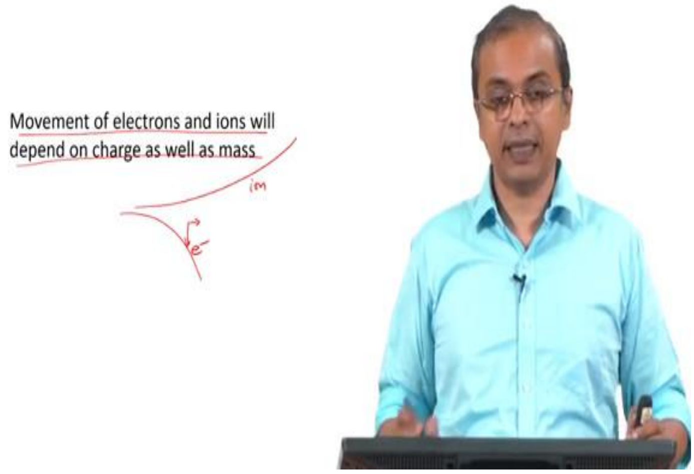

So, if you actually see we can as I said you know the movement of the electrons and the ions will depend on charge as well as mass right on charge as well as mass. And that is why we had this you know movement this way, we had the movement that way, and then even here so, this is electron that is ion, and then here also we were looking at what is the what is the extent of movement this way, what is the extent of movement in that direction and so on. So, all of that is happening in this generator at the same time.

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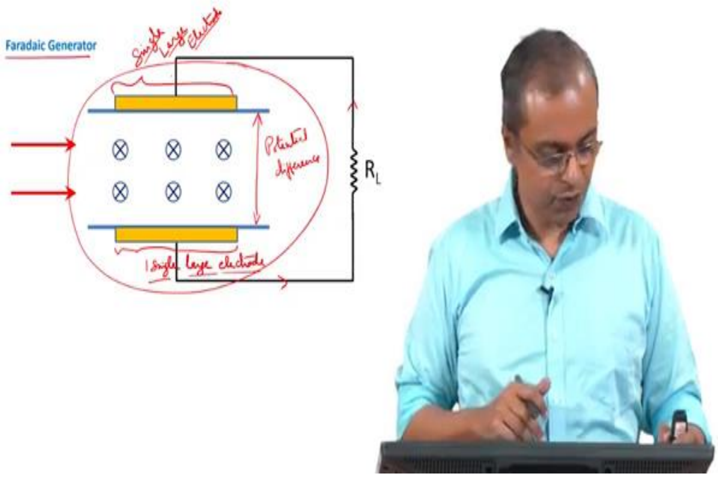

So, to the extent that we tap the voltage, as I said you know there is a potential difference here. So, there is a potential difference between the top, and the bottom of this unit. So, to the extent that we tap this potential difference between the top, and the bottom we refer to it as the Faraday generator ok.

So, so in the context of a magnetohydrodynamic generator you have multiple ways in which you can tap electricity, even from this you know this region this overall region which is the MHD generator, within this region after this it becomes a regular thermal power plant activity. So, and before this is also just the fuel burning. So, in this region you can tap electricity in more than one way; you can think of different configurations in which you can tap electricity, and then they and that you know usually accentuates 1 aspect of this process.

And then we try to capture it in that form, and so for example, this manner in which we are we are capturing energy where we put 1 large electrode here, 1 single large electrode right. So, this is 1 way we would do it similarly on top you will also have another single large electrode, so you put a single large electrode on top and you put a single large electrode to the bottom, and then you know connect the external circuit to it and then you get electricity.

So, you connect the external circuit to it, and then you have a flow of electrons, and you generate your captured electricity you have generated electricity which you are capturing elsewhere. So, what are we done here one of the things that we have done when and the reason that is the reason why I am emphasizing this idea that we have put a single large electrode on that side as well as a single large one single large electrode this side.

The point of emphasizing that is that as I mentioned you will also have the Hall Effect, the Hall Effect is also is related to the fact that this electron is moving in the presence of this magnetic field. And as a result in general it ends up having a relative motion with the plasma that was moving, originally it came with the same velocity as the plasma. Now because of the Hall Effect it may actually be moving with lower velocity with respect to the plasma. And because it is curving away and so, then you have to look at how much no displacement it had in the direction of the plasma.

So, so you have a potential difference that is coming from the horizontal moment of the electron. So, when you put a single large electrode you are sort of smearing that out ok. So, once you put a single metallic surface they are a single large electrode you are smearing that out. So, you are essentially smearing out the Hall Effect so you are smearing out the whole effect. So, the difference in potential in the horizontal direction is being ignored, and it is you know is being converted to 1 flat electrode of a common potential, and from that you are tapping the electricity. So, that is what is happening when we do this single large electrode kind of a configuration.

And there we are only looking at the effect that is in the perpendicular direction, and that is called the Faradaic generator. Now even though you may be doing a Faradaic generator by doing this kind of a single large electrode and smearing out this Hall Effect, you are actually not capturing as much of the energy, because you may have much better potential differences at various locations if you give the opportunity to pick up those potential differences.

So, what we do instead of putting a single large generate electrode on either side of this region we segment the electrode ok. So, the process that is used is to segment electrode. So, that you will now have a series of electrodes on top, and a series of electrodes at the bottom and you can pick them up as pairs. So, now, they are not in electrical contact. So, for example, it will look like this okay.

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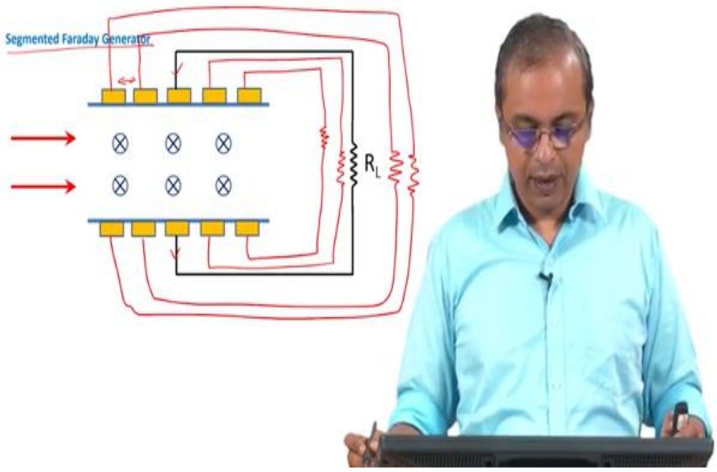

So I have a series of electrodes on top, I have a series of electrodes in the bottom, and I can pick them up in pairs. So, for example, I have shown you 1 path that I have picked up 1 pair here right. So, I picked up 1 pair here which is then connected to this load resistor. Similarly I can pick other pair. So, for example, I can pick this pair then I can pick this pair also and so on. So I can do that for this also right so, we can pick them up in pairs. So and each of them is individually electrically isolated from each other, they are electrically isolated from each other.

So, therefore, there is no it is not a you know it does not force the potential of that entire surface to be the same, if you have a conducting material it will force the potential to be uniform across that conducting surface, if you have the better the conductor the more uniform the potential will be it would be difficult for you to sustain a potential difference across that surface, and therefore you will not be able to capture the differences that may exist from point to point.

So, now on the other hand each of them is separate. So, I can capture this in so many different ways. So, I can have multiple you know generation processes happening where I take advantage of the fact that even in the X direction; the potential is varying from location to location. So, not only is it varying from location to location in the Y direction it's varying in location to location in the X direction. So, this is called a segmented Faradaic generator ok. So, this is 1 implementation in which this the magnetohydrodynamic electricity generation can be done.

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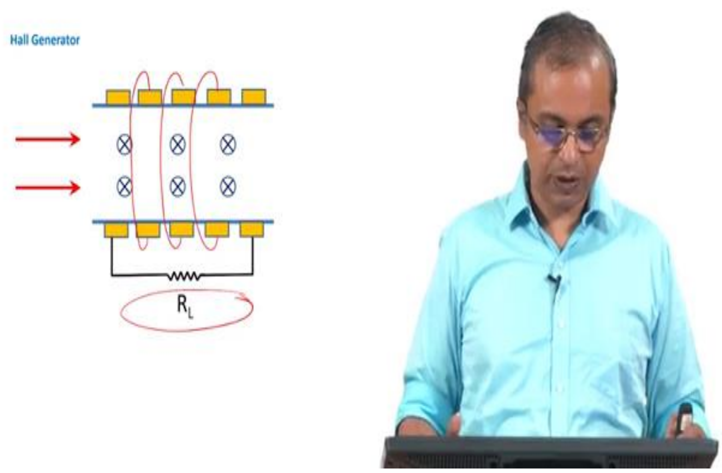

Similarly, we can also do a Hall Effect generator okay a Hall Effect generator is 1 where we say that we will you know short out the Faradaic generation process, we will only focus on the Hall Effect generation processes. So, these are actually shorted out. So, these get shorted out like that, and then you actually take the you know you take the electricity in this direction.

So, this is the hall generator so it uses only the Hall Effect generation Hall Effect related potential difference that shows up between the let's say the first electrode in the last electrode, and then you get the electricity out of it. So, this is the Hall Effect generator there are other implementations also which people look at which are not really in this mode. So, for example they create a disk so, they create a disk kind of a situation where the the fluid comes in the center of the disk, and then goes out radially.

So, you have a situation where the fluid comes in the middle, and then goes out radially this is now going what the images that I have shown you so far are linear I mean it is moving from left to right right. So, it comes in one direction continuous in the same direction there you change the direction you come in from the middle, and then you move outward radially, and then again you apply a magnetic field and so on, and then you generate electricity. So, that's a different configuration that accentuates some ways of generating the electricity makes it more compact. So, these days they focus more on this disk based generation system.

So, that's again something that people are looking at. So, in any case this is the whole generator, so these are different configurations in which you can set up this magnetic field with this ionized stream, and get you to interact with this ionic stream, and generate this electricity, and that is the manner in which this magnetohydrodynamic generation process happens.

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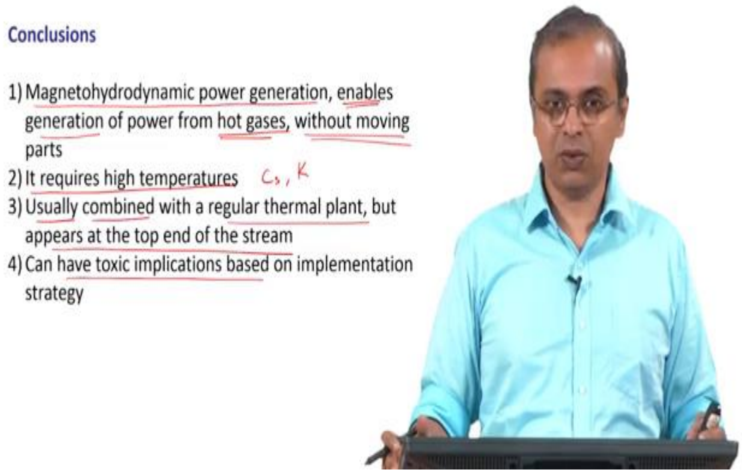

So to conclude our discussion on the magnetohydrodynamic power generation process so, the magnetohydrodynamic power generation process, enables us to generate power from hot gases without moving parts. So, I think that's something that we have to emphasize here, normally we are looking at you know in any thermal power plant and so on, you are looking at some moving part.

So, that there has to be a moving part eventually, eventually you will have to have turbines that are running that turbine rotating and that turbine has to be connected using a shaft and some gear system to a generator, and there you will have the you know you will have conductors which are moving relative to a magnetic field and generating electricity right.

So, at the end of the day there is a lot of moving parts there which are required to convert the thermal energy that's available in your incoming stream to electricity in your you know coming out of the generator. So, typically we require that, but the magnetohydrodynamic method of generating power creates a situation, where you can get electric power from thermal energy in an incoming stream without having any moving parts.

So, we are not talking of the electrons and ions as parts, where they basically part of a gas stream which is moving, and so we don't have any physical parts the solid objects that are moving. So, that is the thing it requires high temperatures, and here we are trying to our best to get away with the most reasonable amount of temperature we can go to without going too high, normally you are looking at you know if you are looking at many other many of the materials that we would know which we can ionize you are looking at few 1000 degrees centigrade requirement to ionize, and create plasma.

Here you can get away with a little lower temperatures, because you are using cesium and potassium. So, hopefully you can get away with a relatively lower amount of temperature in in the in the scheme of ionization so, but it is still a high temperature in the overall scheme of things. As I said it is usually not done in isolation it is usually combined with a regular thermal power plant.

But and it appears at the top end of that stream it appears at the earlier part of that stream, and that is how we you know first pick up some energy from this the incoming stream, using a non I mean; non moving part process, and without using this heat engine in the conventional sense, we just get electricity straight out of this stream, and then we send it to the thermal power plant. Of course, the; I mean the only other issue that we have to keep in mind is that it can have implications that are related to toxicity because you will have some of these ions which will show up in your exit stream, they will be present in the waste material that you generate from this stream, and the ash that will that comes out will have cesium potassium etcetera. So, you may need to do some cleaning process to get these out of the stream before you throw it out throw out the waste so to speak, and so that is an aspect of this technology that you have to pay attention to in the form of during the implementation process.

So, that is something that you have to keep in mind. So, that then is our you know summary of what the magnitude of hydro dynamic power generation process is. And as I said it is not a very common kind of you know power generation process that that we will be hearing about a lot, and that is the reason why most of us have not heard about it; however, it is something that people are definitely interested in and very keen and on looking at, because it increases the efficiency of existing power plants.

So, existing power plants efficiencies can go up; however, you are putting in an additional part into the plant. So, there is some cost involved in it and you may also need additional parts to do the cleanup of the ash after it has been generated. So, you may need additional parts. So, there is some you know infrastructure that is required some cost involved with that that is present here.

So, it is not without cost implications and that is the reason why it is not really caught on because people look at other ways in which they can you know in improve efficiencies of power plants. And in and given that there are competing technologies you have to look at the overall cost implication before you can really consider this as something that you really want to push, and that is the reason why it is still not as widely prevalent as I know many of the other technologies that we have spoken about ok.

So, that's our summary of the magnetohydrodynamic power generation, and a overview of how it works, and a in what is the context in which we look at this generation process. So, now to this concludes the range of you know power generation activities, and non conventional energy sources activities that we discussed through this course.

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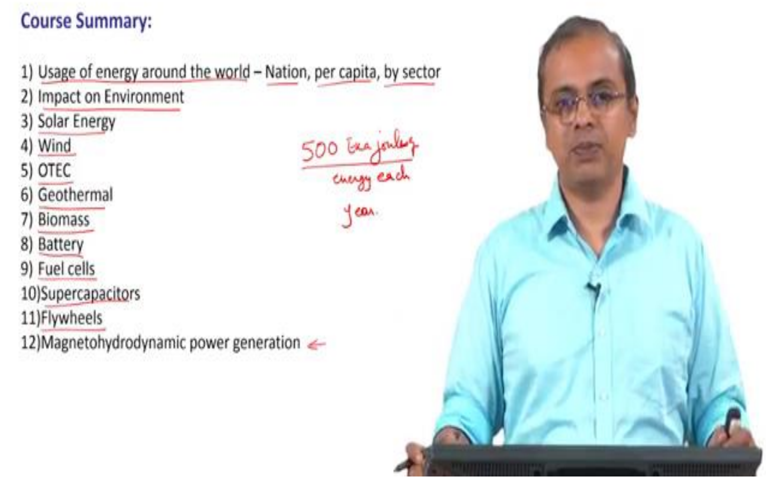

So, I would like to spend a few minutes just to summarize what we have done in this course. So, we started off you know with this 1 number we did some initial introduction where we looked at the usage of energy around the world, in particular we looked in great detail at you know how it varies from nation to nation, how it varies per capita from nation to nation, and also we looked at various things like you know how does it vary by sector.

So, how does the industrial sector use energy how does the you know residential sector use energy, how does the automotive sector use energy, which nations use energy more, which you nations use energy less, in the nation donation what is the difference in the mix of energy that they use the sectors which use more energy in specific nations and so on.

So, lot of detailing we looked at of this kind of you know pieces of information, and we also you know pulled all this information together by saying that human beings on average are using 500 exajoules of energy each year right. So, this is the thing that we saw we also looked at it is impact on the environment we saw you know that this idea that we don't make a difference to the environment is actually very misleading that even in the space of a 50 to 100 years you can easily double the amount of CO_2 in the environment, if you do nothing different, if we just continue in the current manner you will increase the CO_2 content 100 percent in just 50 to 80 years which is well within our lifetime, and the fact that you know there is a very strong evidence that suggests that if CO_2 percent goes up in the atmosphere temperature goes up.

So in fact, we also looked at the idea that you know the information that you know a planet like Venus is so hot because of the amount of CO_2 that is present. So, there is overwhelming evidence that carbon dioxide in the atmosphere raises temperature, and this overwhelming you know is even simple calculation shows you that when you burn fossil fuels at the rate at which we are presently burning fossil fuels, you can double the amount of CO_2 in the atmosphere in you know 50 to 80 years.

And also the fact that we already are at a level of CO_2 which is higher than what has existed in the planet in 100s of 1000s of years ok. So, we have already in the last 50 to 100 years we have reached a very unique situation with respect to the amount of CO_2 in the atmosphere, and we are likely to double that in then the next 50 to 80 years. So, that's the context in which we looked at this all the technologies that we have discussed in this course keeping in mind that there is a major environmental implication here, and therefore we need to do something about it.

And non conventional sources of energy offer us many options which are cleaner and therefore, we should look at them in this context we spend a lot of time looking at solar energy, because as we said you know it just comes down on earth we are doing nothing it is already falling on us most of the time we are complaining about it saying it is, so hot and so on and but that is energy that we can tap, and if you can tap it nicely, then it is very convenient to us we have solar thermal energy that we can tap we have solar photovoltaic energy, that we can tap and this energy is coming down to us roughly at about 1 kilo watt per meter squared that's following on us.

And in fact, every hour we are getting enough energy from the sun that more than exceeds this that matches or exceeds this 500 exajoules of energy that we require for the entire year. So, even with a lot of inefficiency if you just knew how to tap solar energy properly all our energy requirements are taken care of in a very nice manner.

We then looked at wind energy we looked at different forms of wind turbines horizontal axis, wind turbines vertical axis, wind turbines we looked at the limits of efficiency of the wind turbine the bits limit so to speak, and we try to understand what we can do in this context how much I mean, and also the fact that it is a very benign form of capturing the energy, it is also indirectly a solar energy based system because the solar energy is what creates the temperature variations, which results in this movement of wind across the globe.

We looked at the ocean thermal energy conversion, where we basically looked at the difference in temperature between the top surface of the ocean, and water which is about a kilo meter down, and there is enough difference there off the order of about 25 degrees centigrade, and that is there in with large thermal mass this large thermal mass that is sitting with this temperature difference, and then even though the temperature difference is not much and that you are going to get only some small amount of energy out of it the efficiencies are low. Still because it is just there sitting there and there is nothing else that is it is a very benign way of in which you can capture this energy, you can keep on doing this and you can easily set this up; so, that you can get a lot of energy to augment your energy sources. We also looked at geothermal energy. So, while OTEC is something that is now really relevant only for people who are in the coastal area.

Geothermal energy is really relevant to people anywhere in the world I mean anyway I mean the world people could use this of course, traditionally the use has been closer to regions where there are faults underground. So, that you can reach this hot temperatures much sooner, in with much at much lower depths, and then using that higher temperature you can you know convert water to steam, and then use that energy to run a turbine.

So, it's very clean because you are not really burning any coal you are simply using the heat from under the ground. So, that is geothermal energy we looked at biomass basically implies that you are burning plants, and trees and some product of plants and trees to generate your electricity or converting them to some you know converting corn to some form of liquid fuel and then using it, it has pros and cons because as I said on the 1 hand it is considered clean, because you are only reducing carbon that was already captured by the plant.

But on the other hand you have issues such as you may be releasing a lot of other gases or environmentally hazardous gases also out into the atmosphere, and the efficiency with which this the plants will give out the energy or the wood will give out energy calorific value may be less, and so you may end up burning more of those plants.

And also you have to keep in mind that you know a tree takes anywhere from 50 to a 1000 years to grow and that is that is how long it has taken to capture all that carbon, and I know you know sort of sequester that carbon so to speak and, but when you burn it the same tree can be burnt in 5 minutes time based on which plant you are putting it to use in.

So, you are releasing the same carbon dioxide in 5 minutes what was captured in you know say a few 100 years well has been released in 5 minutes, and that is exactly the problem that we have now I mean it’s not that we are suddenly creating this carbon from somewhere, but all this carbon that was captured by the environment by the earth over millions of years is being released very fast, and that rate of release is just not accepted we are not capturing it back at the rate at which we are releasing it.

So, in that context this is not a you know very good energy to form of energy to look at today even though people will argue that it is you know 0 carbon footprint and all that they will argue, but this is the problem that time scale is just not the same, if you want to capture all the carbon back in 5 minutes time you have to capture you know plant a huge number of trees you may have to know they will fill the planet with trees to just capture the same amount of a carbon back in 5 minutes.

So, that is something that you have to keep in mind then we also looked at batteries, and fuel cells which are interesting ways in which we you know get electrical energy using from the chemical energy, and both batteries and fuel cells are essential in the grand scheme of non conventional sources of energy, because most of them require some most of the other forms of non conventional sources of energy require some energy storage require some you know flexibility, and how that energy can be used with time and batteries, and fuel cells play a very unique and you know important role in that scheme.

We also looked at super capacitors and flywheels, mainly because they offer a different combination of specific energy, and specific power relative to say just batteries or plain capacitors. And so they fill in the sort of fill in the blanks between batteries and capacitors in terms of serving an energy requirement, and usually they deal with situations where the transition in energy is high.

So, you are going from you know you are suddenly accelerating a vehicle, suddenly applying brakes to a vehicle, and so you want to capture the energy very fast you want to release the energy very fast, then batteries are unable to do that capacitors are capacitors can do that, but only for extremely small fraction of time. So, super capacitors and flywheels bridge that gap, they give you significant amount of energy released over a period of a few minutes, and that is really what is a few seconds; to a few minutes which is what is necessary in a number of applications where the transition is the important thing that we are trying to cover ok.

So that is the context and finally, today we looked at magneto hydrodynamic power generation, which I told you is an interesting way in which you can increase the efficiency of a plants that generate the power plants that generate electricity. And but it is still not a very common way of a in which it is utilized, but nevertheless it is something interesting that people are looking at, and it’s at least 1 of those things that we should be aware of because that gives you ideas maybe of other ways in which people can try and look at the improvement of efficiencies of plants ok.

So, with that we conclude this course I hope you enjoyed it, I hope you found it beneficial, and I hope it gave you a very good perspective of non conventional sources of energy.

Thank you.

KEYWORDS:

MagnetoHydroDynamic Power Generation Process (MHD) ; Modes of implementation to generate power; Plasma; Creating Plasma; Seeding; Faraday Effect; Hall Effect; Faraday Generator; Segmented Faradaic Generator.

LECTURE:

This lecture describes about an energy/power generation technique called the Magnetohydrodynamic Power Generation, and an overview of how it works, and its application in increasing the efficiencies of existing power plants.