**Wind Energy**

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**Lecture 01: Introduction to Renewable Energy**

Welcome to this particular course on wind energy. So already through the introduction video, you got an idea about what are the topic that we are going to cover in this particular course. I mean, essentially, we start with some of the introductions of the renewable energy and the renewable energy status, and then we'll move to the wind energy. And then obviously we'll look at the different fundamental aspect of the wind energy. And then what we'll do, we'll actually go to the different wind turbines. Essentially, we start with the horizontal axis wind turbine, then we'll move to the vertical axis wind turbine.

Obviously, while doing or talking about these turbines, we need to understand their basic working principle. And to understand that, one has to also understand the fundamentals of the fluid mechanics. and then probably once we talk about this different kinds of turbine. We'll move to the then dynamics and the control of the turbines, and towards the end, we would like to talk about some of the other wind energy harvesting harnessing methods and then probably we may look at different modeling aspects.

So, essentially what we are going to talk about some of the modeling perspective in terms of computational fluid dynamics and how things can be modeled so that's the overview of the particular course and let's start with today's discussion, which is on wind energy I mean the introduction. so as we said, so what we are going to look at it is the looking at the wind energy status or renewable energy status in India and what are the renewable energy sources and things like that so obviously wind energy is one kind of renewable energy so this is one kind of renewable energy so that is wind energy. so before we move on and discuss more about energy the idea here is that We'll look at the energy, renewable energy perspective, and also look at the situation at Indian scenario or the status in the context of Indian RE. So obviously, we'll start with some global energy perspective or some of the database in terms of global energy and things like that.

And then move to, so if you look at the, this is obviously the data that you see it here. This data is based on 2023 yearbook of world energy and climate statistics. So they do publish this kind of data. If someone is interested, they can go and look at the data.

So as for the data, you can see how this different countries they stand okay. so obviously it's a energy consumption so it includes every kind of energy including your day to day life consumption, i mean obviously this kind of includes the overall country's consumption there i mean the not only the human being consumption also there's the industrial consumption then you have different sector of whether it's a public sector or private sector their consumption then it includes your automobiles everything. so what the data shows importantly if you see that they obviously in 2022 this has been slowed down a bit but still it's quite high okay and you know the consequence sequence of that thing. i mean once you have this kind of energy consumption then you have to, i mean there is a i mean it's a cash 20-20 situation you cannot certainly get away with all this i mean energy consumption because once some country is growing if there is a development happening then you can certainly reduce the consumption but yes what one have to think about is that how you have this energy. So once somebody requires some amount of energy then you need to produce that so what one has to look at it is that the ways of product producing this energy, so this is where the across the world the renewable energy production has been emphasis throughout the globe because we cannot really cut down our day-to-day consumption but rather obviously to some extent one can control; but yes, if you are developing if you are happening industrial growth and things like that the energy consumption would definitely increase but to counter that one should have a mechanism in place where you can more produce energy through these renewable sources rather than producing through the conventional sources, which has been the major source of energy till today.

So that's where the whole emphasis across the globe is that how more and more energy production can be done through these renewable sources. This data shows some kind of an gdp and populations obviously again this is a data from world energy outlook 2023 so this data keeps on they keep on updating the data and then their population level and energy consumption like that. Now moving ahead if you see the global energy scenario here you can see the different situations here. so and the different country so this gives you a variation across the countries and their kind of energy production situation and their utilization. And obviously, different country has taken different strategy to elevate this problem of the energy production to the conventional sources, which is one of the major cause behind the global temperature increase.

So every, I mean, every country like United States, European Union, Middle East, India, so they are trying to ramp up their renewable energy production sources and slowly reducing the conventional energy productions. So, once you try to reduce that obviously you will have an impact in the global temperature change or the global impact on the scenarios. So, these are again, these are the database based on 2023 outlook. why also

one has to think about that why do we need to really move for this kind of renewable energy production? Obviously, that one of the major sources that we have so far is the crude oil, but obviously this is not going to last forever then the gas natural gas, obviously coal which is the biggest source of your thermal energy production. so i mean obviously we cannot really think without gas or oil or things like that but as you know these are the these fuels are all essentially hydrocarbon based fuel and once you use hydrocarbon based fuel obviously one of the major concern is that the emission or CO2 emissions CO emissions those emissions or the pollutant formations rather and they are contributing to the global scenario so obviously, if you try to see what are the factors that one has to really worry about or which are actually forcing us to think about that okay now time has come you have to buckle up and start thinking out of the box, so one important is that the your policies in i mean in terms of oil or gas uses so that is what i would like to put them in the volatility in the prices so we are all kind of very comfortable in getting low cost oil and obviously you can burn more and more but obviously oil and gas has their own hazards okay.

then it comes the energy security So, which is essentially talking about imports from usable parts of the world where you have, and more importantly, the environmental concerns. So, this is something of biggest concern, the emission criteria of the pollutants from the fossil fuel burning or rather hydrocarbon fuel burning or rather this conventional fuel burning. So, they are very very key clear in terms of global warming. So this is a key player, key component, I would say, in global warming situation. So one has to kind of make these balances out so that you don't.

So what that has caused is that the climate has changed okay and this is continues to change so you can think about that your global mean temperature has increased by certain factor okay but this has been a increasing trend so you cannot really sit back and relax that Obviously, your global sea level has gone up. Your global precipitation over land has also gone up. Your temperatures are increasing. So these are all what is hinting that we are going or moving really fast towards the global warming or rather these are the things which are contributing to my global warming scenario okay. now, if you see the global emission okay so this shows that you have to estimates or indicate that approximately 80 percent of all your carbon dioxide emission currently from fossil fuel.

So this is what is happening this is the major source of the problem obviously they have come up with an climate change debate and you can see that how your this emission picture pans over different Sectors. Okay. So, this is Carbon dioxide. So, You can see the whole. This is country wise distribution.

So, you have distribution across different industries. Okay. So, That provides a kind of a broad idea or perspective about the situation that you have in terms of these global emissions. So, if I have to kind of put things in a very nice perspective, our primary energy source at this moment is the hydrocarbon based fuel for the fossils primary energy source; but this has a known problem of emissions and all this which is leading to or rather facilitating the global warming scenario and for that we could see there is a huge climate change across the globe. So, every country is getting affected due to that.

So, the whole world is now trying to heavily emphasize that i'd like to go towards the renewable energy sources so, that it can cater to my energy demand because your energy demand is also increasing every day. So, it can cater to your energy demand, but then at the same time, it move towards alternative resources. And every country has taken certain deadline or timeline to buy that certain time or such and such, that they would like to kind of cut down their use of these conventional fuels and move towards that. So it's just like If you are using 80% of the fossil fuel at this moment, probably after a certain time, maybe a few years down the line or over a decade, you would like to use that 80% to be renewable sources, rather than 20% to be fossil fuels. So that can contribute towards all these elements.

Now, obviously, if you look at the potential impact, you have health impact which is very very critical for everybody and which is a growing or burning issue across different countries; especially the developing countries like india you have agricultural impact. So, once you have climate change then your rains and all these things that are going to also change, so the cycle of the rains and the sun and all these so they have severely impacted the agricultural impact. Forest impact, obviously, there are a lot of forest burning happening, and if your forestation goes down, that has again a counter-effective impact on the climate. So these are kind of connected. So then you have water resources, so the supply, quality, availability, everything.

You have huge impact on the coastal areas so that there will be erosion of the beaches, coastal lands, additional cost to protect. Then obviously, you will have overall, you will have impact on the nature. So what is happening in the climate change, your sea level is rising, your precipitation level is rising, your temperature is rising. So, everything is getting kind of increasing day by day. so that these are having a huge impact.

Now, if you look at the climate impacts in South Asia or Southeast Asia, you see this where India actually, so India stays here. This is Afghanistan, Bangladesh, Bhutan, Pakistan, Nepal, Malaysia, And we try to categorize them in different factors. So, if you

see the factors, one, the sea level rise, so where obviously the impact on Bangladesh is comparatively higher. If you look at the glacier melts, obviously all these countries are having heavily impacted. Because then if you see the temperature rise, pretty much except Malaysia, because that's slightly down the line.

In terms of altitude or latitude so the temperature rises and cause of concern flooding worsens, obviously india is there, drought india is there. So, all these factors are kind of affecting these countries in this particular region and Needless to mention that India is not an exception. We are also having problem in each of the sectors which are literally contributing towards the global warming or the global climate change. So, there is a message from our ex-president, Dr. Abdul Kalam. I mean, he told, that cut down the energy losses. So this is a very important statement. One has to really sit down and think about it. See, we are, due to our technological advancement and things like that, we're kind of used to use more gadgets, different items, and all these things.

So we are inherently increasing our energy uses see end of the day it's a energy whether you are using electrical energy, thermal energy ,or different energy ;it really doesn't matter it's an energy and the source is one. So he was kind of pointing that we should reduce that so what was important is that Utilize technologies to provide diverse supply of environmentally friendly energy. So that is another message here. And also what he said that by 2030 we must achieve energy independence including cutting down in all sectors. So that means, we should increase the power generated through renewable energy sources.

So, I mean, this is the nation's first and highest priority. So he told this in 2005 that what one has to kind of adopt for policy should be taken into consideration in terms of energy. that leads to very important question is that why do we need renewable energy resources? that is number one; then why can't we just continue to use non-renewable sources? if you look at the global CO2 emission which is Obviously, the data is up to 2022, which is from IEA side. So CO2 emission has gone really, really high in last seven decades or 70 to 80 years.

Global warming is increasing. Ocean acidification, that's going up. Sea level rising, that's happening. Ice melting, that's also increased. You have retreating glaciers. decreasing arctic ice at a rate of 13-14% in each decade so you need renewable energy which is crucial for mitigating the climate change because your climate change is happening at rapid space so one has to mitigate that.

So, i mean now that kind of tells us why are i mean that why we really need to go for these renewable energy sources i think by this time the kind of convince that the whole world why that is moving towards this energy renewable energy. so what one has to understand what are the renewable energy resources that we have then look at some of this example and which renewable energy resources do we use in india, so if you put them together obviously this is your wind this is your solar this is your biofuel, this is hydro, this is geothermal. So your resources are kind of spanned over different ones. Obviously each of these different kind of renewable productions has their own nuances. There will be some advantages, there will be some disadvantages.

And, certain locations you can use certain type of renewable energy resources and certain locations you may not be able to do that; and what are the research that is now currently going on on renewable energy resource and what kind of key issues the researchers are trying to address obviously important key is that how this energy resource would be used to generate electricity because that is one of our major source of consumption and obviously how much electricity is currently being generated from these resources and how this has changed over time so that once we have some of this information on the database about all this what are the positives of using these energy resources obviously there could be negatives and one has to look at the negatives of it as well okay. So with that motivation in mind one can look at how this renewable energy so the first of that kind as i said i mean this is just to give you an idea I mean, this probably you might have seen across when traveling the different parts of the globe or even within the country. These wind turbines, these are called horizontal axis wind turbine, just for your information, though we are going to talk about more later. This is a typical structure.

You can see these are the blade. You have the nacelle which is holding all the rotor unit and all these things. You have a tower. So you need a basement to hold it. And obviously you can have one of them and you can have multiple of them.

And that's all. If you have a lot of them kind of located in one particular area, they are called wind farm. So obviously, if you have more of them, then you can produce more energy. Obviously, optimizations and all this, how you adapt to all this, that's the question. So what you need, you need strong winds. You probably may need to install a clear place.

Obviously, how you can align your turbines to the wind directions and things like that. So it's a simple... mathematics which can give you an idea how much essentially the wind power give you so that's some of these parameters which is one can estimate the power is

half of the density of the air, area which is obviously the projected area of the wind turbine and the velocity.

So, the power is measured in watt and then you can convert that to in terms of electricity. This is, as I said, the area is the swept area. So that means if an area is high, I can generate more power. That means if I have a larger wind turbine, I can generate more power. If a wind speed is high, I can also generate more power.

$$\text{Power} = \tfrac{1}{2}\rho A V^3$$

Larger wind turbine = more power

$\rho$ = air density; ~1 kg $m^3$
A = swept area ($\pi r^2$ )
V = velocity ($m\ s^{-1}$)

**Power is measured in Watts**

So, that means these two quantities, I cannot really change the density of the air because that's the property of the particular fluid. So what you can definitely change, and that is why we can see that over the decades, how the size of the horizontal axis wind turbine has gone really, really high. One of the reason is that more and more you have, so if you have more area you produce more power, if you have a higher wind speed so you produce more power. so you can see that the simple calculations if your wind speed is having five meter per seconds and if you have a diameter of one meter then you can actually estimate how much power you can generate from this particular wind turbine, now one can always say that i can increase i mean i can locate or install my wind turbine a place where my wind speed would be five maybe 10 meters obviously power goes up. if my increase from one meter to two meter then also power goes up so that's how the researcher they are trying to optimize that obviously it depends on the geometrical locations what is the typical wind speed across the year you had and how I mean, or what would be the best possible size of the wind turbine that you can install in those locations so that you can have more and more power.

So these are some things that which has been what people have been working on. And when you go more details discussion of the horizontal axis wind turbine and things like that; We would also discuss more that it's not always like I keep on increasing my size and I would be able to generate more power because there would be other issues associated with that. Obviously, you have to think about the whole. So, that means it's not

necessarily that you keep on increasing the turbine size or without looking at the other factors, as I said. I mean, there is a restriction of having a really, really large structure like that because one has to consider the impact on the foundation, on the tower design.

So, that part we'll talk about more as we go on with this particular course. I mean, how you optimize your design and what are the parameters that one has to consider. Although we would be mostly talking about in terms of the aerodynamics design of the turbine, but we do touch upon the structural part as well because how the load due to the weight is going to impact on the load of the structure. I mean, one has to look at the complete scenario, not only looking at the power production part. Because if you look at the power production part, perspective, you would like to only, I mean, ideally you would like to increase your area or you would like to install things where you have large wind speed so that you can produce more power.

It's theoretically possible. There are other practical constants which we will discuss as we move on or go along with this discussion in the future. Thank you.