Energy Conservation and Waste Heat Recovery
Prof. Anandaroop Bhattacharya
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 51
Energy storage systems – I

Good morning and welcome to the next lecture of the course on Energy Conservation and Waste Heat Recovery. So, today what we will do is we are going to start with a new topic a very important one at it is on Energy Storage.

So, let me write it down Energy Storage, now what is it that I mean by energy storage? If you look at it the demand for electricity and when we are talking about you know the energy that we use in our day to day lives the most important form is electricity.

Now, the demand for electricity if you look at it has a variation it is not constant right. So, depending on where we are whether it is domestic use, whether it is industrial use, whether it is an educational building an academic campus. What happens is if you plot the electricity demand over a period of 24 hours in a day, we will see that there are certain periods where we need more electricity, which we will call the peak periods and there will be certain days or certain periods during the day when we will have less demand.

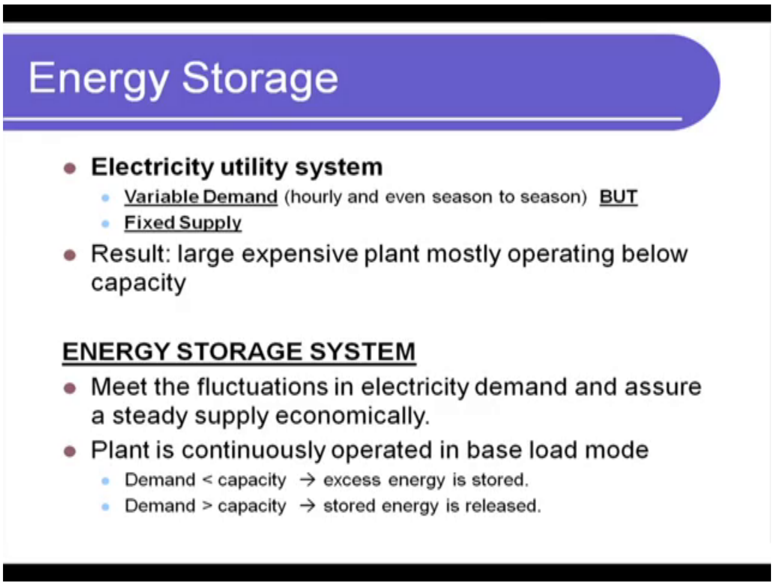
So, there is a fluctuating demand if we plot the electricity demand over 24 hour period we will see that the demand is not constant it is other variable. So, this is true not just on a daily basis, there is also a seasonal variation for example, in our country or at least the part that we are in where the summers can be very hot the winter not so much. We will definitely have the air conditioning load during summer months, which we would not have in winter.

Similarly, if we talk about cold countries it will be the opposite summer if the summer there is mild it is, but in winter you need heating right. So, therefore, we will see as seasonal change from summer to winter and one can be higher one can be lower depending on that.

If we talk of an academic campus like ours we will see that the demand the electricity will be less during the vacation the electricity consumption or demand will be less during the vacation periods because that is the time when class classes do not happen and therefore, the electricity usage in classrooms across the campus is very lower compared to when the semester goes on.

So, that is what is the crux of the problem today the fact that the energy demand is not constant throughout the day.

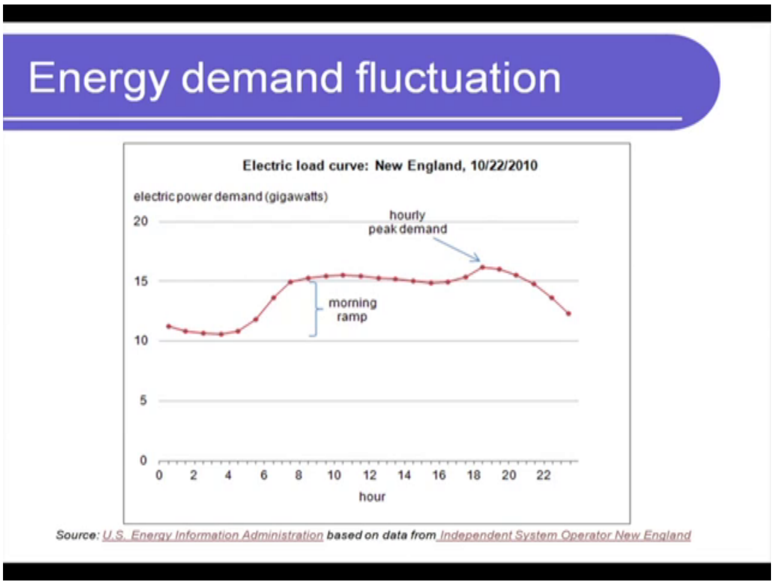
(Refer Slide Time: 03:05)



So, if you look at this slide that is what we are seeing that the demand is variable it is an hourly even season to season, but; however, the supply that we have or is the peak supply that we can have typically from a power plant is constant.

It is well strictly speaking the power plants also have feedback control systems by which they can control the steam and the steam rate therefore, the inner thermal power plant the amount of coal that needs to be burn and spawns and so on, but rock, but if you ask any plant manager in a power plant he would be very happy if the supply throughout the day is constant. So, that is the ideal what they would like to do. So, that that makes things much simpler and the operation also we are simplified all right.

(Refer Slide Time: 03:58)



So, we will come back to this slide this is what we are talking about this is a typical curve that I got from the us energy information administration and this is New England well New England is a state in USA it is not in England it is in the eastern part of USA, that there is an area called it is not a state actually there is an area which consists of few states which is called the New England area. This is a data from 2010 but again this is just to show the trend it is not going to be too different.

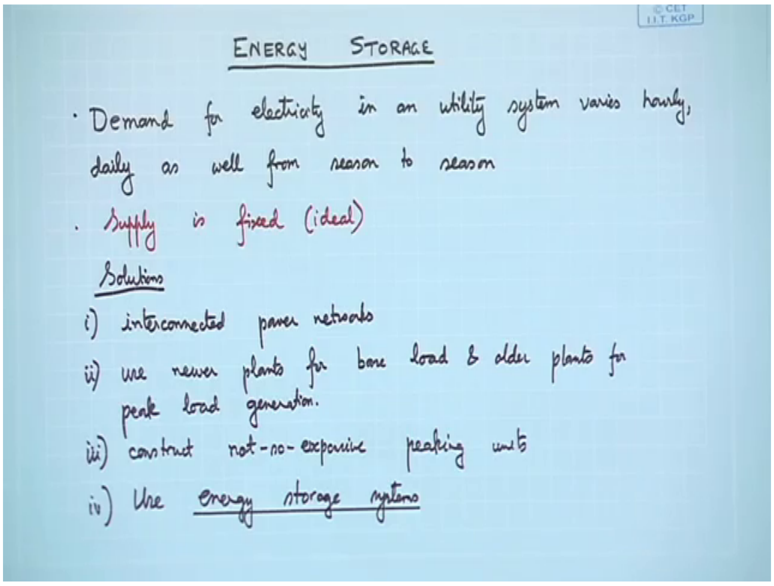
So, if you look at the electric power demand in GIGA watts what do we see from midnight if we look at it from if we start from the left hand side this is midnight. So, this is the time when most of the world sleeps except maybe there is maybe some night shifts that go on maybe the street lights are on and a few other. So, the level of activity is much lower and then people start waking up after 4 o clock between 4 and 6 that is when people wake up. So, then the energy consumption goes up and then the day working day starts at around 8 o clock in the morning and goes on till about 4 5 6 pm like that and this is where therefore, we see that there is a much higher demand for electricity or the load therefore, which dictates the demand is higher.

And then after the working day is over when we come down we will see that the demand slowly comes down, well this demand is still higher compared to you know this midnight and after because this is also the time when business outlet us are open the shops are open and then they slowly start closing down the traffic lights on the streets come out come up. So, therefore, you see all this and then slowly you will see that the electricity demand goes down as the day progresses as we goes towards the time when the world goes to sleep.

So, therefore; however, on this one if I plot the electricity supply then most likely it will be a constant line almost ideally it will be a constant line. So, that is what we are saying that the therefore, what happens is we have to design a power plant for the maximum peak load and that is not a very smart thing to do because this is a large expensive plant mostly operating below it is capacity, and the problem of operating it below it is capacity if something is rated for let us say x megawatts and we are operating it at let us say 75 percent on an average we are operating it at 75 or mostly less than 75 percent of it is peak rating for most of the day. Then it is not a very smart usage of the power plant because it is not only the fact that we are we have over designed something, we also know that if we do not if we operate at part load then the efficiency also goes down . So, therefore, that is not a very desirable thing to have all right.

So, let us now shift to the paper or to the board here and what we will therefore, say is let us just jot down a few points that we talked about.

(Refer Slide Time: 07:15)



We will say that the demand for electricity in a new utility system, which can be anything utility can be industrial can be domestic, can be an academic campus and so on. In an utility system varies hourly there can be day to day variation also. So, weekends will have less demand compared to week days daily as well as from season to season however, but the supply is fixed let us assume this is the ideal condition.

So, I would say ideal condition. So, now, how do we solve this problem? So, let us think about it especially with shrinking fuel availability, I mean I really do not want to waste any additional energy that I generate. So, therefore, what are the things that we can think of what are the ways that we can think off? So, a few things that I can think of for example, is let us have a network of all these different power generating units which will talk to each other and. So, therefore, in one place if it is operating below ah I mean where the demand is low and at some place the demand is high we will have a supply intermittent supply from one unit to another to meet the fluctuating demands.

So, I would say is what are the solutions? So, let us quickly jot down I will say what I just say it is interconnected power networks that is definitely one way, but it is very complicated, but it is possible sure.

Second we can say that we will use the whatever new installations that we have we will have the rating at the base load which is average load and then use the older plants to meet peak load. So, have new and more expensive plants for rated at the base load and use the old and existing plants for supplying the additional power that is required during peak hours. So, let us write that use newer plants for base load newer and more efficient plans for base load and older plants for peak load generation.

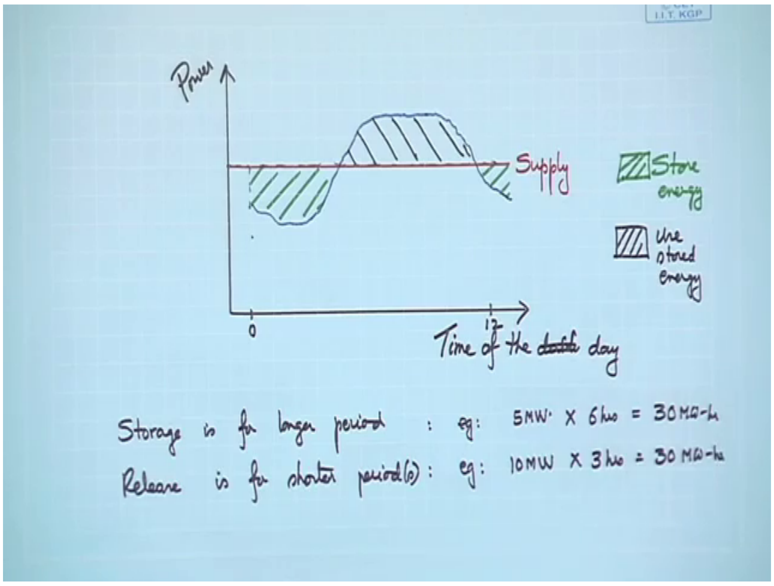
The other thing is hand in hand I would says you construct not so expensive peaking units. So, fine I am going to have all my the rating of my power plant will be the base load and then I will have some not so efficient maybe small lower cost infrastructure plants just to supply that additional power that I need during the peak hours.

The fourth one is use energy storage systems. So, this actually is what we are going to talk about in the next few lectures all right. So, what is energy storage system energy storage system means that during the low of peak hours if mean if it if you say. So, let us say during the night time I am going to generate additional electricity than what I need right. So, I by some means I am going to store that electricity in some form remember electricity by itself cannot be stored electrical energy it is not easy to store.

So, that energy I will store in some form and later we will recover that energy and use it during the peak hours let us say during the daytime when the when the during working hours when the demand is much higher, I am going to supply most of it from my power plant, but there is remaining the average load, but the additional load during for the peak will be given from the stored energy that I the energy that I stored during off peak hours.

So, this is what I am saying that meet the fluctuations he let this amount and assume and assure a steady supply economically. So, plant is continuously operated in the base load mode. So, when the demand is less than capacity which is off peak hours, the excess energy will be stored and when the demand is greater than the capacity the stored energy will be released to meet the additional demand.

(Refer Slide Time: 12:58)



So, if I want to draw that varies in a simple form I would draw it in this manner, I would say this is my power let us say this is power and this is for the time being let us say this is time of the day I am talking about a daily variation time of the sorry . So, what did we see we saw that if we start from midnight and then go on till midnight here we saw something like this, we saw that let me say this is my average I am going to draw just one line here. So, let us say this is my supply this line this red line is my supply, but my demand is going to vary it is going to be low and then slowly it peaks up it remains high and then slowly it kind of comes here this is what we saw.

So, what happens this part is where the demand is less than supply. So, what can I do I can store? So, I would store energy and this part I would say is I would say use stored energy. So, what it means is I have a steady supply which during off peak hours is more than what I need. So, therefore, the additional supply that I have will be stored and which will be used during the peak hour when the supply is less than what I need clear. So, this is how it is done. So, the way I have drawn is a little different actually this line the supply line should be a little higher because what happens is the storage is for longer period typically is for a longer period and release is for shorter period or periods I would say it can be really more than one.

All right. So, example let us say I would say is 5 megawatts times 6 hours. So, this is thirty megawatt hour and the release let us say is 10 megawatts times 3 hours. So, this will be also 30 megawatt hour. As we will see these 2 are never equal because they will always be some losses the amount of energy that we store is the turnaround efficiency as we call it the energy that we get versus energy that we store, they are never the same the turnaround efficiency typically is less than 100 percent. So, which means the energy that I can release from the stored energy is always less than what I initially stored clear. So, this is what is the basic crux of energy storage.

Now, before we move on and talk about the technologies for energy storage, let us just spend some time on what is the kind of energy storage that we require well that depends on the application. So, over here you know what I say it is about megawatt hours that are the amount of energy that is stored clear. So, energy definitely is one important parameter the other one; however, is power now energy and power are not the same remember keep that in mind depending on the application you may need a high energy or high power.

So, let us think about this let us say if I have 2 run an industry during the working hours, then what do I need high energy as well as I need high power because a lot of equipments are running. So, that amount is not less clear. So, that is an example where I need high energy as well as at a moderately high power level clear.

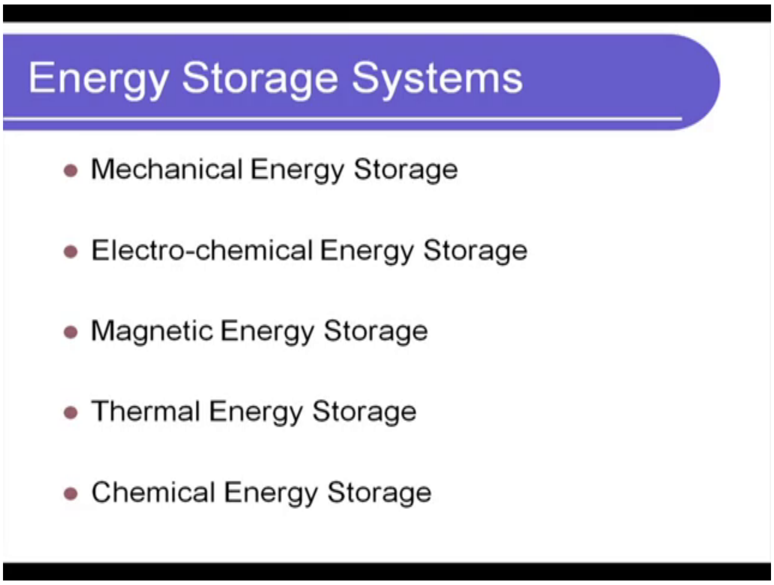
Second one let us think about our cell phones we charge it and we store some energy, but what is the energy consumption it is in Milli Watts k, but we need large battery life right. So, we need to store a decent amount of energy, but the power requirement here is low.

So, that is why our battery life I mean once we charge our batteries it runs for at least on your smart phones at least for a day or it should at least run for a day. If you are a moderate user for a light user it may be even higher for a heavy user it will be less, but typically that is what that is an example where we store the amount of energy stored is decent of course, I am not talking about megawatts and power plants and all, but the power requirement is much lower. So, therefore, the period for which the stored energy is released is long clear by the way this is not this is not per say an example a correct example for a power plant energy storage, but this is just to give you an example of an application where power is low, but energy is moderate.

Another one example is let us say in the morning if you go and start a factory then what happens immediately I would expect all my equipments to be running or at least to be optimal to be ready for operation. Now there is always a lag I mean my generator is not going to start I mean it is not the energy that I am going to get will be from the kinetic energy of the of my generator shaft. So, therefore, I am not going to get it is going to be difficult. So, what will happen is slowly the speed of the generator will come down and therefore, the frequency will come down then that will be sensed by the by the control system of the power plant and so the fuel burning rate will be adjusted. So, that more steam is generated which is fed to the turbine which in turn turns the generator and then the power and so which is fed to the turbine therefore, more work is generated more mechanical work is generated and therefore, the generator which is fed to the generator and then I get the power demand.

But after the initial period for a few seconds I need an additional supply of energy, from some stored means and this is an example of an application where the amount of energy that I need is probably not very high, but the power requirement is very high I may be needing it for a few seconds, but at a very high level right. So, these are examples I mean if I store energy depending on where I use it is important to know what are the energy and power requirements clear.

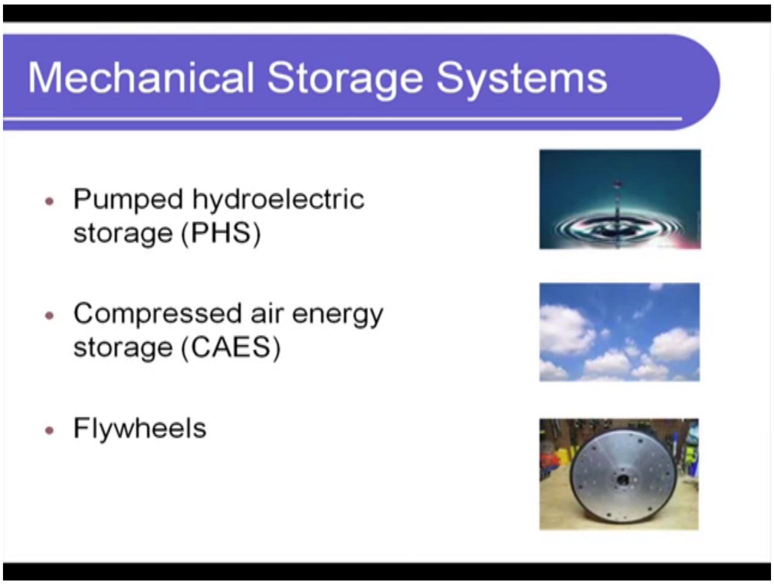
(Refer Slide Time: 21:01)



So, with that now let me move on to what are the different kinds of energy storage systems that we can think off. So, what we are going to study here we are going to study some forms of Mechanical Energy Storage, we are going to talk about Electro-chemical Energy Storage electro chemical probably is the one that we are most familiar with which is batteries. When we talk about energy storage portable systems the first things that come to our mind is battery. So, electrochemical energy storage 12 is the one that we use most of us use in our daily lives, we are going to talk about magnetic energy storage thermal energy storage and chemical energy storage this chemical energy storage is different from electrochemical energy storage keep that in mind all right.

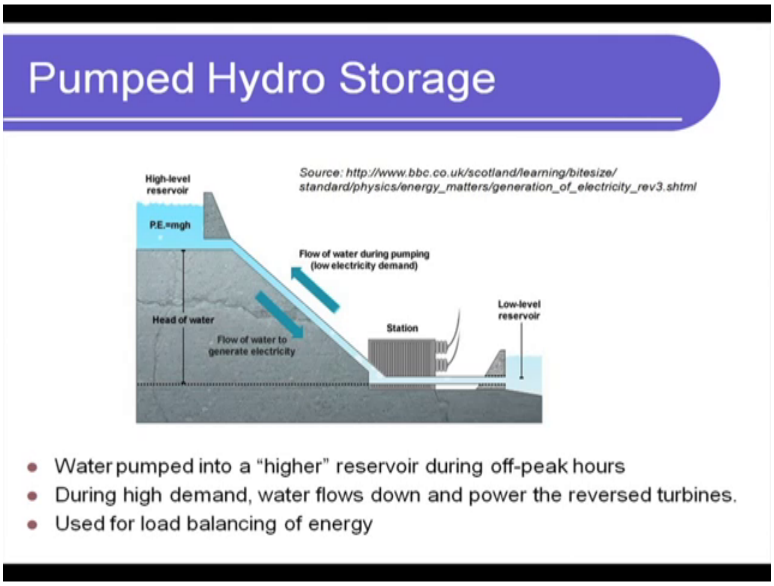
So, what we will do is we will first look at 3 examples or 3 types of mechanical energy storage schemes.

(Refer Slide Time: 21:52)



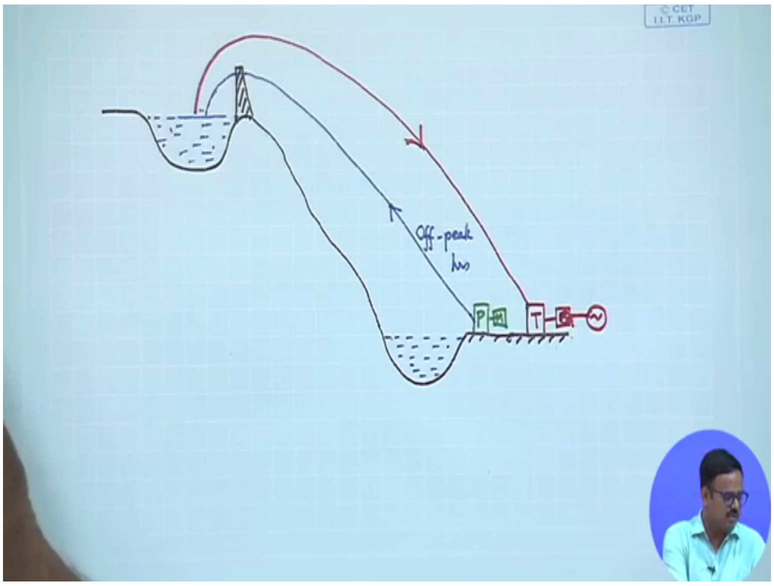
So, these are the 3 the first one is called pumped hydro electric or pumped hydro is what we are going to talk call it in short. Next one is compressed air energy storage or CAES and the third one is flywheels fly wheels probably as mechanical engineers you would have studied and during our mechanical engineering bachelors course we are going to recap that once more in the context of energy storage.

(Refer Slide Time: 22:31)



So, the first thing that we are going to talk about is pumped hydro electric storage or pumped hydro. So, what is pumped hydro? So, pumped hydro storage actually means that or what it consists of is let me explain that it is shown in this picture that you see here, but let me also draw it in the on the board or yeah on the paper here what it essentially consists of is for pumped energy storage you need a height or a cliff or a hill or whatever at the bottom of the hill you need a reservoir a water reservoir and at the top of the hill also we would like to have another reservoir.

(Refer Slide Time: 22:56)



So, typically we would also have a dam over here right now what happens over here is that during the off peak hours, I am going to use the additional electricity that I have at my disposal to run a pump, that is going to pump up the water from the lower reservoir to the higher reservoir. So, which means during off peak hour I will have a pump let us say this is a pump connected to a motor and what will happen is during off peak hours the water from the pump will be transmitted and just showing it in a schematic.

So, what happens this is during off peak hours all right, now what happens during peak hours the same water which was pumped up will now be brought down. So, let me have a turbine here where is my red pen yeah here, this is where I need more energy. So, here also I have a motor and during peak hours what happens is this water comes down and hits the turbine and rotates it and generates electricity. So, this is a sorry this is not a motor this is a generator. So, this is what this is the overall concept of pumped hydro or yeah a pump hydro energy storage.

So, the way I have drawn the schematic is it is definitely in the in a pictorial manner in reality what happens is the pump and the turbine are not necessarily separate turbo machines. So, as we know from our mechanical background Francis type of turbine it can work both as a pump and a turbine clear. So, that is possible and from electrical engineering viewpoint if you have studied electric machines you would know that the same rotating machine can be used both as a motor and a generator. So, essentially what I have drawn here pump and motor as one assembly and turbine and generators as another assembly is not necessarily to separate assemblies there are many a times the same.

So, this is what I have am I am again showing over here which is a picture from BBC from one of the sources which I have mentioned here. So, this is the high level reservoir and this is the low level reservoir. So, during off peak hours what happened the water is pumped up and therefore, it attains potential energy. So, that potential energy during high demand is released as the water flows down and it powers the reverse turbines as I said transistor turbine is one example and that is how we generate additional electricity.

So, this in a nutshell is the principle of pumped hydro storage. So, what we will do today is we are going to stop over here and in the next lecture we will take off from here and do a little more analysis a deeper analysis of pumped hydro storage and also look at some of the examples of installations across the world as well as in India.

Thank you very much and see you in the next lecture.