Design of Power Electronic Converters
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Lecture 01
Introduction

Welcome to the course on Design of Power Electronic Converters. Power Electronics is the electronics that is used for conversion of power from one form to another form. Power may be available at a one voltage or frequency level and we may need it at a different voltage and frequency level. So, we have to convert it and power electronics is the means by which we do that.

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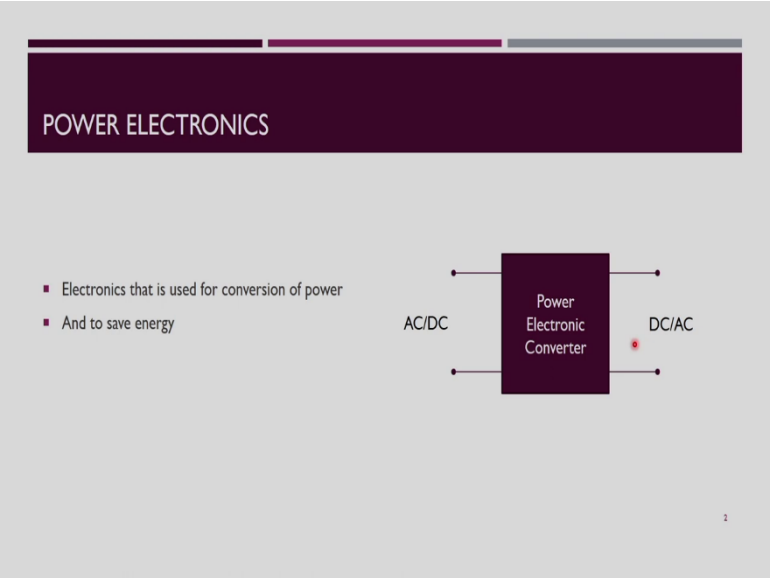

Power electronic converter can be represented like a box. Here as shown in this slide, you will have the power electronic circuit inside it. So, on one side you may have AC or DC. If it is DC, then the voltage level may be one. In the output side, we may need the DC at another level. Or, on the input side we may have AC at a particular voltage or frequency level, and on the output side, we may need it either in the DC form or in the AC form at a different voltage or frequency level. Then what we need is the power electronic converter. And while doing this conversion, we do not want to lose any energy. We want to have maximum efficiency during this process. So, we would like to save maximum amount of energy. So, power electronics is the electronics that is used for conversion of power while saving maximum amount of energy.

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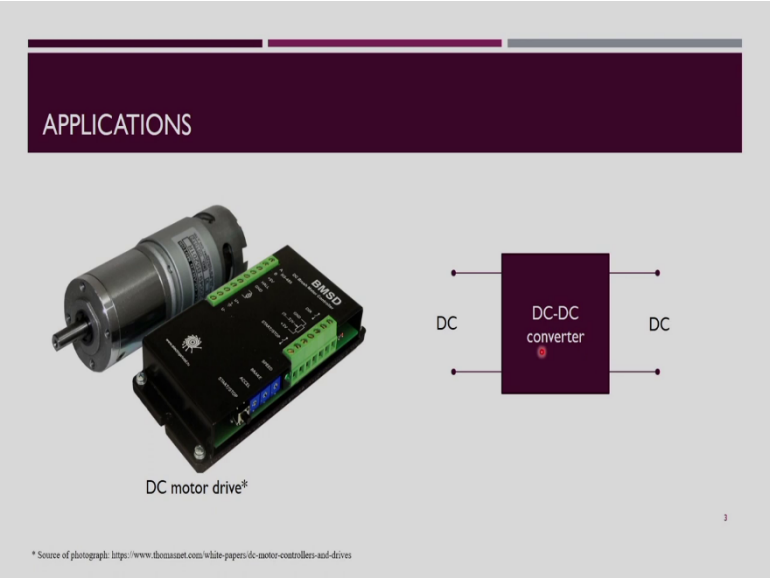

Before beginning the course, let us look into some of the applications of power electronics. The very first application of power electronics is in electric drives. This is the picture of a DC motor drive. So, this is the DC motor and this contains the power electronic converter inside. So, this will have a DC-to-DC converter and this DC-to-DC converter is going to do the speed torque control of the DC motor. So, together we call it as the DC motor drive. Now, different types of power electronic circuits may be used in this DC-to-DC converter.

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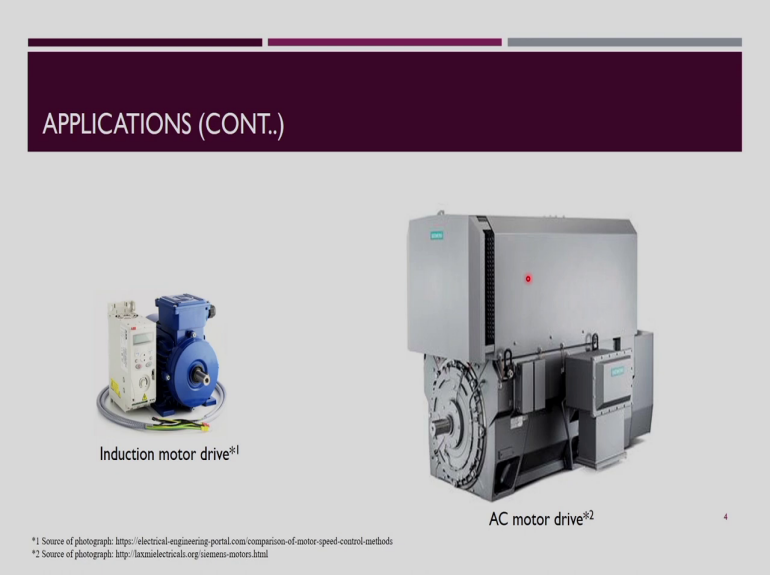

This picture shows an induction motor drive. This is an induction motor drive by ABB and this is just of a few kilowatts. So, inside this is the converter and the control for the induction motor. And this one is the picture of an AC motor drive by Siemens. And you can see from the picture itself, how much is the difference in the size as of megawatt level. So,

this one has the motor in it on the bottom and at the top it contains the power electronic converter.

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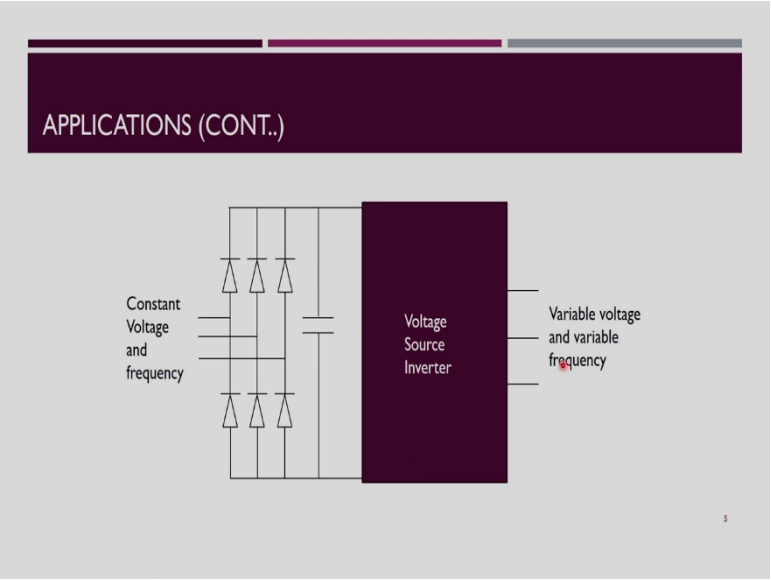

Now what could be inside this kind of AC motor drives? It could be a rectifier if the supply is 3-phase, so that 3-phase supply can be rectified and converted into DC and then after that a DC to AC power electronic converter can be used. We call it as the voltage source inverter. So, this box is just a representation of the DC to AC conversion. There may be different power electronic circuits that may be used for this voltage source inverter. And on the output side, we will have variable voltage and variable frequency obtained by controlling this voltage source inverter. Now, this variable voltage and variable frequency is going to do the speed torque control of the induction motor.

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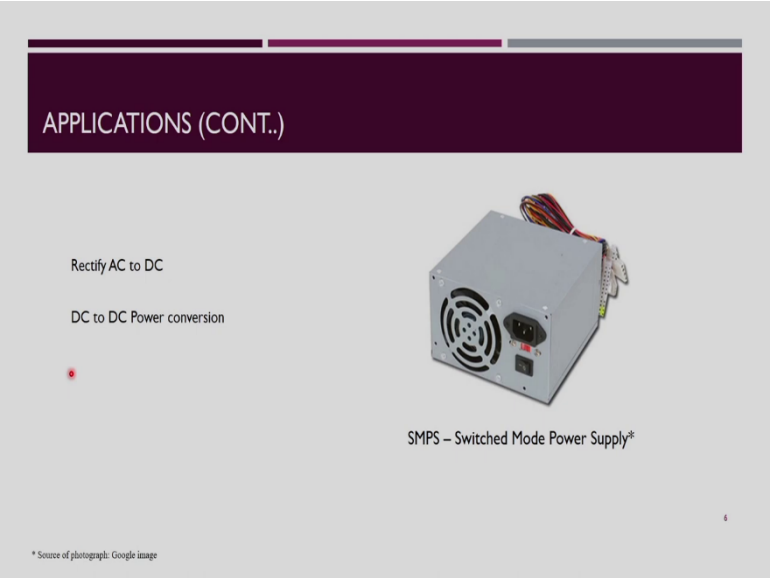

Next application area is in DC-to-DC conversion for SMPS applications. You use SMPS in your computers and you also use it for different charging applications and different appliances where we require switch mode power conversions. Now this one is the SMPS that you see inside your desktop computers. You might have seen it if you happen to open your computer. So, what it contains inside is first the rectification stage. It rectifies AC to DC and then it has the DC-to-DC power conversion stage. Now, our computers need 12 volts, 5 volts, 3.3 volts and so forth. And so, all these different voltages are produced or obtained by using the DC-to-DC converters.

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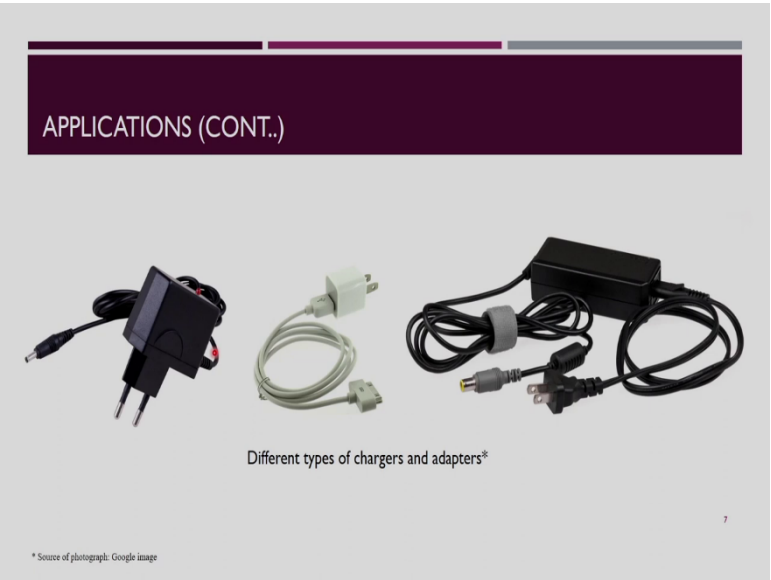

Further these are chargers, like your phone chargers and laptop chargers. They are available in various power ranges. Usually these are available in small power range from few watts to

maybe up to 30, 40 or below 100 watts. The chargers and different adapters we keep on using in our everyday life also contains power electronic converters, basically DC-to-DC converters inside them.

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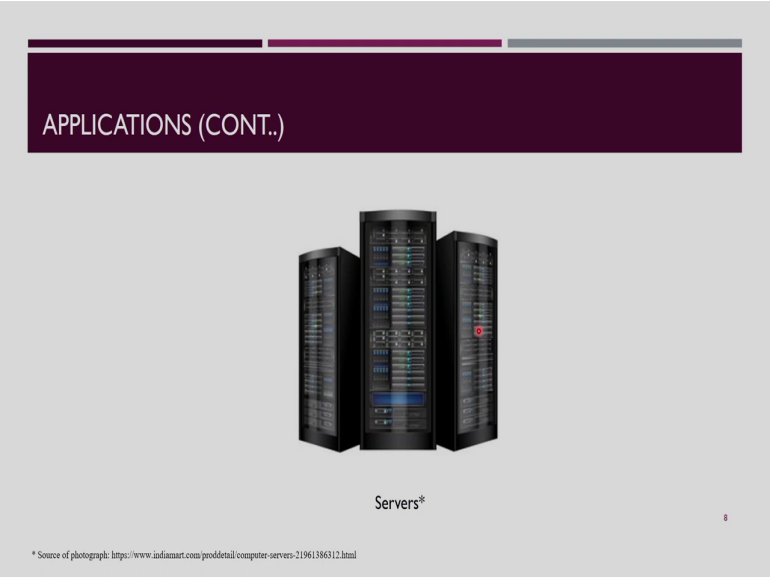

The DC-to-DC converters are not that they are needed only for small power levels, they can also be needed for high power levels in the range of few kilowatts. So, this is the picture of a server and they also need DC power and their power requirements are higher in the range of kilowatt limits. So, there we have to design DC to DC converter in the range of kilowatt levels.

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Further these are pictures of inverters in UPS that comes under DC to AC power conversion. Now, these inverters you may be having at your home also. These are also made in various power levels for home application. It may be a kilowatt or a few kilowatts and for industrial drives application the same inverter may be much higher level of up to 100 kilowatts or even higher than that. So, in various power ranges and voltage levels, DC to AC power conversion is performed and the design of converters have to be accordingly.

Then, these are pictures of UPS, uninterruptible power supply which also we keep on using in our everyday life. This is a picture of the small UPS which is used for desktop computers usually in the range of 600 watts to 700 watts. And then further these UPS can be of higher power levels also in kilowatt levels. So, that can be used according to the application in industries or in a big area where you want to provide UPS. Bigger UPS is required in labs. So, what I want to say is that UPS also contains DC to AC power conversion and is also manufactured in various wide power ranges.

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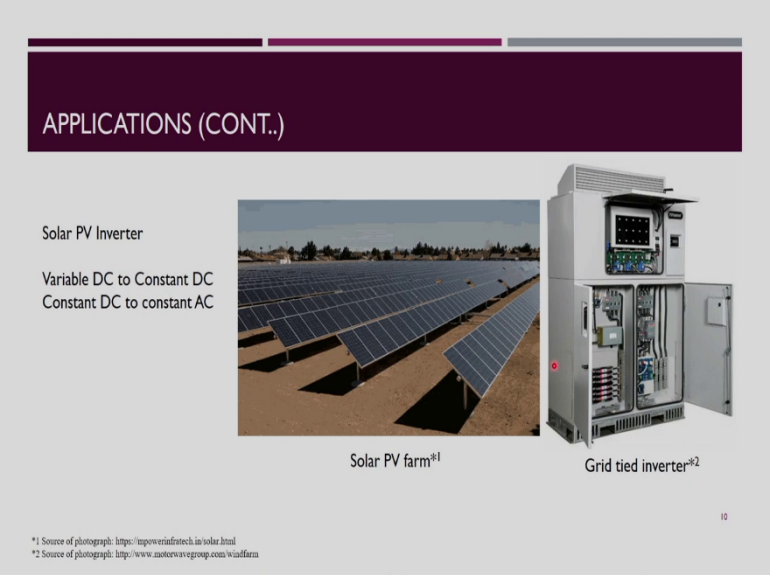

Further power electronics is also used for renewable energy applications. Renewable energy like solar and wind, very much depend on power electronics for power generation. This one is the picture of a solar PV farm and for big farms, the power range may be in the level of megawatt. Up to 3 to 4 megawatts is what we have in India.

So, you know that solar PV gives power in DC form and it is a variable DC because the sunlight keeps on varying. So, the DC output of it also keeps on varying and then whatever power we get that we want to transfer to the grid. But the grid is fixed voltage and fixed frequency. So, it has to be converted and that is done using power electronic converters. So, you may have not just one type of conversion, but multiple conversions taking place. First the variable DC, then we convert it into fixed DC and then fixed DC can be converted into AC. So, this one is the picture of a grid tied inverter and in the range of megawatt levels. Here you may be having the kind of conversion that I just told you.

Now, solar need not be just used in large farms, they can also be put on your rooftop. So, there the power levels will be in the range of kilowatt levels. And further, you may be just using one panel of maybe about 100 watts. So, there the power level will go down to that much and the converter has to be designed for that lesser power levels. Or, you may be using it further down for just some simple battery charging applications and there the power may be much lesser than that. So, in solar PV applications, as the power levels are very wide in which they are used, power converters also have to be designed accordingly at different power levels.

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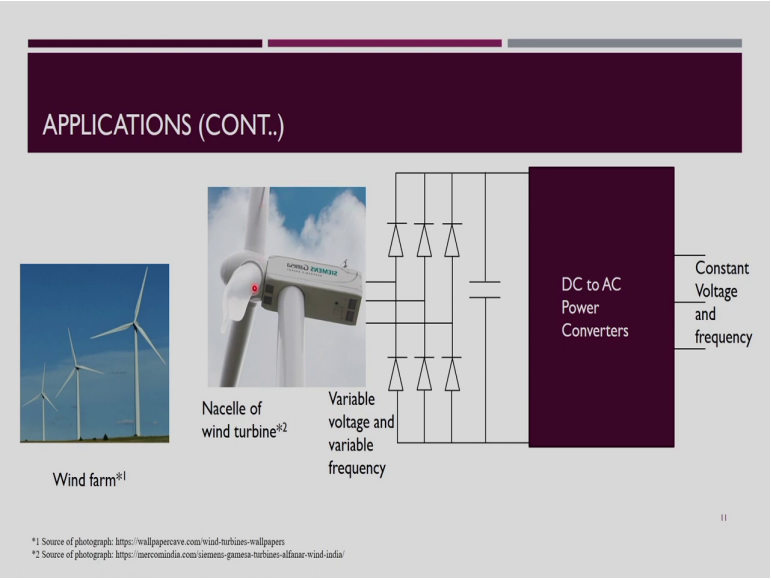

For wind application also, we need power electronics. So, this is a picture of a wind farm and in wind turbine, this is the turbine which is connected to the generator. So, this is called as the Nacelle of the wind turbine and inside it contains the generator, different types of

servo motors to control these turbine blades and also the power electronic converter. So, here various types of power electronic converters may be used. Now, we know that wind speed keeps on varying. So, you will be getting variable voltages in variable frequencies from your wind turbine generator that you are using. And if you want to use it, if you want to transfer it to the grid, we again have to convert it into fixed voltage and fixed frequency. So, that variable voltage and frequency have to be converted to DC and then that DC can be converted to AC again. So, this is just again to give you an idea you can rectify it, get a DC and then use DC to AC power converter. Now, just for simplicity I have shown it and various different types of power electronic converters can be used for this purpose. And for wind applications, it is like medium power applications up to megawatt levels. But these wind turbines that are there today, there accordingly the power converters have to be designed at high powers.

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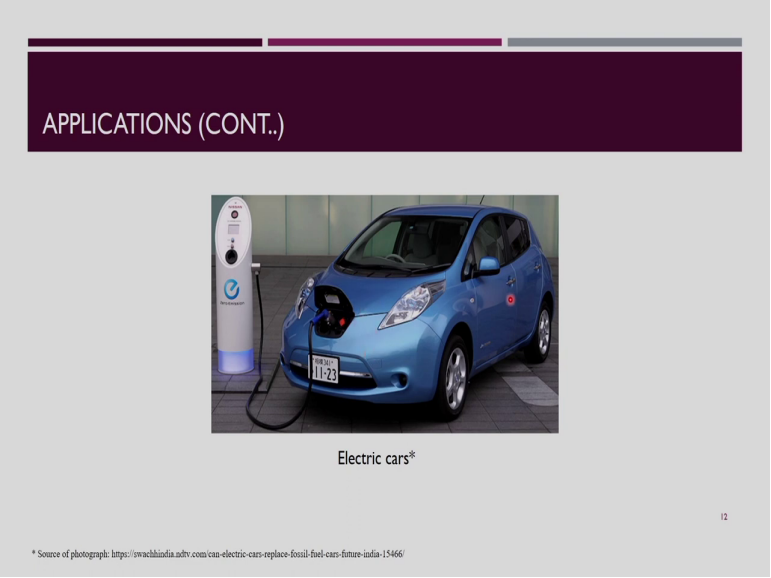

After that, electric car is a very, very emerging area today. Electric cars are replacing the conventional vehicles very quickly and they are heavily dependent on power electronics. So, wheels of the electric cars are driven by a motor and that motor is controlled by a power electronic converter. And then further, it has got batteries which need to be charged and that charger can be inside the car or it may be outside. This kind of charger may be there and that also is actually a power electronic converter. And for fast charging, you need very high levels of currents. So, accordingly the power electronic converters have to be designed or the circuits that you choose have to be such that, which can supply those levels of currents

and matching the voltage requirements. So, electric car is also one of the very big applications of power electronics.

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Next application is your hybrid electric bus. So, hybrid electric bus runs on diesel as well as on battery power. But irrespective of whether you are using diesel or battery power, it contains power electronic converters inside. So, basically these motors, which run the wheels, are again driven by power electronic converters and the batteries have to be charged and they also require power electronics converters for them. So, electric vehicle is a very, very big application area of power electronics.

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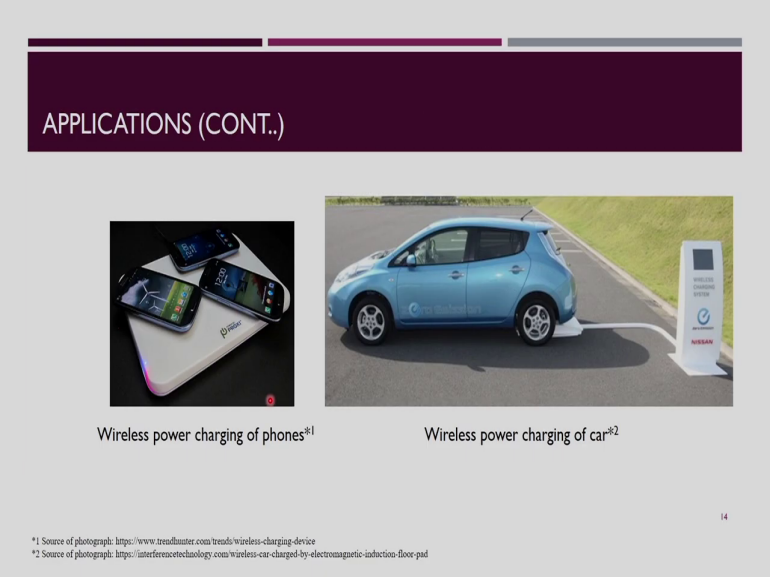

Another area of application is wireless power charging. So, this shows a wireless power charging of phone. So, in it, what you generally have is have the primary coil and, on this side, the secondary coil. So, it is like an air core transformer. It is used as a converter which

will be having a transformer in it. But it is an air core transformer. They are not the normal transformer which you are used to of seeing and then there will be coupling among them and the power transfer is going to take place. So, basically when you put your phone on this pad the circuit gets completed and the phone gets charged. Similarly, in wireless power charging of car you drive in and place your car on this position, where below the road you may be having the charger or via this coupling coil, this charger may be outside also and the circuit again gets completed by the transformer and charging of the car happens. So, it is the same thing, you have the coil here, you have this secondary on this side and then you have the converters which are connected and then they get the power and via this charging is going to take place.

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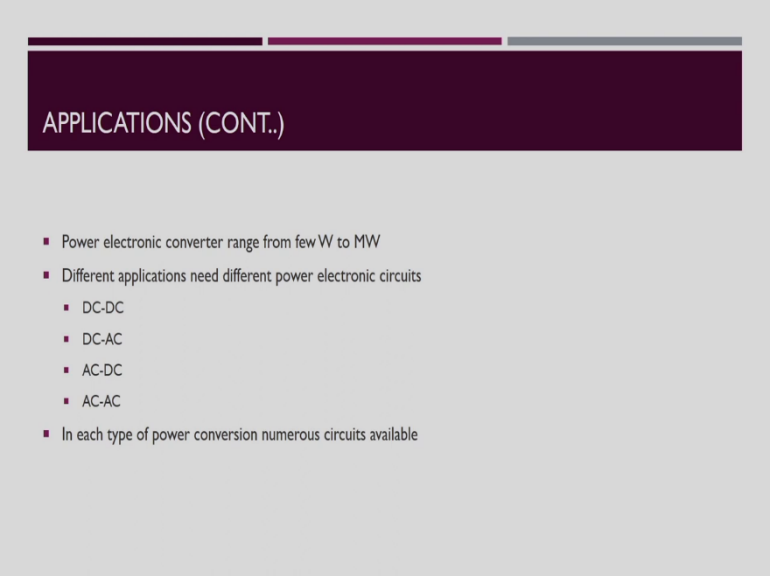

So, what we see from here is that power electronic converters range from few watts to megawatt levels. Now, different applications need different types of power electronic converters. They may be DC to DC, DC to AC, AC to DC or direct AC to AC. In one type of power conversion also there may be multiple circuits which can be used for a particular application.

Now, it is the job of the power electronics engineer to decide which of the power electronic circuit is most suitable for that particular application. And many of the applications require multiple stages i.e. you may require DC to DC, then you may require DC to AC and so on.

Or, you may require AC to DC conversion and then you may be converting DC to DC. So, multiple stages of power conversion may be needed for a particular application.

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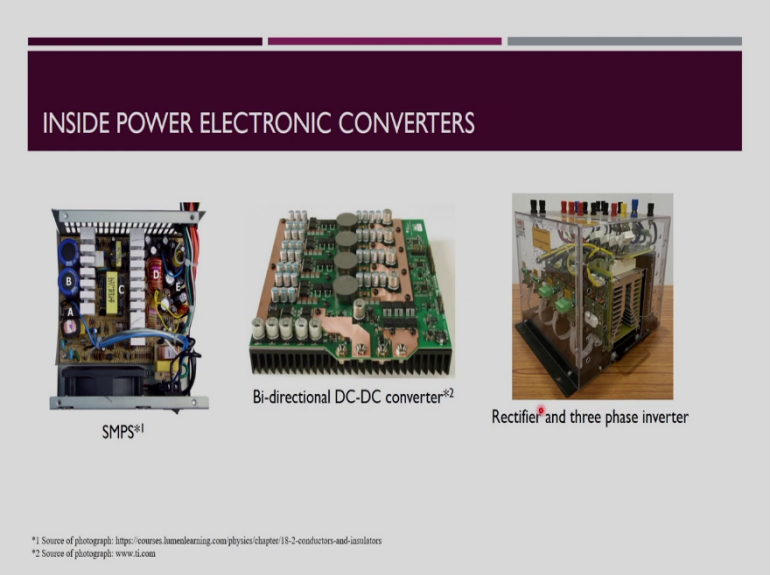

Now, if you happen to look inside a power electronic converter, you will be seeing power semiconductor devices, inductors, transformers, various types of small electronic ICs, heat sinks and so forth. Now, this is the picture of an SMPS opened, you can see here, these are inductors and then these are heat sinks, and these capacitors and various resistors are there and then there is a fan as well and some wires. So, there are numerous components that are placed inside the SMPS. Now, this is a bi-directional DC to DC converter designed by Texas Instruments. And you can see here as well the various components that are there and these kind of copper bars which are also kept here and then different ICs that are there, different connectors and heat sinks and capacitors. So, different types of components are there in this bidirectional DC to DC converter. Then this is a picture of rectifying 3-phase inverter designed by Semikron. And you can see here these are drivers, then these are device modules and further this is the heatsink and there are other many other components inside it. So, when you look inside, you will see that they all appear to be very different in design from each other.

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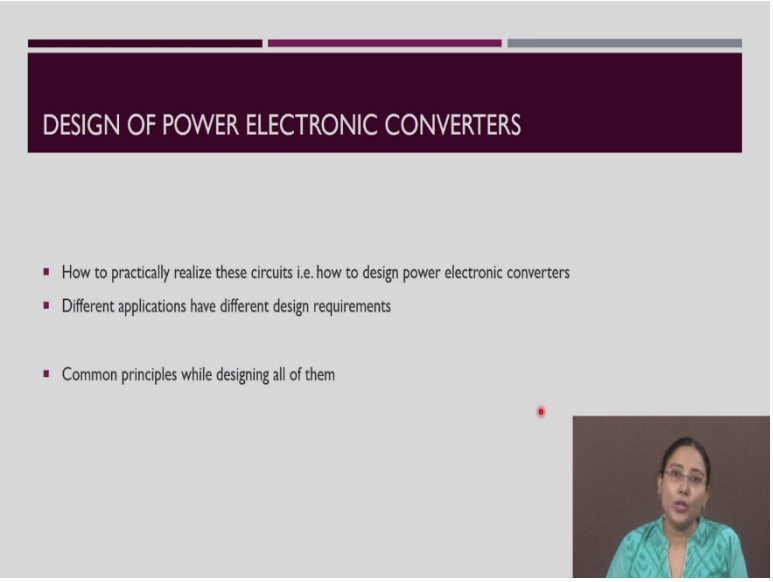

So, you might have done a first course in power electronics and you may be familiar with power electronic circuits and you may be knowing how to analyse those circuits. But the question is how do you realize it practically? Because in real life, you need to realize them practically. So, for that, how do you design it?

Now, all these different applications require different types of converters and different types of circuits may be inside them. So, do you have to learn design of each one of them differently? The answer is no. There are some common concepts which are applicable for all of them. So, if you learn them, then you can apply and design the converter that you need for your specific application.

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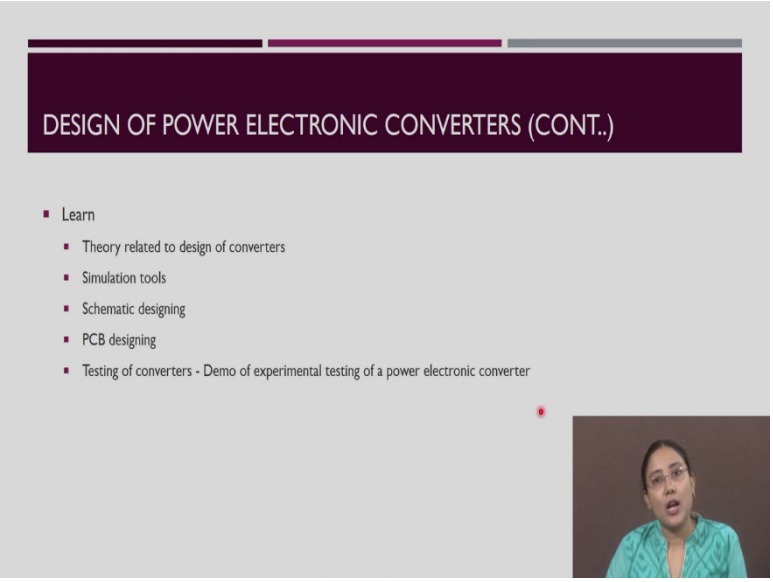

What are you going to learn in this course? You will be learning the theoretical concepts related to design. Now, usually I have seen that students do a first course in power electronics, they know the circuits and then they think that now they can start designing i.e. implementing the power electronic hardware without proper knowledge of the design concepts and that usually leads to a very novice design and unsatisfactory performance. So, you need to know the theoretical concepts related to design of power electronic converters and that is what this course plans to do. Further you will be also learning the simulation tools that you can use for power electronics design. You will be also learning tools for PCB designing and schematic designing and towards the end of the course we will also give you demos of how to experimentally test a power electronic converter.

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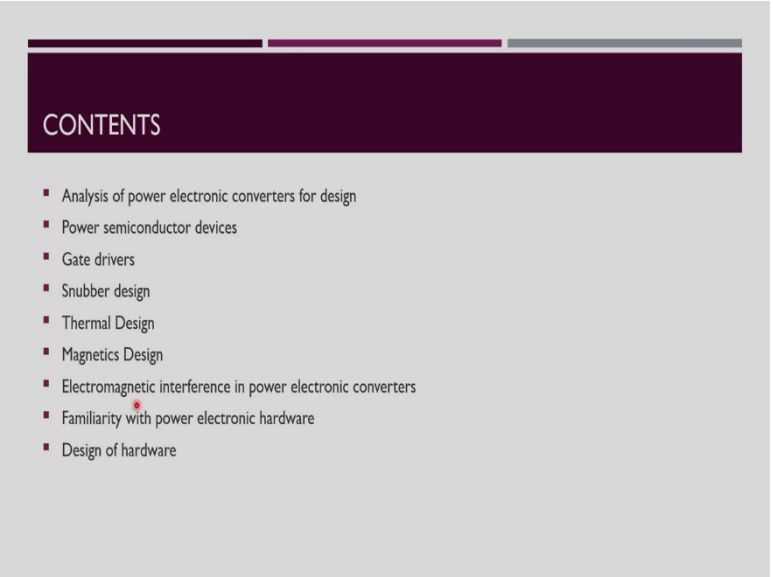

So, the contents of this course are analysis of power electronic converters for design. You might have analysed power electronic converters in the first course. But in this we will be seeing the analysis from design perspective. What are those things which you have to look into to obtain the ratings and specifications of your components for design purpose, that is what we will cover. Then, we will also relook into power semiconductor devices from design perspective, from a practical point of view, like how do you read data sheets, how do you choose specific components from design point of view. Then, next we will be discussing gate drivers which can drive the different devices. Then the snubber's design to protect devices. Then further we will be looking into how to do thermal designing. Thermal design basically means how do you cool the devices. You choose heat sinks to maintain the temperature of the power electronic converter. Then the magnetics design which means, you will be knowing how do you design the transformers and inductors that are part of the power electronic converter. Then, this course will also introduce the problem of electromagnetic interference in power electronics and some of the ways of reducing it. Further it will make you familiar with the power electronic hardware and a demo will be given to you that how do you do design of one particular power electronic converter and how do you experimentally test and verify it.

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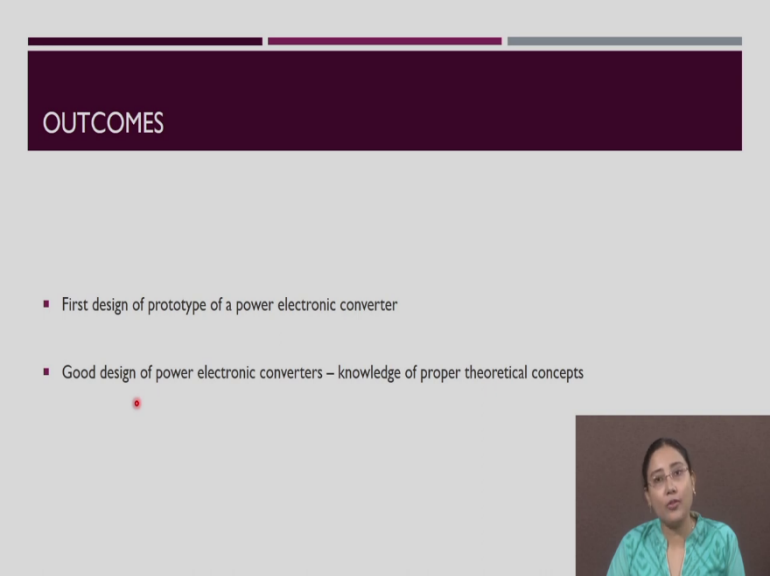

So, the outcomes of this course are that after doing this course, you will be able to do first design of a power electronic converter. If you have never done any hardware design of power electronic converters after doing this course, you will be able to do that on your own.

And if you have already done some design, you will have the knowledge of proper theoretical concepts of how to do good design of power electronic converters. Thank you.