Introduction to Internet of Things
Prof. Sudip Misra
Department of Computer Science & Engineering
Indian Institute of Technology, Kharagpur

Lecture – 51
Smart Grid- Part – I

So, this lecture on internet of things focuses on the smart grid.

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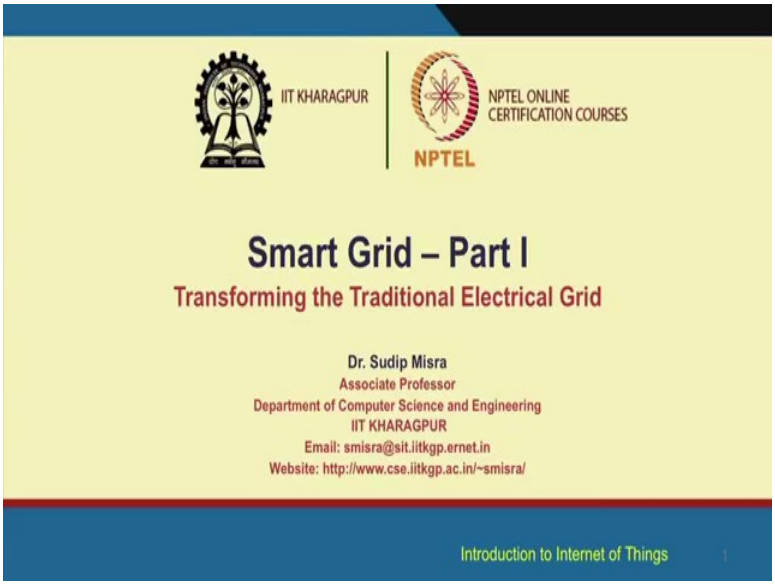

So, in the first part, we will be talking about the basics of smart grid, some of the motivations behind why smart grid is required and there after some of the more; you know a advanced concepts will be covered in the second part of the smart grid lecture. So, first part we are going to do is we are going to understand that what is smart grid, and what is its role in the overall building of internet of things, and what are different components of smart grid.

So, let us first look at what smart grid is all about.

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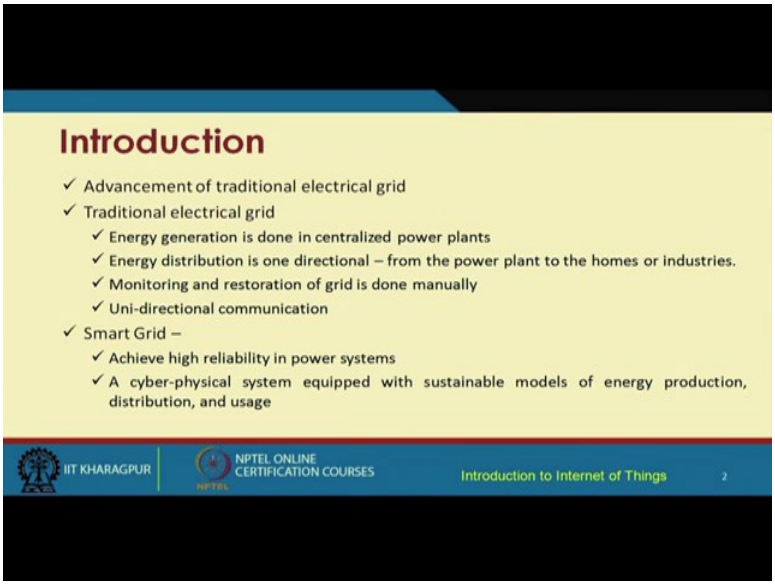

We all are familiar with the traditional electrical grid; in the traditional electrical grid what happens is, you know what we have is we are consuming electricity that is generated by some generating station and is basically carried through different electrical you know electrical transmission devices and transmission lines to either homes or to offices. So, most of it most of it is all about the traditional electrical grid; is all about from the generation; that means the source of the energy being generated, renewable or nonrenewable depending on you know how the electricity generated.

So, from the source how it is going to be transmitted and then at intermediate points there are going to be different you know substations, which are going to relate the electricity to different parts of the city for further use, and also about the storage of electricity and so on and so forth. So, end to end from the generation through transmission to the final consumption at homes and offices the traditional electrical grid is all about. So, this is what the traditional power systems you know people who focus on power systems and electrical grid, this is this is what they study the; this is what they do they want to study how it can be done efficiently.

Now, as it happens with the internet of things as well, you know internet of things; when we talk about there are you know. So, its the advancement in terms of the use of different advanced information and communication technologies, to make everything smart and when we talk about that one of the important components is electricity distribution to homes and offices. So, that also has to be that has that also has to be made smart. So, that is where the smart grid comes into picture, the traditional electrical grid being made

smart. And how will it be made smart? Through the use of the ICT tools different advanced information and communication tools, being used to make the traditional electrical grid smart is all about it is the concern of the field of smart grid.

Now, when we talk about smart grid, it concerns energy generation and energy generation is typically done in a centralized manner at the different power plants, and this generation can be as I said before this generation can be of two types either you know through nonrenewable sources like you know coal and so on and so forth nonrenewable sources electricity can be generated, or from the renewable sources like wind, solar power and so on.

Now, this energy that is generated at the different power plants through the centralized mechanisms typically in the traditional field, that is then you know distributed in a typically traditionally in one direction. From the power plant to the homes or industries or offices and traditionally this particular flow of electricity is monitored and the restoration like if something goes wrong, the restoration of the grid is also done manually. So, what happens is what we have is unidirectional communication not that the energy flows unidirectionally, but also the communication is also unidirectional from the source to the end consumers.

Now, in a smart grid basically there is a divergence from this traditional concept of that means, that additional electrical grid concept, in the smart grid as I was telling before that you use the information and communication technologies the different variance of it the different types of it, to achieve higher reliability in power systems number one and overall making the system smart and what kind of system we have here? It is a cyber physical system. It is a cyber physical system that is equipped with sustainable models of energy production, distribution and final use by the consumers.

And what is a cyber physical system by the way in a nut shell its cyber physical system is an integral component of internet of things, in a nut shell what happens is in any cyber physical system smart grid being a good example of it in any cyber physical system, the cyber part; that means, the internet or the network part is intertwined very tightly with the physical system. So, physical system the cyber system cyber based system; that means, the internet based or the network based system being intertwined very tightly in order to make it smart. So, that it can do things much more efficiently than the

traditionally you know exclusive physical system. So, this is a cyber physical system which is being used wide widely in the building of internet of things.

Now, let us move ahead.

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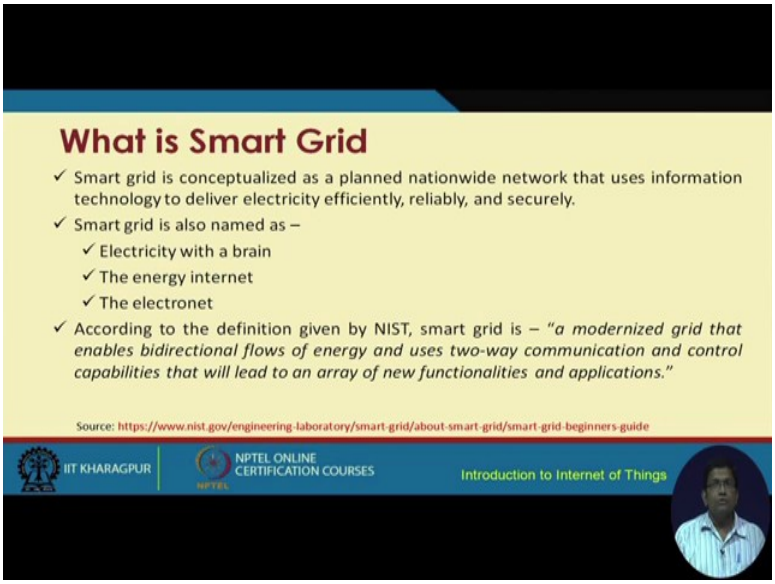

So, we have a smart grid which is conceptualized as a plant nationwide network, that uses information technology to deliver electricity efficiently reliably and securely this is very important you know. So, we have so many different problems with the traditional smart grid the sorry traditionally electric grid. So, what is you see we you in our country for example, I mean many countries you know with the distribution generation to distribution and use there are lot of problems. We have theft of electricity you know electricity being stored stolen while in transient, before it is actually being used by the legitimate consumer.

So, smart grid basically also tries to address this particular problem that how securely this electricity can be transmitted to the legitimate and the actual consumers the internet consumers. So, delivering the electricity efficiently, reliably reliable means if something goes wrong how things can be taken care of and if something it may be some subsystem goes down may be a substation for example, in the overall distribution system goes down. Then even if it goes down the smart grid is going to still function without any interruption and everything will be remain fine. So, that is not possible with the traditional electrical grid and which is possible with the smart grid.

So, you know smart grid as we are using computer based methodologies information technology, communication technology etcetera it becomes very interesting. So, some people prefer to call smart grid as electricity with brain, some people prefer to call it as the energy internet, some even prefer to call it as the electro net. So, NIST which is an organization based in US. They defined smart grid as a modernized grid that enables bi directional flow of energy and uses the two way communication and control capabilities that will lead to an array of new functionalities and applications the overall thing is service electricity is a service right. So, offering the electricity the end consumers are getting this service in their homes and their offices and in the industries and you know workshops and so on and so forth.

So, but what makes electricity smart grid smarter or interesting is that we have two way communication two way communication, not only from the source towards one direction is from the source towards the end users, and the other direction is from the end users to towards the source or in the interim the different substations micro grids and so on. So, these are some of these terminologies that will become more familiar as we proceed through, but you know so like this there are other functionalities as well and it is a mod modernized power grid that that is the core concept the heart of the smart grid.

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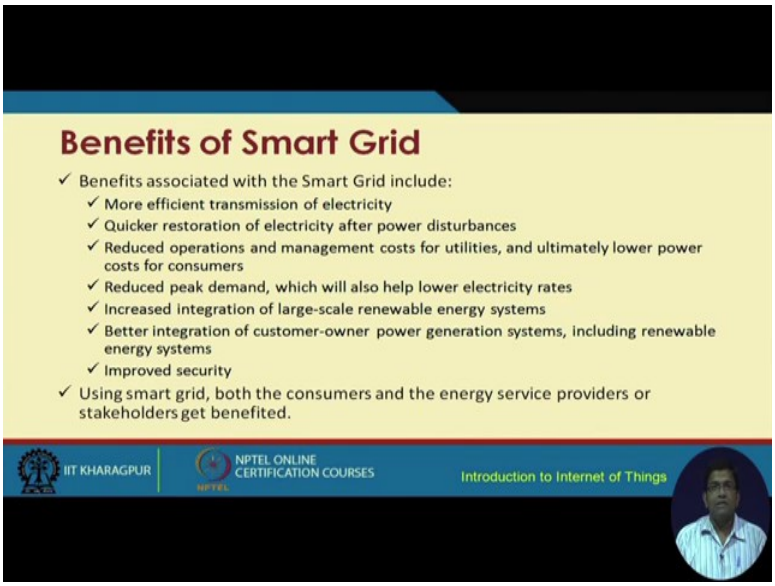

There are different benefits of smart grid; one is that it is possible to more efficiently transmit electricity than the traditional one traditional electric grid, it is it has quicker

restoration of electricity after power disturbances reduced operations and management costs for utilities and ultimately lower power costs for consumers, reduced peak demand which will also help lower electricity rates. So, what it means is basically you know there are certain peak times of electricity uses and during that basically you know what happens is during the peak time most of the users are connected and they consume lots of volumes of electricity, and with the smart grid it is possible to have reduced peak periods and overall distribution of electricity use is moderated over the entire length of the day.

So, this is possible with the smart grid better integration of customer owner power generation systems including renewable renewable energy systems, now days as we have already experienced. So, not only we are using power from the main power distribution centers, but also many of us we have you know other you know we exploit the different other sources of energy the renewable sources of energy, we have many of us we use these the solar power panels right.

So, the solar panels are used to you know harness the solar energy similarly small wind turbines are also used wind sources of energy can be you know exploited can be used and they can not only be used locally by the by these different users, but if there is any surplus energy that is generated through these renewable means they can be even stored and can even be distributed and that surplus energy can be even fed back to the main grid. So, these are all possible with the smart grid which was not possible before with the electric traditional grid.

Then improved security is very interesting because you know power theft is one thing and the second thing is there are different other you know different attacks that is possible on the on these like it is a cyber physical system. Like any other cyber physical system or any other computer based system, you know smart grids are also vulnerable to different attacks and if it is a traditional electrical grid that attacks are even more you can you know it is possible to bring down a particular electrical grid due to different attacks. So, you know improved security is one such feature which tries to overcome these problems of the traditional grid.

So, using smart grid both the consumers and the energy service providers or stake holders can get benefited everybody gets benefited all kind of stake holders get benefited.

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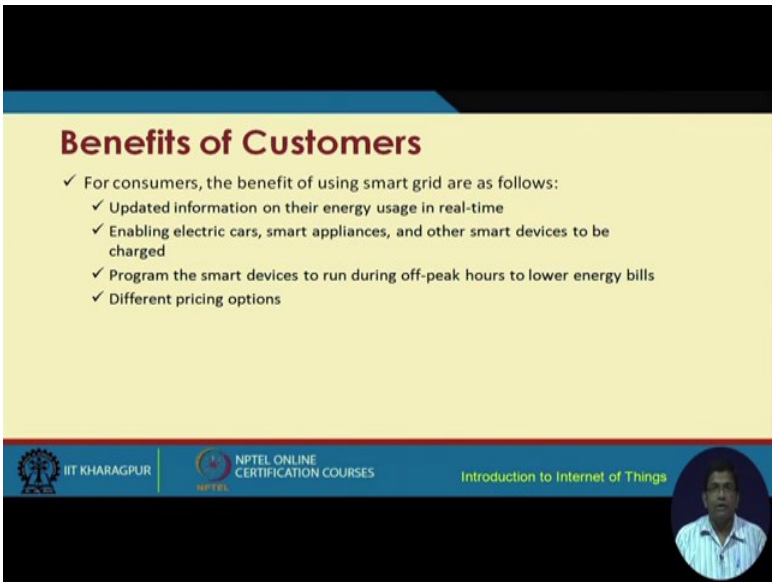

So, let us look at the different benefits for the customers let us first look at it, everybody gets benefited what are specific benefits to the customers. For customers or the consumers the benefit of using smart grid are that they can get updated information of their energy usage, in real time at any time basically whenever they want you know customers basically you know they can get an update about how much energy they are using. In fact, not only that cast you know customers they can also not only that they can monitor their inner energy usage, but they can also program that in ok. So, this during this time of the day you know I will be using this much energy I planned to use this much of energy during the other times I will be using you know this much of energy, some other amount of energy and so on.

So, all these different planning everything can be programmed by the customers of the smart grid customers in the smart grid; another thing is electric cars there you know. So, now, days we are taking about plug in electrical vehicles hybrid electric vehicles and so on. PVs, PHEVs and so on; these are possible in to be used by the customers in the smart grid smart appliances. So, appliances which can like you know we have smart air conditioners, smart refrigerators and so on and different other smart devices everything is possible in the whole world of smart grid. It is possible to program the smart devices to run during the off peak hours to lower energy bills. So, you know so there is some at certain times of the day there is peak the it is a it becomes a peak hour, peak hour means that during that time basically you know everybody is trying to you know have different

appliances connected and use consume electricity much more than few other times of the day.

So, those are the off peak hours. So, during the off peak hours you know if one customer wants they can run certain appliances during the off peak hours and the other the bare basic necessities those appliances can be run during the peak hours and so on. So, it can be distributed and all of these things can be done by the customer himself or herself and that is all possible in the in the world of smart grid. And the different pricing options are also possible. So, in the traditional electrical grid as it happens you know. So, there is a single rate you know. So, at one particular rate that applies to all customers at all times of the day the week the month and so on.

So, in the smart grid it is possible to have the customers can enjoy different pricing levels different costs at different times of the day, week month and so on. So, all these things are possible and the customer gets benefited by using smart grid in different ways.

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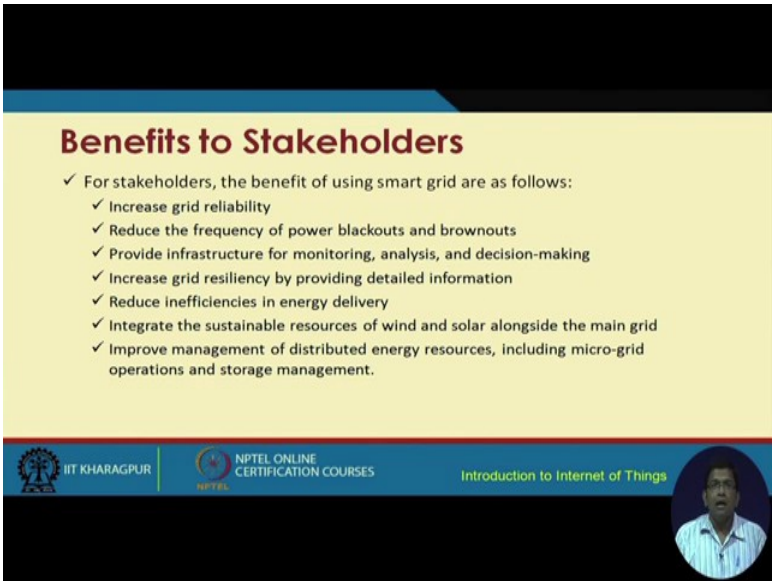

Other stake holders can also benefit from this smart grid as follows; for example, you know overall by the introduction of the smart grid the grid becomes more reliable as I already said before. The possibilities of blackouts and brownouts; so, black out means that that you know power consumption is no longer possible. So, there is a complete you know power is completely cut off for longer durations of time.

So, that is a power blackout what is burn out brown out sorry what is brown out? Brown out is basically that for few hours there is going to be reduced levels of voltage for example, you know that we often experience that at certain times of the day at certain times not always, that some are particularly you know if we are using the bulbs the incandescent bulbs. We see that the bulbs are glowing at lower strength and like this you know so that is because the overall electricity load in the line in the grid is lower.

So, brown outs can happen when we have you know intentionally, typically intentionally it can be unintentional also that for few hours the electricity load in the grid is lower. It is not a complete black out, but with reduced load so that is the brown out. So, the stake holders the other stake holders they can basically make it possible to have black outs or burn brown outs sorry to reduce the possibilities of black outs and brown outs. Providing infrastructure for monitoring analysis and decision making is possible, increasing grid resiliency by providing detailed information.

Reducing the inefficacies in energy delivery you know if there a certain points, where there is some energy leakage or something. So, those things those inefficiencies can be you know more efficiently addressed by the smart grid and that is very important particularly for the stake holder the service providers and so on. And there are other important features also it is possible to you know supplement these traditional power grid with the renewable sources as I said before for the customers as well and same thing is possible for the stake holders and the stake holders get benefited as well because you know they can supplement the main source of energy with wind sonar and other renewable sources through the use of micro grids. And overall the; you know over all the management of these distributed sources of energy, their storage from the generation to the storage and use everything can be done everything can be managed in a much more improved fashion.

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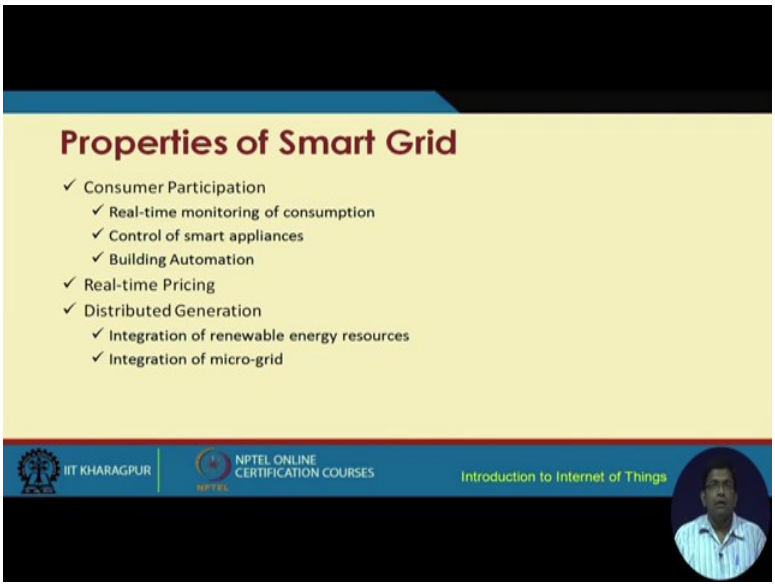

There are different properties of the smart grid consumer participation with respect to that, we have real time monitoring of consumption control of smart appliances, building automation. So, all these things are possible with the help of smart grid, and I have already mentioned about real time pricing you know at different times of the day, different whenever there is a requirement whenever there is necessity you know prices can be changed by the stake holders, and can be enjoyed by the consumers of course, there has to be certain policies and those policies have to agreed upon by a between these end consumers and the service providers.

So, that is a completely different issue, but this is made possible by this technology real time pricing is possible with the help of smart grid distributed generation integration of renewable energy sources and integration of micro grid. Other properties include a power system efficiency. So, including power monitoring it is possible to monitor the power in real time at all times asset management and optimal utilization is possible in a smart grid context distributed automation and protection.

So, everything is possible in the case of smart grid and making the overall power system efficient. In terms of power quality self healing behavior is exhibited by smart grid, self healing means if something goes wrong the system will be able to heal up on its own a some component may be has broken down, some subsystem a transformer has grown

out, still the system can continue you know it will heal up on its own and it will continue to function as usual without much interaps interruption.

Frequency monitoring and control load forecasting that is possible and I do not think I need to elaborate that the overall electrical load can be forecasted in the smart grid and accordingly the power distribution can be made possible and reducing the overall black out and burn times sorry brown out times is possible with the help of load forecasting. And anticipation of any any type of disturbance any type of interruption is possible with the help of smart grid.

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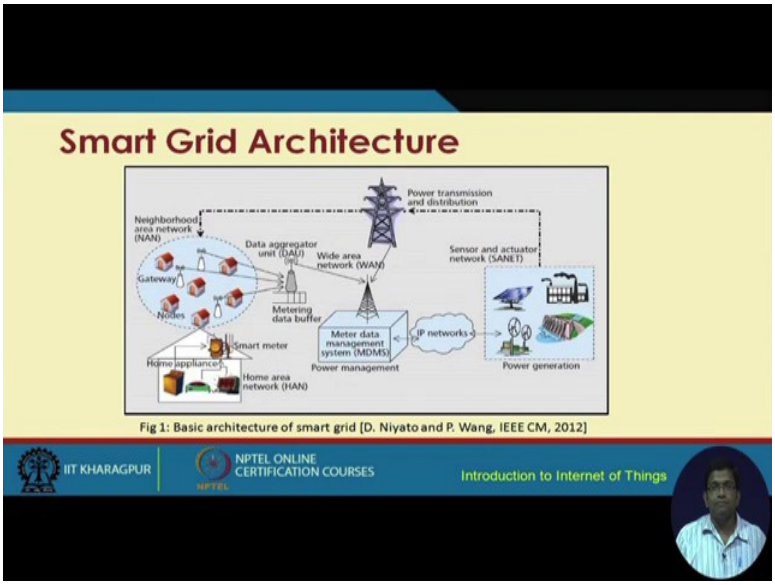

So, here is the smart grid architecture if we look at you know. So, what we have is we have the source of power generation. And from the source of power generation which can be from the renewable as well as the nonrenewable sources this energy is as you can see through the different transmission lines and distribution systems these energy is fed to different offices and homes, and these form something known as the neighborhood area network and then each of these homes have different appliances smart appliances including a smart meter the; you know it is a smart meter not a traditional regular kind of meter, but it is a smart meter which can be programmed as well. So and different smart appliances and the homes smart meters you know. So, these can be made possible.

Now, what is what is interesting is that. So, this is this is the traditional basically this is more of like a traditional flow of energy, but alongside what we also have is that

connectivity to different networks. We have the sensors and different actuators being used a in this source you know in the power generation sources, then IP networks can be connected to the something known as the MDMS the meter data management system, and these can impact the MDMS can be connected by when or even the other internet connectivity to the power distribution systems, then we have the data aggregator unit which is basically sort of like from each of these homes, this information they can be aggregated at the data aggregated unit and this data aggregated unit has a metering data buffer which basically stores and buffers the data and so on.

So, as we can see that we have basically and handshaking with or handshaking between the traditional power distribution and the information flow. So, we have you know in a smart grid we have both the flows energy flows and a energy flow and also the information flow together.

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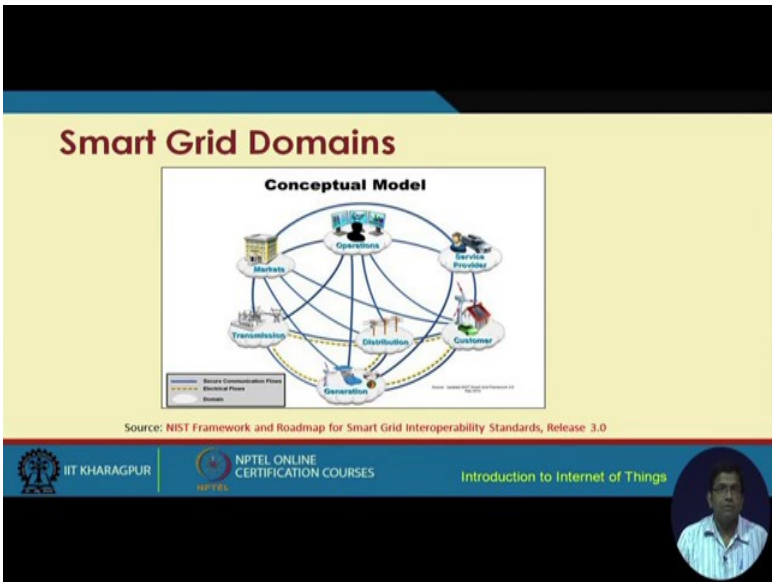

So, here is the conceptual model of the smart grid, we have different components as we can see over here, we have the customers, we have the service providers, we have the operation centers, we have markets transmission systems distribution systems and of course, the generation system. So, this is specifically showing these different you know flow of energy as well as the communication flows these dotted lines over here are showing the communication flow. Sorry the this is this is the sorry this is the electric electrical flow these dotted lines are the electrical flows between the customer the

distribution system transmission system generation system and so on and these blue colored ones are basically the it they are showing the it is a depicting basically the flow of communication and it is a secure flow of communication in the case of smart grid.

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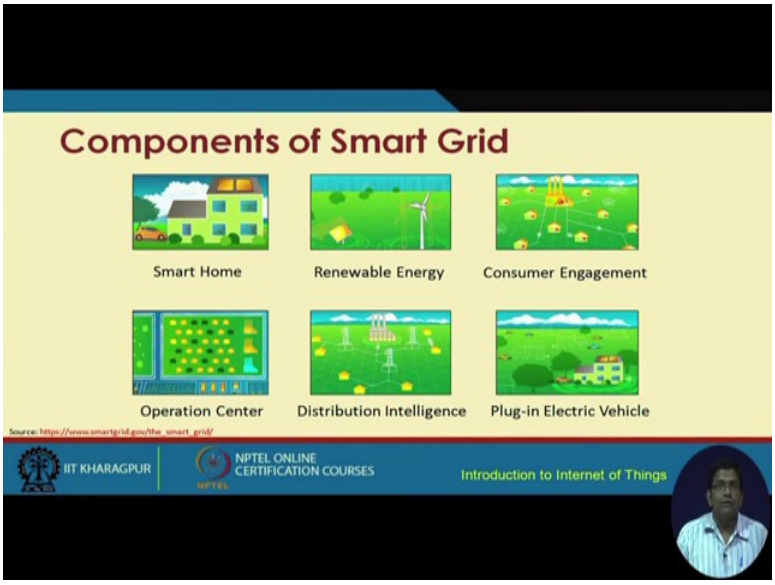

So, there are different components of the smart grid; we have the smart home, then we have the renewable energy, consumer engagement, operation center, distribution intelligence, and plug in electric vehicles. So, we are going to take up each one of these one by one and we are going to discuss them in more depth.

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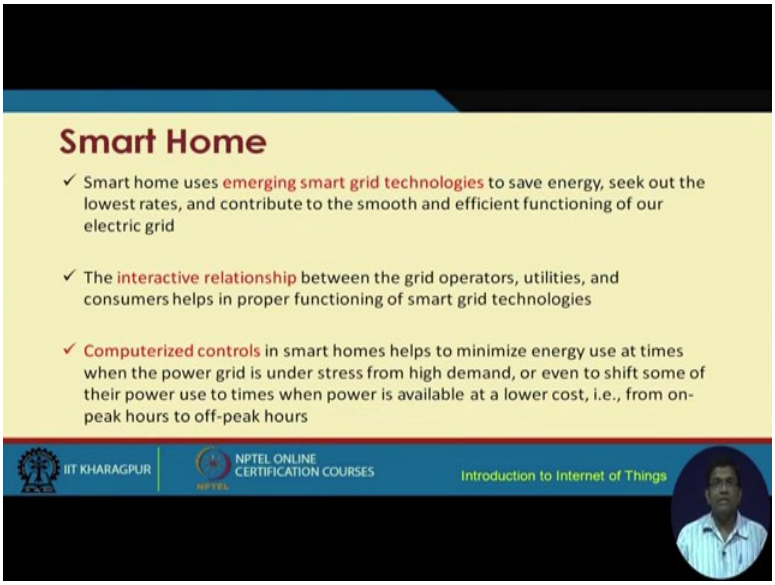

So, we will start with the smart home. So, in a smart home what we have our smart appliances and they use these different emerging smart grid technologies to save energy. And at lower I mean different rates you know prices different rates and the different prices can be used and these contribute to the smooth and efficient functioning of the electric grid.

The interactive relationship between the grid operators utilities and consumers help in proper functioning of the smart grid technologies and there are different in a smart home, there are different computerized controls that help to minimize the energy use at different times of the day from the power grid and if the power grid is under stress; that means, there is high demand etcetera then this power load can also be shifted in the in a smart home. And so that basically you know what can happen is power can be distributed between the on peak hours and the off peak hours, and that way the power distribution in a smart home can be rationalized so that the users are benefited by you know. So, they can be having different appliances that can be connected at different times of the day depending on whether it is a peak hour or it is an off peak hour.

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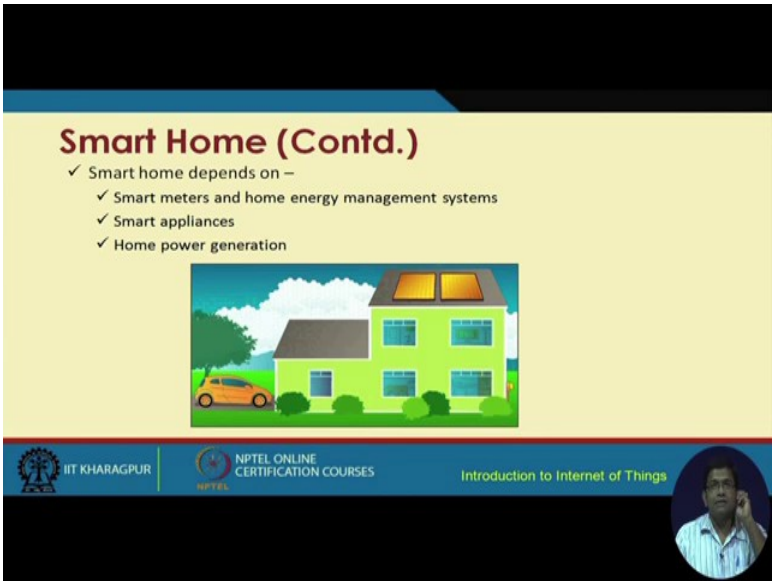

So, in a smart home what we have is something like this. So, we have smart meters smart appliances and there is a home power generation system as well. So, you know on the roof tops there can be these power panels the solar panels and the solar panels can

additionally generate some electricity to supplement the electricity that is that is supplied to the home.

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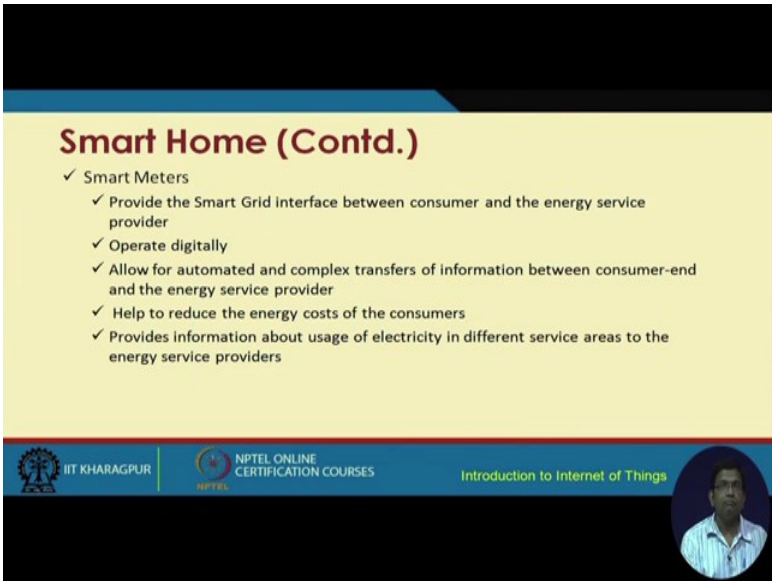

In a smart home the one of the important components is the smart meter and this is a programmable meter, and this meter can be programmed in such a way that at different times of the day, the different appliances can be enjoying the different you know loads of electricity at different rates.

So, the smart meters basically they provide the smart grid interface between the consumer and the energy service provider and they operate digitally; that means, computerized you know. So, they have small computers embedded in them, and they allow for automated and complex transfer of information between the consumer and the energy service provider and that way the consumers can enjoy reduced energy cost.

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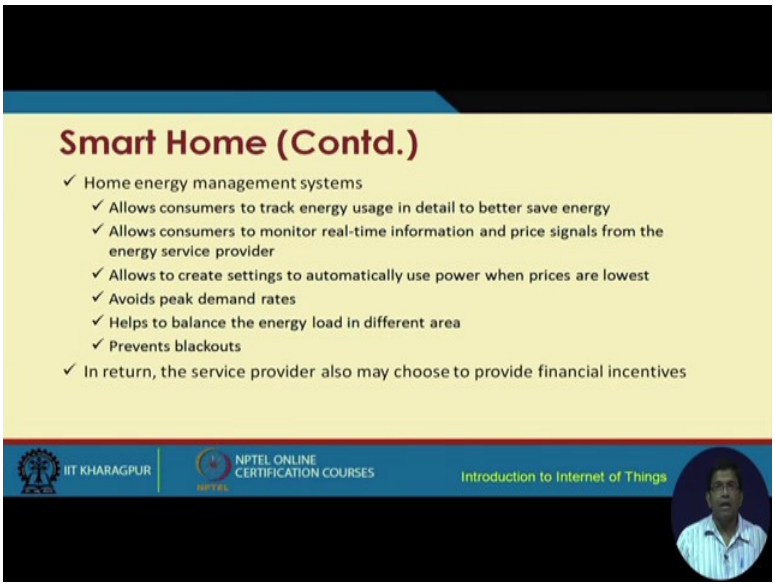

So, in a smart home the you know smart home basically allows the consumers to trace sorry to track the energy use in detail to save energy in a better way. So, basically you know what happens is you have something called the home energy management systems. So, these home energy management systems basically allows these particular thing to be done, these home energy management system also allows consumers to monitor a real time information and price signals from the energy service provider, it also allows to create settings to automatically use power when prices are lowest, it helps in avoiding big demand rates prevents black outs and brown outs, in return the service provider may also choose to provide financial incentives.

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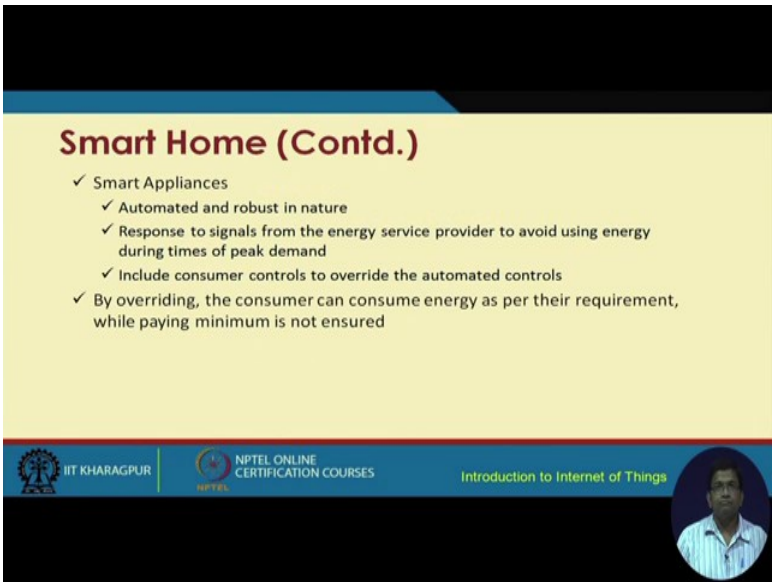

Smart appliances in addition to this smart meters smart appliances will be there, which can be automated and they can be robust in nature. They respond to signals from the energy service provider to avoid using energy during peak times, these smart appliances also include consumer controls to override the automated controls and by overriding the consumer can consume energy as per their requirement, while paying minimum that is not ensured.

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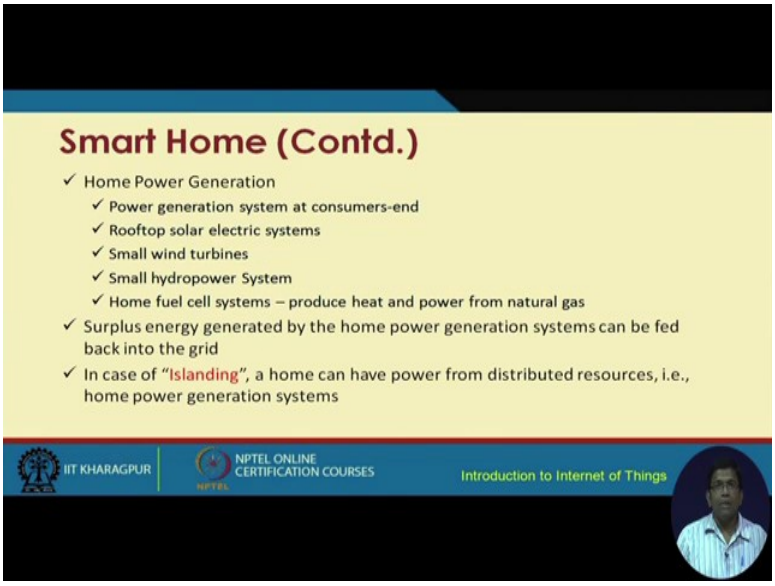

In every home these homes are also equipped with home power generation systems on the roof top there can be these wind turbines which can be fitted, or solar panels can be fitted to supplement these regular flow of energy.

Surplus energy that is generated by the home power management systems can be fed back into the grid additionally, and these consumers can in fact, act as service you know the energy generators and they can in fact, on some additional money through this particular process and in case of islanding a home can have power from distributed sources that is they can have power home power generation systems.

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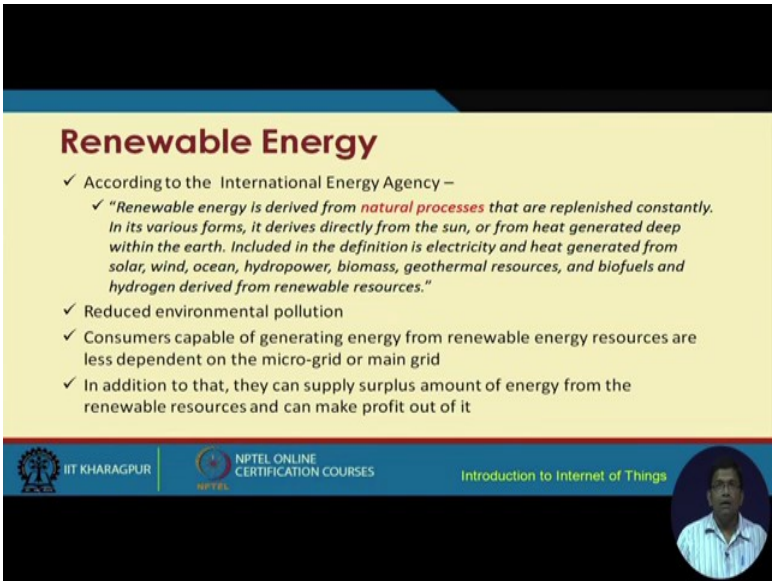

Renewable sources are an important component of smart grid, I am not going to talk about what is an renewable source the definition is given for you, but there are as we all know from our basic knowledge that wind solar and different other forms. These sources of energy they are they have lot of advantages in order to reduce environmental pollution. So, and these are very attractive and renewable sources of energy are important components of a smart grid.

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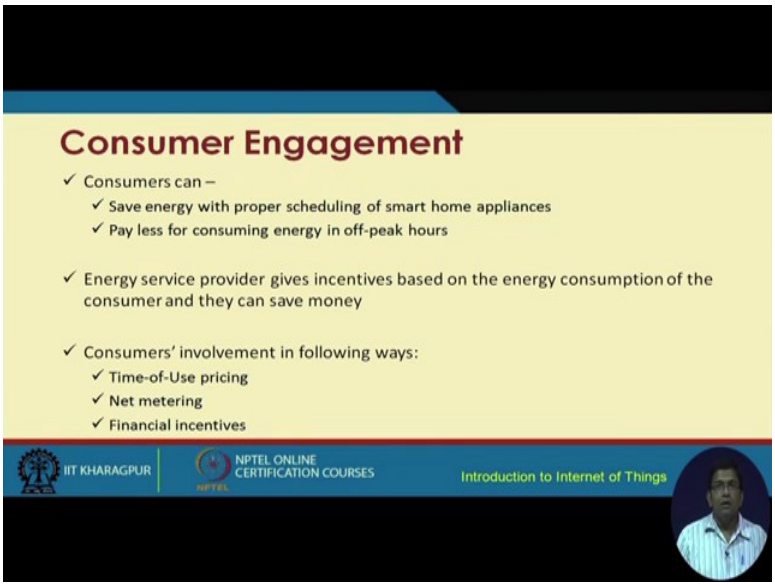

Now, let us talk about the consumer engagement in a smart grid, as I was mentioning briefly before it is possible for the consumers can also to get engaged in the overall process and the system in the functioning of the system, that way the consumers can save energy with proper scheduling of smart home appliances paying less for consuming energy in off peak hours these become advantages to the consumers. So, consumers get engaged in the process and they get advantaged through these means.

Consumer involvement comes in different ways, timer pricing is one net metering is another and financial incentives we are going to talk about each of these in brief.

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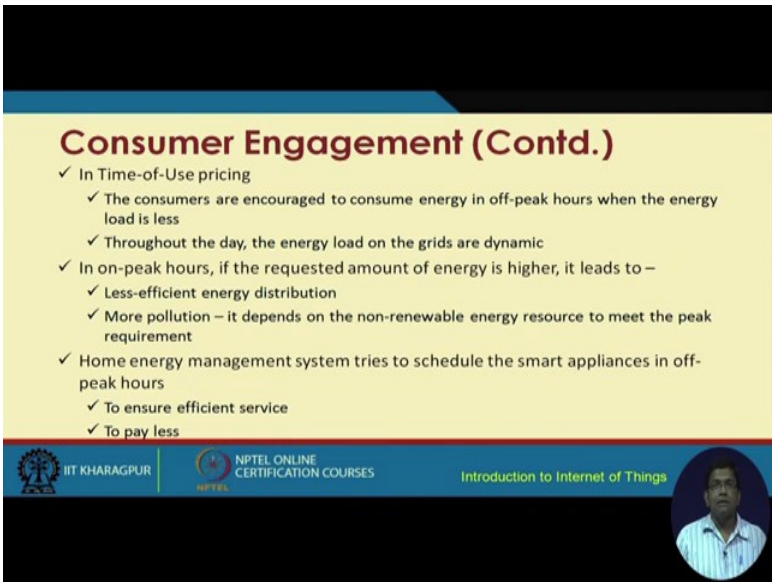

In time of use pricing basically what happens the consumers are encouraged to consume energy in the off peak hours when the energy load is less. So, it benefits both the service provider as well as the consumers. Consumers get you know during if their enjoying the power during the off peak hours that way you know. So, they have lower rates of electricity they are paying at lower rates and it also benefits the overall grid the different other stake holders like the service provider because that way they can manage the overall load in the city or you know where ever the electricity is being provided they can manage it better. And throughout the day the energy load on the grid becomes dynamic.

So, dynamically you know it can be made possible to use the different consumers they can use the grid the energy load in different times of the day in a dynamic fashion. In the on peak hours if the requested amount of energy is higher it leads to less efficient energy distribution more pollution, and home energy management system basically tries to schedule the smart appliances in the off peak hours to ensure efficient service and to pay less.

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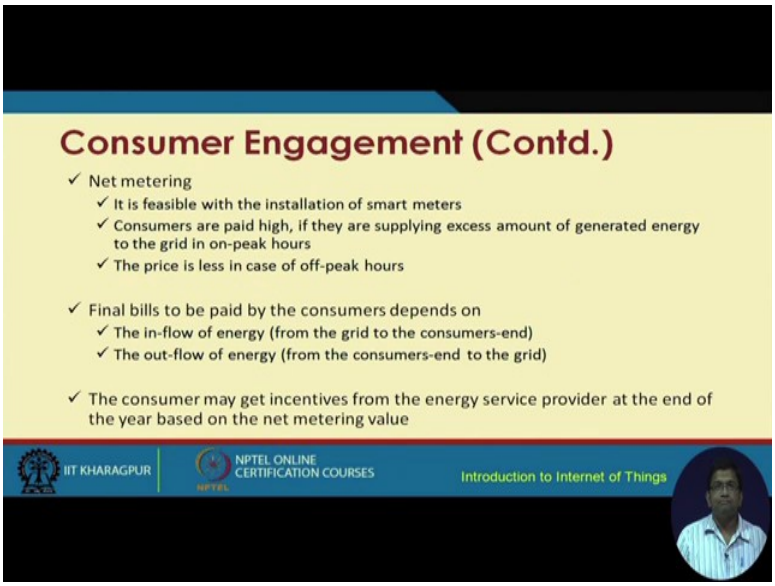

Net metering it is one feature through which it is feasible with the installation of it is feasible net metering can be done with the help of installation of smart meters. The consumers are paid high if they are supplying excess amount of generated energy to the grid in the on peak hours, and the price is less in case of off peak hours. The final bills to be paid by the consumers depend on the inflow of energy from the grid to the consumer end and the outflow of energy from the consumer end to the grid. The consumer may get incentives from the energy service provider at the end of the year based on the net metering value.

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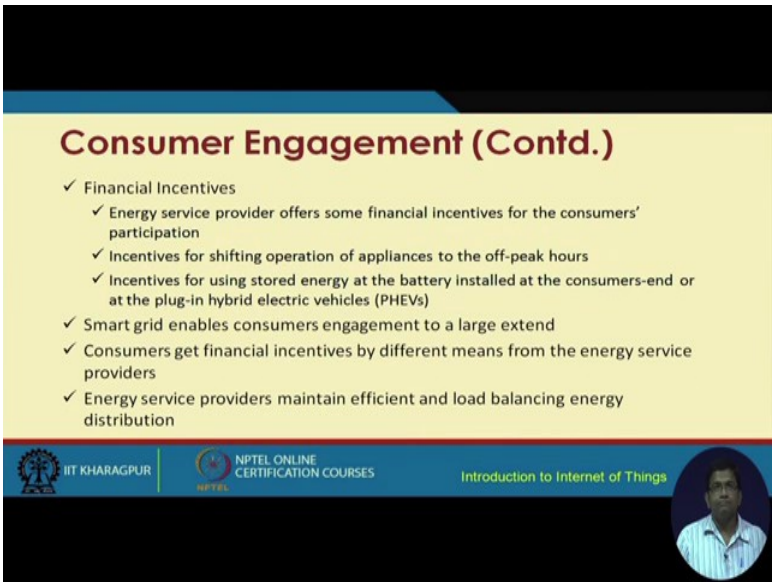

There are financial incentives as well through consumer engagement, energy service provider offers some financial incentives to the consumers participation incentives can be there for shifting operation of appliances to the off peak hours, incentives can also be provided for using stored energy at the battery installed at the consumer send and at the plug in hybrid electrical vehicles or the plug in electrical vehicles as such. Smart grid enables consumers engagement to a large extent, consumers get financial incentives by different means from the energy service provider through this particular process.

With this we come to an end of the first part of the smart grid as we have already seen that vision of smart grid is very attractive. So, it basically tries to transform the traditional power grid to a new system new cyber physical system, where ICT tools are used in a big way and these traditional smart grids can be made much more efficient, much more secure, and much more useful to the consumers and so what we are going to do is we will continue with our discussions. We have already seen some of the components of the smart grid we have seen the smart home and the consumer engagement and there are few other facets of the smart grid and that is what we are going to discuss in the second part of the smart grid.

Thank you.