Introduction to Internet of Things
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Lecture – 52
Smart Grid- Part– II

We have discussed in the first part of lecture on smart grid. We have already seen the different advantages of smart grid over the regular traditional electrical grid. We have also seen that this smart grid has different components; different facets, we have already discussed about 2 such facets of smart grid one is the smart home the other one is the consumer engagement when are going to continue and look at the other four facets of smart grid.

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So, we will start with the operation center.

So, we have different draw backs of the traditional operation center for example, traditionally these operation centers they try to make sure that the amount of generated energy is getting used the grid is unstable if the grid voltage drops due to excess energy generation there is limited control capabilities and there is no means to detect oscillation which leads to blackout and there is limited information about the energy flow through the grid in a smart grid. It is possible the smart grid basically overcomes some of these different difficulties with respect to the operation center by providing information and

control on the transmission system making the energy grid more reliable and minimizing the possibility of wide spread blackouts.
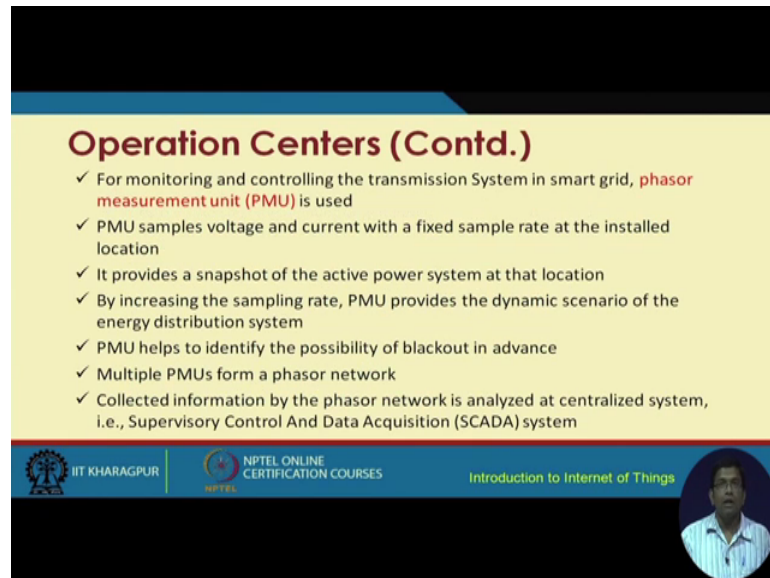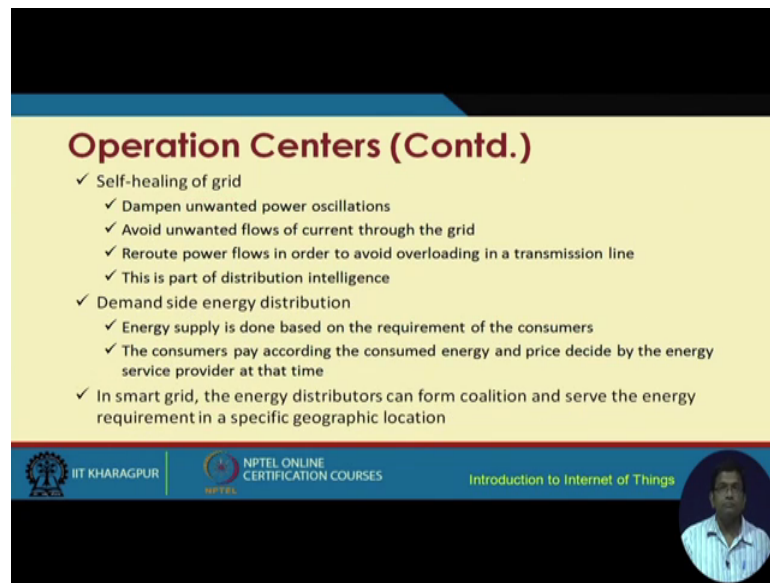
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For monitoring and controlling the transmission system in the smart grid something known as the phasor management units or the PMUs are used these PMUs what they do is the sample the voltage and the current with the fixed sample rate at the installed location and then provide a snapshot of the active power system at that particular location and this way it increases the by increasing the sampling rate. The PMU provides the dynamic scenario of the energy distribution system the PMU helps to identify the possibility of blackout in advance and these multiple PMUs can be connected together can be networked together to form something called the phasor network and this connected information of the phasor network can then be fed to the SCADA system may be there could be a server or something some centralized system with some data acquisition and analytics and analysis ability it can fed and further analytics can be performed for better use of that particular information.

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So, these operation systems operation centers they have the self healing capability. So, these self healing by the self healing mechanisms it is possible to dampen unwanted power oscillations; that means, that you know power oscillations power voltage fluctuations etcetera, etcetera they can be dampened and then avoiding unwanted flows of current through the grid rerouting power flows in order to avoid over loading in a particular transmission line and this is possible through the distribution intelligence or distributed intelligence incorporation of it in to the system demand side energy distribution is also possible energy supply is done based on the requirements of the consumers the consumers pay according to the consumed energy and price decided by the energy service provider at that particular time and as I told before that this energy.

Now the price can vary at different times of the day and the consumers they can connect their different appliances they can schedule their different appliances to function at different times of the day depend on the on peak or off peak hours and everything you know each of these is possible through the help of advanced computational methods. So, in smart grid the energy distribution can form coalition and serve the energy requirement in a specific geographic location.

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So, this distributed intelligence or the distribution intelligence implies that the energy distribution system is equipped with smart devices sensor based devices smart IoT devices internet of things devices and this is where smart grid becomes very attractive to the consumers. So, along with the smart meters distribution intelligence can help to identify the source of power outage there are different sensors that are used. So, from the sensors and their different data that are equipped through from each of the locations of the sensors.

It is possible to find out automatically in a very intelligent way that where things are going wrong what is the source of the power outage ensure power flow automatically by combing automated switching optimizing the balance between the real and reactive power in the case of reactive power the devices that store and release energy and devices can store and release energy and cause increased electrical currents without consuming real power the intelligent distribution systems can maintain the proper level of reactive power in the system and protect and control the feeder lines in the transmission system.

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Now, let us look at the other component on the facet as I was calling it of the smart grid which is called the plug in electrical vehicles PEVs or if it is a hybrid electrical vehicle plug in hybrid electrical vehicles or PHEVs smart grids have the the infrastructure that is needed to enable the efficient use of plug in electrical vehicles and what happens to these PEVs is in the same way as we have these gas stations in the gas stations what happened is these vehicles go and they you know they basically connect to the petrol pump and the petrol gets petrol or the diesel the fuel basically is injected into the fuel tank of the car or the vehicle and then according to the bill that is generated the basically the consumer or the user he or she pays for that that much of the petrol or the diesel the fuel that he has purchased.

A similar sort of thing happens in the case of PEVs as well. So, there are charging stations as we have petrol pumps or the gas stations the here there are charging substations in the city. So, these electric vehicles they are going to go and they are going to connect to these different points where it can charged the vehicle can be charged and depending on you know how much charge has been has been received by the vehicle the owner of the vehicle basically the owner or you know driver basically pays for a that that much unit of charge that has been consumed that has been used that has been transferred to the vehicle.

A very similar sort of analogous situation happens in the PEVs. So, these are very interesting and plug in electric vehicles PHEVs basically you know what happens; it is hybrid vehicle; it is a hybrid electric vehicle. So, you here you have not only electric source of energy that drives the system, but also the traditional you know gasoline or you know traditional diesel gasoline and so on. So, we have hybrid sources of energy driving the vehicles. So, sometimes it will be running on diesel a bus can be running on diesel the hybrid bus hybrid electrical vehicle sometimes it can be running on the electricity. So, we have both the sources of transmissions of power.

PEVs basically help in reducing the dependency on oil and these are clean and clean sources you know because electricity is a clean source. So, there is no pollution when running on electricity PEVs rely on power plants to charge their batteries and energy service provider encourages the consumers to charge the batteries of PEVs in off peak hours PEVs also can be used as a energy source in on peak hours.
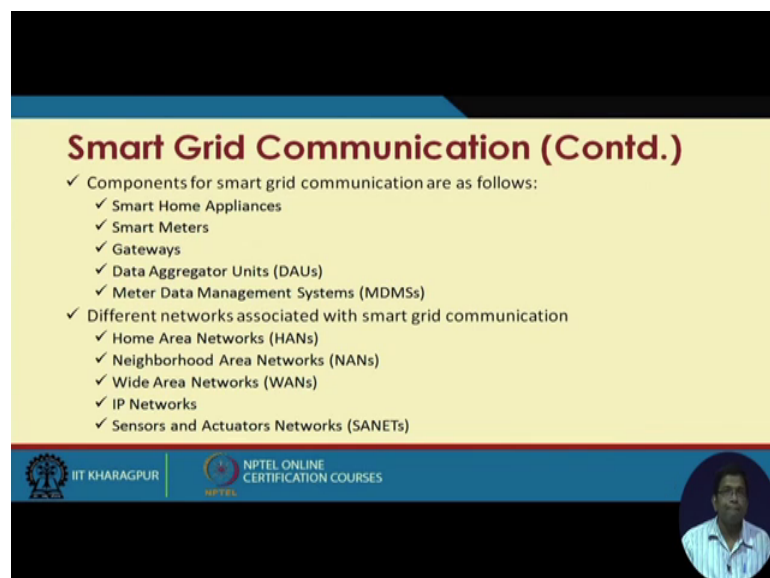
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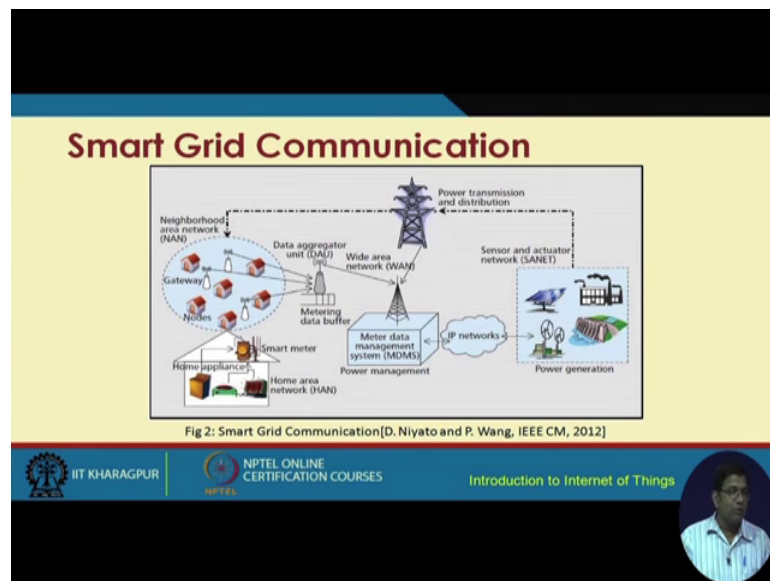
So, let us look at this particular figure. So, what we have as we can see is here we have the power generation system and this is the figure that we have seen earlier as well, but here we are going to look at it from a different perspective. So, we are going to look at it from the communication perspective here as we have seen that we have 2 types of flows of information sorry of 2 types of flows one is the flow of energy the other is the flow of

information. So, we have the traditional flow of power the energy the electricity and we have the additional information flow.

So, this has to be you know. So, and why it is required it is required because sometimes it might be required to for the consumers for example, to operate upon some of their appliances or can feed some information to this to the to the power center to the service provider service provider can be receiving some information their intermediate systems can be receiving some of these information through a from the consumer through their smart meters and so on.

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So, you see that what we have is not only the flow of energy, but also the flow of information. So, communication is very important smart grid one of the important components is the communication component and here we have the smart appliances smart meters and gateways these are communication gateways the network gateways and we have the data aggregator units. The DAUs the data aggregator units basically aggregates data from these different appliances at different homes from each of these homes each of these homes and their corresponding smart meters are connected to the DAUs and then we have the meter data management system the MDMS.

So, these are the different components of the communication aspect of smart grid. So, as you can see that each of these components they can form different nodes of the traditional networks that we are familiar with as we discussed in a previous lecture. So,

different networks are associated with the smart grid communication we have in the case of smart grid we have different terminologies like neighborhood area network wide area network IP network and sensor and actuator networks. So, we have different types of network.

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So, for smart grid appliances the available protocol that are used are C-Bus DECT, the EnOcean and the universal power line bus and I am not going to go through, but the corresponding data rate.

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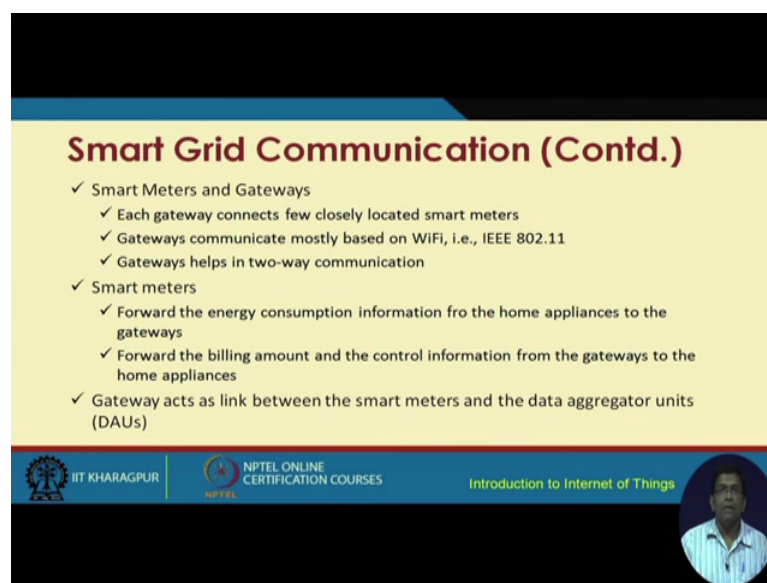
And the main feature are given in the slide in front of you similarly what we also have other thread the Zigbee and simple cable solution SCS with the corresponding data rate and their corresponding features a given over here some of some of these like Zigbee is something that we have already discussed in a previous lecture and this is not very you know Zigbee; Zigbee is very attractive to have you know low data rate small short range communication established between different nodes in the network for example, different sensors it is possible sensors in the smart grid is possible to have Zigbee communication between them.

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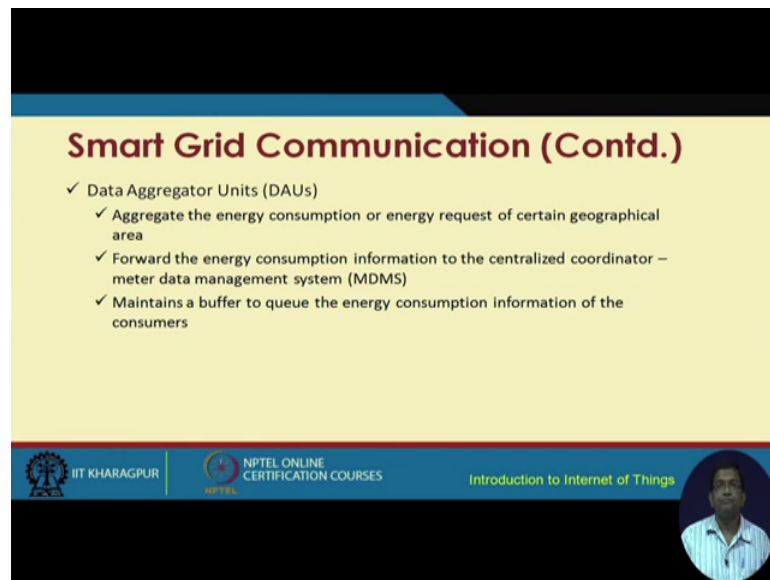
We also have different other components like the smart meters and the gateways where each gateway connects very closely to the smart meters the gateways communicate mostly based on Wi-Fi which is 802.11 the gateway helps in the 2 way communication and the smart meters forward the energy consumption information from the home appliances to the gateways and forward the billing amount and the control information from the gateways to the home appliances these gateways act as link between the smart meters and the data aggregation units.

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The data aggregation units aggregates the energy consumption or energy request of certain geographical area this is very important and this is very much required. So, what we have is we have a very complex problem and this complex distributed problem can be solved with the help of the traditional you know grouping or clustering based mechanisms. So, use of DAUs is very similar to clustering approach. So, what we are trying to do is for every few entities in a particular area we are going have this DAUs this DAUs are going to be the aggregators of the information and the energy consumption etcetera and then this DAUs after aggregation they are going to forward the energy consumption information to the centralized coordinator through the MDMS.

So, the MDMS basically you know helps in connecting to the centralized back end and it maintains a buffer to queue.
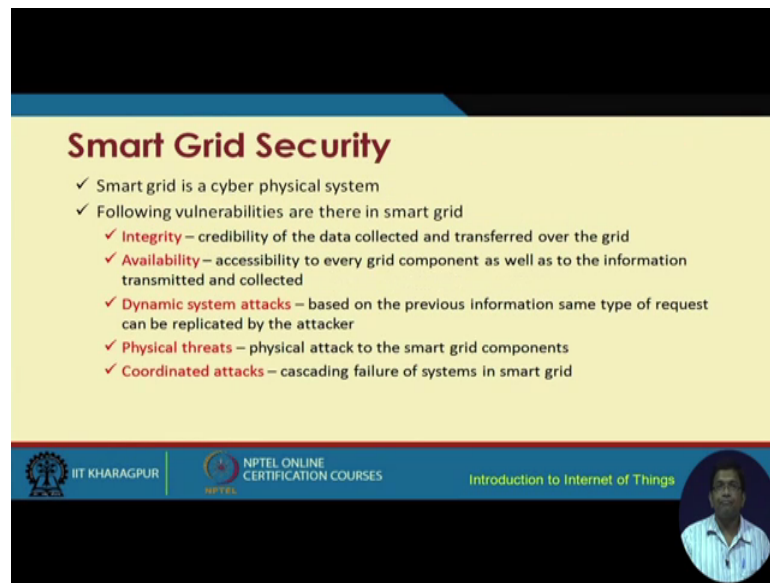
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The DAUs basically they maintain a buffer to queue the energy consumption information of the consumers the MDMS acts as a centralized coordinator for smart grid communication it handles it is handled by the service providers and it is part of the operation center the MDMS decides the price per unit energy to be paid by the consumers. So, it plays the MDMS plays a very important very crucial role in the functioning of the smart grid. So, we need to understand this thing very well the DAUs basically send the data to the MDMS which is located which is you know which is located in the smart grid back end at the service provider end and it is a centralized coordinator for the entire smart grid and it is part of that operation center and decides the price per unit energy this is very important, it decides the MDMS decides the price per unit energy to be paid by the consumers at different times.

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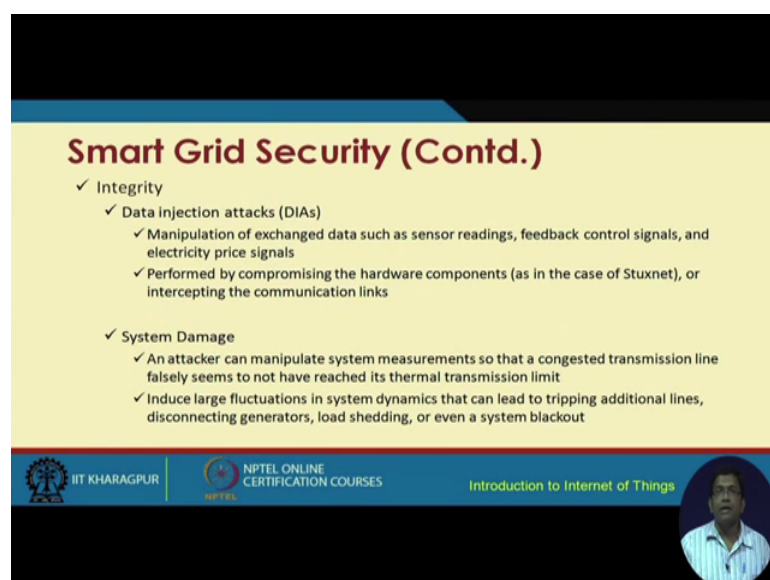The next part is very crucial in this smart grid communication which is the security aspect and it is very very crucial because we are dealing with not a traditional power system, but a cyber physical system and in as it happens in any cyber based system and any cyber physical system security is very important there are different types of vulnerabilities in a smart grid we have issues with integrity availability dynamic system attacks are possible different types of attacks are possible different types of physical threats on the different components of the smart grid are possible different types of other complex and coordinated attacks can be launched on a smart grid.

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So, these are very important to be looked into when we are trying to build a smart grid integrity is very important you know because you know it is all about use of data different types of data are fed in to the system.

You know different types of attacks can be performed consequently for example, the data injection attack DIA attack can be performed on a smart grid and there by effecting the overall integrity of the functioning of the smart grid system can be damaged very easily an attacker can manipulate the system measurements. So, that the congested transmission of the falsely of the all the of the false data seems to not have reached to the to the thermal transmission limit this induces large fluctuations in the system dynamics that can lead to tripling additional lines disconnecting generators load sharing or even a system blackout. So, as we can see that overall system can be damaged if this is not taken care of. So, this is a very important security concept.
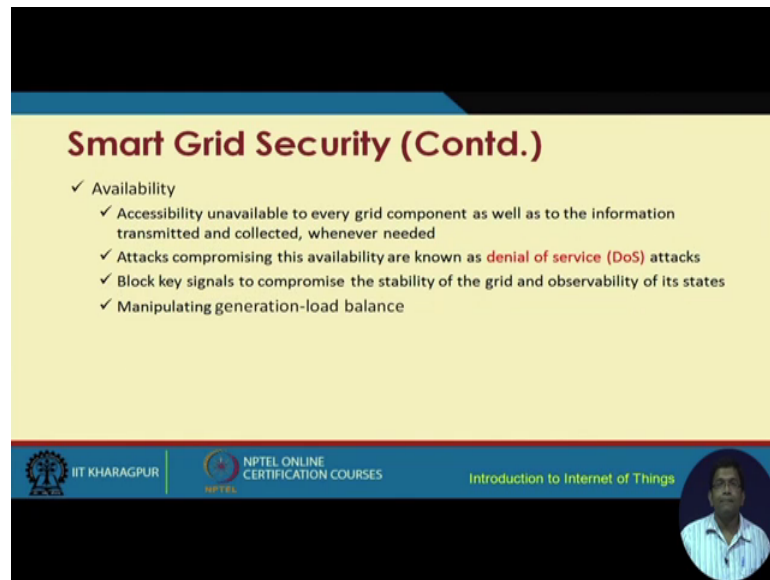
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Financial benefits can be there to hurting the integrity of the system for example, you know the attacker can manipulate the electricity prices by doing this one can by energy with lesser price from a service provider and make high profits and as you as you can understand that it is very easy to do because the cyber system basically connects to the physical system and through the cyber system attacks can be launched on the physical system and it is possible to basically indirectly steal the electricity at lower prices or even at low process without paying it without paying any price electricity can be stolen.

Different time synchronization attacks can be launched where an adversary can manipulate the time reference of the time stamped measured phasors to create a false virtualize a visualization of the actual system conditions there by yielding inaccurate control.
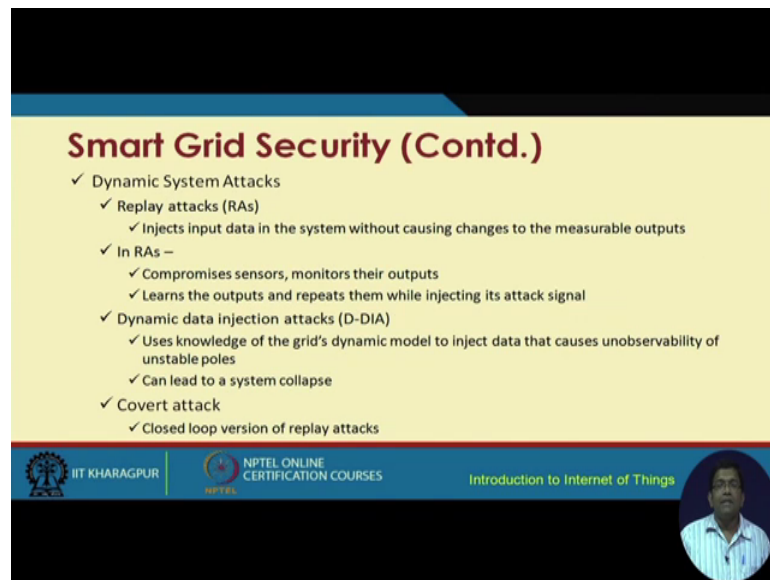
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And protection actions availability is a very important issue in the case of security of smart grid different types of denial of service attacks different types of replay attacks can be launched in a replay attack basically what happens if the attacker injects the input data
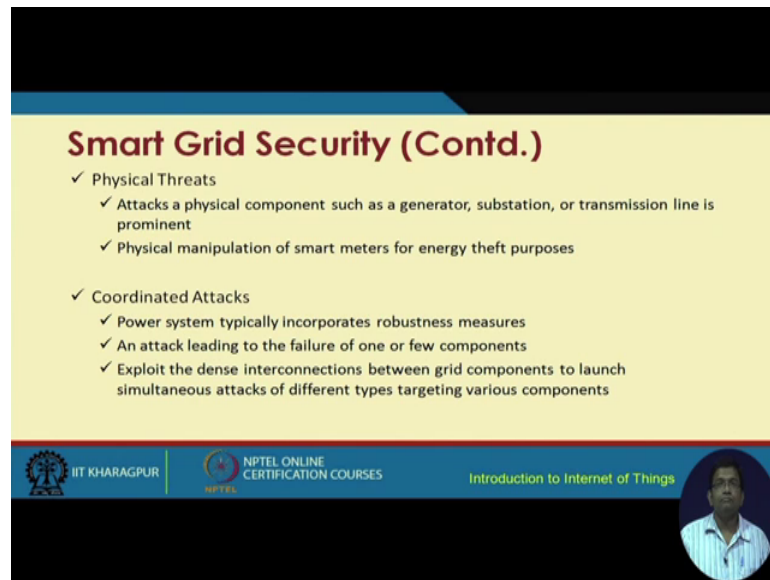
into the system without causing changes to the measurable outputs different types of other distributed data injection attacks can be dynamic data injection attacks can be performed where in the attacker uses the knowledge of the grids dynamic model to inject data into data that causes of un observability of unstable poles.

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Physical threats can be launched attacker basically physically damages some of the components for example, the generator can be damaged the substation or the transmission lines can be damaged and different other types of coordinated attacks can also be launched.
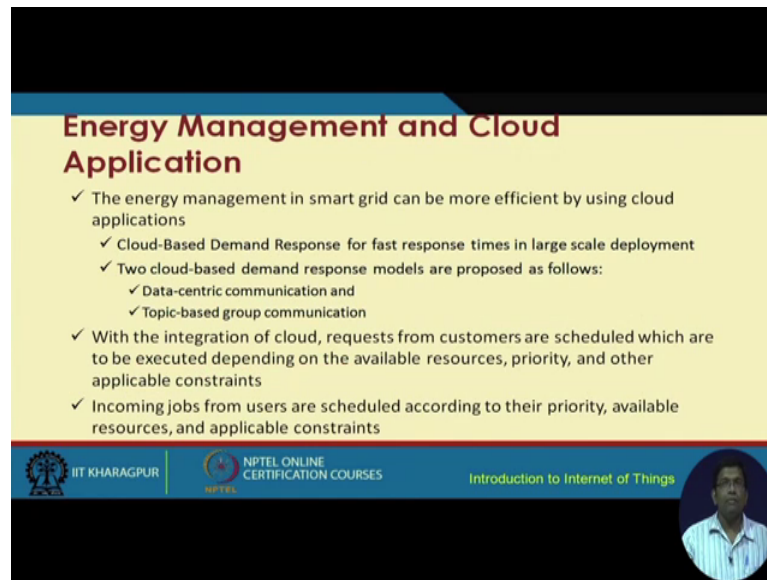
Now, one very important issue is that the smart grid can exploit the use of the cloud technology as well because this smart grid as we have seen is a source of generation of lot of information that information can be stored at the cloud and therefore, there are the very important things that can be done with the help of augmenting with the cloud technology.

So, cloud applications can take a lead in different several aspects for example, with respect to energy management information management and security management. So, I am going to briefly talks about each of these highlighting their use, but this is available in the paper in the research paper that for the reference of which is given on the slide. So, this paper has been published in the I triple e transactions on parallel and distributed systems in the year 2015 and this particular paper basically serves as an important reference about how smart grid and cloud technologies can integrated together to harness the benefits of each of these and making the power system much more attractive.

So, as we can see in this particular figure what we have is we have the substation micro grid customers the traditional power lines and then we also have the communication link and this communication link basically feeding this data to the cloud data storage and here on the other hand on the other side as we can see over here we have another type of cloud which is the energy storage. So, we have the cloud energy storage which basically stores the electricity over here and on the other hand this information can be stored in the

cloud data storage. So, bringing the energy storage and the data storage together 2 different types of in a cloud conceptually we are talking about is made possible with the help of these cloud integrated smart grids.

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So, energy management and cloud applications are very interesting the energy management in smart grid can be more efficient by using cloud applications with the integration of cloud requests from the customers are scheduled which are to be executed depending on the available resources priority and other application constraints.

So, this is very interesting because you know. So, on the cloud side there are different models of cloud which can be utilized over here by the smart grid for energy management for example, we have this platform as a service we have the software as a service we have the infrastructure as a service. So, not only that we will you know will be using the cloud for storing the information, but different algorithms different you know different systems different you know software can be executed at the cloud end and that basically you know helps the smart grid to harness the benefits of the cloud technology.

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Integrating cloud computing applications for micro grid management in the form of attractive in the form of different module such as infrastructure power management and service the number of supported customers basically increase that way and with the cloud applications it is possible to integrate and analyze the information that streams from multiple smart meters simultaneously in order to balance the real time demand and energy curves.

So, as we can see over here lot of dynamic aspects you know can be managed efficiently dynamic because you know when we are talking about energy management in the smart grid things are very dynamic not only the pricing is dynamic everything is dynamic energy generation energy distribution energy use pricing each and every thing is dynamic and all of these requests smart algorithms and software to help in you know in achieving all of these particular features these specific features and the cloud can help in achieving this particular objective then another advantage is real time energy usage and pricing information can be shared because you know. So, in the cloud we have these; the communication backend the network everything is network together. So, this information about the energy usage pricing information they can be shared with that potential customers and not only customers, but also the other stake holders.

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So, that was the energy management then we have the information management. So, information processing in smart grid fits well with the computing and storage mechanisms available for cloud applications information from different components and the supply and demand state conditions can be shared with the help of cloud computing real time distribution data management and parallel processing of information can be utilized using smart grid data cloud application. So, if you can look over here in this particular figure what we have are end users substations micro grids utility providers communicating bi directionally with the cloud data ware house.

So, cloud data ware house basically has all the data. So, all these data can be stored in the cloud data ware house also from this particular end it is bidirectional because the data can flow also from this end to these different components. So, we have this information flow in both the directions and this information flow has to be managed properly.

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So, then comes the security aspects some of which I have already mentioned before. So, security in the smart grid is very important and electrical power system an electric power information security information security and protection system can be developed using the cloud security mechanisms private cloud platforms are suitable for scaling out and processing millions of data from the users and using the cloud computing platforms the electrical utilities can quickly and efficiently deal with malicious software.

So, here you know this particular figure is very interesting to look at we have at the very bottom the users the utility micro grid third party and through different authentication and authorization mechanisms these and in the interim we have this web services you know. So, these basically can feed in the data from these different devices authorized data in a secured data can be fed in you know and can be stored at the loud end and the other direction also the same way because we have these different models of the cloud IaaS, PaaS and SaaS and these data can be basically you know shared bidirectional between these devices and the cloud models and that way these components the intermediate components and the layers can be made much more efficient and secure there by making the system much more secure than the traditional smart grid. So, cloud basically helps in this particular in the security process cloud basically helps in a big way.

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So, security and protection system for cloud here we have the servers that act as the cloud and take decision according to the clients data their privacy issues in the smart grid that also can be can be used can be can be solved can be addressed by the help of the cloud in a much more better fashion, but again cloud security as cloud security and privacy particularly is also a very a important concern and so we have the privacy concerns in the case of cloud which are inherent to the cloud plus we have the privacy concerns in the case of the smart grid the traditional smart grid and how these 2 privacy concerns can be further addressed in an integrated way is something that different people different researches are looking into.

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So, with this we come to an end here are some of the references for you to go through. So, this particular paper you know it is authored by me it is published by I triple E communications magazine and there are few other papers I was already mentioning about plug in electrical vehicles and plug in hybrid electrical vehicles this particular paper you can have a look at to understand how in the smart grid and PEV or PHEV context how dynamics pricing can be made possible this is one such solution which talks about it integration of cloud to smart grid this particular paper which is been published in the I triple e transactions on parallel and distributed systems.

This is a important this is a very interesting source I can say and this is one of the kind and you know. So, by going through this particular paper one can understand the different aspects of or the different challenges that are going to be phased by integration of cloud with the smart grid and different aspects like the how residential energy management can be done in the smart grid you know there is one such paper given over here and in vehicular energy networks you know how energy can be managed this is given in this particular paper at the end.

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So, these are different papers that talk about different aspects the few other papers are also given over here very important papers are listed. So, one can you know if you if you are interested further interested to learn about smart grid you know these are the important rich sources of information about smart grid. So, what you must have noticed is you know. So, what I tried to do in this particular lecture is to you know keep our discussions at the level of motivating and trying to understand how smart grid is important, but we try to abstain ourselves from deeper discussions about how to build a smart grid. So, that is you know the; here basically you know our focus is not on how to build a smart grid, but what are the different aspects of smart grids smart grids.

If somebody is interested you know particularly somebody from power systems background if they are interested to build a smart grid what are the different issues that have to be taken care of and so, these are the this is this is the focus of this particular lecture and how smart grid plays an important role in the IoT context because our course is on IoT; internet of things we do not want to really really understand deep into each of these technologies, but we want to get introduced about the different aspects smart grid is one such technology or one such aspect we wanted to understand and. So, this is the reason you know we try to keep ourselves at this higher level of understanding about smart grid and not deeper in to how a smart grid can actually be built.

So, this basically requires you know building of a smart grid is a different semester course that can be you know that if somebody is interested with electrical engineering background they can attend, but this particular you know course because we are focusing on IoT we you know it is important to understand the different important subtleties that are involved in the building of the smart grid and why smart grid is required and what is the what is the motivation behind building smart grid in the IoT context. So, with this we come to an end of discussions on smart grid in the case in the context of internet of things.

Thank you.