**Introduction to Smart Grid**
**Prof. N. P. Padhy**
**Department of Electrical Engineering**
**Indian Institute of Technology, Roorkee**

**Lecture - 35**
**Demand Response Analysis of Smart Grid**

Welcome you all to the NPTEL online course on Smart Grid. Today we will be talking about Demand Response Analysis of Smart grid. As we have seen in our previous lecture where the demand side management analysis due to the presence of smart grid have been analyzed, where most of the cases we have focused how to make the load curve flat by reducing the peak and increasing the of peak and that is majorly on a system site. But today we will focus on demand response analysis which is ideally focus to the customers connected to my low voltage networks.

Now, if you go through the smart grid features, mainly it to wish to incorporate maximum volatile renewable energy into the system, and ideally the renewable energy and the load demand characteristic do not match. As we have seen especially for both wind and solar the peaks do not match with the system peak. So, what we can do perhaps we can incentivized our customer, those are connected at low voltage site, so that they can follow a shape of consumption pattern as well as the time of consumption pattern such that, the consumption pattern do match with my renewable generation plentily available.

So, that we can avoid our storage and perhaps we can reduce the consumption of energy taken from the main grid. With this focus let us understand one of the key objective of smart grid; when we proceed for smart grid we have to make sure it is not that being design just to make my distribution more interactive, but we have to extract the maximum advantage of this infrastructure which has been placed through demand response program. Then only we can claim that the smart grid is really working well where the peak reduction is possible, the energy load demand characteristic become flat and the peak of consumers do match partially with the renewable energy availability peak.

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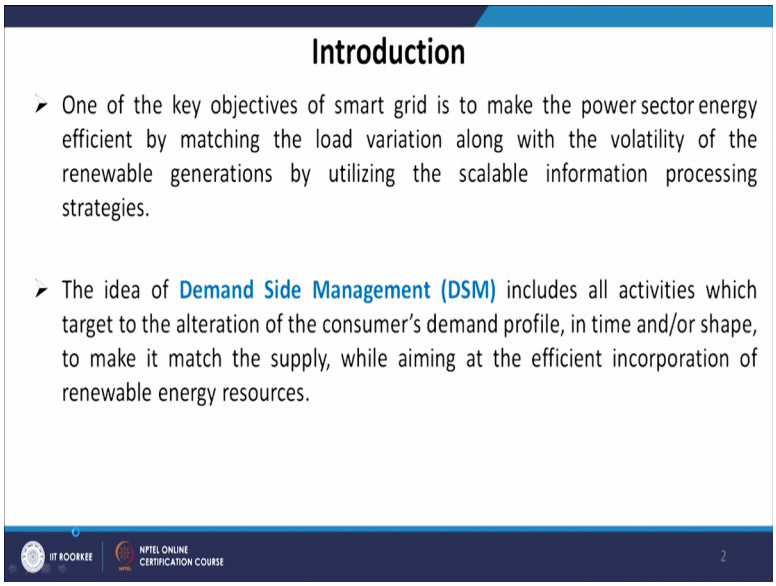


One of the key objective of smart grid is to make the power sector energy efficient, by matching the load variation along with the volatility of the renewable generation by utilizing scalable information and processing strategies. And those information exchange is now possible because you do have smart grid in place. Now moving further the idea of demand side management include all activities, which target to the alteration of the consumers demand profile in time and or shape, to make it match with the supply while aiming at the efficient incorporation of renewable energy sources.

Now, one of the main demand side management strategy is demand response. So, demand response according to me is a subset of the overall demand side management program, but sometimes demand side management is being aim to a high voltage networks, where is demand response is ideally aiming to low voltage network where the customers can directly you know play an important role to manage your load profile. Now what is demand response? If you see different part the world the demand response is being defined differently similar to the smart grid definition, and if you concentrated on US department of energy definition of demand response.

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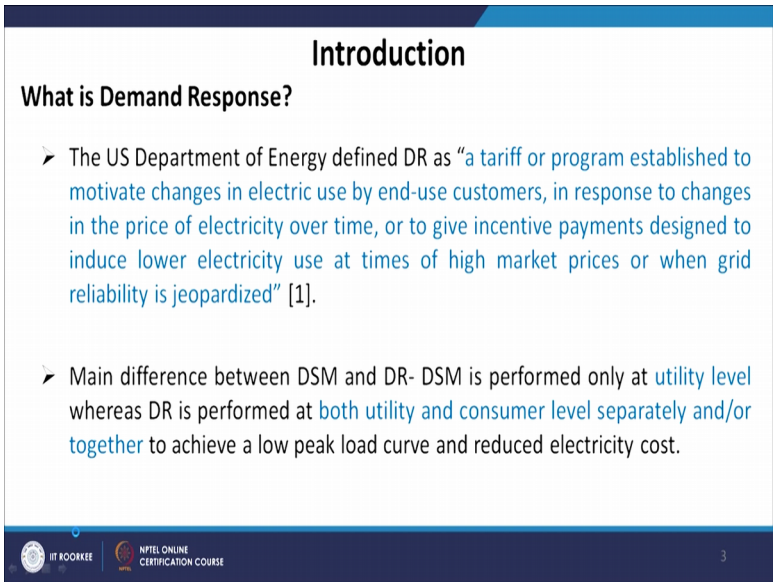


That says a tariff or program established to motivate, changes in electric use by end use customers in response to changes in the price of electricity over a period of time.

Means if the consumption rate or tariff if it is going on keep on changing, then our consumption pattern expected to change or to give incentive payment design to induce lower electricity use, a times of high market prices or when the grid reliability is jeopardized. What it says: now me being a customer, now if you tell me that the energy price is very high at this period of time, and if I am bit sensitive then certainly I will avoid consuming energy at that period until unless I mean there are some critical loads that I cannot compromise.

But if some of the loads that can be compromised at a given period of time, when the cost is very high, certainly I wish to prepone by activity by couple of hours when the price is cheaper. So, what I am doing basically I am not stressing upon my system ok, and I just enjoy make sure my electric bill is very low. One more important challenge is that if my system is in great trouble, they need the help of the low lower customers to behave or act according to the systems requirement, the system is great trouble the load has to come down. So, that case perhaps we can put a high penalty on electricity consumption price so that most of the consumers will stop using it and hence my system is protected.

Now, the main difference between the demand side management program or demand response based DSM program is performed only at the utility level. Whereas, the demand response is mainly performed at both utility as well it is consumer level. So, that is important to achieve the low peak load curve with the reduced electricity cost means, if you can follow the price and vary your consumption pattern. So, the overall energy bill or the electricity bill, that you pay become cheaper so, the consumers are happy number 1. And number 2 by doing so, you are really not stressing the system at peak hours all right. So, what are the main aims of demand response analysis?

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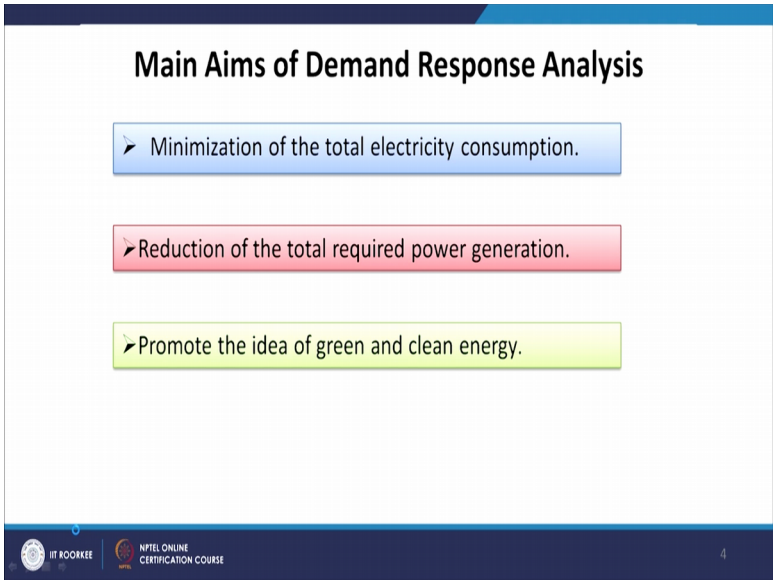


Minimization of total electricity consumption is one of the target; reduction of the total required power generation because the peak is reduced. Promote the idea of green and clean energy. Promote the idea of green and clean energy means I think most of the renewable energy now can be tapped elimination of line overloading because you your down do not try to stretch your transformer, because the pattern of consumption is now balanced.

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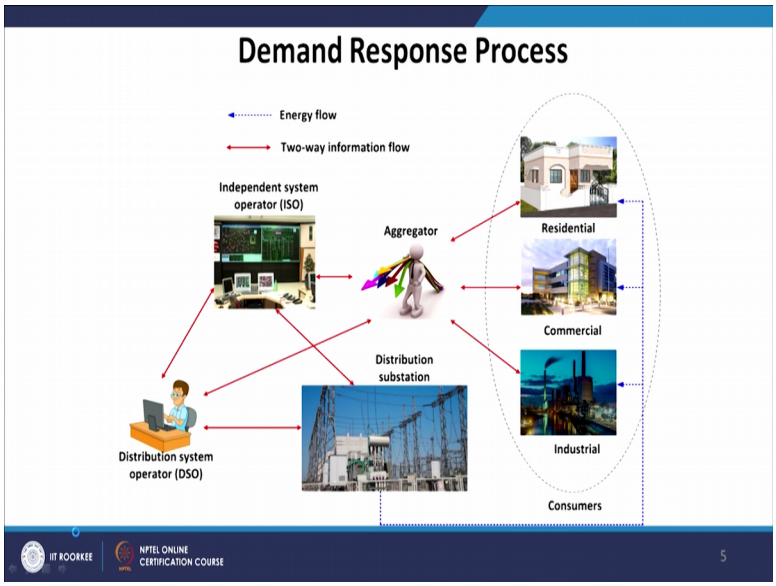


Now, if you look at the kind of architecture of demand response process, now we could see that residential, commercial and industrial customers those are connected and you can see the blue line that shows the energy which is flowing from my main substation to all these 3 category of customers.

But very importantly aggregate do play an important role and who can speak to both ISO as well as to the all 3 category of customers like residential, commercial and industrial. So, now, what happens the aggregate basically once the ISO setup the load pattern, then the aggregator perhaps actually receive those information and go back to their customers and talk to them, how many of them are interested to participate in demand response activity and for which period. And based on that aggregate do plan its characteristic and come back after talking to their customers back to ISO and that will be the kind of load curve will be adopted by the system.

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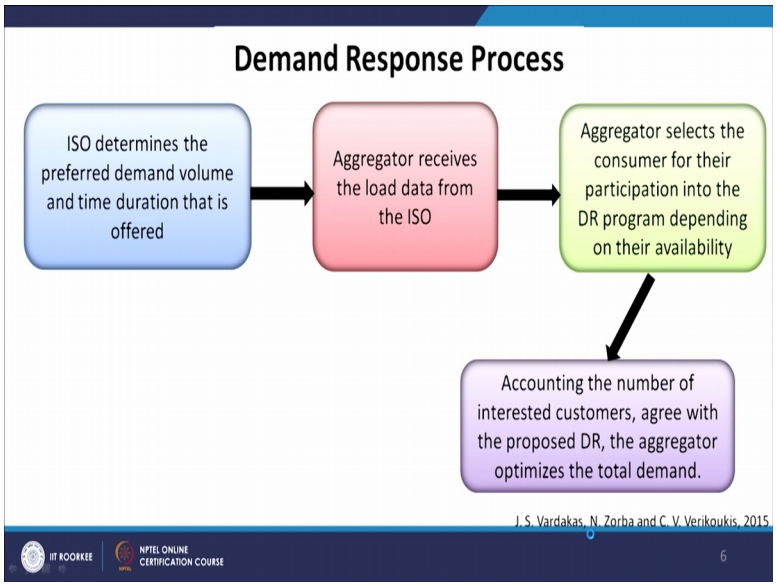


Now, what exactly the process involves? First one ISO determine the preferred demand volume and time duration, that is offered further aggregator receives the load data from the ISO. Aggregator selects the consumer for their participation into the demand response program, depending on their availability or support or agreement. Further accounting the number of interested customer, duration of time, agree with the process of demand response participation, the aggregator try to optimize the load pattern means, at what time I can take them out, what time I can bring the mean you know so that aggregator can have an optimal load pattern and goes back to ISO with the new load demand data, and that is how the system works.

Now, DR demand response is applicable to all category of customers, now looking at the industrial customers, I mean this is quite huge it is in the form of megawatt scale, and load have critical temporal dependencies and must be scheduled with high time precision. Because we cannot effort to delay much and we cannot compromise on the accuracy of the load shifting so, that is quite important here. The demand response program should capable to monitor and control the loads in the scale of milliseconds.

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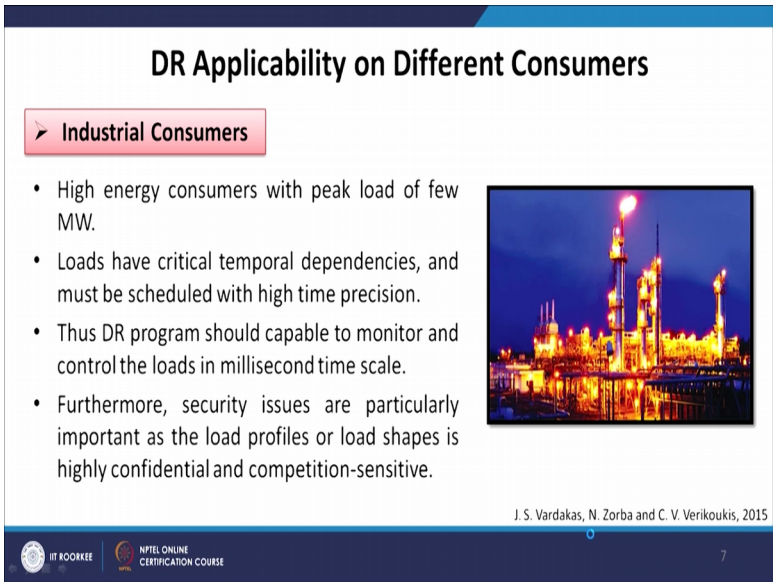


Furthermore security issues are particularly important as the load profiles or the load shapes is highly confidential and competitive in nature.

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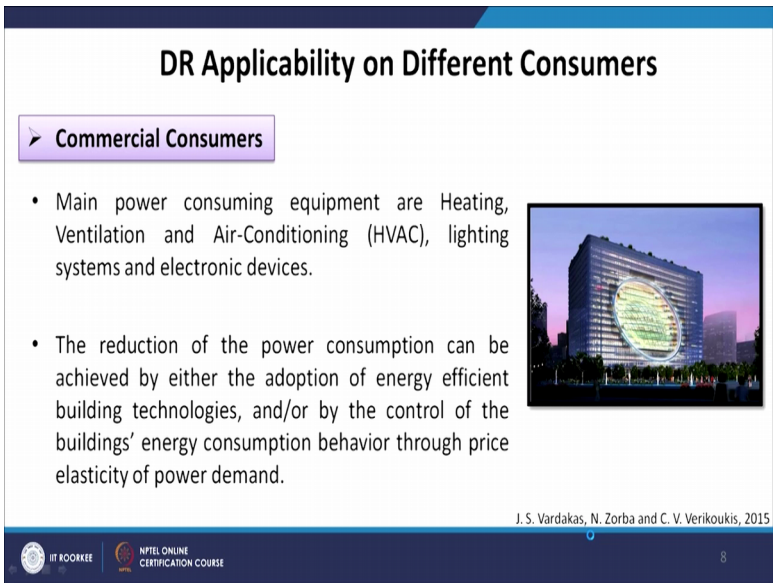


Now, when you go back to commercial, I think the main power consumption in commercial buildings are air conditioning and the reduction of power consumption can be achieved by either the adoption of energy efficient building technologies or having control strategies for buildings energy consumption behavior, and perhaps we can also incorporate the price elasticity a behavior; like if the energy cost is very high normally

the commercial buildings do plan accordingly so, that the overall energy bill is reasonably low.

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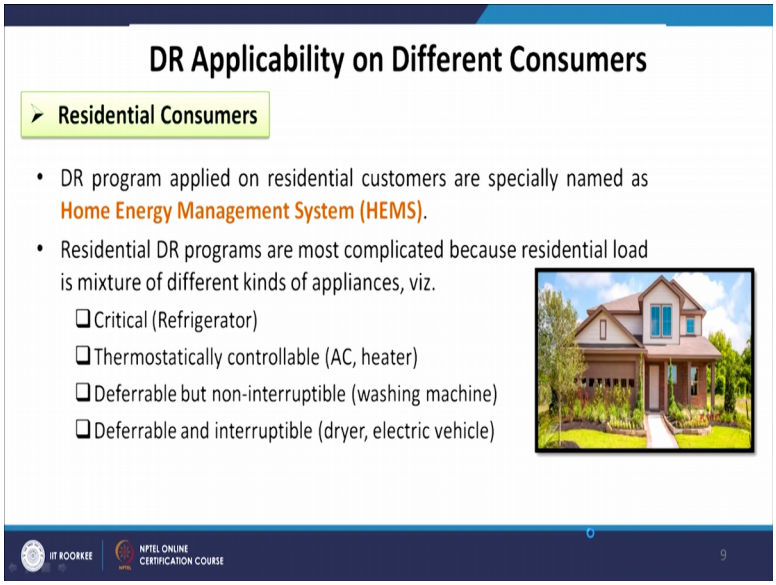


Now, looking back to residential customers, and the sophisticated software or the d m d demand response program applied to residential customers are specially named as HEMS Home Energy Management System. And residential demand response program are most complicated because the residential loads do have different nature and types of load starting from I am in a 0.1 kilowatt to a few kilowatts. Now the very few important things like fridge you cannot compromise it is a critical load, and then we have thermostatically control ACs and heaters and a deferrable you can defer, but non interruptible that is washing machine you need washing machine has to run in a day and, but you cannot stop it and similarly deferrable and interruptible that is my a dryer and electric vehicle.

So, I think this is a great range of devices connected to my resident and so, that is why we believe the demand response program should target maximum to the residential customer, to have a successful demand response program within a smart grid environment. Now the DR program should provide a plenty amount of incentives for the I mean small scale customers like we, to be part of this DR activity until unless significant incentives are available to the families, they may not be interested to participate or compromise their energy consumption pattern in single go.

Now, the very important part under this circumstances we required the quality of service which is very important, we cannot compromise and interoperability which is one more important factor scalability and flexibility. And finally, security those four points need to be taken care.

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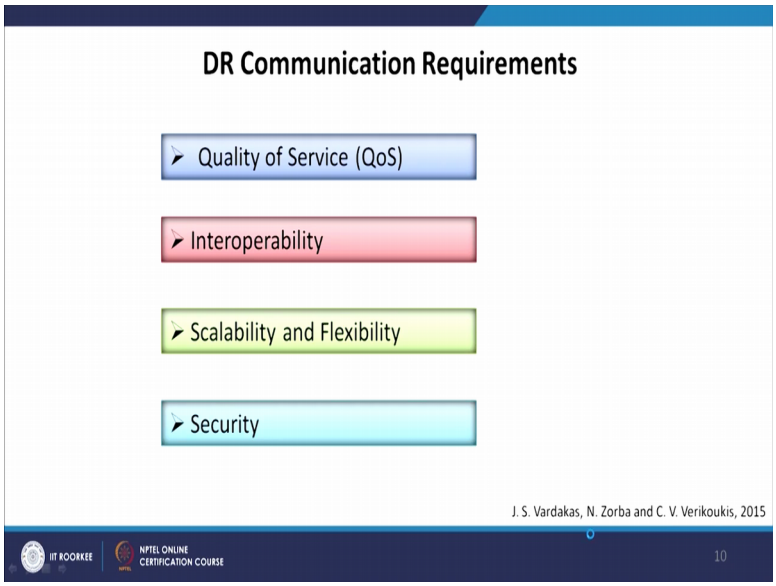


When you talk about demand response analysis of I mean the resistors as well as we have to focus, what is my goal. The goal could be to utilize the maximum renewable energy, low carbon footprints, a social activity it is sounds good, but when you come to action most of the residential consumers may not so, seriously take the program I meant to be implemented until unless there is some financial or revenue support.

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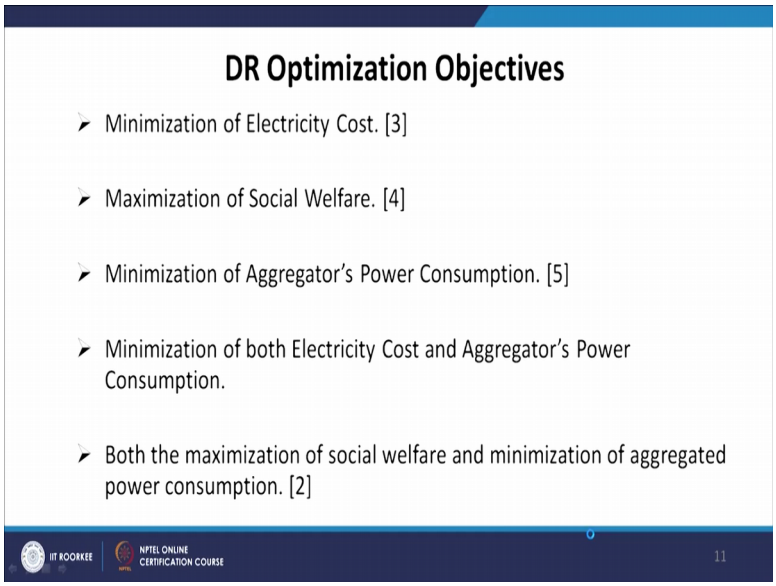


So, first of all we have to minimize the electricity cost of the bill and then maximization of the social welfare, that is a system should get maximum benefit and then minimization of aggregators power consumption and hence that reflection can be made available to the consumers at low voltage level, minimization of both electricity cost and aggregators power consumption. Both the maximization of social welfare and minimization of aggregators power consumption. So, there are lot many things like whether different layers one is system level and then we have aggregator, then we have consumers.

Now, who I mean certainly when you adopted here demand response activity, that is going to benefit all of us, but who will take the maximum share of that and to attract most of the consumers to be part of this activity, I think you have to share the benefit to book I mean to both certainly to the consumers and then aggregator and maybe a part can go to the utility or the social welfare site. So, if you can distribute the benefit I mean to all the 3 parties involved in making your demand response program successful, I think that is sounds good.

Now, classification of demand response program, there are different ways through which we can carry out this program; the first one is actually based on different control strategies. Now we can have a centralized control and then we can have decentralized control to achieve demand response activity. Then we can have based on the price, we can have a dynamic price at different point of time as well as we can have incentive of

penalty best price. To through price I can adapt my demand response activity or it is based on the load that is task related load or energy related demand response. So, we could be depending upon the task or energy that also can be seen.

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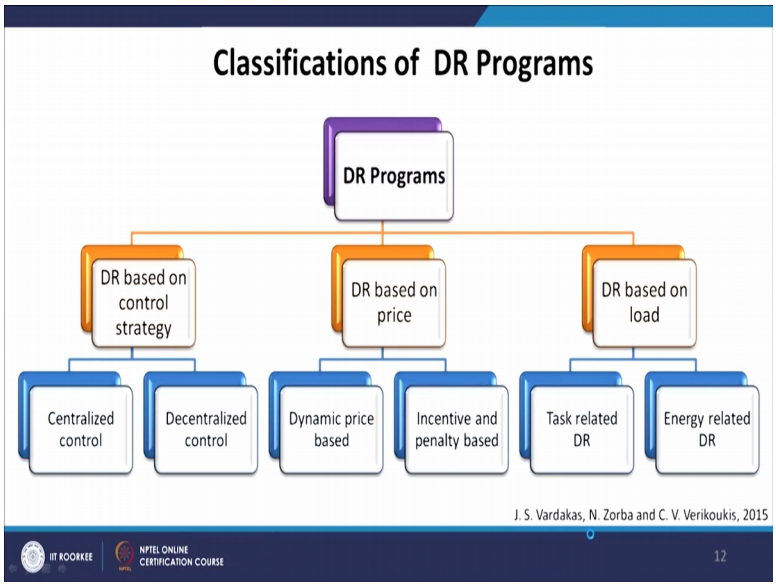


So, overly the demand response program can be taken care or can be implemented in field based on the type of load, price as well as the control strategy. Now let us concentrate what is centralized and decentralized control. Now when you have a community it may so happened that the each and every individual do not speak to themselves, but they speak to a common point ok.

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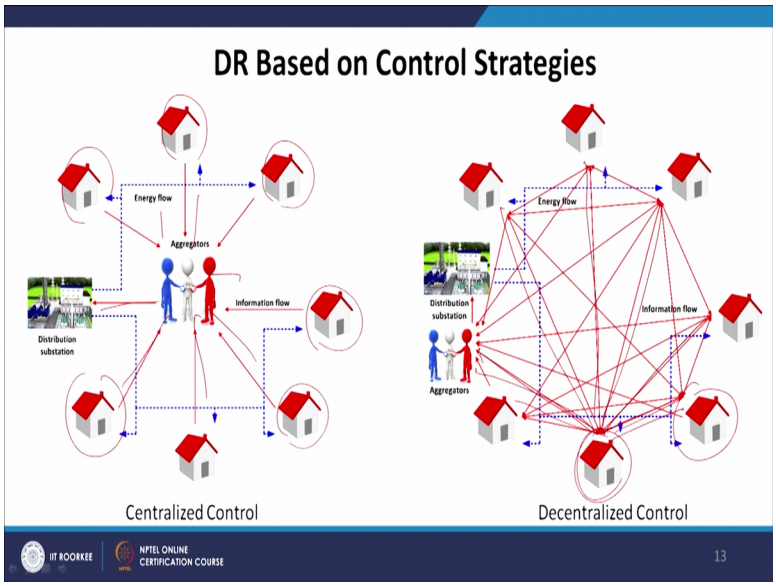


That is if you talk about the centralized control, we could see that the residence 1, residence 2, a residence 3, residence 4, residence 5 and all of them actually do talk to the aggregator directly. And then finally, the aggregator talk to the distribution system and ISO further.

Now, in case of your decentralized strategy, where r 1 and r 2 both the residences do talk to each other and they also talk to the aggregator means, the residence do talk to all the other community fellows and also talk to the aggregator. So, this is very open and decentralized system.

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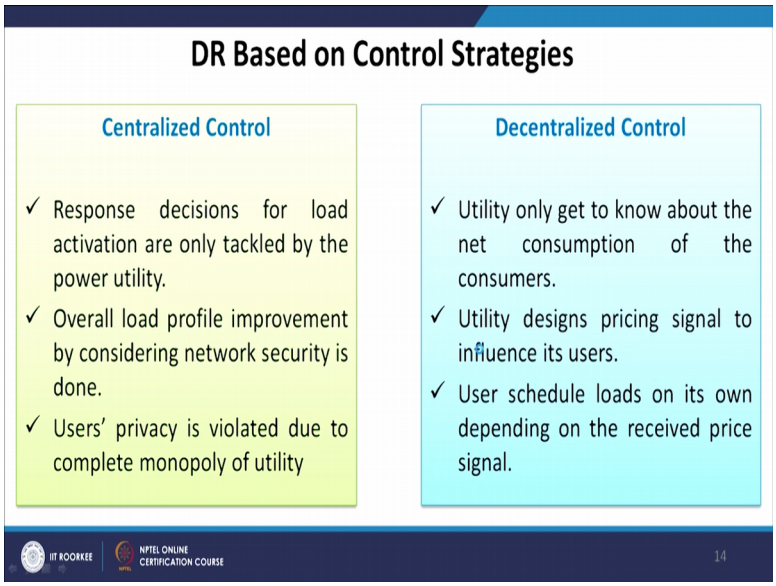


Now, in case of centralized control, response decisions for load activation are only tackled by the power utility, overall load profile improvement by considering network security has been carried out.

Users privacy is violated due to complete monopoly of the utility, because you do not work is a community you talk is an independence so, not necessary that your expectations will be met by the utility all the given time. Now in case of decentralized control, utility only get to know about the net consumption of the consumers, utility design a pricing signal to influence its user as whole, users schedule loads on its own depending on the received price signal. So, based on there are price the community can plan how they like to use their devices and so, decentralized control is much more smarter compared to centralized control schemes.

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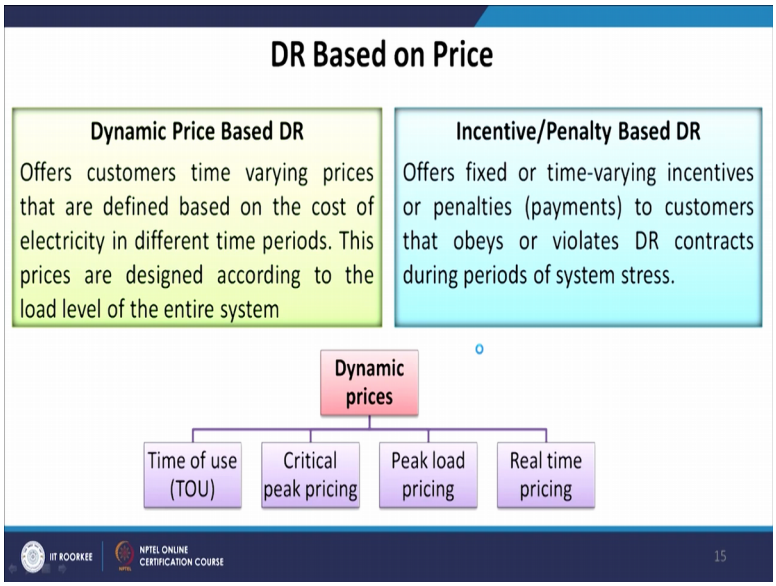


Now, if it is based on the price, dynamic price based demand response in which we offer the customers time varying prices means given hour 1 hour 2 hour 3 will have different prices and based on the cost of electricity at different time zones, this prices are designed according to the load level of the entire system ok. Ideally during the peak hours the price is more and during the op peak hours the price is low, that may force most of my customers to shift to a of peak hour.

Now, dynamic prices we have different schemes time of use so called TOU, critical peak pricing peak load pricing and real time pricing. Whereas, in case of incentive or penalty based demand response offers fixed or time varying incentives or penalties even, to customers that obey or violate demand response contract during period of system stress.

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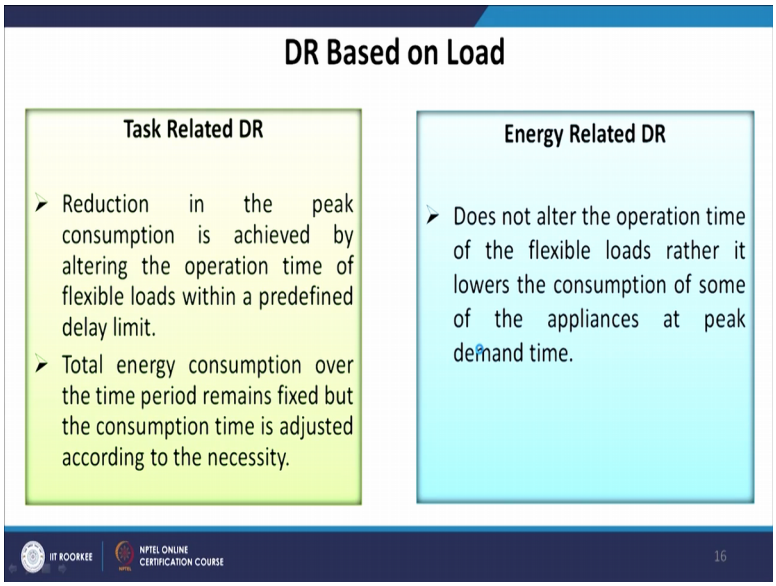


Now if you go to the load as we mention there are 2 types task related demand response that is basically the reduction in the peak consumption is achieved by altering the operation time of flexible loads, within a predefined delay limit.

Now, the total energy consumption over the time period remains fixed, but the consumption time is adjusted according to the necessity. But in case of energy related demand response does not alter the operation time of the flexible load, rather it lower the consumption of some of the appliances at peak demand time. So, time remains same, but the energy varies. There are different ways because as you know it is too complicated to optimize your decentralized demand response activity. So, there are different algorithms available game theory is 1 of the important algorithm is being currently used by a many researchers as well as partially utilities and aggregators.

What we do in case of demand response activity, the main objective is to achieve the following. A successful implementation of demand response program is possible if the users participate in to the activity willingly, without compromising their comfort level or living style. Because it is not necessary that you achieve a demand response program with a very bad temperature ok. So, without compromising your basic living style, if you can change your consumption pattern that helps the utility utmost, and then only you can say the demand response program is successful.

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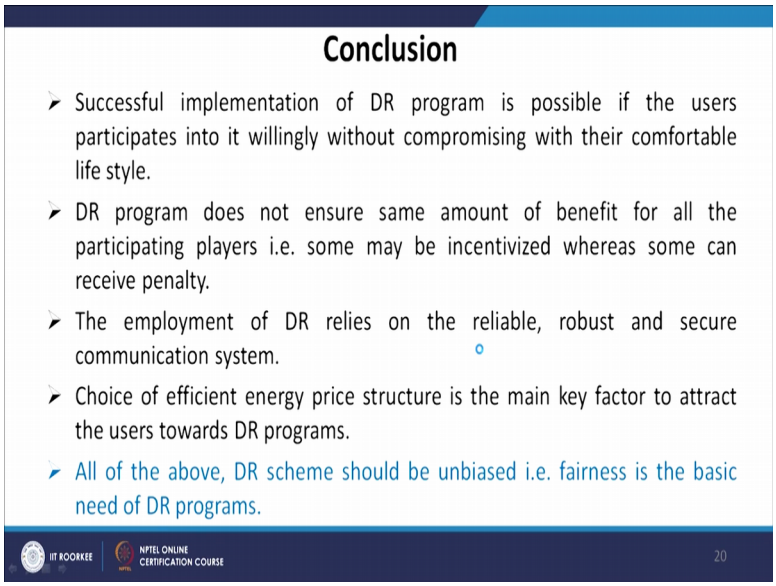


Now, demand response program does not ensure same amount of benefit for all the participants' player, that some maybe incentivized whereas, some may be penalized. Because if you agree to be part of the demand response program and when the aggregator expect you to not to consume more than x kilowatt of power or maybe x kilowatt hour of energy, and if you do not obey then there could be a penalty. And hence the benefit that being distributed across the customers are not necessarily same.

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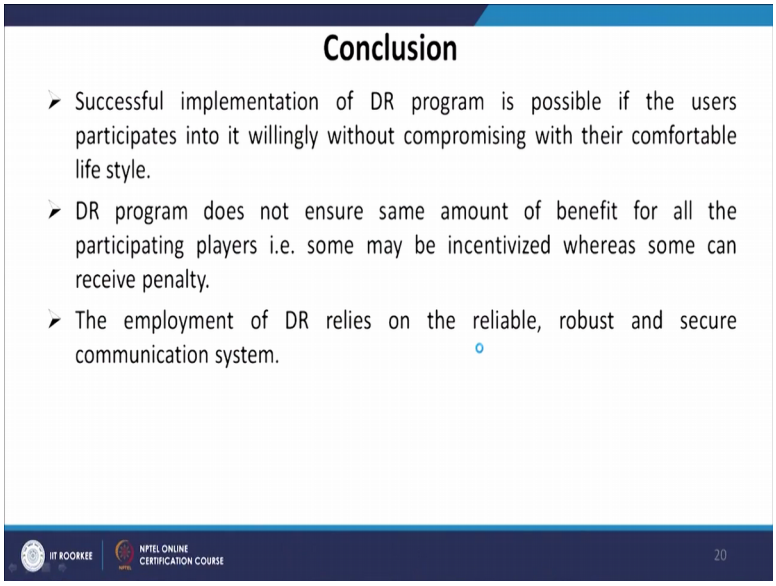

The employment of DR relies on the reliable robust and secure communication system, because until unless there is a robust communication system in place demand response program cannot be made successful or achieved well. Choice of efficient energy price structure is the main key factor to attract the users towards demand response program. So, when you have different a price set given day, there until unless you select the price well.

So, the price elasticity means, how the consumer is going to behave differently based on the energy price. So, until unless you attract maximum customers to deviate from their consumption pattern as desired by the aggregator or the utility or the ISO, and then otherwise the demand response program is not successful or cannot be made successful until unless the price selection across the day or a week must be perfect.

All the above demand response scheme should be unbiased and fair on the basis of need of demand response program. And to conclude I do a wish that the benefit should go to the customer as maximum as possible to bring them to the board and make them participate in actively in the demand response program to make the overall demand response program successful, that indirectly benefit my system to engage customers actively tap all the renewable sources available to me and manage my peak load well.

Thank you very much.