Introduction to Smart Grid

Prof. N. P. Padhy
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture – 38
Design of Smart Grid and Practical Smart Grid Case Study- II

Welcome you all for today's NPTEL online course on Smart Grid and during last lecture we were discussing about the execution of the smart grid concept on an laboratory scale of hardware setup. We have seen the different facilities available in the laboratory and we were talking about how a DC microgrid can be simulated at three different operating conditions both at peak load conditions, off peak conditions and isolated mode or islanded mode of operation.

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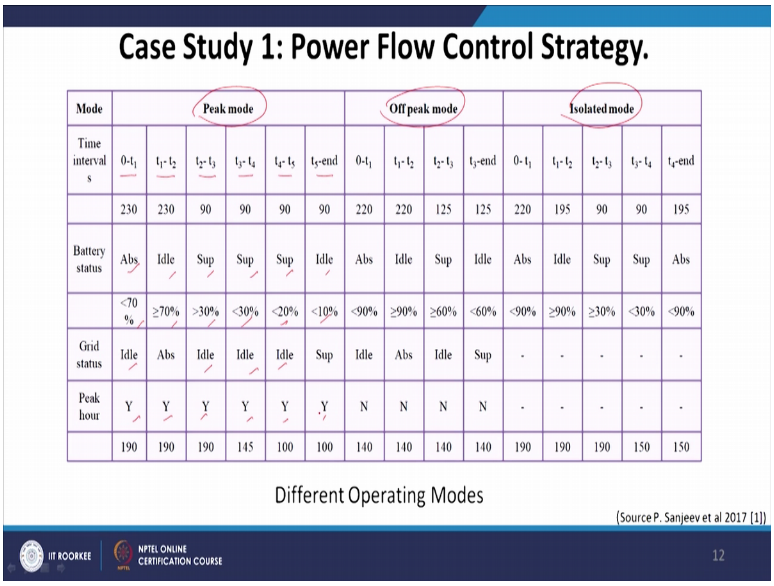

Now, during this case study like to explain you all what kind of time intervals have been considered, the status of the devices have been identified. During the peak mode we have considered actually different time period like 0 to t 1; t 1 to t 2, t 2 to t 3 and t 3, t 4; t 4 5 and 5 to end. So, we have considered different time of operates time intervals and these are the battery status whether it is absent or ideal or super capacitors operation.

And these are the SOC status whether it is 70 percent or greater than 30 percent, less than 30 percent, less than 20 percent, less than 10 percent etcetera. And we can said the grid status when it is idle when it is idle idle idle etcetera and whether it is a peak hour; yes it is a peak hour, peak hour, peak hour, peak hour, peak hour.

Now, one point let us all understand when we talk about peak mode of operation or peak hour of operation means my utilities experiencing a peak hour. And whatever the explanation we have done we have considered that at this point of time the system is facing a peak ok. So, the peak condition of the system has been you know sensed and based on that peak hour point with allow our DC microgrid to operate accordingly so that my grid will not be stressed mode and similarly off peak.

But still there are bit of challenges how do how do we sensed the peak period; whether the peak period based on your frequency that can be identified or based on the pricing of energy at that given time. So, that is another challenge that need to be seen how do you like to identify the peak hour; based on the pricing or based on the frequency.

But what we are focusing here if the system is it peak; how do I have my control strategy and manage all my devices not to stress more to the utility. Now, similarly the off peak and isolated mode now we will get into the hardware simulation which is very important.

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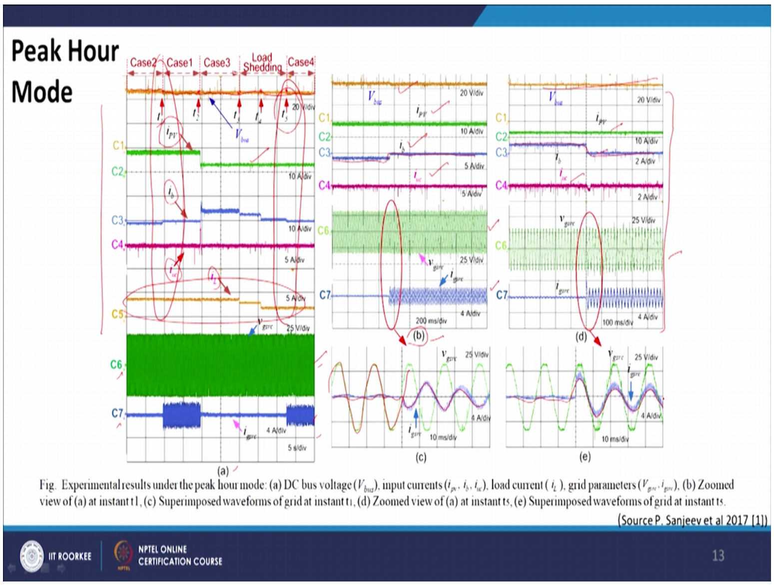

I need your attention please focus in our the peak hour mode we can see this is there are so many characteristics I will be interested to explain you one by one very slowly. This is my time period t 1 and this is a t 2 and t 3, t 4 t 4 and t 5 and this is basically the DC bus voltage; could you see the variation this is what the bus voltage have been voltages have, bus voltage has been monitored that is V bus and then we can see that the P V current battery current as well as ultracapacitor current characteristics.

So, this characteristic the green one which is you can see this one which is my current characteristic of the P V and the blue one which is the current characteristic of my battery and the pink one is the current characteristic of my ultracapacitor. And then we will see the load which has been connected to my grid which is the load current, which is keep on reducing.

And then the main important part here we have C 6 and C 7 characteristic which is my grid voltage and current characteristic grid voltage and current characteristics. And the to see further we have actually zoomed the b characteristic you can see which is the zoomed view of the first characteristic that is a characteristic and at instant t 1; so we have different time instant.

So, mainly this area which has been zoomed; now we can clearly see how my bus voltage looks like and this is P V current, battery current, ultracapacitor current and further we can see the grid voltage and grid current. And we have not considered perhaps the 1, 2, 3, 4, 5 and 5 has not been the load current has not been considered in the zoomed characteristic of the b.

Perhaps we can see the superimposed waveform of the grid at instant t 1 this 2 C 6 and C 7 the both voltage and currents have been superimposed. Just to understand how my voltage profile is varying and how the current characteristic is keep on varying; so the basically the combination of these two. And perhaps the d that is we have consider one more time instant that is t 5 and we have also zoomed this zone that is t 5 instant and you can see further characteristics in detail.

And C 1 which is my bus voltage and then we can see the P V current battery current; the one significant here you can see the battery current actually stepped up. And whereas, it is again stepped down depending upon different loading conditions that has been considered and then you can see altered capacitor and again my grid voltage and current characteristics.

And those two have been you know superimpose just to see and you can see the way the current characteristics behave compared to the previous one; just to understand the system perspective. And this is the way actually the peak our mode operation being performed.

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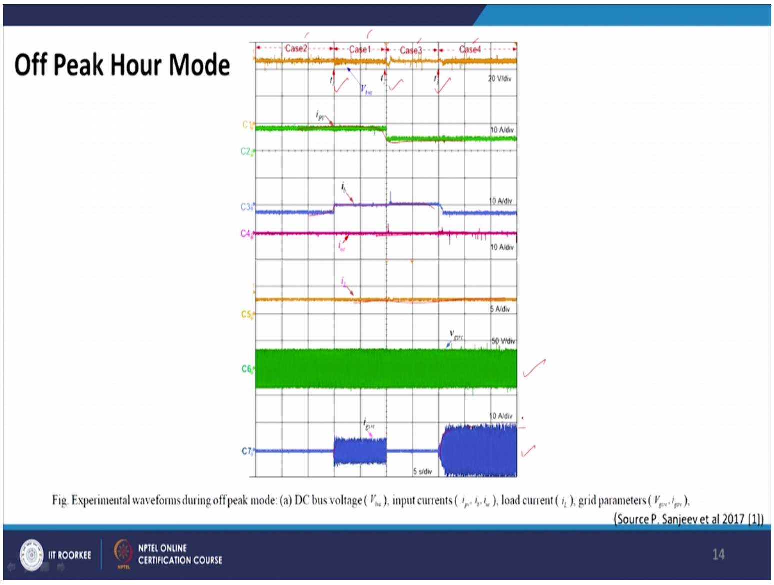

And if you move to the off peak hour mode and off peak hour mode actually we can see this like once again my bus voltage at off peak. And then we have the P V current and certainly then we have the battery and then we have my alter capacitor characteristics. And then that is a load current which is constant and then we have grid voltage and current characteristics.

Now, depending upon the different cases like case 1, case 2, case 3, case 4 and different time instant t 1, t 2, t 3 you can see the characteristics behave from t 1 to t 2 and again from t 3 to t 4.

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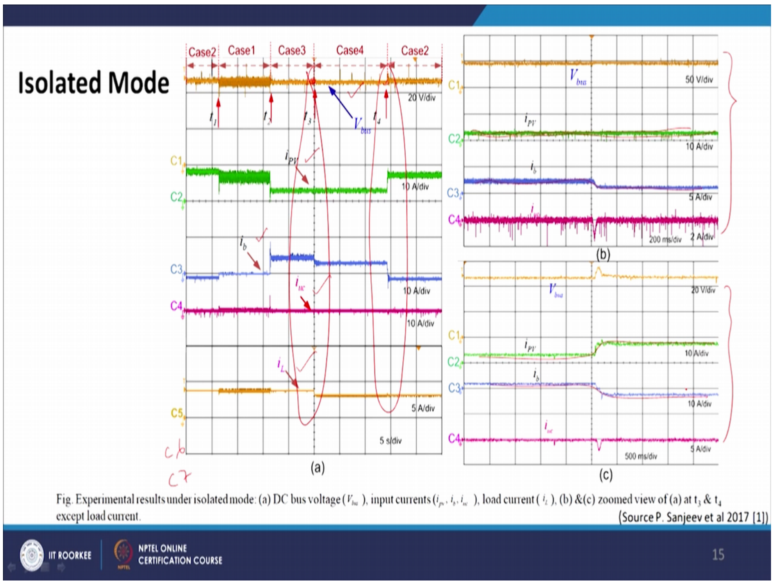

Now, in case of isolated mode we can clearly see my grid is actually absent. So, when my grid is not there; that means, both the C 6 as well as C 7; they are not present because grid is not available to me. And it is just within the microgrid we have captured the bus voltage DC bus voltage and then we can see the P V current as well as battery current ultracapacitor current as well as load current this 5 characteristics have been tapped. And that is what actually the first characteristic a look like and whereas, that the b and c are the zoomed characteristics of my t 3 and t 4. So, we have considered previous case we have consider t 1 and t 5, now we are talking about both t 3 and t 4.

So, this area as which has being zoomed here and this area which has been zoomed here; So, we can clearly see especially if you focus the battery which is not varying much sorry the P V is not varying much whereas, the battery drop down. In case of t t 4 you could see the PVs gearing up whereas, the battery which is in the same way similar to my previous t 1 scenario.

And the opened all when it is the grid is not available the whole energy has to be met within the system. And certainly we have to curtail some of the critical sorry non critical loads as an when the battery SOC goes down and step by step we can curtail the non critical loads to manage your energy scenario. Further we have considered a interconnection between 2 DC grids; if you remember in my simulation we have considered 2 DC grid one is it 380 volts the other at 48 volts and we try to control the scenario of having 2 DC grids. And now in case of this case study we have considered one micro grid their autonomous microgrids.

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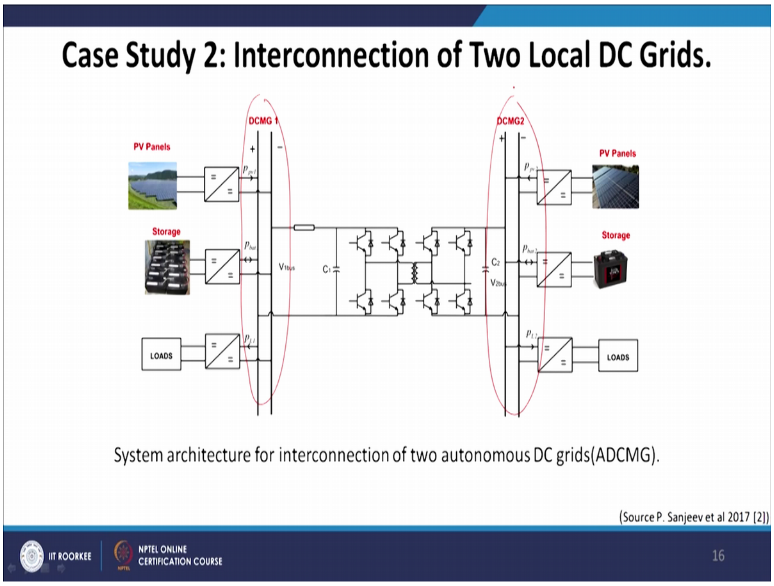

And during practical implementation we have considered one grid at 48 volts and the other grid which is at 100 volts.

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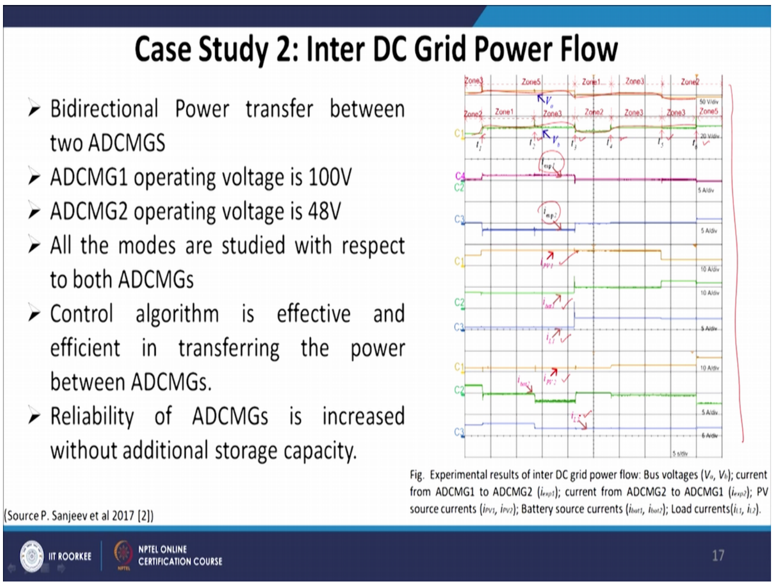

Now, in case of inter DC grid power flow bidirectional power transfer between two autonomous DC microgrids. And the autonomous DC microgrid the first microgrid allowed to operate at 100 volts whereas, the second DC microgrid allowed to operate at

48 volts. All the both the microgrids are autonomous and you can see the experimental results of through microgrids we have considered the time zone t 1, t 2, t 3, t 4, t 5 and t 6. Now, for better understanding we can see there are 2 V a that is the first grid and thus this is my second characteristic that is V b the green one and the first one the i 1 represent my autonomous grid number 1 and i 2 represent my autonomous grid number 2.

So, similarly for both the grids we can have P V characteristic for the first grid, battery characteristic for the first grid, load characteristic for the first grid and similarly battery P V and the load characteristic for the second microgrid. So, we do have 2 microgrid in place during theory we have discussed 2 microgrids are of two different voltages; one is at 380 volt the other is at 48 volts and the simulation strategy has been discussed.

But during the practical implementation instead of 380; we scale down to 100 volts and the second grid is 48 volts and then we performed both the grid simultaneously. And then one more step up where we thought of expanding the microgrid scenario to a larger scale. The impact of microgrid or a smart grid into a national grid perspective, where we assume that there are 100 and 1000’s of microgrids may present in future and what sort of impact that the national grid can visualize. We have seen if the system is it whether it is a peak condition or off peak condition or there is no grid available to me my smart grid has to manage its energy within itself.

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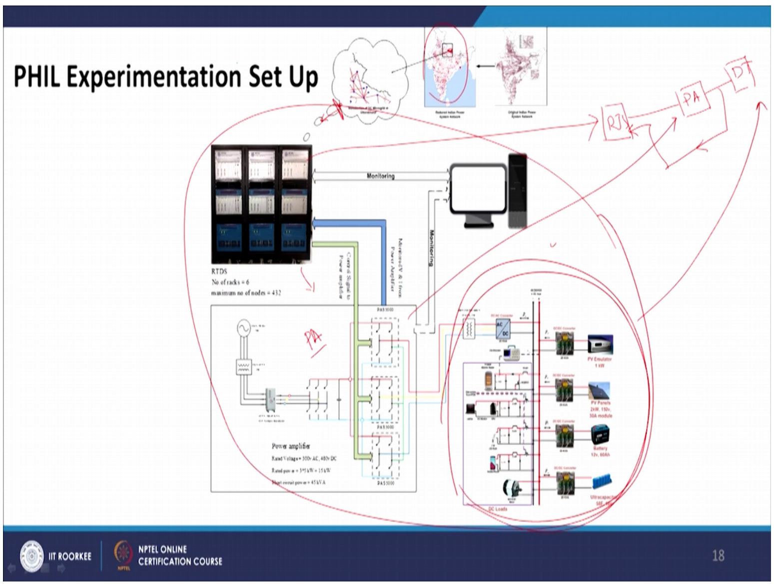

Now, if you take the Indian grid at large; so this is my Indian grid and at a particular point of the one of the bus of that Indian grid, we can come down to the distribution level and that bus we can connect our DC microgrid; with help of real time simulator as well as power amplifier.

Now, the same setup closed loop setup we have let say your real time simulator and then we have your power amplifier then we have the device on test all right and further we can give a closed loop signal to my real time simulator. And I am not whereas, focusing here the conversion with between digital to analogue and further analogue to digital conversion before giving back to my RTDS.

Now, this is what actually the test page which represent my device on test and this is what my amplifier look like and this is what my simulator is all about. Now the concept is the point of selection is one point of the national grid where we experiment this. And we repeat this kind of setup at each and every bus of the national grid to see the overall impact of energy management at each and every microgrid; how it can really enhance the system capability at a national level.

And we have considered one case study that is case steady number 3, where the DC microgrid of our laboratory has been integrated with the IIT, Roorkee distribution system. In case of reduction of the Indian network if you look at the Indian network at large which is a very huge and simulating Indian network within our simulator capabilities impossible; that is why we try to reduce the all India this network transmission system to a reduce system.

So, that that system can be simulated or burned within my simulator and at one transmission bus scaling down the voltage to a distribution; bus we can integrate the IIT, Roorkee network. And further within the IIT, Roorkee network at one bus electrical engineering department; we can integrate our DC microgrid and see the overall impact changing the behavior of your DC microgrid control by adjusting both battery ultracapacitor and P V emulator, as well as load how we can see the impact of managing the peak scenario faced by the utility or the system.

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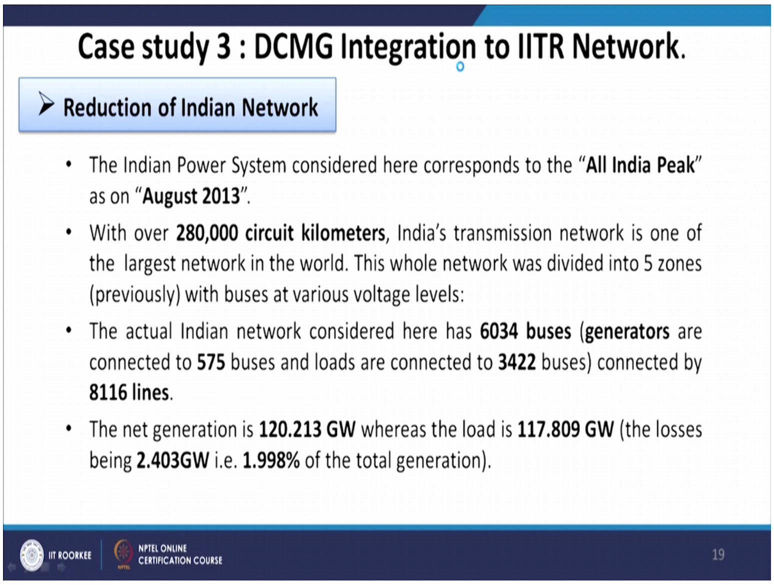

Now, we have considered the all India peak of 2013 during the month of August. And we found that over 280000 circuit kilometer of the transmission network at different 5 zones and truly the Indian network which had 6034 buses out of which 575 buses had generators and 3422 buses had loads and altogether there were 8116 transmission lines and simulating such huge network having 6000 buses were impossible.

So, an attempt has been taken by the research team of this laboratory to reduce that network to a smaller scale so that at least we can simulate the all India network with the simulation capability available in our laboratory. Now, the net generation at that point was 120 gigawatt approximately and the load was 117 a gigawatt.

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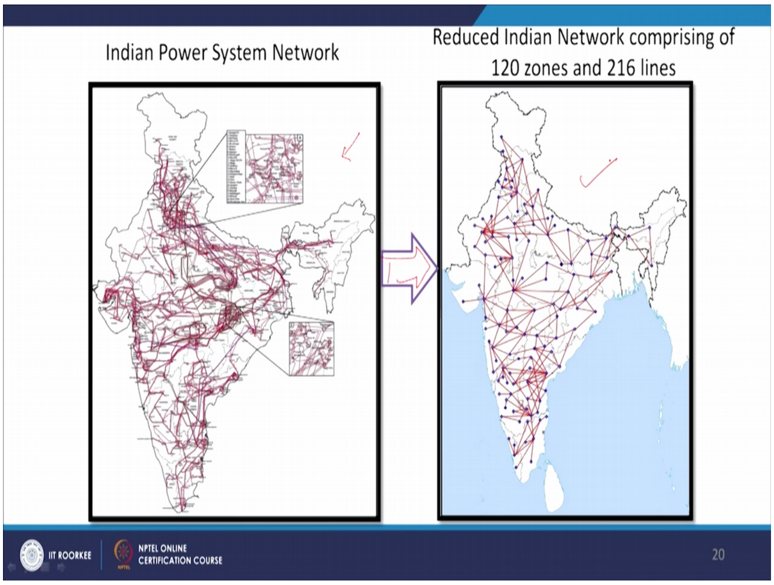

Now, this is how my network look like; so this is the original all India network which had approximately 6000 buses. And this network through rigorous simulation, have been reduced to a network of 120 nodes with 216 lines.

So, what we have done basically each and every zone have been squished to a single node based on certain algorithms. And then now my all India system is being represented by 216 lines and 120 buses. So, it is easy for me to simulate 120 bus all India network instead of going for 6000 buses at large. We have also analyzed the feasibility study of DC microgrid integration to IIT, Roorkee distribution system.

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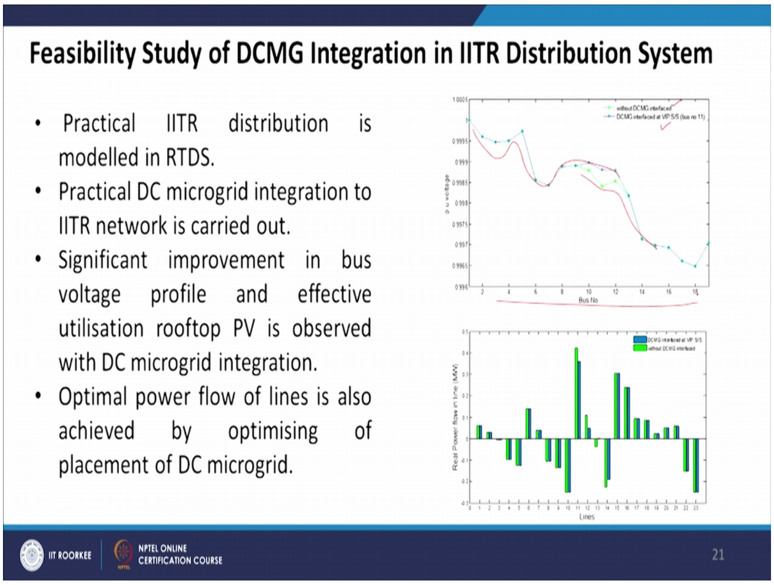

And the practical IITR distribution system is modelled within RTDS and we have taken the practical data of IIT Roorkee system and simulated within the RTDS. And you can see without the DC microgrid and DC microgrid interfaced; you can see the different voltages at different buses of the network.

And it has been felt that having DC microgrid interfaced certainly we can improve the voltage profile of the system. A significant improvement at bus voltage profile and effective utilization of P V is observed with help of DC microgrid integration. Optimal power flow of the lines is also achieved by optimizing the placement of DC microgrid the DC microgrid can be placed at different locations. So, by varying the location we felt that optimal utilization of the lines as well as the voltage profile can be achieved; it is a runtime window of IIT Roorkee system.

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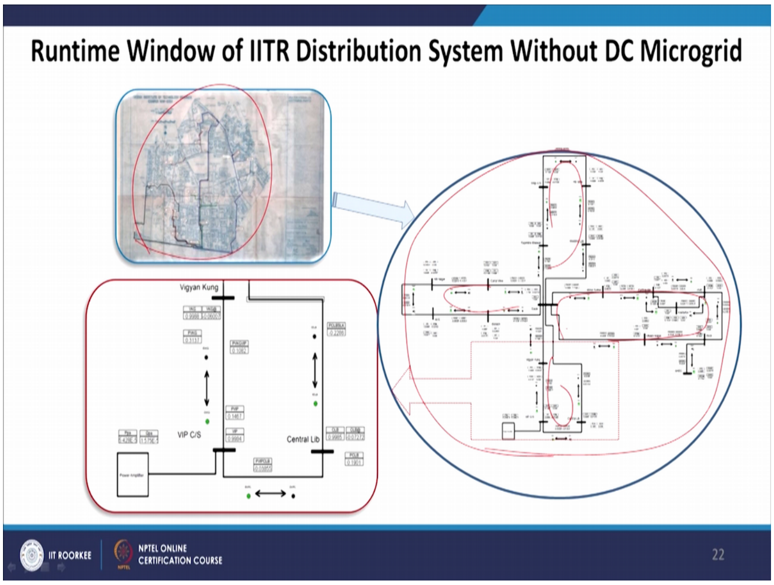

I mean this is what the pictorial view of IIT, Roorkee campus and this is my network we can see this radial, but we have many rings in between. And this is without the DC microgrid and then further actually we have integrated DC microgrid and carried out PHIL experimentation of IIT, Roorkee campus along with DC microgrid interfaced.

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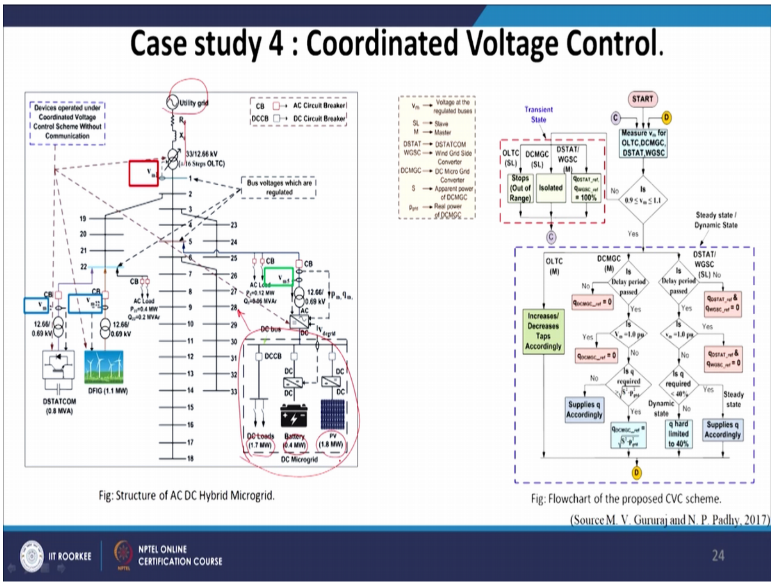

We have also performed couple of case studies on coordinated voltage control and in which we had the utility; which is the utility grid. Then we have taken a distribution system of 33 bus and then you can see the DC microgrid which has been interfaced to a

IEEE distribution system and connected to my utility. And the DC microgrid which has 1.7 megawatt of load and then 0.4 megawatt of battery and 1.8 megawatt of P V; which is at the simulator level, but they have not scaled down 1000 times to realize in the laboratory scale and this is what the setup look like in the laboratory.

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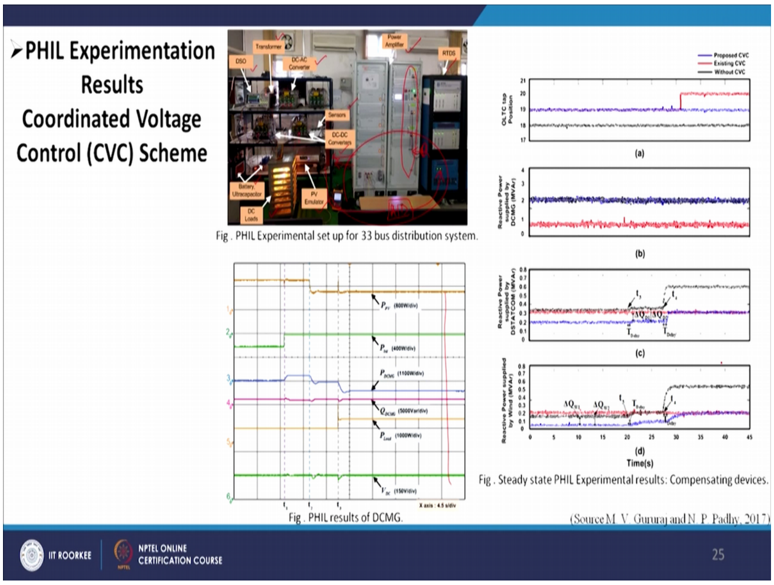

Just to emphasize you can see the RTDS here, amplifier, we have P V emulators, DC loads, battery and ultracapacitor DC DC converters, sensors, DC AC converters, oscilloscopes and transformers.

This experimentation the very interesting part is I told you this is the amplifier and the signal which has been fed to my setup which is the device under test. After receiving the signal in the digital form and then we convert that D to A give to my amplifier and then feedback to my system and then the further analogue to digital conversion and it can be given back to my RTDS. So, this is basically a close loop PHIL experimentation setup and once again similar to the previous discussions we can see the characteristics power characteristics for both P V and DC microgrid.

The proposed voltage controlled then existing and without CVC; different comparisons. So, finally, it has been claimed that with help of DC microgrid certainly the coordinated voltage control can be achieved better compared to a system without having a microgrid. With this we come to an end of today’s lecture overly I like to emphasize that we have discussed on the hardware implementation of the cases that have been discussed earlier during previous lectures; where we simulated many case studies.

Then we took those concepts or ideas into simulation level first and then we executed on a hardware setup. Though there are bit of challenges, but fortunately all the simulations for energy management and then integrated with the IITR, Roorkee distribution system interfaced with all India network and coordinated voltage control schemes have been very perfectly executed with help of a DC microgrid in place.

Thank you very much and good luck.