DC Microgrid and Control System
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Lecture - 25
Energy Management in Microgrid System

Welcome to our lectures on the Microgrid and the Control System. Today, we shall continue with the first part of the system, that is energy management system of the microgrid. So it was continued from the previous lectures.

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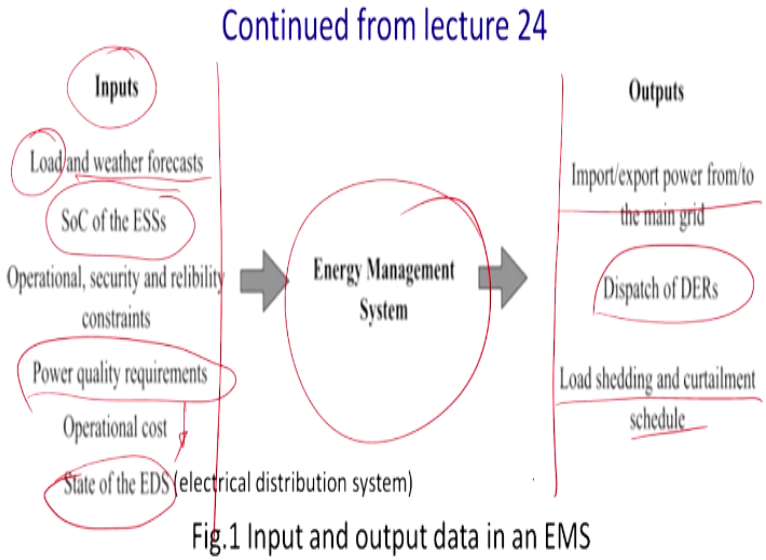

Fig.1 Input and output data in an EMS

So these are the inputs you know loads and the weather forecast. From the historical data, you are aware of the load pattern and thus you can have a load forecasting based on that and their artificial internetworks AI, find lot of application on it and same way for the weather forecasting, Met Department will provide the precise data or the precise time of generations and then also it is important to know that state of charge of the batteries and all those issues, these are mainly SoC of battery or any other storage elements conditions.

Then comes into the picture operational security and the reliability constraint. So you may put operational constraint that battery should not be charged from the grid, it has to be charged from the solar. So this kind of constraint and there is a reliability constraint, so you want to have some kind of Soc. Before that, you can have a switch on to the maybe the load shedding mode or the shutdown the noncritical mode.

And of course, you require to a power quality requirement like you are you want to make it a PQ control and you should inject, you should inject power at unity power factor with a very low THD and also whole purpose would be to reduce the operational costs and thus by the electrical, we required to know the electrical distribution systems. These are called the States. So please don't confuse, generally what we understand states are the current through the inductor and the voltage across the capacitor were states, can be the different stakeholder, different nodal point can be the states.

So you apply the energy management system and the import/export power from the main grid so that is something you will decide depending on their these inputs, thereafter dispatch of the distributed energy resources that comes with the generating unit and the energy storage element and load shedding and curtailment scheduling of your non-critical loads. So this, so this will act, this will be the input and this will be the actions and you may have an if-then logic also, and for this reason, FLC kind of system works very fine in the microgrid.

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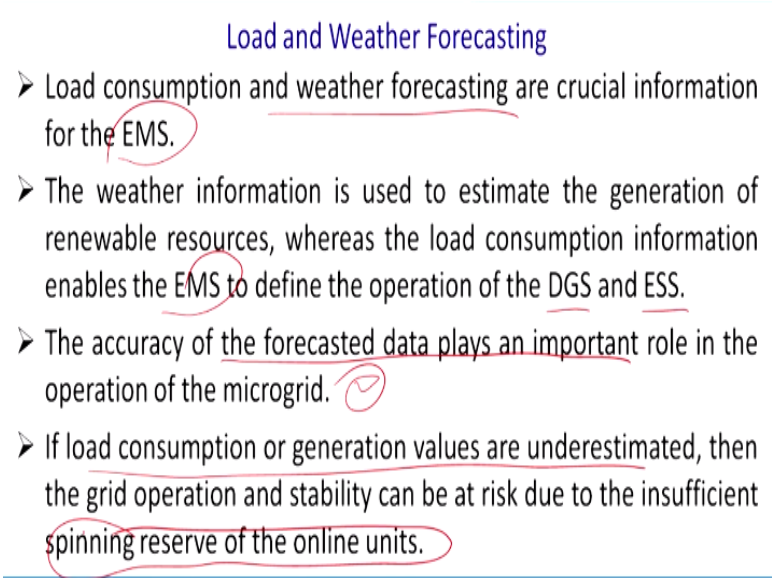

Now that is how we are going to elaborate now in this lecture. Load consumptions and the weather forecasting are the crucial for the energy management system. So you require to know when your peak will occur and how far it is from the input peak of the solar and wind. So how can we try to match these two peaks by shaping the behavior of the people, by the differential tariff let us say.

So this is a task of the energy management system, weather information is used to estimate the generations of the renewable sources whereas the load consumptions informations

enables the EMS to define the operation of the distributed generations an ESS. The accuracy of the forecasted data plays an important role in the operation of the microgrid, so that is something we require to consider very seriously, that accuracy of the forecasted data plays an important role in operation in the microgrid.

So more precise and more accurate are these datas, so you can deliver our results more better, so more better will be the other control and the operations and changeover can be smooth, and if by some how the load consumption or the generation values are underestimated, then the great operation and the stability can be at risk. So if you don't consider some kind of load will be uncontrollable and they put up this load and again the extent and you don't have that information, then you will make whole system vulnerable.

So for this reason, we required to track those information like can be in a part of the microgrid, you might be organizing a conference let us say in our campus in IIT Roorkee if you treat as a microgrid and when we have a convocation, all of a sudden power consumption will go off or when we have our technical fest this is coming, so that the way power consumptions pattern will change. So those information has to be realistically accommodated in the system, that is very important.

Then the grid operation and the stability can be at risk to due to the insufficient spinning reserve of the online units, that is very important. So you know that your you have planned for energy resource, and if it is not accommodating, then we have to consider only that part with this battery resource and the rest of the part you consider to be the critical, non-critical load and accordingly you have to reschedule your operation.

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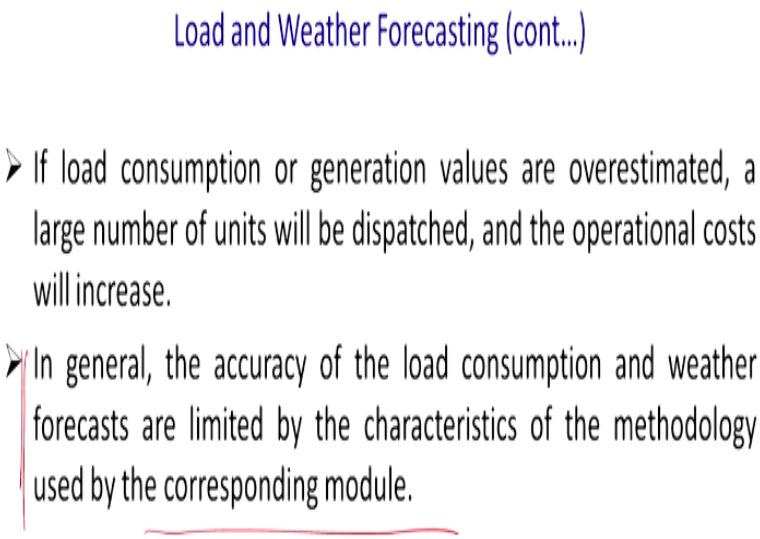

If load consumption or generation values are overestimated, a large number of unit will be dispatched and the operational cost will increase. So if you have more generation than what you have estimated, then of course and you cannot store into the your energy storage system, so you require to dispatch that power to the grid and thus you can have an operational cost or operational resource.

There are different kind of tariff in India that because if solar, if you take the rooftop model, you can exchange power in a year and you may have a power surplus or power surplus is more or less and here generally what happened you get the concession, but if you export more, you don't get the payback. So ultimately, you have to be the net load, that is a policy maybe the government. So accordingly, you have to act within it.

In general, the accuracy of the load consumptions and weather forecasts are limited by characteristics of methodology used by corresponding module, that is something we require to consider.

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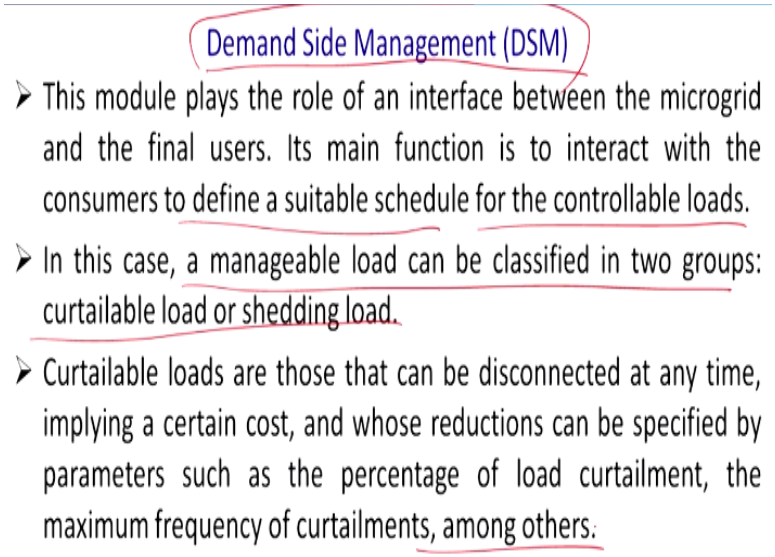

Now we have to understand, so this is a new concept and we are deviating from the conventional grid in this way in the microgrid. It says that demand side management, we generally say that demand, this is a consumer's prerogative and they may say that I require this much of load and accordingly the consumers will be given that load and due to that what happens, they now you can feed power when you have an energy surplus, it is not that when the consumer require it.

So for this reason, we required to also understand the demand pattern and we require to also manage it properly, so that we can better match with your generation pattern. This module plays an important role in an interface between the microgrid and the final users. Its main function is to interact with the consumer to a to a to define a suitable schedule for the controllable loads. So if you have a controllable load, it should be required to be scheduled.

So all the high-power load should be controllable and this has to be program initiated, so that is something that automation, it is required to be done in case of the microgrid. In this case, a manageable load can be classified into 2 groups. Curtailable load or the load shedding load, so that is something when you have energy surplus, then only you operate, if you don't have an energy deficit or if you don't have any surplus, it is an uncommitted expenditure, something like that, you should off it or whenever you got a some kind of an energy surplus due to the high production of the solar and wind, then you negotiate those loads.

Curtailable loads are those that can be disconnected at any time implying the certain cost and whose reduction can be specified by the parameter such as percentage of the load curtailment

and the maximum frequencies, maximum frequency of curtailment among others. For example, corridor lights, corridor light there will be some emergency lights, you can put those emergency light and off your corridor lights when there is a when there is a constraint of the generations. So these are the few things you can work on it.

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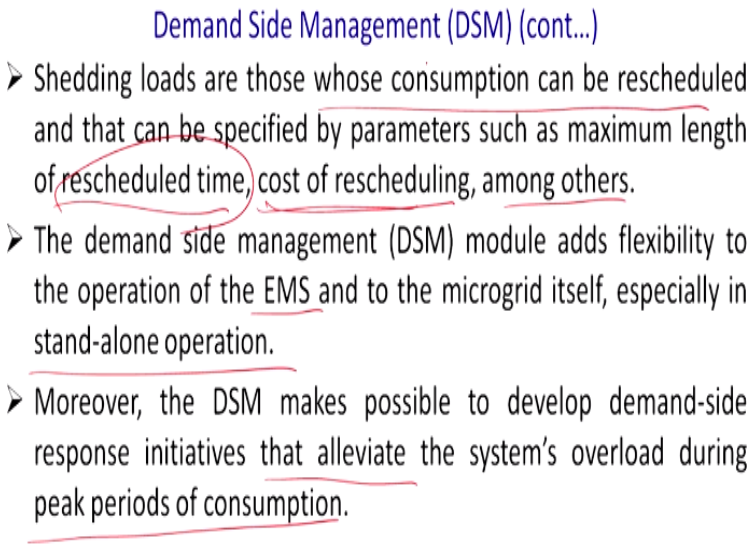

Shedding loads are those whose consumption can be rescheduled and that can be specified by the parameters such as maximum length of the rescheduling time and cost of the rescheduling among others. For example, let us take a condition that you came home and you require to go out, and for the season, you require to take shower and you are going to use geyser and you have to require to charge the electric vehicle and third and of course you want to wash your clothing.

Anyway, you can see that may among these three entit 3 requirements, you can set a priority from an individual level and the microgrid can set for itself and so it can set that you know clothing may be you require tomorrow morning. So for this reason, what you can put the least priority to the your clothing wash, cloth wash. So what happens you know you geyser and the battery charging of the electric vehicle will take the precedence in that case and so you are rescheduling the time, you may require half an hour or 45 minute to wash your clothes and that is your rescheduling time and cost of rescheduling.

So you are shifting the load from this point to this point, so you require you came from the office, so it is around 6 p.m., so it is your energy is the consumption peak is there. So when there is a plenty of energy available in the grid side, maybe at 12:00 or 1:00 a.m. in night, so

you can reschedule it. So in that way, we can go for controlling the high demand load. The demand side management of DSM adds flexibility to operation of the energy management system to the microgrid itself, especially in stand-alone operation.

When it is stand-alone, so we have to we have to sustain our genera our load y our own generation, and for this reason, that is highly important. You have to take in a queue process once there is an energy available and it will be you ensure that availability can be fulfilled for that duration of the time, then only you have pet for it. So it is not that solar power generations and best and also you require to check the state of the charge of the battery.

If some way or somehow, the solar power come down, so whatever your task you have initiated, you can fulfill it, it is not that your washing machine will you stop half of the after 15 minutes washing machine will stop working. So once you have allotted, it should complete its work. So moreover, the DSM makes it possible to develop demand side response initiative that alleviates the systems overload during the peak period of consumption, that is something we required to understand.

So this demand-side management makes possible to develop demand-side response initiative that mean to see what if I if I would have been in a in a normal grid connected mode, even if I came at 6 p.m. in evening, there is a peak load, do I bother to start my dishwasher or washing machine, which may not I require at that moment. I will simply switch it on because tariff is same, but here by this initiation of this DBMS, this DS this demand-side management.

So you essentially curtail down your peak load and thus it helps to the overall energy management system to reduce the peak load.

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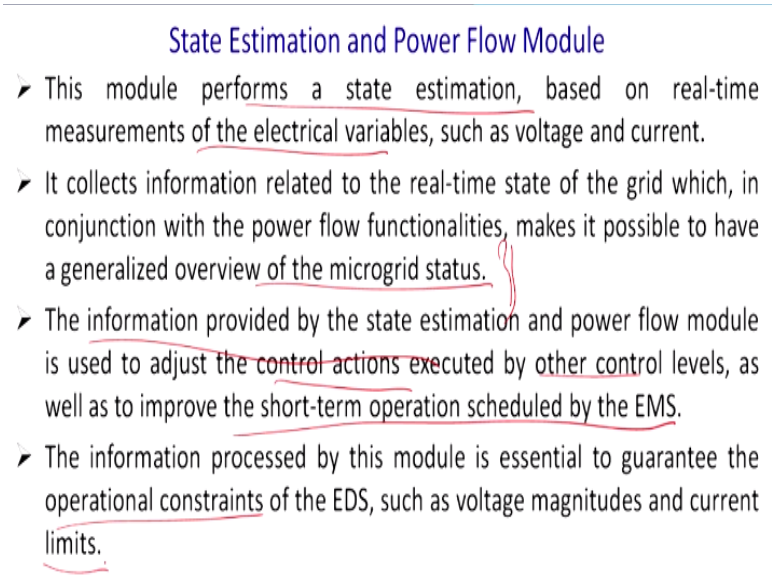

This module perform state estimations. As I told you that node voltages can be a state, based on that, real-time measurement of the electrical variable such as a voltage and current have each node. It collects informations related to the real-time states of grid which in conjunction with the power flow functionalities, it makes it possible to have a generalized overview of the microgrid status.

So you have overall idea how much volt how much power surplus is available, how much you have leeway is available to accommodate another load for half an hour of time, or once this some machine, once may be actually one of the neighbors is washing once they curtail their load after half an hour, you can start something like that. These informations will be available here.

The information provided by the state estimations and the power flow module is used to adjust the control action executed by other control levels as well as to improve the short-term operation scheduled by the EMS. So that is also we required to understand it. So informations that actually we get from the state estimation, the power flow module used to adjust the control. So we got a different level of voltage and current, from there, we can understand and we can apply that droop control or any other control technique.

So from the other control level, we can ascertain whether we can accommodate another load or not. So that is something it is a short-term operation scheduling of the energy management system. Information processed by this module is essential to guarantee that operation constraint like you know you have the leeway to accommodate another load or not for the

period or half an hour though or whether you have droop control will allow within the tolerance limit of this distributed generations as the voltage magnitude and a current limit within the system.

We have to check that the load carrying a particular node how much it has increased and whether it can be accommodative and same way, we have to check the node voltages so that how much it has been dropped. If it is in well acceptable drop to accommodate, we will go for it to accommodate another loading.

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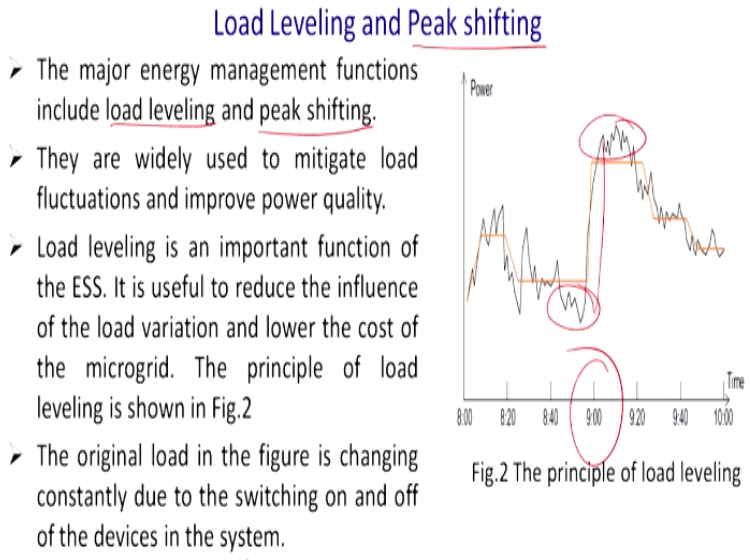

So another important aspect in a microgrid that help us to shape up our pattern of consumption also, that is load leveling and the peak shifting. In India, we have a 2 peak loads generally, but it is oversimplified pictures and we have seen for the duration of the 2 hours we can have a plotted for the 24 hours. We have a peak load demand generally 8 to 10 a.m. in morning and it is 6 to 9 p.m. in evening.

So you can see that, and we may capture the data in the morning, you know you start your activity from 8 a.m. and thus your load has increased and then again it will come down maybe for a short interval of time, and at 9 all of a sudden, your office starts and you switch on the ACs and all those things, your peak load all of a sudden will jump by 20% or 30% and will be continued to so, then gradually again it will come down and it will be settle down to this load.

Ultimately what we required to do you can see that these zigzag lines are the actual load

patterns and you want to shift this peak to here and so that you have a peak shifting and your power demand at the peak has been reduced and been shifted here, and how can you do that, of course, by shifting some of the loads when your loads are less. So let us see that the major energy management functions include load leveling and the peak shifting. So, they are widely used to mitigate load fluctuations and improve the power quality.

So your load change will, we have zigzag line, so that you can flatten out by this behavior taking. The load leveling is an important function of ESS. It is useful to reduce the influence of the load variations and lower the cost of the microgrid because your if you know difference of the actual generation and the load has to be supported by the your energy storage element, more the mismatch, bigger will be the size of the energy storage element.

Also to store that energy, you require to increase the size of the solar installations or any other renewable energy installation, and for this reason, the load variation and the and lower the cost of the microgrid. So for this reason if you have a less load variation, it will reduce the cost of the storage element as well as the renewable energy installation and thus it will reduce the costs. The principle of the load leveling is shown in this figure. The original load in the figure is changing constantly due to the switching on and off of the devices of the system.

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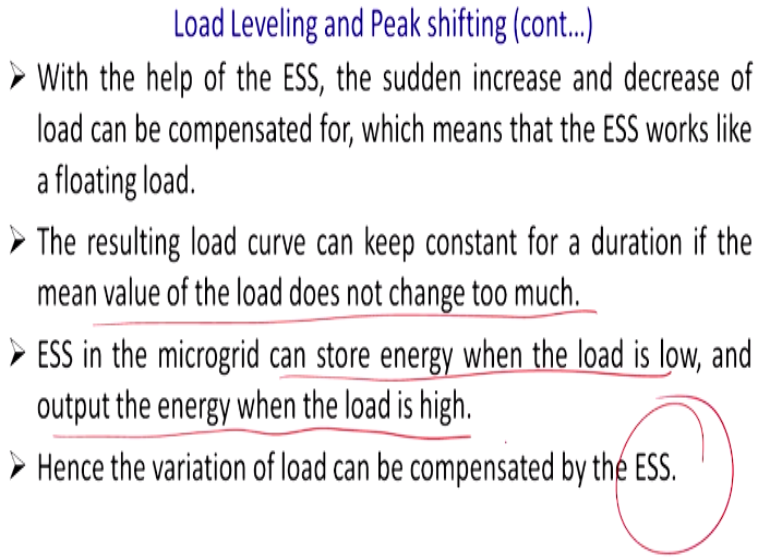

With the help of the ESS, the sudden increase and sudden decrease can be compensated for, which means that ESS works like a floating load, floating bipolar load, I mean to say it can be positive or negative, it may absorb power or you can give you the power. The resulting the load curve keeps constant during the fluctuation if the mean value of the load does not change

too much. The ESS in the microgrid can store energy when load is low and the output of the energy when the load is high. Hence, the variation of the load can be compensated by the ESS.

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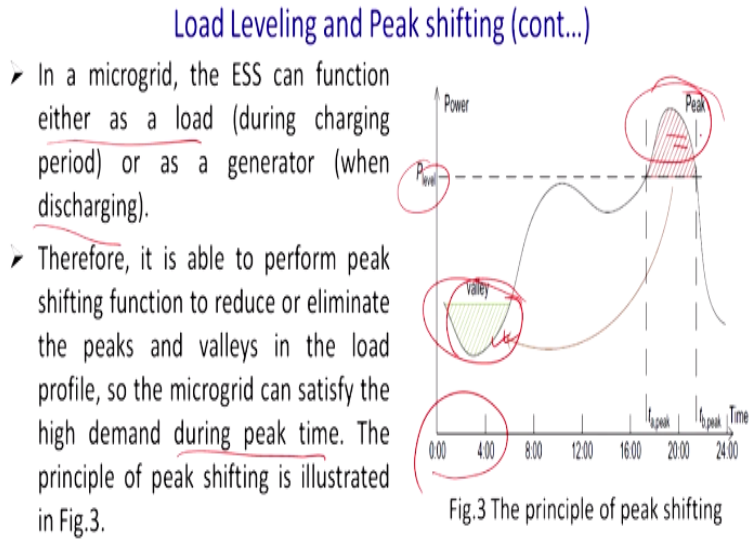

Let us see that how load leveling and the peak shifting works. So this is the power level and somewhere you got a peak here and somewhere you got a valley and you wanted to shift this peak from here to there. This is a 24 hours load pattern and you can see that you have a peak load from 1700 hours to 2100 hours maybe, and this is a peak, and at early morning you don't have any load almost and that is the valley period. In a microgrid, the ESS can functions either as load during changing period or as a generator when discharging.

Therefore, it is able to perform peak shifting functions to reduce or eliminate the peaks and the valleys in the load profile. So microgrid can satisfy the high demand during peak time. The principle of the peak shifting is illustrated in the figure. So this part you will at this time, you will store the battery, store the energy into the battery in excess power and you try to deliver in your peak demand time.

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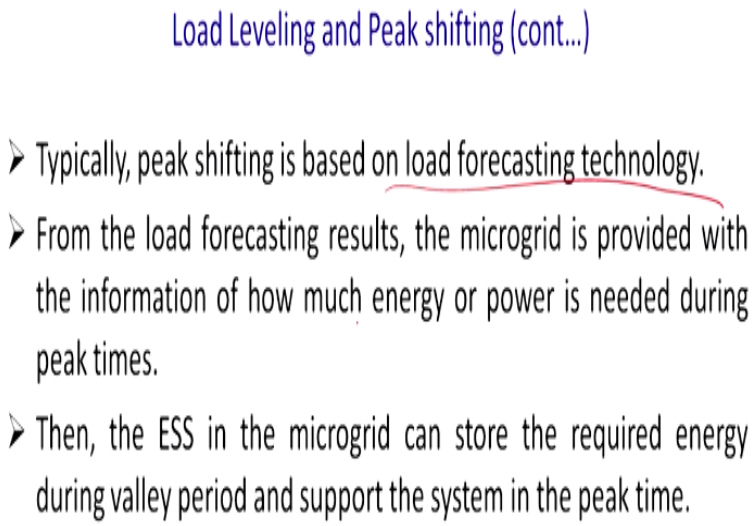

So typically, the peak shifting is based on the load forecasting technology. You should have a historical data, based on that, you should work on it and also you take a deviation of different day profiling. If it is a Sunday, your load profile will be different than the weekdays, and if you have a special festivals or marriages, your load profile will be different. So for this reason, you should have an actual accounting of the datas, historical datas, and based on that, you will use the intelligent system to do that anyway, so that has to be quite proper.

From the load forecasting results, the microgrid is provided with the information how much energy or power needed during the peak time, that you should know from the average value, this was a peak and this much peak was crossed at the day, this is the historical demand, and then, the ESS in the microgrid can store the required energy during the valley period and support the system at the peak. So this is the way it should work. Of course the valley may be less to pay the to payback at the peak, but of course you can reduce the peak.

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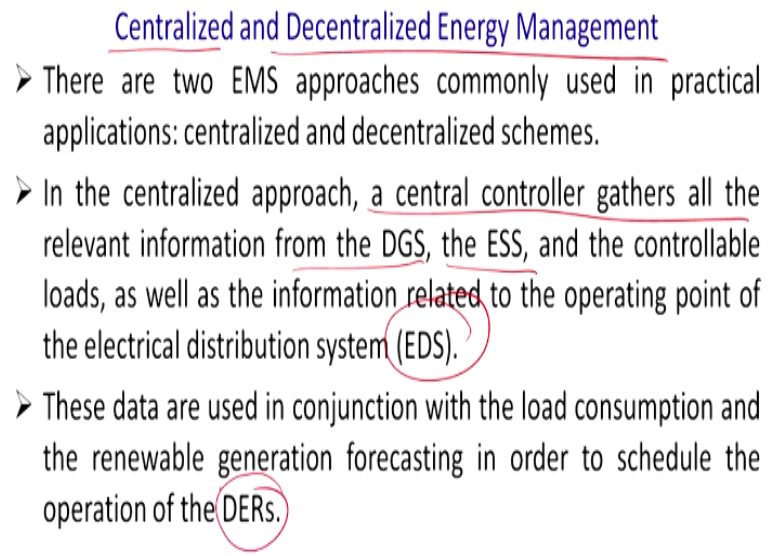

So there are 2 approaches to do that, that is centralized and the decentralized energy management system. So there are 2 EMS approaches commonly used in practical applications, centralized and the decentralized schemes. In the centralized approach, a central controller gather all the relevant informations from DGs, the ESS, and the controllable loads as well as the information related to the operating point of the electrical distribution systems or EDS.

These data are used in junction with the load consumptions and the renewable generation forecasting in order to schedule the operation of DERs.

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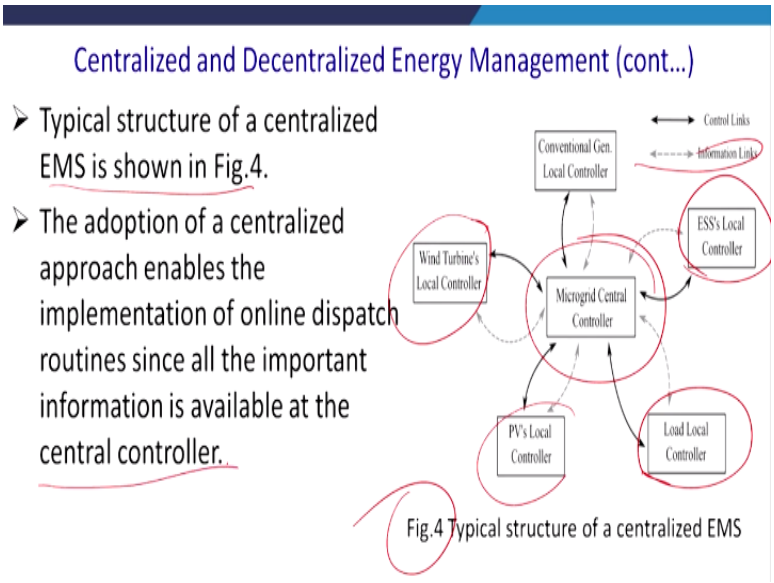

Now let us see that this is the typical centralized structures. You got microgrid controller and from there you have a input from the wind generation you have from the solar generation,

this is a local controller of the load and which will be scheduling the load, whether you can start initiate any action, any major action in the load, it is not a switching on the LED lights, that is quite less, but once you are switching a bulk power, so that is something we have to estimate.

So local controller will allow you, that yes for an half an hour you can do that job, and same way it will take the input from this storage element and thus it will control. So there is a 2 link, one an information link these are and another is control link, if the mp, whether it will check that it is running MPPT or not, then it will shut down the local load if required or not allowed to enter a new load and according it will check the status of the energy storage elements and it was charged or discharged that pattern also be changed.

The typical structure of a centralized EMS is shown in the figure 4. The adoption of a centralized approach enables the implementation of online dispatch routine since all the important information is available at the controller.

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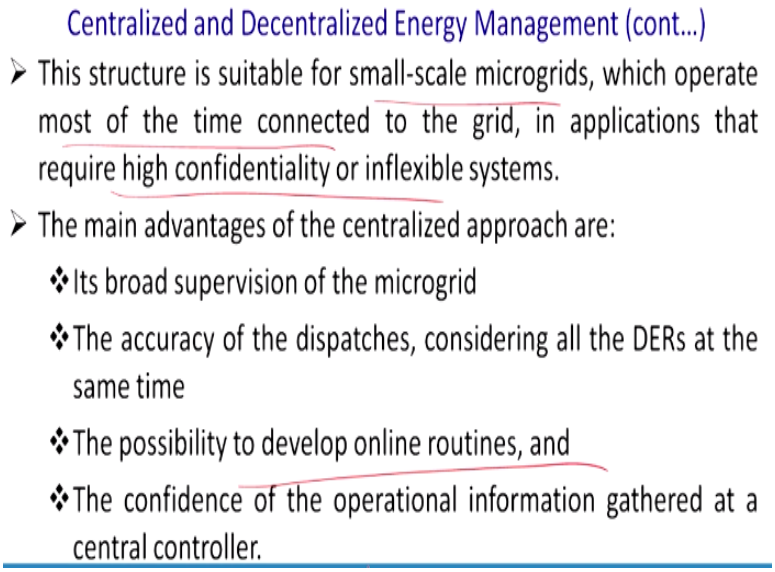

Now few features of the centralized and the decentralized management system, this structure is suitable for small-scale microgrid if it is centralized. So one controller can walk upon the total part, which operate most of the real time connected to the grid, in applications that require high confidentiality and the inflexible systems. The main advantage of this centralized systems are the broad supervisions of the microgrid, it has a look over the total microgrid, so it doesn't.

It is not like that it cannot see the part of the microgrid if it is a centralized control, and thus accuracy of dispatch considering all the distributed resources, it can see at the same time with accuracy. Possibility to develop the online routines, some scheduling or something, and confidence the operational information gathered in a central controller, accordingly it will be processed centrally. So but if the data are huge, it will take huge time to compute, for this reason, we require to take the decentralized approach in a little bigger system.

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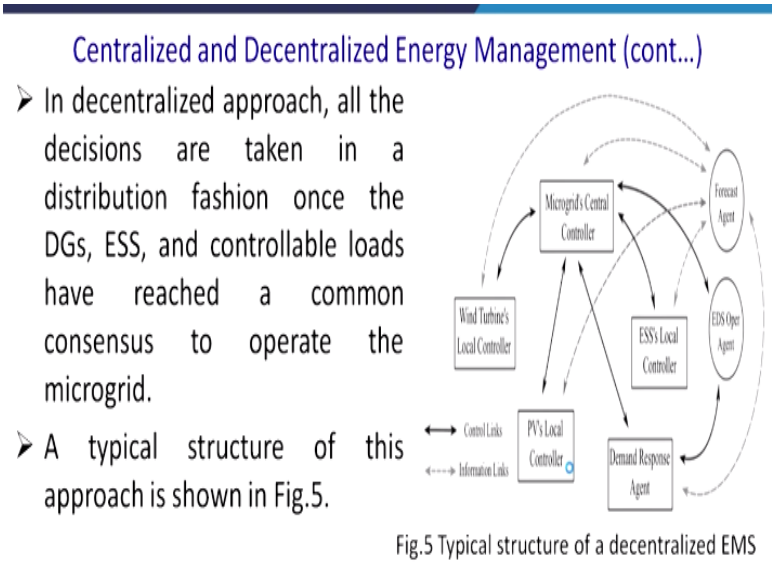

Fig.5 Typical structure of a decentralized EMS

Whereas, that is a decentralized system, all the decisions are taken in a distribution fashion once DGs, ESS, controllable loads have reached a common consensus that what should be the mode of operations in a microgrid, whether it will be islanding mode, whether it will be a grid connected mode, whether it will be a V/f control in case of the AC microgrid or it will have a PQ control and this is a typical structures of it.

This is a microgrid controller, and they generally communicate with the wind turbine, but once they got into the consensus, they take its own decision to operate inside it. So that is the way it operates.

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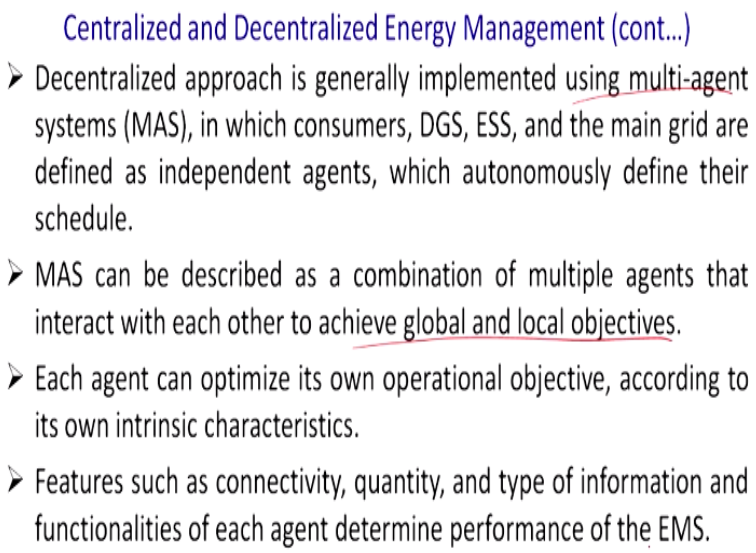

Decentralized approach is generally implemented using the multiagent system that which we have discussed in a previous class, which is consumers, distributed generation, ESS, and the main grid are defined as an independent agent and they take their own decisions and autonomously define their schedule. MAS can describe a combination of the multiple agent that interact with each other to achieve the global and the local objectives.

Each agent can optimize its own operation, thus control become better according to the objective required or set by this, the local goals. Features of such as connectivity, quantity, and the type of informations, functionality of the each agent determines the performance of this EMS.

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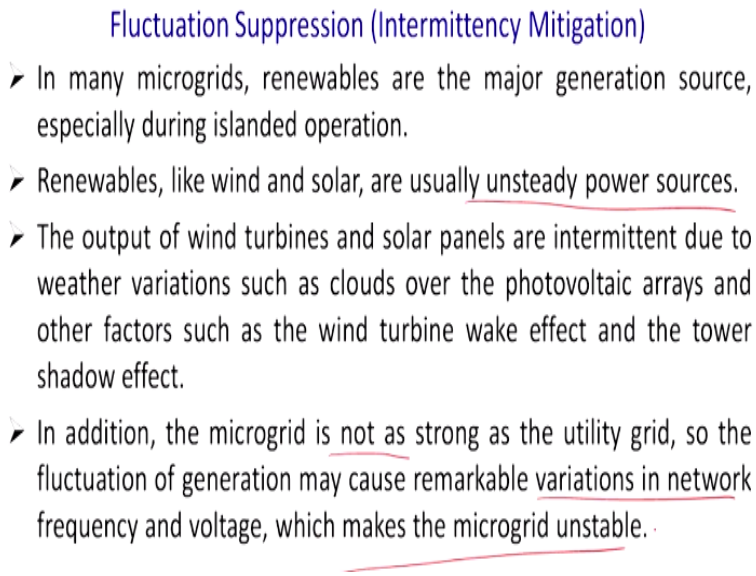

So this is very important topic you know, that is fluctuation and the suppressions of the

intermittency and mitigations. In many microgrid, renewable energy are the major generation source, especially during islanding mode. Renewable energies like wind, solar are usually unsteady in natures, so it will can keep fluctuating many times. The output of the wind turbine and the solar panel are intermittent due to the weather variations and such as cloud over the photovoltaic arrays and the wind speed for the wind turbine.

In addition, microgrid is a strong and the utility, it is not so strong like a utility grid and the inertia is less, so the fluctuation of generation may cause remarkable variation in the network frequency and the voltages in case of the AC microgrid and the voltages in case of the DC microgrid and thus it makes the microgrid unstable.

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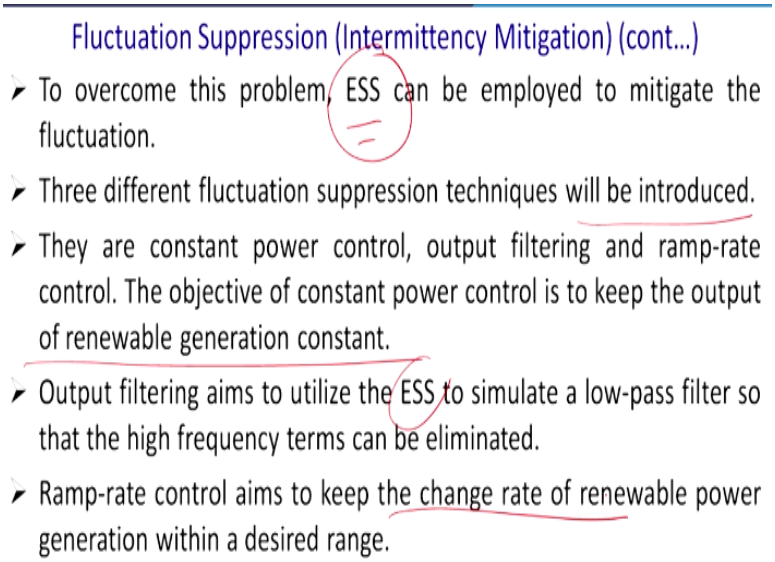

For this reason to overcome this fluctuation pattern of this power of the renewable energy, we require to implement the ESS to mitigate the fluctuations. The three different fluctuation suppression techniques are generally considered or introduced. They are constant power control, they will maintain that power constant, so it will charge or discharge the battery according to energy surplus or energy deficit or the energy output filtering and the ramp rate control if the power is ramping on, then also you can take the objectives.

The objective constant, the objective of constant power control to keep the output of the renewable energy constant, that is something we require to do that in case of the constant power. The output filtering aims to utilize the ESS to simulate the bypass filter so that high frequency, that means the fluctuation part of the load can be eliminated from this storage element.

The third one, the ramp-rate control aims to keep the change of the rate of change of renewable power generation within a desirable range. The generation at 9 am and the generation at 12 a.m. has a vast difference. So for the season, we require to have a ramp-rate control, an extra power should go to the storage element. Thanks for your attention. We shall continue our discussion in our next class.