Introduction to Smart Grid
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Lecture – 26
Operation and Control of AC Microgrid- II

Welcome you all today for the lecture on Operation and Control of AC Microgrid part 2, in which we will once again talk about what is the importance of microgrid control, hierarchical controls, intelligent control techniques, and finally, the overview of microgrid controls.

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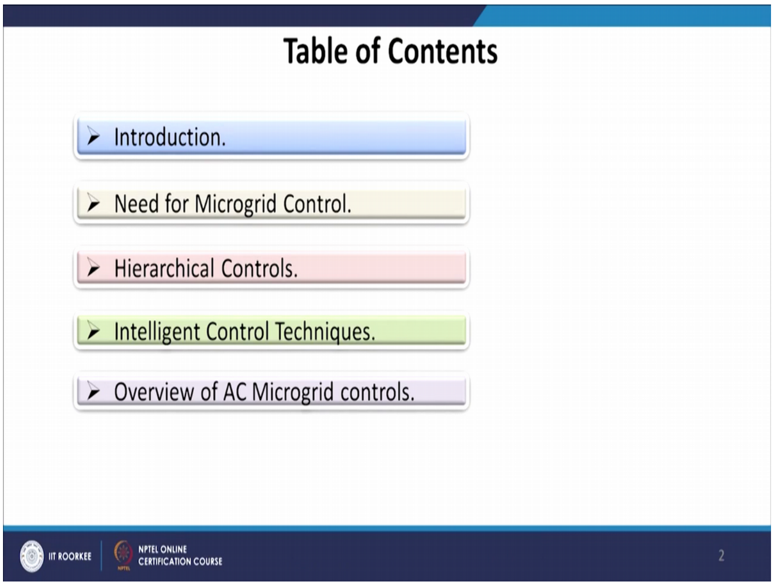

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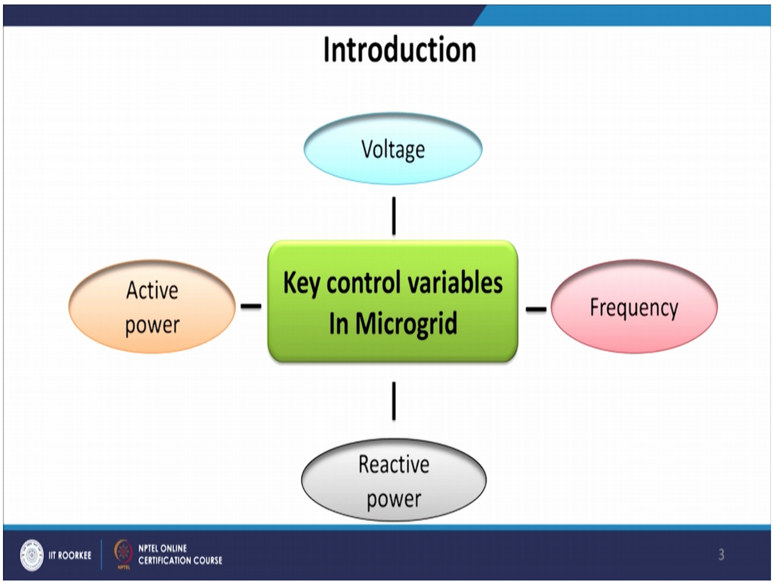

Now, the major key control variables in a microgrid is voltage, frequency, reactive power and real power. So, there is a whole 4 variables real power, reactive power, frequency and voltage decides the overall key control variables of a microgrid.

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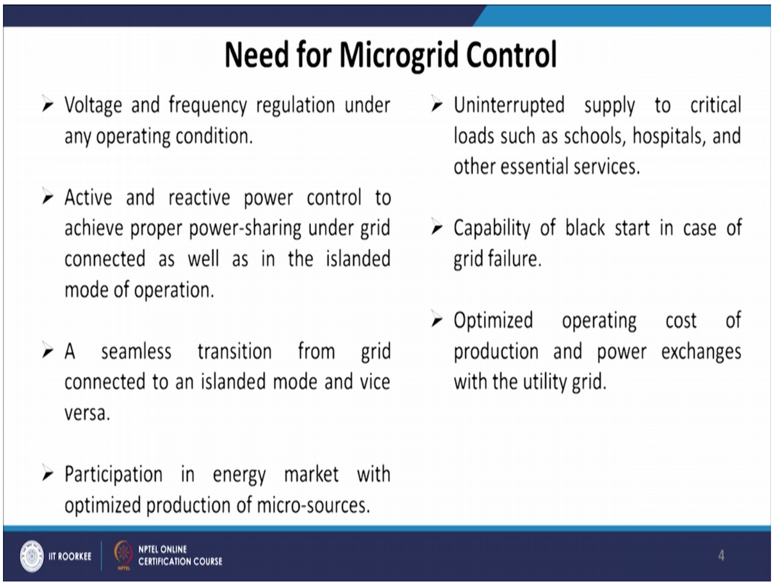

Now, voltage and frequency regulation under any operating condition is must, active and reactive power control to achieve proper power sharing under grid connected as well as in the islanded mode of operation is possible through microgrid controls. A seamless transition from grid connected to an isolated mode and vice versa.

Participation in energy market with optimized production of micro – sources. Uninterrupted supply to critical loads, such as schools, hospitals and other essential services possible, capability of black starts in case of grid failure optimized operating cost of production and power exchanges within the utility grid.

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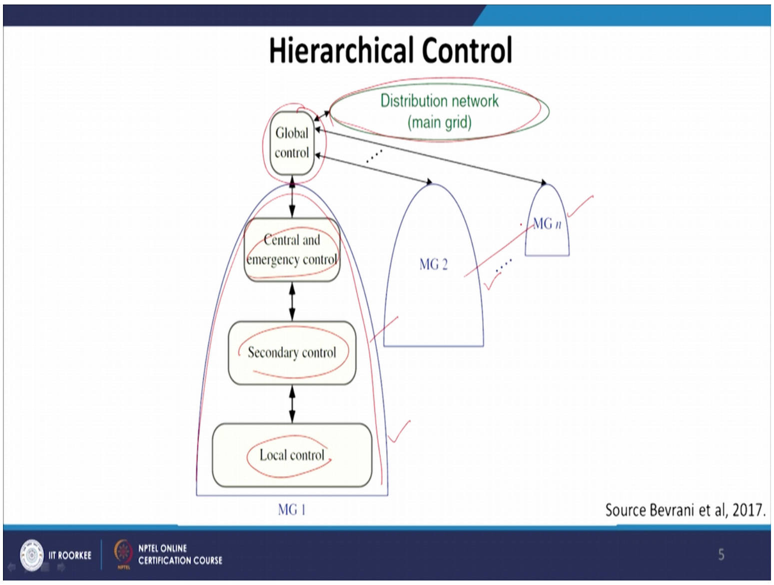

Now, let us move in to hierarchical control, now in case of a hierarchical control we can see the distribution network which is my main grid and which is been connected to the global controller. And now, if you do imagine that I have and we have connected micrograms at different buses of the distribution network and there could be many as many n number of microgrid could be connected to my distribution system.

Considering this is by microgrid 1, microgrid 2, microgrid n, now how all those microgrids can experience a common control goal and in case of a single microgrid we will first experience the local control, followed by secondary control, and hence central and emergency control and this kind of scenario must be repeated at each and every level for the local control. So, that all the microgrids can operate effectively those who have been connected to my distribution system.

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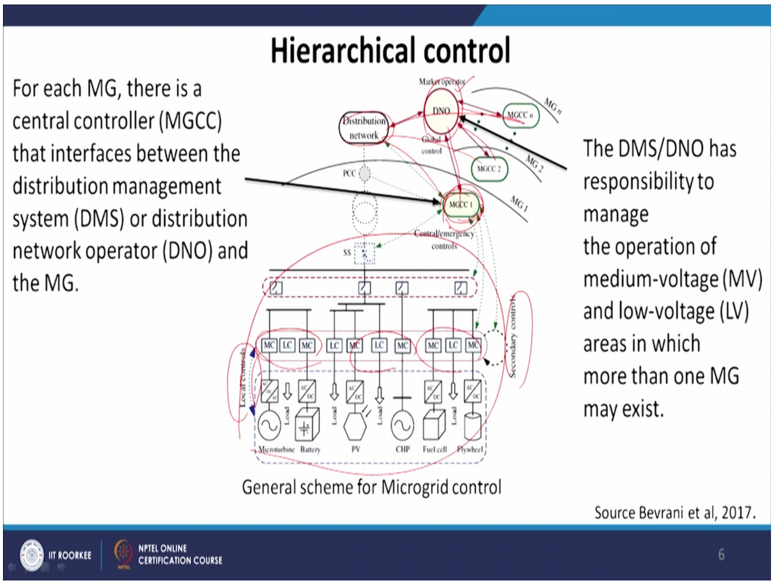

Now, getting deeper in to these, now this is my local control set up between my microgrid and do we have secondary control at each level. And now, the distribution network owner or operator that links to my microgrid 1, 2 and n and each microgrid will experience those secondary control as well as a local controllers and microgrid control connected to my distribution system and the signal may come from each and every individual microgrid controller from different microgrid through DNO.

Now what is distribution network operator or owner, now the demand the distribution management system or the distribution network operator has the responsibility to manage the operation of medium voltages and low voltage area in which, more than one microgrid is connected. Now, if you have a single microgrid certainly there is a one to one communication, but if you are having multiple microgrid it utilized all the microgrid effectively so, that the DNO can nicely manage all the microgrids effectively.

Now in case of for each microgrid there is a central controller know as MGCC that interface between the DMS distribution management system or distribution network operator and the microgrid and the microgrid. So that means, the microgrid and the DNO has been connected through my microgrid central controller.

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Now, to balance the market in the local need because the market is expected to have lot of profit, where as the customers at this consumers and expect high demand efficiency and good power supply. So, there is a local need as well as there is a market need and those two need to be matched simultaneously now in case of local hierarchical control.

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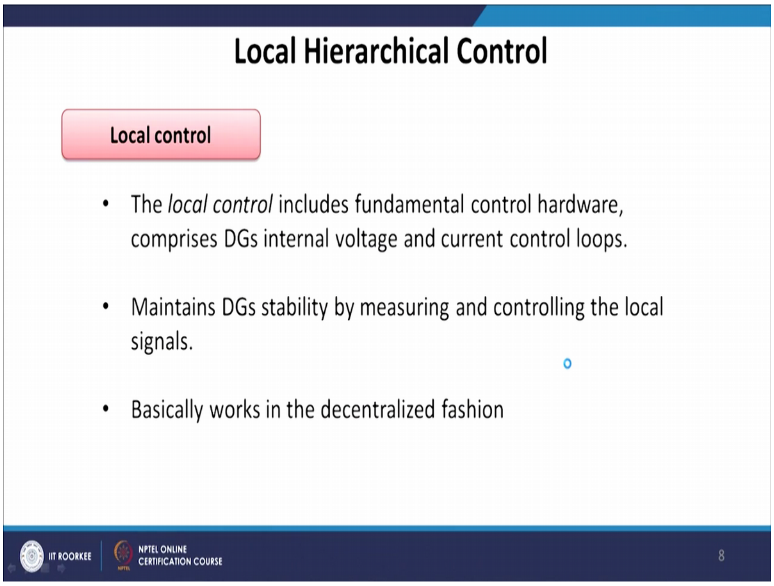

The local control includes fundamental control hardware, comprises distributed generation internal voltage and current control loops. It maintains distribution generators stability by measuring and controlling the local signals, basically works in the decentralized fashion.

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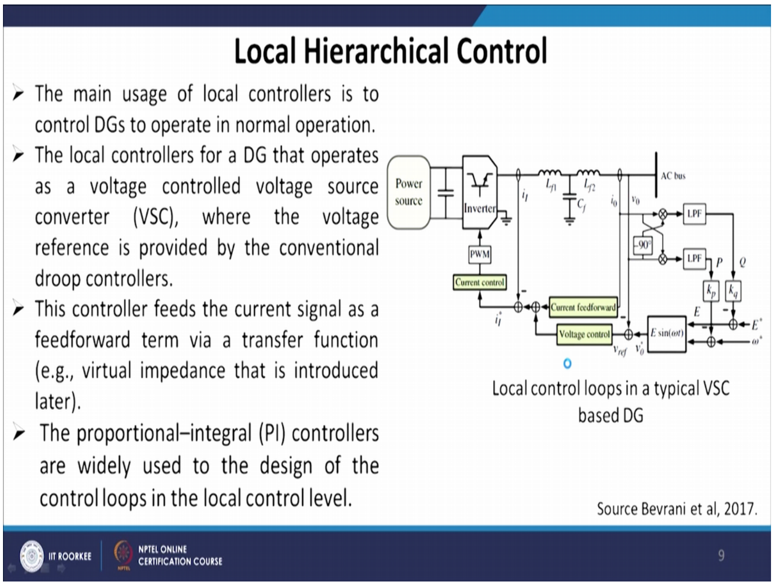

Now, the main usage of local controllers is to control distributed generators to operate in normal operation. The local controllers for a distributed generator that operates as a voltage controlled voltage source converter that is VSC, where the voltage reference is provided by the conventional droop controllers. This controller feeds the current signal as a feed forward term via a transfer function that is virtual impedance that will be introduced in the later of this course. The proportional integral PI controllers are widely used to the design of the control loops in the local control level.

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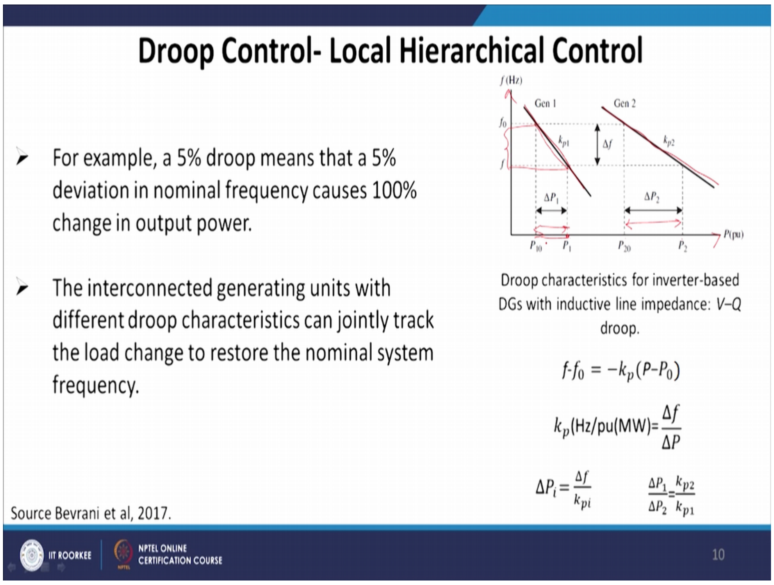

Now, let us try to understand the concept of droop control for example, the moment we say 5 percent droop means that a 5 percent deviation in normal frequency causes 100 percent change in my output power. The interconnected generating units with different droop characteristics can jointly track the load change to restore the nominal system frequency.

For example if you consider droop characteristics for inverter based DG with inductive line impedance V Q droop if it by P f characteristics this is my P and f. Now what it says that for a change in frequency from this point to this point change the power from this point to this point. Now this characteristics it may suitable for generator 1, similarly we can have another droop characteristics for generator 2 for the same frequency change the power may change, but the change in power for the generator 2 is different than the generator 1.

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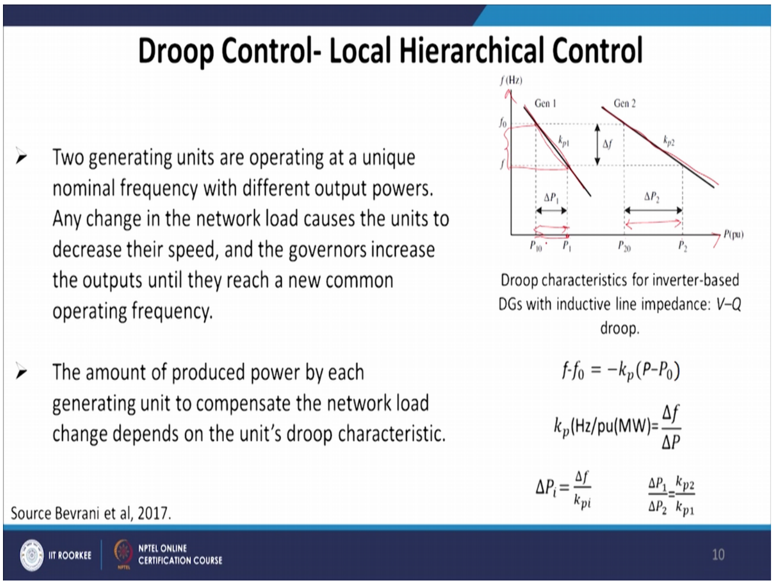

Two generating units are operating at a unique nominal frequency with different output powers. Any change in the network load causes the units to decrease this speed, and the governors increase the output until they reach a new common operating frequency. Yes we have to keep on changing until the both get the new common operating frequency, the amount of produced powered by each generating unit to compensate it the network load change depends on the units droop characteristic droop control.

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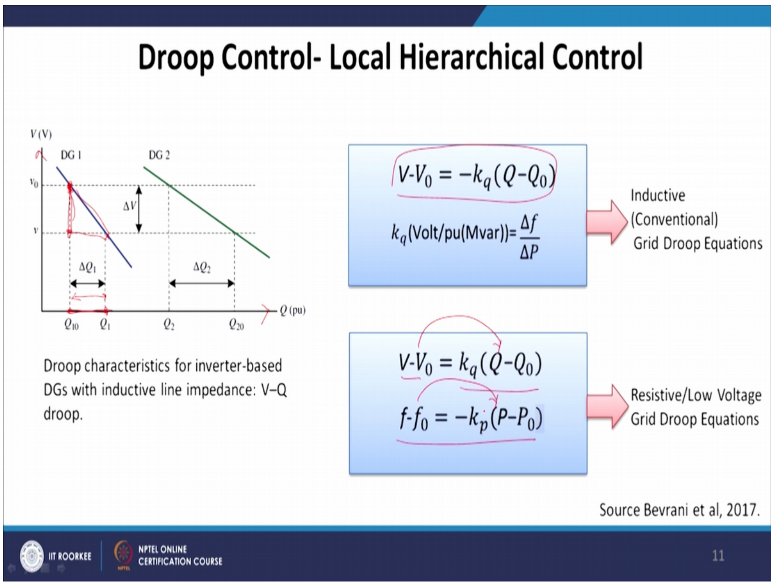

Now, if I consider one more droop characteristics between Q and V you can clearly see the voltage if it is dropped by this magnitude then my Q is reduced by delta Q magnitude or indirectly if you increase the Q by delta Q 1 the voltage may come from this point to this point. So, there is a strong relationship between in V as well Q a voltage variation. So, V 0 leads to Q 1 0 when voltage dropped to V, now the Q become Q 1. So, droop characteristics for invertor based DGS with inductive line impedance V Q droop

Now, we may have different V as well as Q characteristics for other generators. So, as though the generators are different the V and Q characteristics, droop characteristics become different. So, for a given voltage change you will experience different reactive power changes.

Now the inductive conventional grid droop equations we can obtain the V minus V naught, which is k times q minus Q naught with the negative sign as we have seen or otherwise I can say V minus V naught is k q times Q minus Q naught and where as for frequency it is by P minus P naught. So, that we can see there is strong relation between v and q and f versus p and the change can we plotted as pf or qb droop characteristics.

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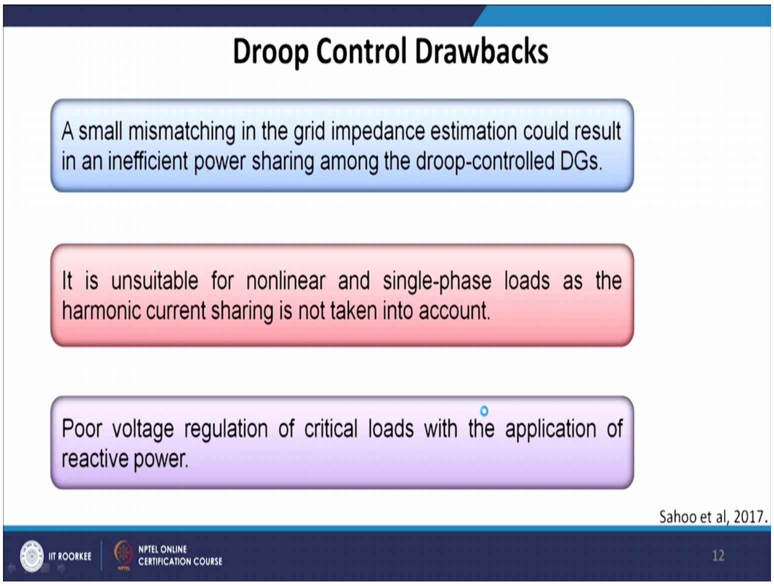

Droop control drawbacks, what are the major problems. So, the limitations of a droop control applications, a small mismatch in the grid impedance estimation could result in an inefficient power sharing among the droop controlled distributed generators. It is unsuitable for non-linear and single phase load as the harmonic currents sharing is not taken into account, poor voltage regulation of critical loads with the application of reactive power.

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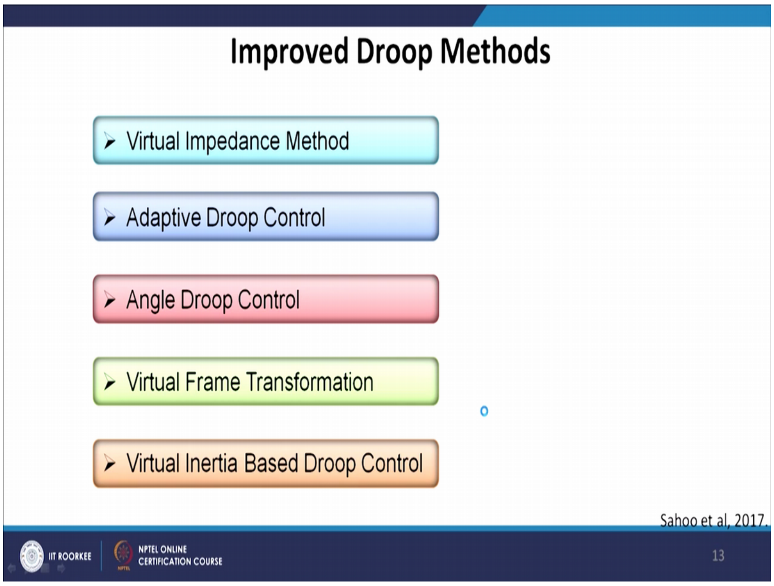

So, the droop control approaches further improved with different approaches, the first one is virtual impedance method, adaptive droop control, angle droop control, virtual frame transformation, virtual inertia based droop control. So, now, concentrate on virtual impedance based droop control.

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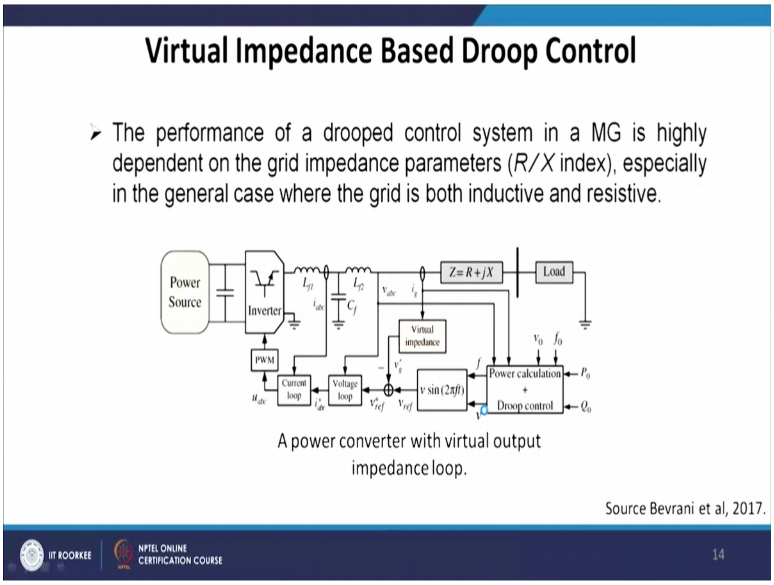

The performance of a drooped control system in a microgrid is highly dependent on the grid impedance parameters, that is R by X index especially in the general case where the grid is both inductive and resistive.

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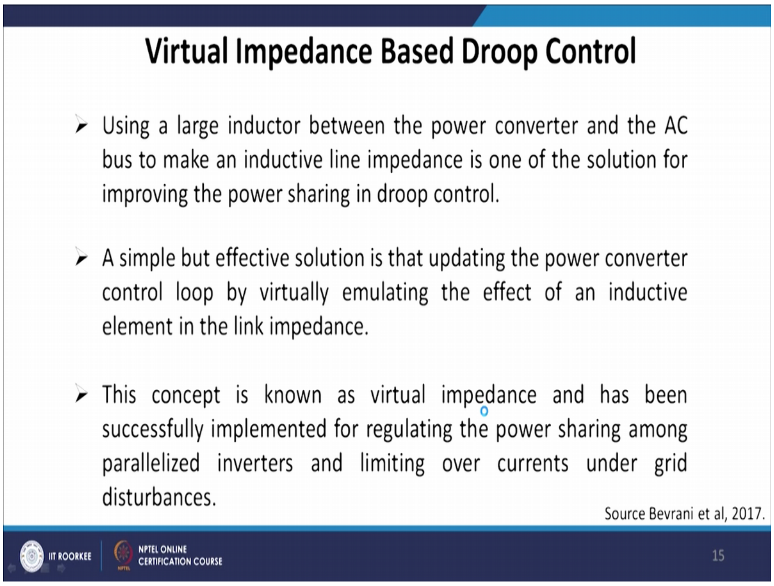

Using a large inductor between the power converter and the AC bus to make an inductive line impedance is one of the solution for improving the power sharing in droop control. A simple, but effective solution is that updating the power converter control loop by virtually emulating the effect of an inductive element in the link impedance.

This concept is known as virtual impedance and has been successfully implemented for regulating power sharing among parallelized inverters and limiting over currents under grid disturbances. Improved droop methods, now in case of adaptive droop control.

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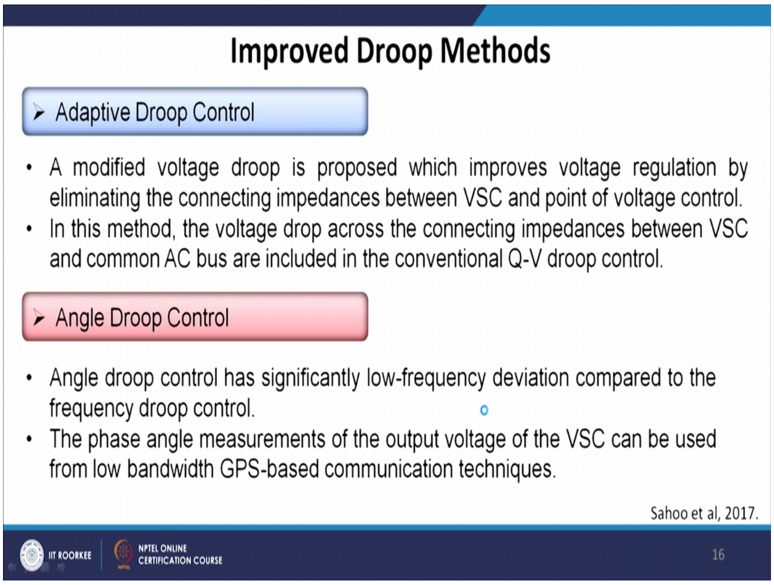

A modified voltage droop is proposed which improves voltage regulation by eliminating the connecting impedances between VSC and point of voltage control. In this method, the voltage drop across the connecting impedance between VSC and common AC bus are included in the conventional Q-V droop control.

Angle droop control, angle droop control has significantly low frequency deviation compared to the frequency droop control. The phase angle measurements of the output voltage of the VSC can be used from low bandwidth GPS - based communication techniques.

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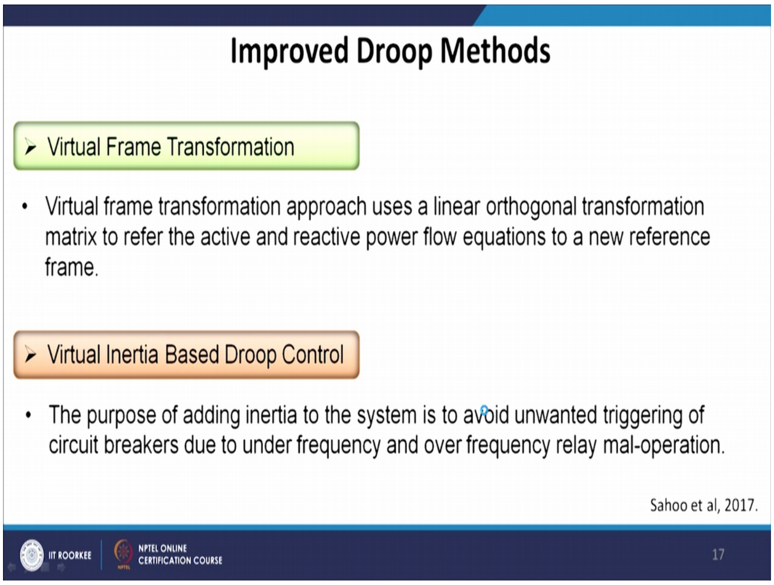

Now, in case of virtual frame transformation, virtual frame transformation approach uses a linear orthogonal transformation matrix to refer the active and reactive power flow equations to a new reference frame. Virtual inertia based droop control, the purpose of adding inertia to the system is to avoid unwanted triggering of circuit breakers due to under frequency and over frequency relay malfunctions.

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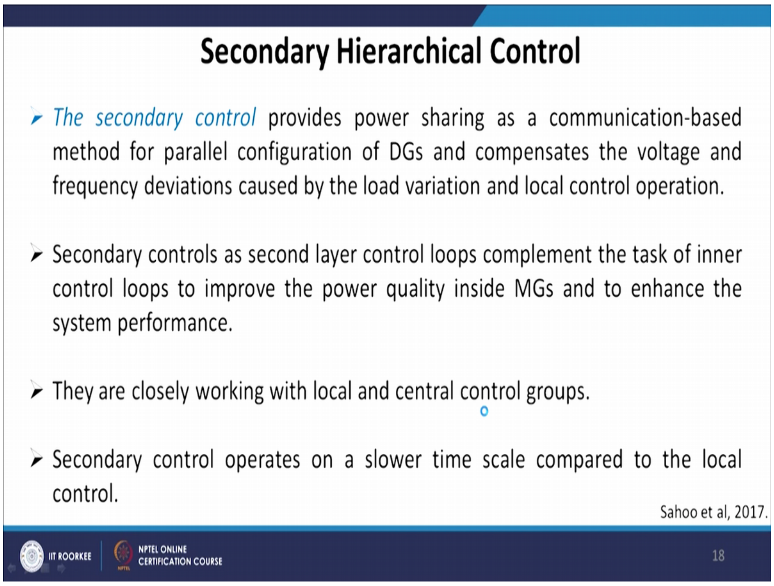

Now, the second hierarchical control, the secondary control provides power sharing as a communication based method for parallel configuration of DGs and compensates the voltage and frequency deviations caused by the load variation and local control operation.

Secondary control as second layer control loops as we have seen in the previous diagrams, complement the task of inner control loops to improve the power quality inside microgrids and to enhance the system performance. They are closely working with local and central control groups, secondary control operates on a slower time scale compared to the local control.

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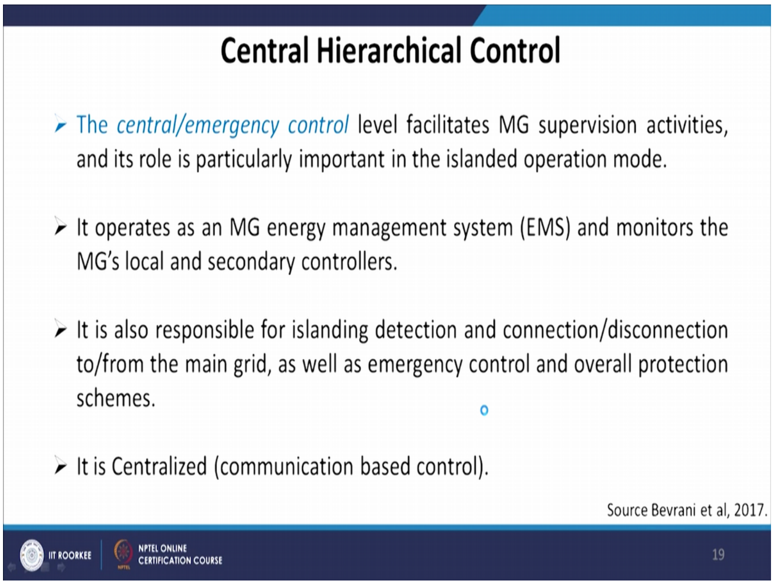

Now the central hierarchical control facilitates microgrid supervision activities and it is role is particularly important in the islanded mode of operation. It operates as an microgrid energy management system and monitors the microgrid local and secondary controllers. It is also responsible for islanding detection and connection, disconnection to or from the main grid as well as emergency control and overall protection schemes, it is centralized and mainly based on communication based on communication.

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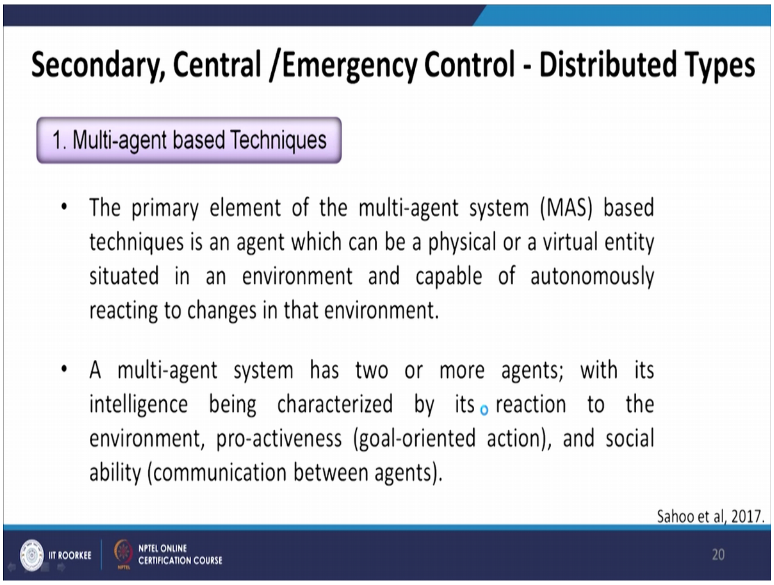

Secondary central emergency control distributed types, let us discuss on multi -agent based techniques, the primary element of the multi agent system based techniques is an agent which can be a physically or a virtual entity situated in an environment and capable of autonomously reaching to changes in that environment.

A multi agent system has two or more agents with it is intelligence being characterized by it is reaction to the environment, pro activeness goal oriented action, and social ability that is communication based agents. Moving in to model predictive control techniques model predictive control so, called MPC.

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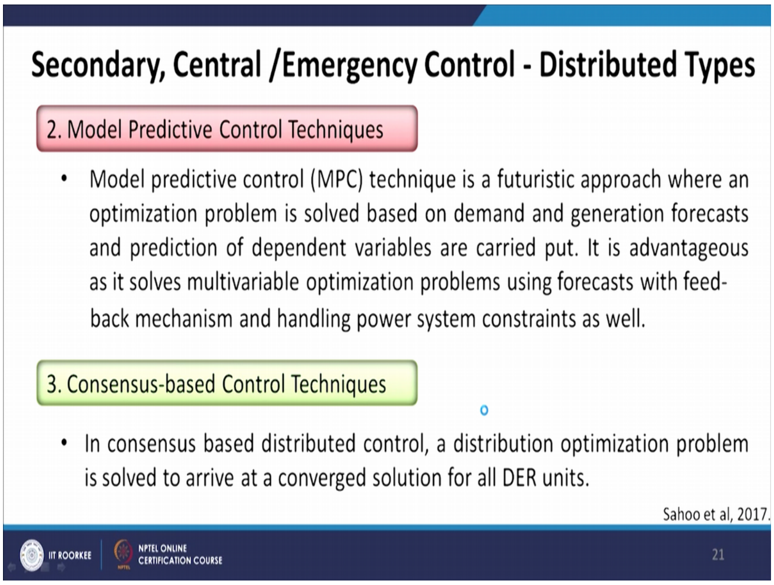

Technique is a futuristic approach where an optimization problem is solved based on demand and generation forecasts and prediction of dependent variables are carried out. So, here we imagine step ahead it is advantageous as it solves multi variables optimization problems using forecasts with feedback mechanism and handling power system constraints as well. Consensus based control techniques, in consensus based distributed control a distribution optimization problem is solved to arrive at a converged solution for all distributed energy resources units present in the system or connected to a microgrid.

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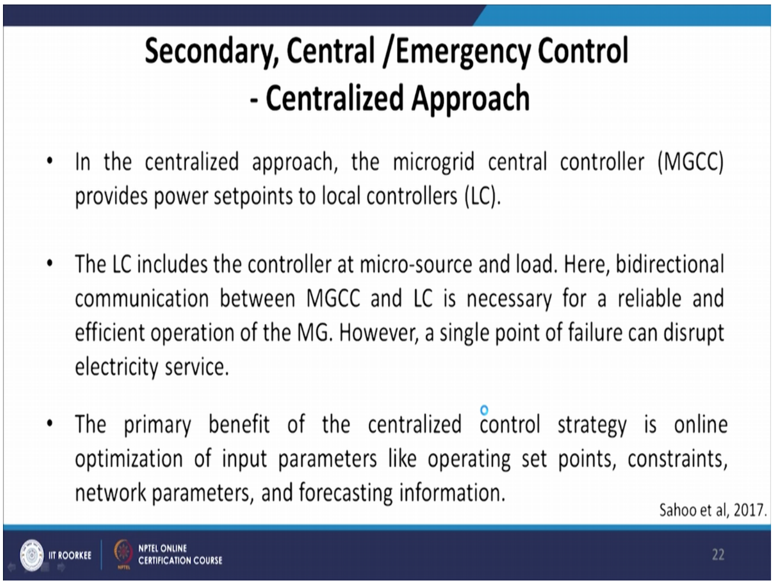

Now in case of a centralized approach, in the centralized approach the microgrid central controller that is MGCC provides power set points to my local controllers LC further operations. So, here to create a local controller points and those have been created by the MGCC. So, that each local generation points can behave based on the instruction available to me from the MGCC, assume in a small microgrid and if you have around 3 to 4 different sources and those sources will have my 3 to 4 local controllers.

And with the single MGCC the LC can communicate with my MGCC and take action at local end as desired by the MGCC. The LC includes the controller at micro source as well as the load here bidirectional communication between MGCC and LC is necessary for a reliable and efficient operation of the microgrid. However, a single point of failure can disturb a complete electricity services.

The primary benefit of the centralized control strategy is online optimization of input parameters like operating set points, constraints, network parameters, as well as taking caring of forecasting information’s.

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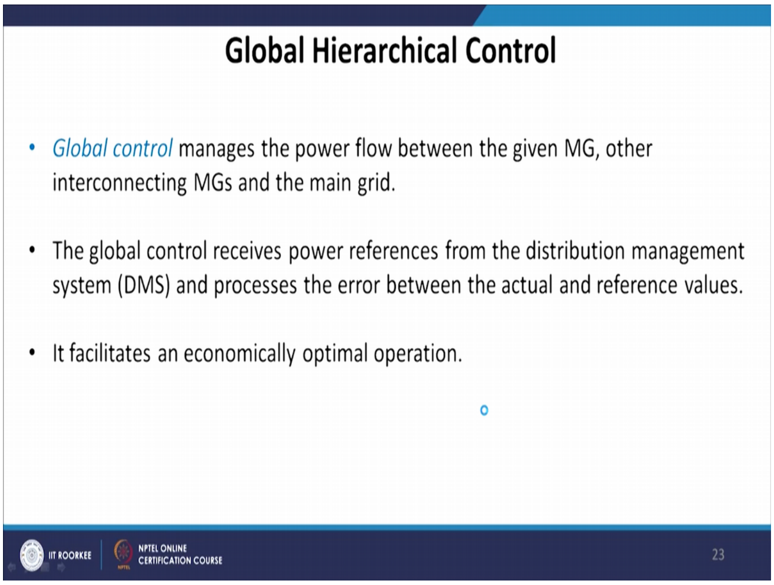

The global control manages the power flow between the given microgrid other interconnecting microgrids and the main grid. Now, the global hierarchical control is a step above where it manages the power flow between the given microgrid interconnecting to other microgrids. The global control receives power reference from the distribution management system that is DMS and processes the error between the actual and the reference values, it facilitates an economically optimal operation.

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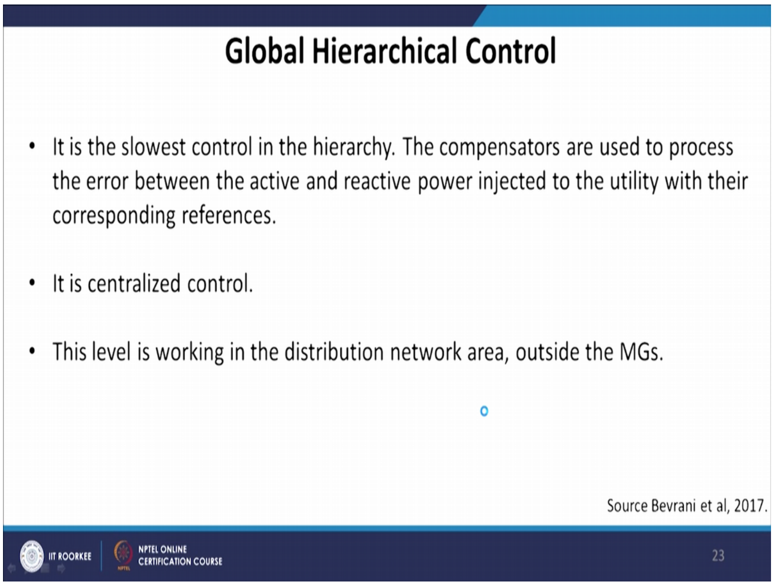

It is the slowest control in the hierarchy, the compensators are used to process the error between the active and reactive power at each level injected to the utility with their corresponding references, centrally it is centralized control, this level is working in the distribution network area outside the microgrid.

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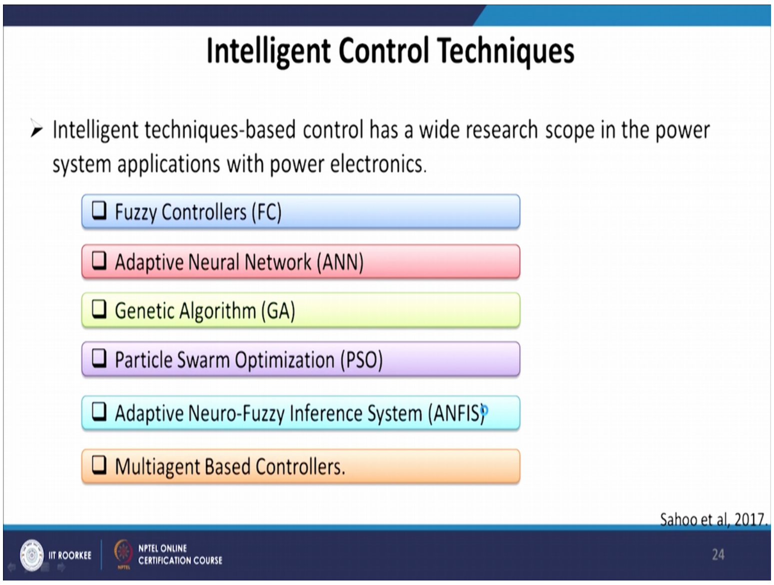

Finally we get in to intelligent control techniques because we all know that control schemes are never ending and for the microgrid the complicity extremely high and we have to evolve in new technique next to achieve target oriented error for a problem association with a existing technique.

So, currently many intelligent technique as been evolved intelligent techniques based control has a wide research scope in the power system application with power electronics, the first one is fuzzy controllers, adaptive neural network, genetic algorithms, particle swarm optimization, adaptive neuro - fuzzy inference system, multi agent based controllers.

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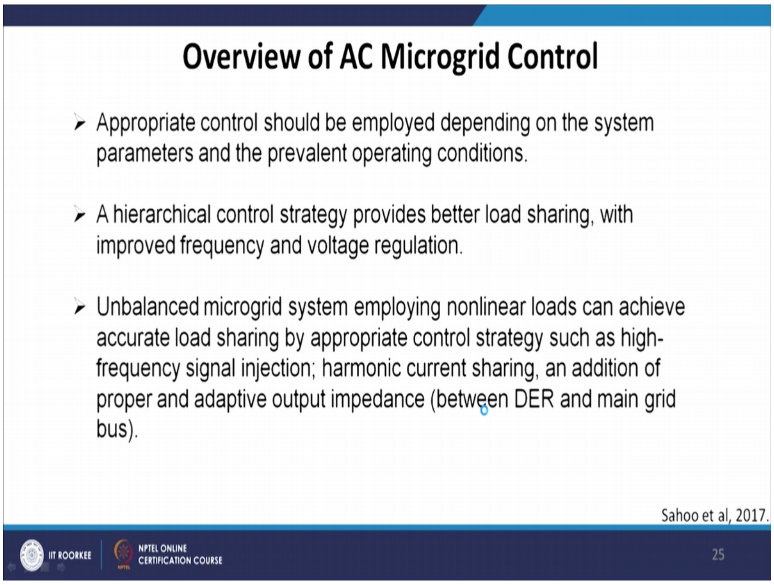

And to conclude to this lecture let us understand the overview of ac microgrid control, now to focus in this case in the control mechanism as we have seen at each and every level the droop the droop control is commonly widely used, but it has certain limitation though it is robust, it has been involved over a period of time.

But looking in to the microgrid control scheme considered to be one of the most important because please try to understand do have a microgrid connected to a n number of load and energy is coming from n number of sources. And those sources are intermitted means you cannot guarantee the outcome of a each and every energy sources at a given time certainly the customer behaving randomly.

So, the energy at each and every bus you know being injected is keep on varying the loads are keep on varying. So, at a given time the load and generation to be balanced and that balance is to be possible efficiently optimally to exercises to a local energy sources and it could be grid interface or may be islanded operation different control schemes are involved, but let us overview of the control mechanism what we learn in last 2 lecture.

Appropriate control should be employed depending on the system parameters and the prevalent operating conditions, a hierarchical control strategy provides better load sharing with improved frequency and voltage regulation. Unbalanced microgrid system employing non-linear loads can achieve accurate load sharing by appropriate control strategy such as high frequency signal injection, harmonic current sharing, an addition of proper and adaptive output impedance between DER and main grid bus.

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Communication less control strategies such as droop control are independent of the geographical distance between the DGs and it is loads; however, they are less reliable due to the absence of interaction between distributed generators. Decentralized control techniques are gaining popularity due to reduced risk of single point failure of control unlike centralized control strategy with cooperative and intelligent control and multi agent based methods. These two references are very frequently used in today's lecture.

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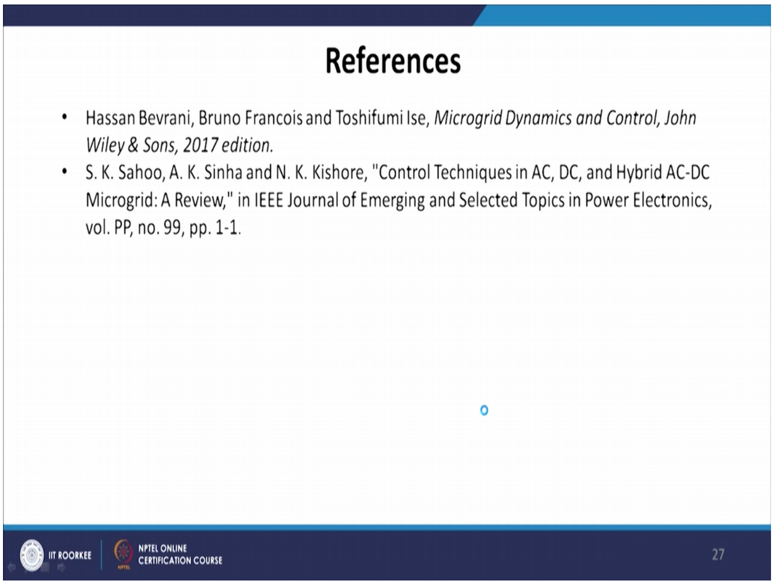

So, I request all of you to please refer, this two references thoroughly.

Thank you.