**Power System Engineering**
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**Lecture - 45**
**Load frequency control (Contd.)**

So welcome to the next topic that is a load frequency control; so, little bit I have told you just now, right.

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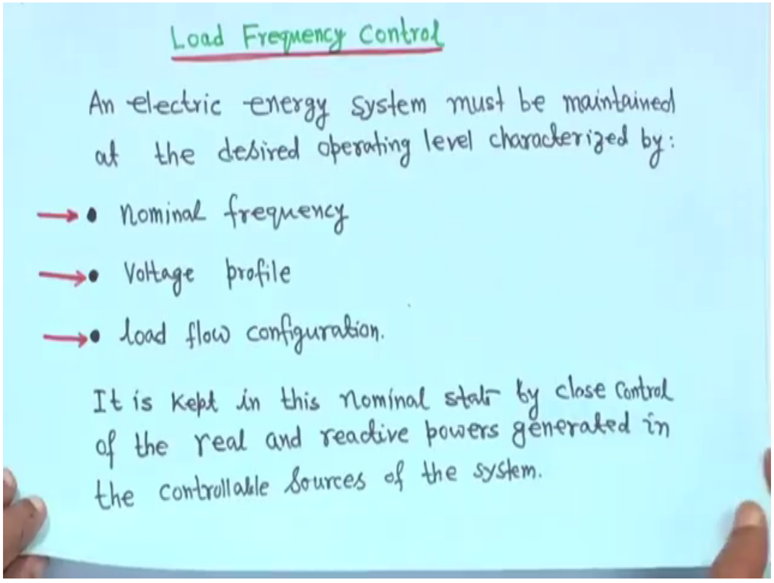


So, question is that load frequency control because of the deregulation also certain things have changed right concept has changed, but after making all these analysis for conventional scenario conventional scenario only, then little bit clever, I will give you regarding the deregulation such that you know you will have a better understanding.

So, here what that generally brief something something, I have written, I will explain that an electric energy system; that means, in general, it is a power system must be maintained at the desired operating level characterized by one is the nominal your frequency nominal system frequency; that means, it will operate at a 50 or 60 hertz system, right there, it should be operating its voltage profile also should be you know good and load flow configuration, right.

So, it is kept in the nominal state, I mean in this frequency right by close control of the real and reactive power generated in the controllable sources of the system ; that means, you have to control both real and reactive power, but later, we will come to that, but frequency case it is a real power right.

So, basically you know that power system here, it is a huge network right and some power system one group of power system is interconnected to another group of power system or one power system which connect connected to another power system or sometimes power system operating totally isolated way. So, different versions are there right.

So, question is that that we have to maintain that your nominal system frequency of course, under normal operating conditions right.

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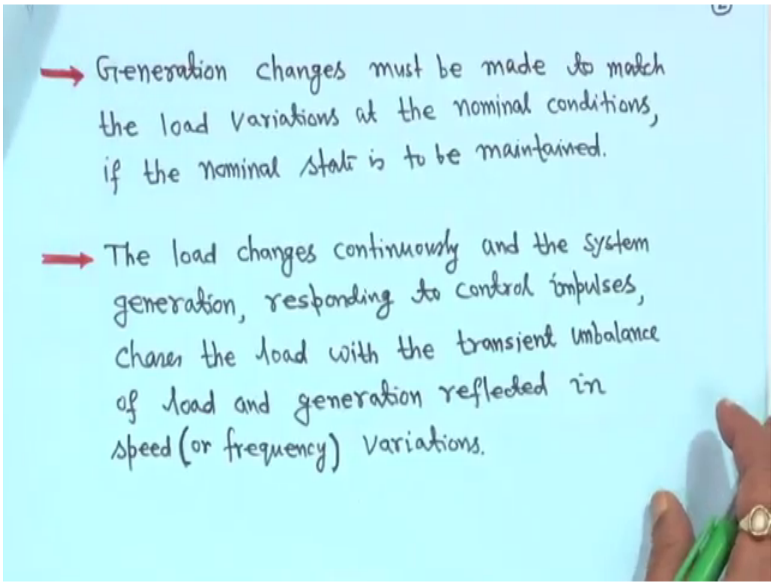


So, question is that generation changes must be made to match the load variation; that means, suppose, when there is a change in load, suppose, there is a increase of load. So, generation actually power system actually chases the load right sometimes, we call it is a load following generator chasing the load or following the load. So, it is a load following.

So, they because I mean when the load is increased suppose all of a sudden the power demand has increase 100 megawatt. So, generators whether it is a suppose, if it is a thermal unit; that it cannot generate power 100 megawatt, instantaneously, it takes some time; that means, there is some transient imbalance will occur between generation and load because there will be shortage of generation and load an increase. So, some transient imbalance will be there. So, accordingly generation slowly and slowly will pick up the load. So, generation actually chases the load sometimes we call load following that generator is following the load, right.

So, that is why generation changes must be made to match the load variation at the nominal conditions, if the nominal state is to be maintained right if you want to maintain this nominal state then naturally that generation and load, it should match, right, if it is not, then it will be obtained in some way, right at the departure of the system frequency we will come later.

The load changes continuously because in the power system that load will change continuously, I will switch on switch off it is going on apart, but we are not considering have any fall studies or anything, right, we are considering normal operating conditions, all right. So, and the system generation responding to control impulses chases the load; that means, whenever your whenever there is a change in load right. So, some mismatch will happen. So, in that case; so, you have to have your what you calls, I am load chase your what you call that your generation increase or decrease mechanism something you have to check, right.

So, the signal will go to that right because you have a speed governing system right and accordingly you have to adjust the generation will adjust the load. So, that is why that is why responding to the control impulses later I will come chases the load with the transient unbalance of load and generation reflected in speed or frequency variation because if this is a question to you, I am putting it you will answer it that if real power, if real power increases there will be a decrease in frequency in the decrease of the speed of the your moved in to your generate a turbines set at the power system right because generate a turbine coupled together.

So, if real power changes, if you load increases I mean real power load increases, there will be a decrease in the speed that is decrease in frequency. So, decrease in speed of that turbine generator system and if load decreases less frequency or the speed will increase of the turbine generator system because turbine and generator coupled together.

Now, question is my question is to you it is very interesting question you should answer that if load increases right, then frequency will fall; that means, suppose, machine was operating at your 50 hertz say its speed is a generator speed is 3000 rpm at the your power station generating power station and turbine generator is coupled together, it is a huge mass, right.

Now, load has increased. So, all the machine will not lose synchronism, but that there will there will be decrease in the speed because load has increased my question is if load increases speed decreases if load decreases speed increases why it is happening; what is the technical reason this is a question to you, this is a first question second question is that if load increases the speed is falling that is generator turbine mass rotating in a 3000 rpm speed decreases mean that will loss of kinetic energy right.

My question is where that kinetic energy goes right. So, this is second question. So, first question is if there is a change in load there will be change in speed or frequency right. So, why this happens and second question is that if your load is increases speed decreases right and if load decreases speed increases, but my question is either of this you can answer that if load decreases increases speed decreases; that means, turbine generator mass speed is decreasing right because frequency decreases. So, there will be loss of kinetic energy because generator and turbine is a huge mass where that kinetic energy goes it cannot be vanished into the blue right. So, this is a question it is a physics type of question, but you should answer this, right.

So, that is why chases the load with the these answer, you will write and send, it to me email if it is correct I tell you, otherwise, I will correct you, right with the transient unbalance or imbalance occurs between the I told you between the generation and the load there will be a transient imbalance, if the load increase then it is change in load between generation that will be difference between generation and load right.

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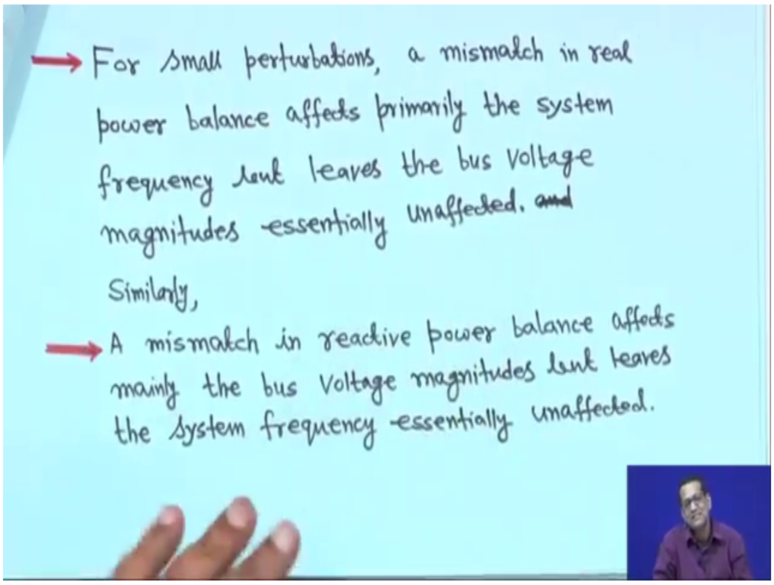


So, for small perturbation when I mean disturbance is very small right a mismatch in the real power balance affects primarily the system primarily the system frequency same concept that decoupled load flow, I have use know. So, almost same thing; but leaves the bus voltage magnitudes essentially unaffected.

So, if there is a small change in real power then it will affect that your what you call the voltage angle; that means, the frequency here or here is the speed that is omega right, but leaves the bus voltage magnitude essentially unaffected of the system, there will be decoupled.

Similarly, if a if there is a change in the reactive power mismatch in reactive power balance it basically affects the bus voltage magnitude, but leaves the system frequency essentially unaffected; that means, these two things are decoupled; that means, real power frequency control we and that reactive power voltage control they are decoupled right.

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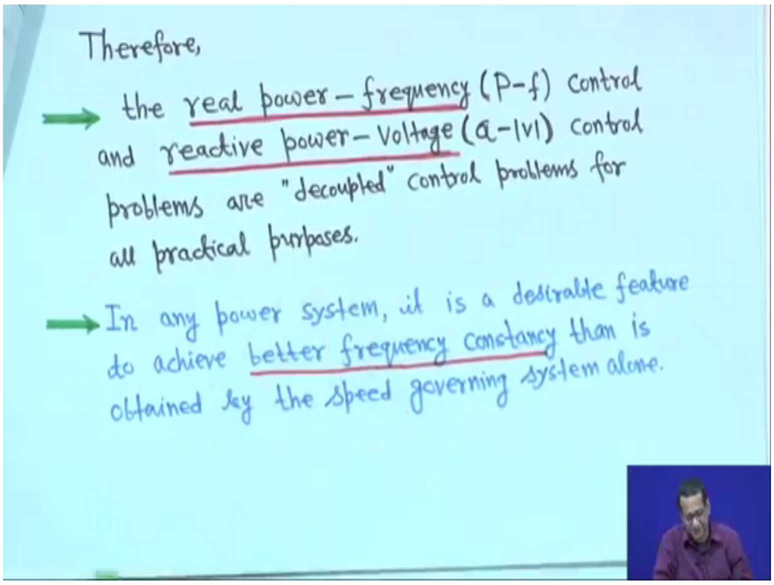


So, that is why the real power frequency we call P-f control right and the reactive power voltage we call q v control it is magnitude written here right problems and decoupled control problems for the all practical purposes right.

So, in any power system, it is a desirable feature to achieve greater system frequency greater frequency constancy than is obtained by the speed governing system alone speed governing system will come at the beginning itself will come right in an interconnected power system.

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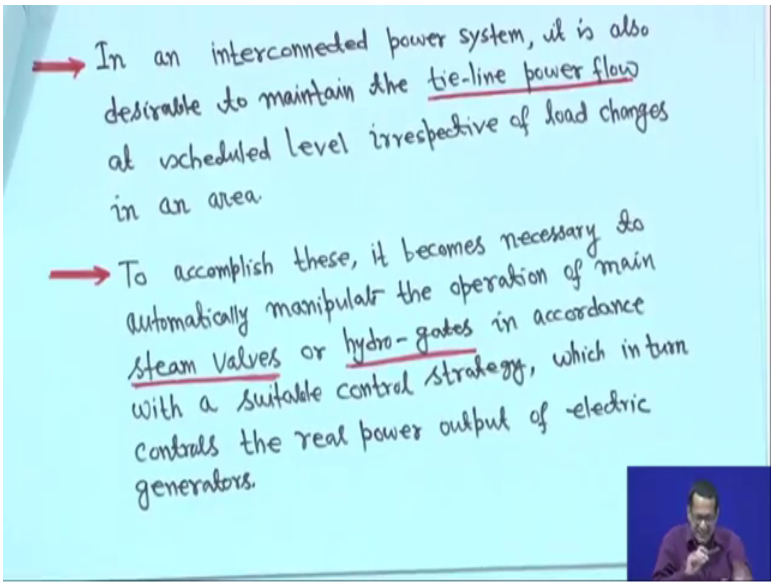

It is also desirable to maintain the tie line power flow at schedule level irrespective of the load changes in an area, just we will come to that this thing details will come, but the idea is something like this.

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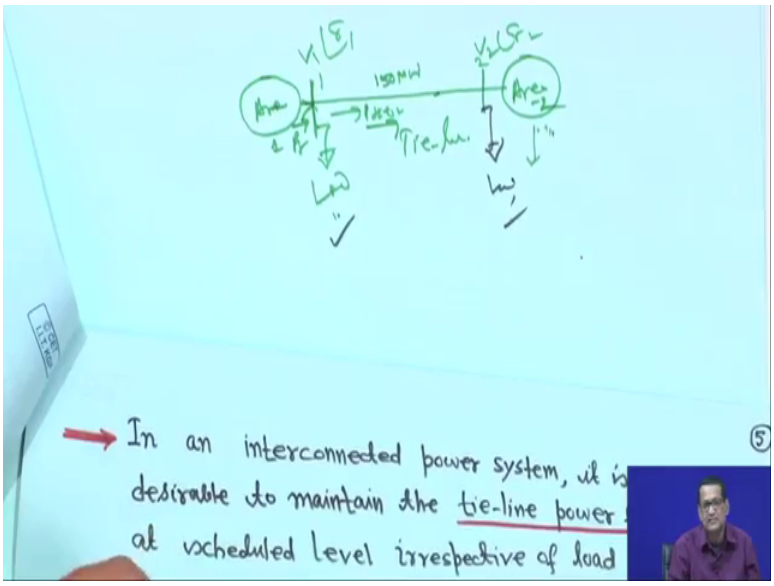


Suppose, we have one power system here, what is area 1 and area 2, later will comes suppose, this is one power system, it is collected by the 3 phase tie line of course, this is your area 2 right and this is your this is actually tie line this is 3 phase line actually tie line means these two powers are interconnected and tied together that is why you call tie line.

So, it is a 3 phase line here voltage magnitude V 1, V o, V 2 angle delta 2, V 1 angle delta 1 and tie line power a power is flowing, right. So, this is one this is two. So, power flow is P tie 1 2 and load is here load is here and generation is here this is the generation coming out from this. So, basically generation is equal to this tie power plus this load is schematic diagram suppose total load is showing like this.

So, this is schematic diagram. So, it is ; that means, this suppose these two areas are there suppose power flowing from this direction to that direction; that means, this area actually has some contact, of course, you have some contact that are certain time you can buy power if you are of course, here if you are in storage of power, then this particular power system say here is a power system right later, we will come to the definition of that. This particular power system can buy power from this power this power system if they have sufficient is spinning reserve capacity right.

So, question is that they are in that case your what you call that it will draw power from this time. So, this is a P, it a real power only showing because our objective will be real power only reactive power will not study in this course right so; that means, here P g is the generation if this is the pg should be is equal to the P tie 1 2 plus the load right. So, e and second thing is suppose at a particular hour suppose contact is 150 megawatt. So, it will draw 150 megawatt from this side from this power system will draw 150 megawatt from this side.

So, that is why your that int is it is also desirable to maintain the tie line power flow at to do level irrespective of load changes in an area we both the both the side loads are there here also loads are there right here is a loads are there whatever load is changing this side or that said it does not matter if I have a contact that 150 megawatt I will draw there will be it will it should maintain that it should maintain that right

To accomplish this it becomes necessary to automatically manipulate the operation of mainstream valve or hydrogate in the case in the case of steam turbine it will be steam valve or you have to or hydrogates because if you open the steam valve then more steam input will be there if you try to close it steam less right or hydrogates if you open the hydrogates more water input will be there to the your turbine right.

In the accordance with the suitable control strategy because whether speed is decreasing increasing according to that it will receive the signal and according to that valve will be closing or opening or hydro gates for hydropower plant it will open or close right which intellectually controls the real power output of the electric generator, this way electric output of electric generator will be controlled course, but in this course I have no interesting to consider the hydro turbine right only thermal 1, we will consider, but one or two things regarding hydro turbine actually in hydro turbine that you have a reservoir right you have a dam you have a reservoir and basically water your traveling to the penstock to the turbine right.

In case of hydro turbine actually we will not discuss there, but hydro turbine governor actually pid time, governor purposefully integral derivative governor, but that is not the thing here in the case of a hydro turbine at the water is traveling through the penstock.

So, what happened that if suppose the load had increased right. So, as soon as the load has increase that that high, it was the signal you will go to that hydro gate and this thing and hydro gates will open as soon as that hydro gate opens immediately water instead of traveling to as a turbine actually because of the back home created inside the penstock and water will be there will be rivers flow of water.

So; that means, initially what happened for hydropower station if load increases initially generous and decreases right for some movement and after that because and after that it picks up so, and this is called actually that is the water gate you open that water will travel back in the instead of coming down. So, it is called actually water hammer effect right. So, this will not be considered and whenever we considered the hydro turbine model actually it is it is for it is become actually in the function of tan hyperbolic.

But we make it first order transfer function, but I hope I will not considered that it will be then although things are simple, but if you do the simulation for hydro turbine, you will see that initially generation is negative they decreasing and after that it just takes up right whereas, thermal power plant it will not happen another thing is for hydropower plant actually, if it actually it if load per suppose, a hydropower station, it supplying load suppose load demand has increased. So, hydro can quickly meet the load demand much faster than your what you call the thermal power plant.

Because hydro actually is your what your what I will say is constant and not that stringent like your steam power plant right because in the steam power plant you have boilers economizer many other many other parts right, but in the case of hydro gates it picks up the generation very faster suppose 10 megawatt load has increased and suddenly, it can meet the demand very quickly whereas, in the case of steam valve it cannot that because generation rate constant are limit if you want that thermal power plant or steam turbine right non reheat or heat type turbine if it is there it will generate a 100 megawatt in few second, it is not possible, it will it has some limit right or it has some constant.

So, you I mean it is although it is a machine it has some physical limit. So, it cannot generate power as fast as hydro, right. So, these are certain differences. So, so as so that is why that your to maintain that everything frequency maintained tie power schedule maintaining that you have to have some control mechanism.

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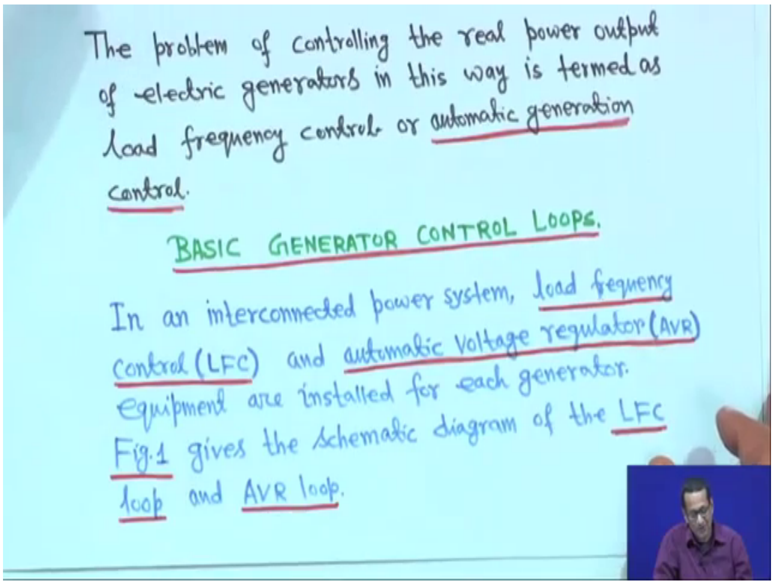


So, that the problem of called therefore, the problem of controlling the real power output of electric generators in this way is termed as load frequency control or automatic generation control, right. So, I told you at the beginning that automatic generation control means suppose one hundred megawatt one hundred megawatt load demand has increased suppose you have a 5 units that hundred megawatt you share among 5 units such that your economic your economic fuel cost will be economical or minimum because 5 generators may have different fuel cost character and 100 megawatt you just see that how things are happening.

Suppose one generator can give nineteen megawatt another may be 23 megawatt like this instead of equivalent sharing. So, in that case, you will find that your an accordingly you send the signal to its generator such that it will generate all these powers as a total your 100 megawatt will be yours generated; so, so, anyway. So, that is economic load dispatch.

Now, second thing is the basic generator control loop right. So, in an interconnected power system load frequency control that is you can short you call LFC or automatic volt and automatic voltage regulator we call AVR equipment are installed for each generator right. So, figure one gives a schematic diagram of the LFC loop and AVR loop.

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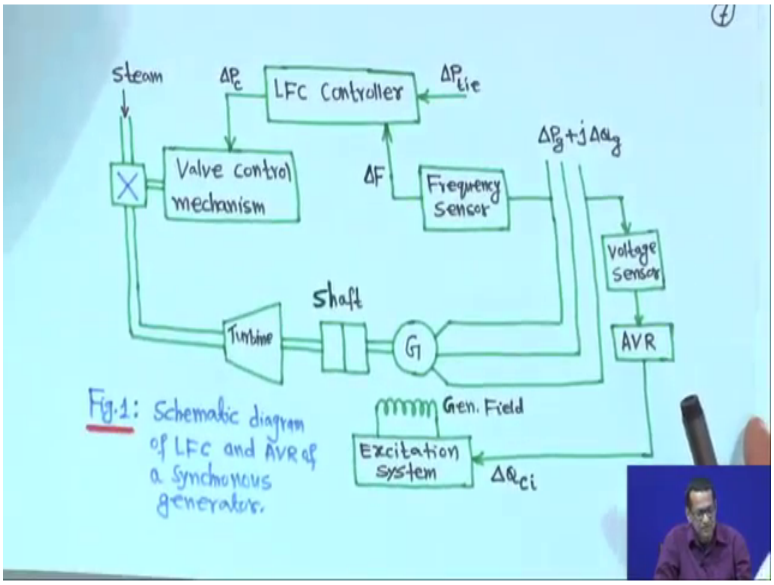


So, this is figure one. So, this is a your figure one suppose this is your say this is a steam power plant. So, it is steam or if it is your; what you call here it. So, valve control mechanism there may be maybe 2-3 stages of valve control mechanism will be there, but here it is here it is not shown right it will take the simple thing.

So, if it is a hydro then it will be hydro gate right open it. So, it is a steam, now here it is your what you call this is a turbine shaft turbine generator connected to the shaft right and this is the generator and this is 3 phase line right. So, giving the small changes delta pg pd or delta your Qd whatsoever, right. So, delta pg plus delta Qg generation changes will be there and this is a here it will says the frequency frequency sensor is there tie line power also will be measured this is delta F tie line power will be measure and LFC controller will be here and output signal will be delta pc and the it will go this will go to the valve control mechanism whether valve will be open or valve will be closed right.

So, and this one these side voltage sensor will be there automatic voltage regulator will be there and this is your the excitation system and this is that your generator field and this is delta Qci, right, this is overall there schematic LFC and AVR of a synchronous generator this is together this is a schematic diagram, but this AVR generated field excitation system that is actually that is comes actually power system dynamics and control that beyond the scope all the looks here very simple there right, but those things are not easy you have to you have to consider so many things right.

So, but our cases is we will only consider that load frequency control will cannot consider this part will not consider this part. So, this is a schematic diagram as a whole for the system.

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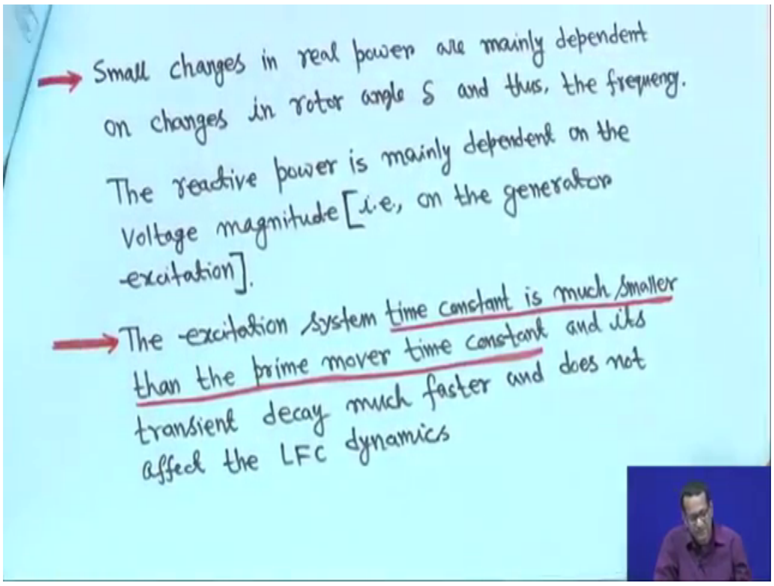


Now, small changes is real power are mainly dependent on changes in rotor angle delta right this is very simple and that is the frequency, the reactive power is mainly dependent on the voltage magnitude that is called the generation excitation that is this side, right that is the this side excitation side right.

The excitation system time cost is actually very small the much comp then the prime mover time constant; that means, and it is a transient decay is much faster and does not affect the LFC dynamics actually that if you consider AVR loop all this excitation system is time constant is very very small compared to the prime mover dynamics, right. So, if you even if you try to couple them, you will find that when that actually, this LFC side transient action starts right by that time its a its a transient decay is much faster it will be fully finished in two 3 second. So, there will be almost no effect on the LFC dynamics right.

So, that is why these two are people are treating as a this thing your; what you call as a separate thing your real power frequency control and reactive power voltage control right..

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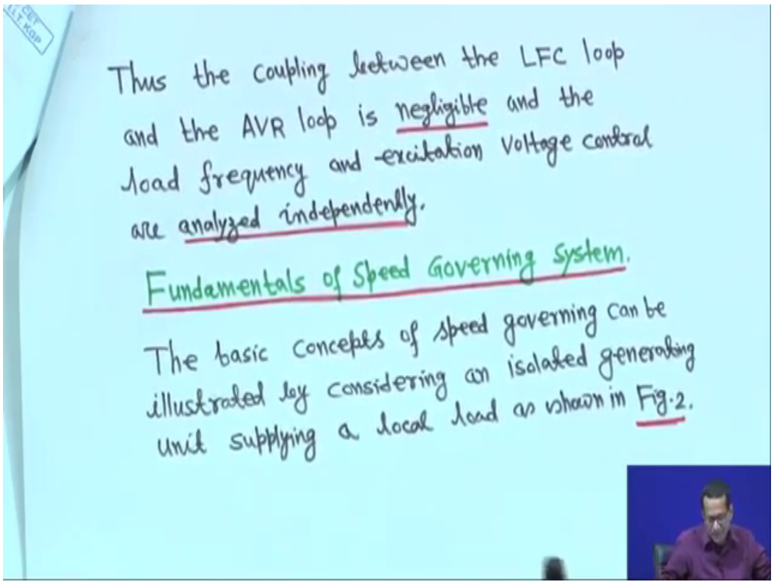


There is the coupling between the LFC loop and the AVR loop is negligible better, you avoid this and the load frequency and excitation voltage control are analyzed independently they are separate right they are separate.

So, with this your what you call, we will come to the fundamentals of speed governing system right. So, the basic concept of speed governing can be illustrated by considering an isolated and isolated you are generating unit supplying a load as shown in figure 2, I will come to the figure 2, right.

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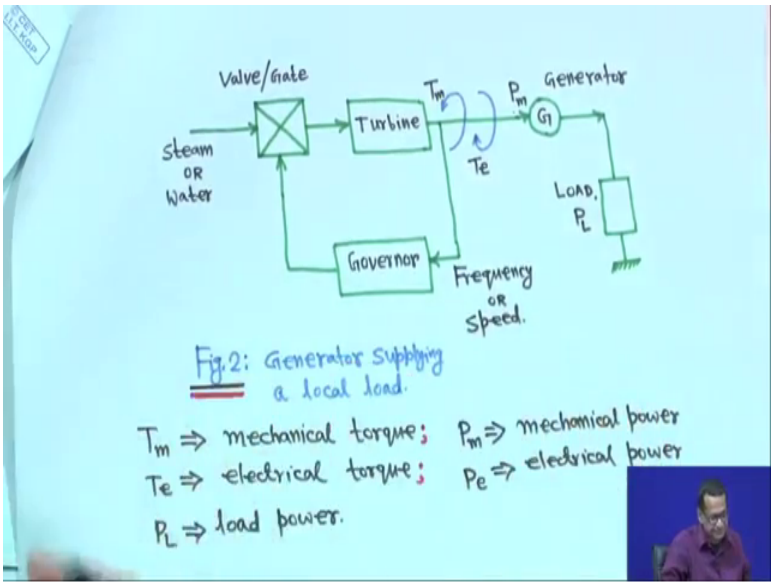

So, suppose you have isolated load means not interconnected right, suppose you have a this is valve if it is steam plant if it is a gate hydrogate then it is a hydropower plant, but general that is why written steam or water if it is a steam it is thermal power plant water means it is hydropower plant right and this is turbine and this is your what you call this is a mechanical torch this is a electrical torch T m is the mechanical power and this is a generator this is a schematic diagram and this is the load and this is the frequency or speed this is the governor, right. So, speed actually sensed this is turbine generator staff this is turbine generator shaft speed can be sensed right.

So, this is generating supplying a local load this is a load. So, tm all this thing and P l is load for everything is given this is. So, water means it is a hydropower plant for water and steam for thermal this is a simple schematic diagram and for generator your governor turbine generator and the load supplying an isolated load right isolated load.

So, this is schematic diagram; we will come to that later right next is that isochronous governor.

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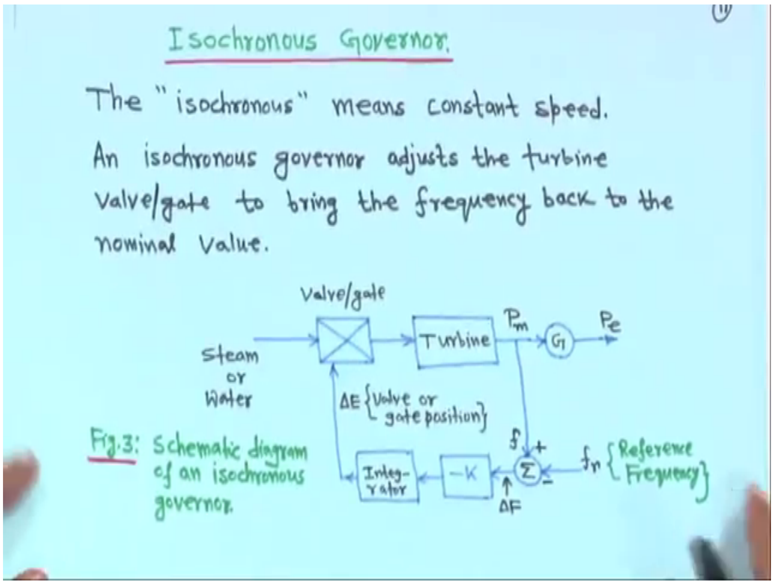


Isochronous governor means that it is a constant field your what you call isochronous meaning is the constant speed. So, an isochronous governor adjust the turbine valve or gate to bring the frequency back to the nominal value right if; that means, it will try to bring your what you call it will adjust the I mean it control actually, in the case of steam plant, it will be valve or in the case of hydro plant it will be hydro gate right to being the frequency back to the normal you are what you call nominal value.

So, this is steam or water same thing for thermal power plant steam or hydro water right. So, this is valve or gate this is your turbine this is pm just now I have shown this is your generator this is electrical power output right this is going to your just now, I have shown this diagram right this is your pm and this is electrical power output not shown here this is P e right P e and what whenever we will assume all this thing analysis we will assume that turbine is a lossless there is no loss, right. So, turbine is a lossless. So, in per unit P m and P all will remain same right it is a lossless.

So, now from this for this is a turbo generator shaft this is pm, but speed can be sensed from here. So, this is a reference frequency say F r, it is it may be omega r also no problem right and this is that is your frequency sensed from these from these shafts speed is sensed. So, it can put it in frequency form this is plus this is minus. So, delta F is equal to F minus F r; this is a change in frequency right and this is taking some constant say minus k, this is an integrator and output of this one that is delta e actually valve or gate position actually it is signal is coming here, it is controlling the valve or hydrogate steam valve in the case of steam power plant or hydrogate in case of your hydropower plant and this is the turbine turbine maybe non reheat turbine or your what you call heat turbine only schematic basic thing will go for that for turbine right and we will assume it is lossless right.

And this is valve in the case of steam valve or gate position in the case of hydrogate this is a schematic diagram of an isochronous governor right, but this ico isochronous governor is your what you call it is suitable for such kind of operation when only it is your what only one generator and it is your what you call supplying your what you call load right, if you have two generators if one generator two and n number of generator does not matter, but only one generator has to supply the load if there are two generators, then there will be problem for isochronous governor because you will set certain things the reference frequency setting manually right.

In that case when you set it for two or 3 generators and human error maybe there, right ; so, it cannot be const to same in that case shaft level these difference for one generator will be different another generator it will be different. So, all the generator shaft; we will try, they will try to set that frequency to their reference value. So, there will be a fight among them that is why isochronous governor is suitable for only one generating unit right.

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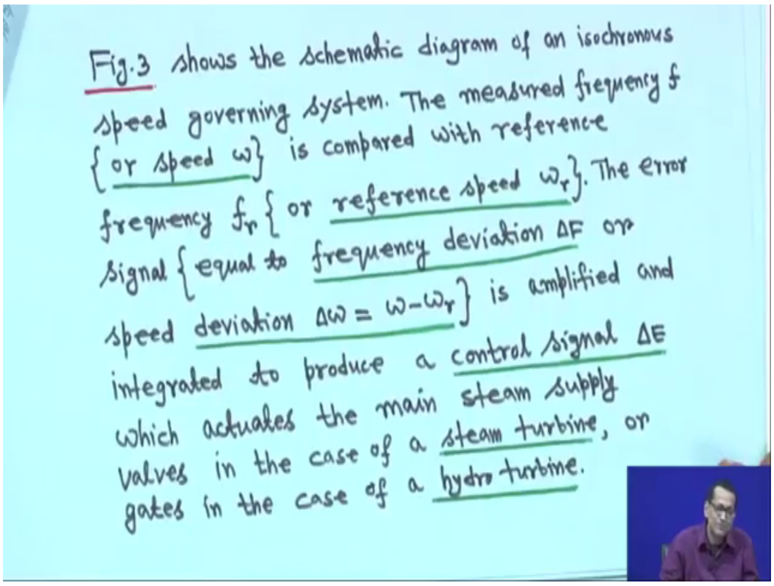


Therefore, this is actually figure 3 this is figure 3 whatever I told I have written here for you. So, figure 3 actually shows the schematic diagram of an isochronous speed governing system just I will showed you the measured frequency per speed omega you can take also is compared with the reference frequency F or reference speed omega r. So, the error signal equal to frequency deviation delta F or speed deviation delta omega is equal to omega minus omega r is it will be is amplified and integrated to produce a is amplified means this gain is there. This gain is there right is amplified and integrated to produce the control signal delta e this is the control signal delta e is produced it is integrated right which actuates the main steam supply valves in the case of steam turbine or gates, in the case of a hydro turbine that means this diagram in this diagram right now.

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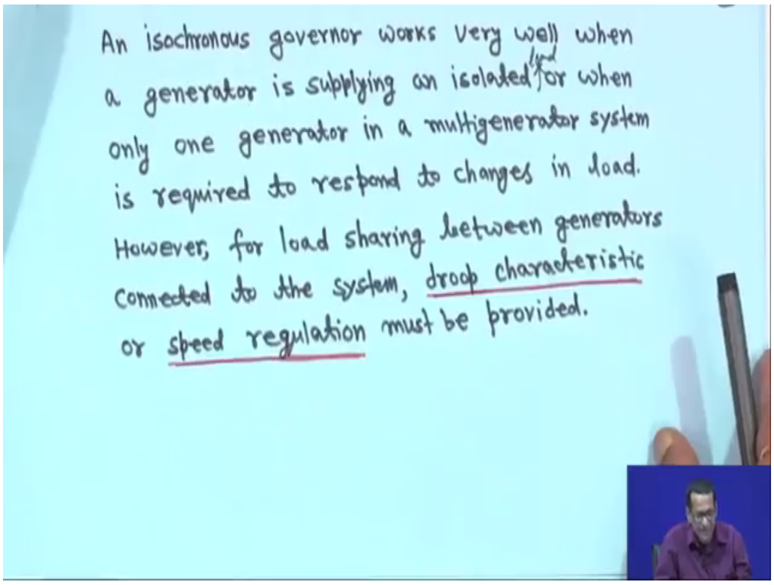


Now an isochronous governor works very well when a generator is supplying an isolated load or when only generator one generator in a multiple multi generator system is required to relly respond to changes in the load, I mean one generator supplying load, it is fine; for it is fine for your multi generator your isochronous governor ; however, for load sharing between generators connected to the system droop characteristic or speed regulation must be provided, right, otherwise, it will create problem, right. So, that is why you are what you call this isochronous governor suitable for supplying only one generator supplying the load that is all.

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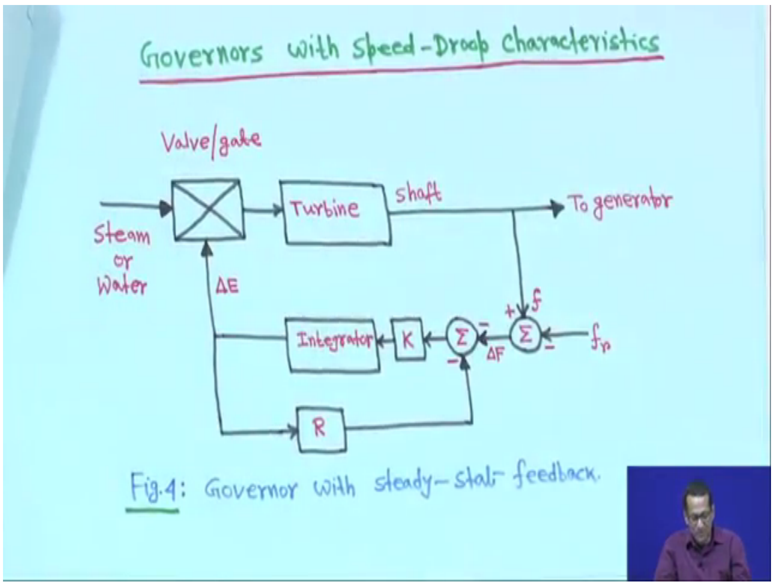

Now, governors with speed group characteristic. Now we have seen this one we have seen this one, but here we will add one for your were feedback path right. So, governors with speed droop characteristic listen here whatever governors this thing this thing; I will show right your what you call it will be a zero it will be quite easy for you, right. So, this is same thing steam valve or valve gate this is turbine right this is shaft right this is to generator as usual right this was earlier there, but here it is plus minus now it is minus minus delta have it was there here it is. So, it is a delta feedback is there. So, we have taken the this minus K was there. So, here you have taken it is minus of delta F and there is a feedback from here it is minus r and this now it is K and it is integrator right.

So, then this is that you are signal delta e. So, one feedback path is put it here the regulation we call r is a speed droop characteristic or your; what you call the regulation parameter of the governor, right. So, this part in this portion actually this portion actually that your, what you call governor part right this portion this portion is a governor part.

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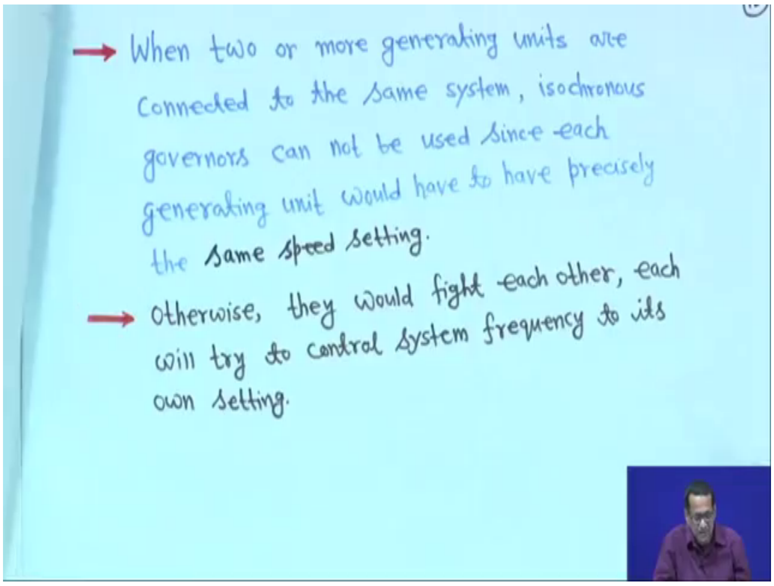


Now, when two or now we getting isochronous governor when two or more generating units are connected to the same system isochronous I told you isochronous governor cannot be used since each generating unit would have to have precisely the same speed setting right otherwise the since precisely the same speed setting it is difficult manually, you are doing it if there is a error then they will try there will be talk between the among the units, right, if 2 units are there, then between the units otherwise they would fight each other and each will try to control system frequency to its own setting right that is why isochronous governor it suitable only for your what you call that when one generator is supply one load.

Thank you very much, welcome.