Power System Engineering
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Lecture - 46
Load frequency control (Contd.)

So, let us come with the same thing that load frequency control continuation.

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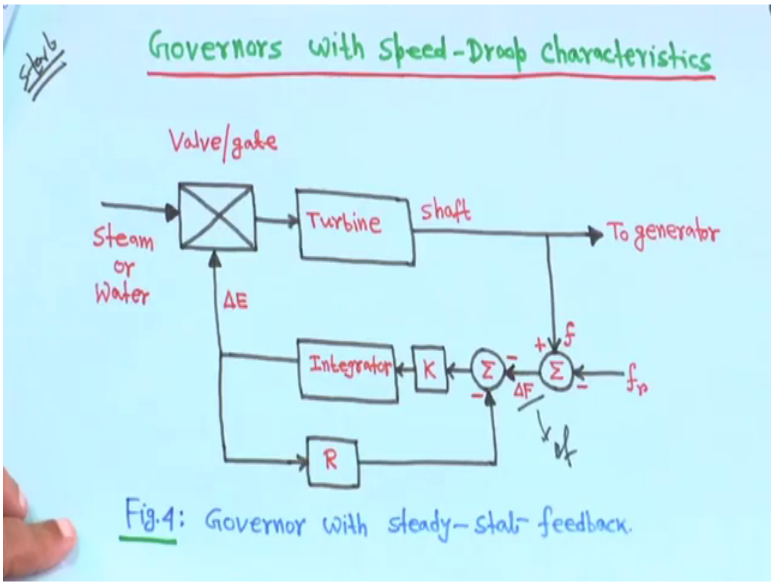

Next one is a governors with speed droop characteristics, right. So, up to this we have seen that you are it is a valve in case of yours hydro gate or high turbine in case of hydro plant right that is why have written steam or water what actually for hydro power plant right. These turbines shaft to generator, and this portion again is there integrator and one additional feedback loop R is used there, right. So, governor with steady state feedback with one feedback there that is we call later will see this R actually we call that is your speed regulation parameter. So, this feedback is taken right.

Once you do this and this one already I told you that this a shaft. So, your speed or frequency being change from the shaft because the generator turbine is coupled together and it rotating right if it is a 50 hertz system then it is rotating at 3000 asynchronous speed generator synchronous generator rotator synchronous speed at 3000 rpm right, if it is a 50 hertz system right and therefore, we are sensing the speed or the frequency. If you sense the speed that is omega, omega is equal to 2 pi (Refer Time: 01:33) a frequency also right.

So, and this is the reference set point this the reference frequency and difference is delta F what I will do is delta F capital I have written, but we can take delta F small because this is small this is small. So, it does not matter whether it is capital or small both are same right. And this additional feedback that is speed governor governing parameter R equal speed regulation parameter this feedback is taken.

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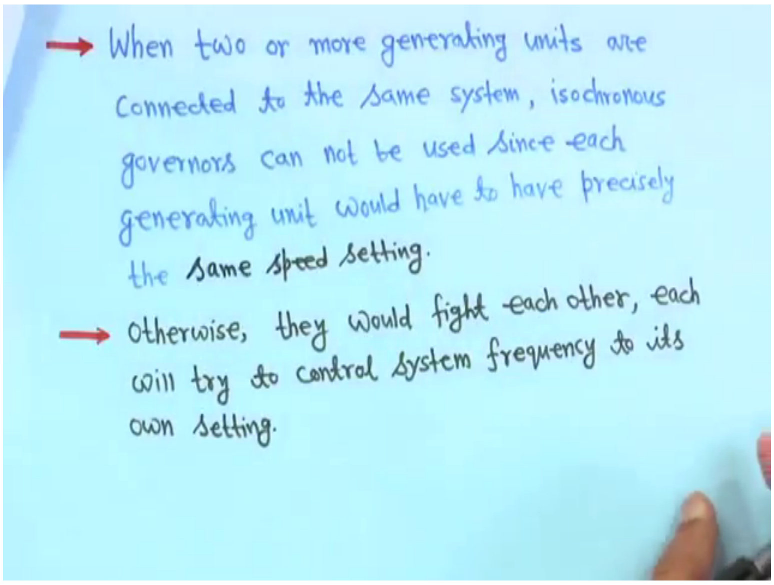

Now, what we will do, so when two or more generating units are connected to the same system right isochronous, isochronous told you it is means the constant speed, cannot be used since each generating unit that would have to be precisely the same speed setting speed right. That mean if you go for suppose you have a two or more generator the reference speed setting has to be same, but you if you are setting it manually it may not be accurate.

So, there will be tug of war. If two generators are there between the two generators, and if you have more than two generators then among the generators that you are there will be tug of war everybody will try to set the frequency its own setting. To avoid that this speed regulation parameter is used for each generating unit, right.

Otherwise that is why I have written otherwise they fight with each other each will try to control system frequency to its own setting I mean this is the setting. So, if you have more than two or more generators then everybody will try to set its own setting, right. So, that is why this speed droop characteristic is used.

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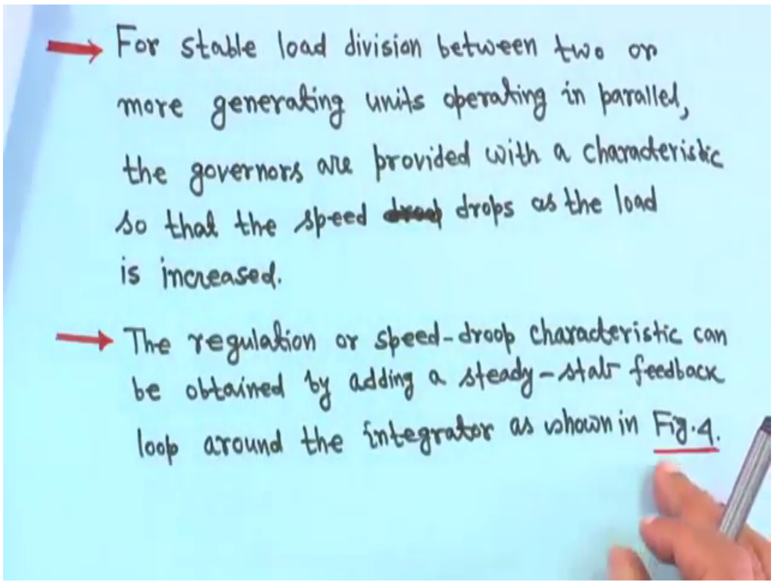

So, for stable load division between two or more generating units operating in parallel the governors are provided with a characteristics so that the speed drops as the load is increased; that means, this feedback is required this feedback is required right.

And the regulation or speed droop characteristic can be obtained by adding a steady state feedback loop around the integrator as shown in figure 4, this is figure 4 around this integrator the steady state your what you call feedback is used right. So, while you use this is actually called speed regulation parameter later will see.

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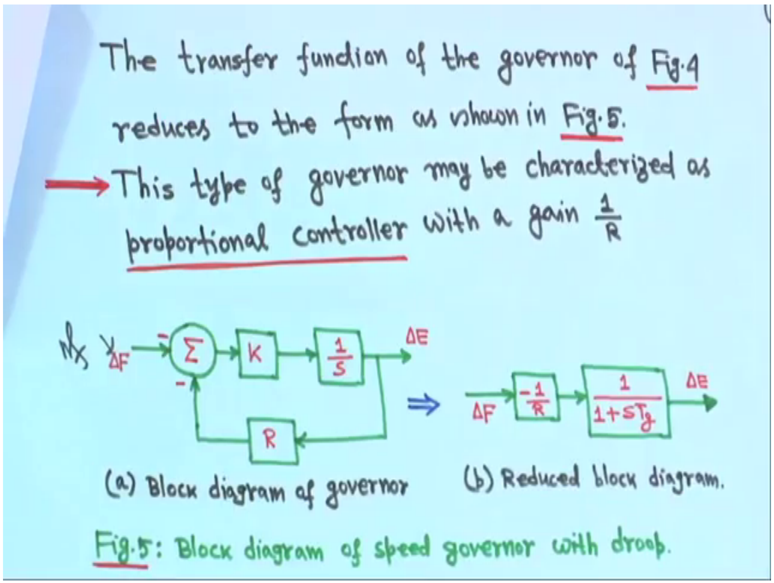

Now, the transfer function of the fig governor figure 4; that means, only these portion will see now, only this portion, only this portion, turbine generator will see later this side will see later, but only this portion, this is the output of the governor valve delta capital E, this is the output right.

So, we do say as shown in figure 5; that means, here what we have what I am doing is this is your this portion as when you look into this thing this portion to your right hand side and this is to left hand side, but what will do this portion will I mean this one we will make it 180 degree safety in making the block diagram. So, this portion will come to the this side this portion will come to this side, but meaning is same I mean everything is same just look. So, this is your delta F, this is f, f r minus r, if you look into this delta F is that here what you call this is same thing that is small delta f same thing right capital delta F.

So, this is your this side you are making F minus f r the output is delta F. So, look this is delta F; that means, this right hand portion you are making from the left side right that is all. So, and then this is the gain and this is the integrator. So, this is the gain and integrator means 1 upon S and look output here it is delta E output of the valve position delta E. So, this is delta E and the steady state feedback this R coming here left hand side it is like this, but as we are taken to this side this side that that is why it is your what you call this way it is minus R, so minus delta F. So, this is actually minus delta F and there it is minus your R feedback. So, it is minus delta F and minus R, right.

So, this is your what you call the block diagram of the governor. Governor means on this portion this portion right this portion if I make it like this I mean this portion this portion is the governor part this portion right. So, once you make this one and this right hand side actually we have made it to the what you call left hand side because will move from your what you call that your governor then your there is steam valve or governor then will move to the turbine then will move to the regenerator part right. So, that is why this, but this not same this one and this one is same only this portion as being brought to this side and from this side.

So, if you, if you what you what you call try to take the your reduced block diagram. So, here I have written that it is delta F then it is minus 1 upon R if you reduce it and it will be 1 upon 1 plus ST g and this delta E how things are coming. Just look into this that suppose this is the that this is the block diagram this is minus delta F this is minus R. So, it will be basically minus delta F plus R into K by S, right. So, here it is delta E also here. So, it will be look minus your delta F right this one and then your what you call this is delta E input is here.

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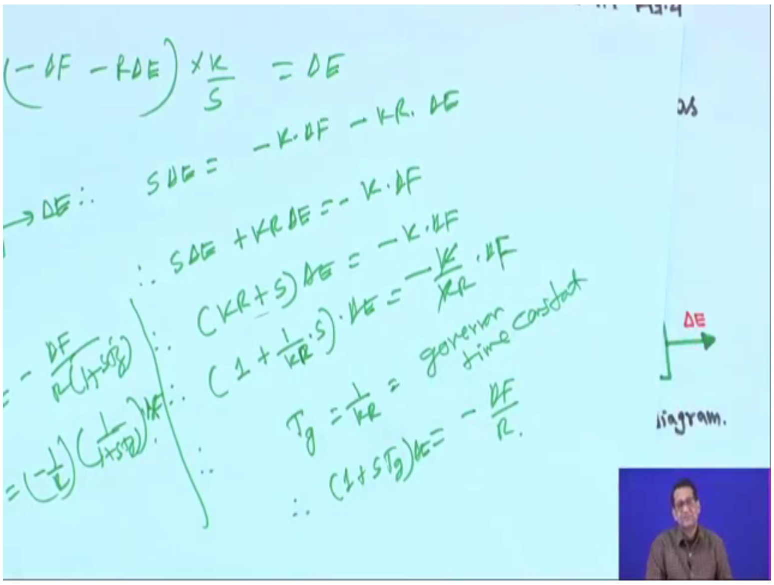

So, R delta E, so minus R delta E, so minus R delta E bracket close into K upon S right integrator and this is the gain into K upon S right is equal to that output delta E. So, delta

E is equal to your this one minus delta F minus R into delta E into K upon S is equal to delta E.

If you simplify this, if you simplify this then it will be S into delta E is equal to minus K into delta F minus KR into delta E or S delta E plus KR delta E is equal to your minus K into delta F right therefore, you take delta E common. So, it will be KR I am writing first plus S delta E is equal to minus K into delta F. Now, what you do? Both side you divide by KR.

So, it will be to divide by KR both side it will be 1 plus 1 upon KR into S right into delta E is equal to minus K upon KR into your delta F ir your what you this K, K will be cancelled therefore, and define that T g is equal to your what you call 1 upon KR you define T g right. So, your that means, your this one you can write 1 plus ST g is equal to minus delta F upon R right, delta E I missed here delta E. Therefore, delta E is equal to minus delta F upon R into 1 plus ST g right that is why this block diagram is written delta F minus 1 upon R into 1 plus ST g right.

So, in this case just have a look, just 1 minute. So, what you from this one, from this one right this is written like this.

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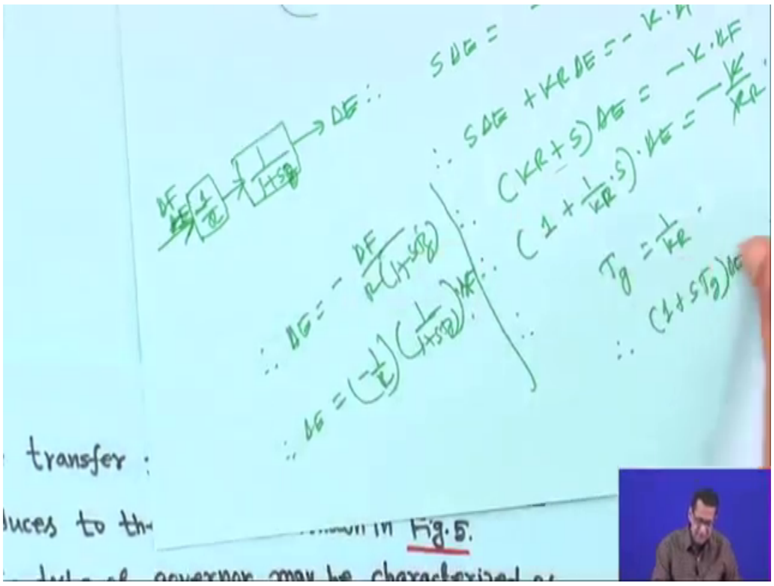

That means this one we can write like this know delta E is equal to we can write like this minus 1 upon R into 1 upon 1 plus ST g into your delta F this way you can write.

Therefore, this block diagram also made it like this delta E is equal to minus delta F upon R into 1 upon 1 plus ST g; that means, this equation this equation if you put in the block diagram form this equation if you put in the block diagram form, then this will be your input delta F and this will be your minus 1 upon R minus 1 upon R into your 1 upon 1 plus ST g. So, it into your 1 upon 1 plus ST g right output is your delta F right sorry delta E. So, this is your delta F, that is that your this input this input that delta F input.

So, same block diagram same thing that I showed you this simple derivation I showed you here right how we are getting it. That means, your this delta E is equal to minus your delta F delta F upon R into 1 plus ST g. Then what is T g? And T g I told you T g equal to 1 upon KR this is actually sometimes we call governor time constant right it is in second it is in second right.

So that means, this is reduced block diagram this is actually governor transfer function of the governor part, this delta F which coming from where that will see later when everything will be completed. So, this is actually block diagram of speed governing governor droop charac; droop characteristics these all equals droop characteristics or sometimes we call regulation system regulation parameter, right. That is why R is speed regulation parameter or sometimes we call droop and T g is equal to 1 upon K R that is governor time constant right T g.

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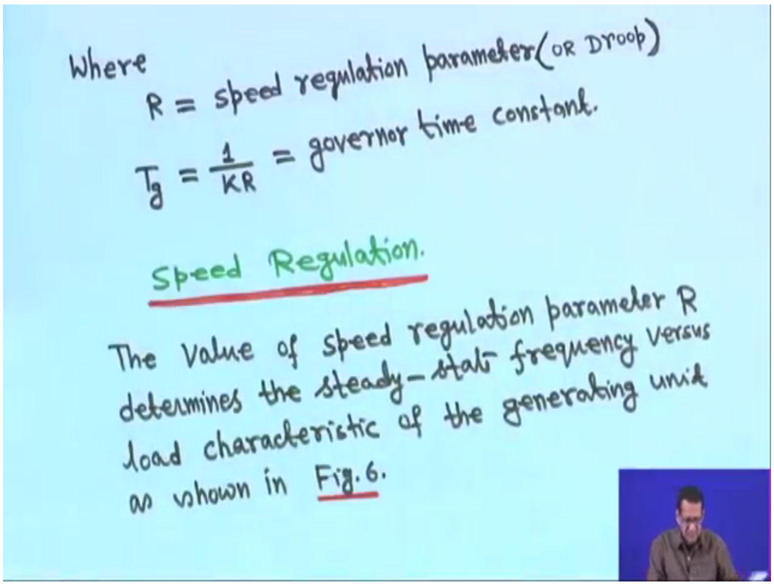

Next is this is the speed regulation that is R. So, the values of speed regulation parameter R it determine the steady state frequency versus load characteristic of the generating unit as shown in figure 6. So, actually this whatever value we choose right, that actually determine the steady state frequency versus load characteristic of the generating unit as shown in figure 6. How? slowly and slowly will see this.

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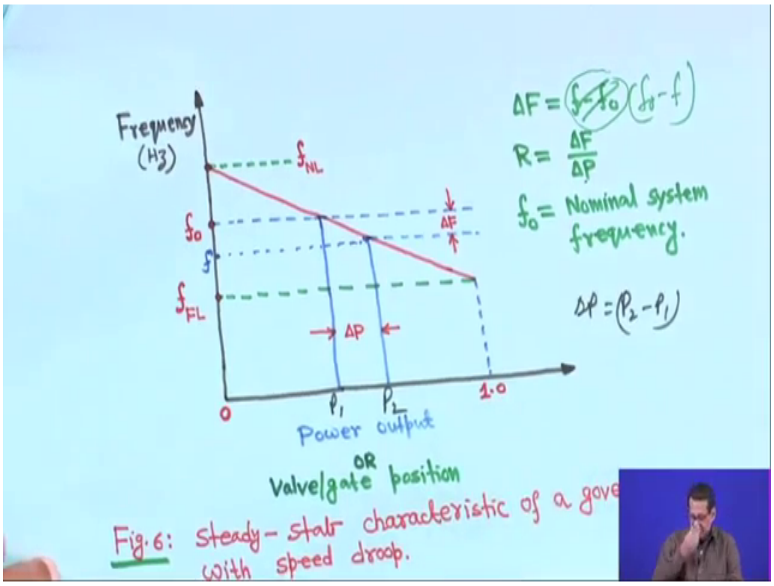

So, if you look at figure 6 right. So, delta F here know this f minus f 0 what we take I think it should be f 0 minus f right, so not this one. So, whatever, whatever you take, suppose you have a this is a frequency this is the frequency and f 0 is that nominal system frequency say right and this is the power output in per unit this is the maximum say 100 percent. So, 1 per unit and this is the speed droop characteristic; f 0 is the nominal system frequency I mean if the operating frequency 50 hertz, then f 0 is 50 hertz if the operating frequency is 60 hertz then it will be 60 hertz right.

So, this is your that is that at no load suppose this is your f NL this that operating frequency at no load slightly a higher than your nominal system frequency and this is that full load full load means. So, generating unit loaded 100 percent. Suppose it is one per unit suppose your generating unit is 100 megawatt and if it is operating at 100 megawatt it is called full load and this is your f FL that suffix is full load FL means full load and this f NL, f NL the suffix NL means no load and this is nominal frequency.

Now, characteristics is linear right, linear characteristic and this is your delta P suppose change in power. Suppose it is operating at some frequency F say some this blue ink some frequency F make an horizontal line. So, del F will be actually f 0 minus F this f 0 minus F, so R the slope this because this is the slope. So, R will be actually this is delta F this width is delta F.

So, it will be delta F upon this power change is delta P right. Suppose the idea is something like this suppose machine you are operating at a at a nominal frequency f 0 right, at that time, at that time your what you call that power was say it was P 1 and when that further load is increased. So, at that time frequency will fall if real power increases frequency will fall. So, that is why suppose it has come down to F at that time this difference is P 2 sorry, this power generation is P 2.

Therefore delta P will be here if you write delta P will be actually P 2 minus P 1 right. And similarly delta F is equal to delta f 0 minus F therefore, slope of this characteristic R is equal to delta F upon delta P it is written here, delta F upon delta P right. Therefore, from that you can get what is your what you call that the slope this is linear characteristic.

So, and this is your one per unit means that you are what you call that is your maximum your power generated by the generating unit and this frequency is in hertz, this is in per unit. And this is the power output and or you are writing valve or gate position listen. In per unit whatever assuming it is a lossless system. So, in power unit whether it is a power output or voltage or gate position it will, it is may per unit they will remain same valve means steam valve or gate means that hydro gate.

In per unit this will remain same that is why I have written power output or valve slash gate position right. So, per unit everything will remain same. So, second thing is, so this is a steady state characteristic governor with speed droop right speed droop means speed droop characteristic R.

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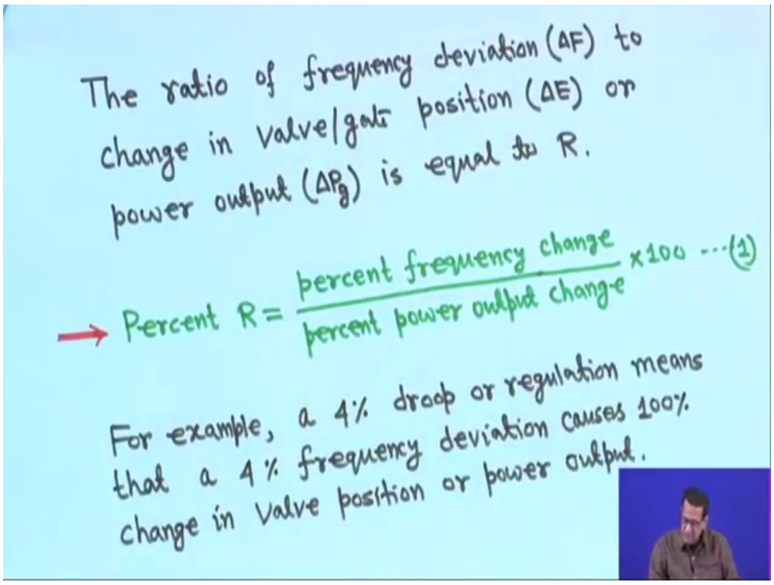

Now, therefore here we are writing the ratio of frequency deviation delta F to change in valve per gate position that is delta E or power output delta P g is equal to R. That means, percent R that is speed regulation R is equal to percent frequency change divided by percent power output change into 100 this is the equation 1; when we take for example, when we take the numericals at that time you will see, right.

For example a 4 percent droop or regulation means that a 4 percent frequency deviation causes 100 percent change in valve position or power output right. Suppose you are just for the sake of understanding suppose you are power generating maximum capacity is 100 megawatt and 4 percent droop or regulation means suppose your system is your 50 hertz; that means, it will be your 50 hertz into 4 percent. So, it will be your what you call that is your 2 hertz, right.

So, in that case that four percent frequency deviation means it will, that is too harsh frequency deviate to harsh on 50 that it will become 48. If the generating is 100 megawatt it will generate 100 megawatt meaning is like this right in if it is in power, but or in if it is in per unit you can say valve position or power output right. So, percentage R is equal to percent frequency change by percent power output change into 100, right. So, this is you have given equation 1 much more will see later, right.

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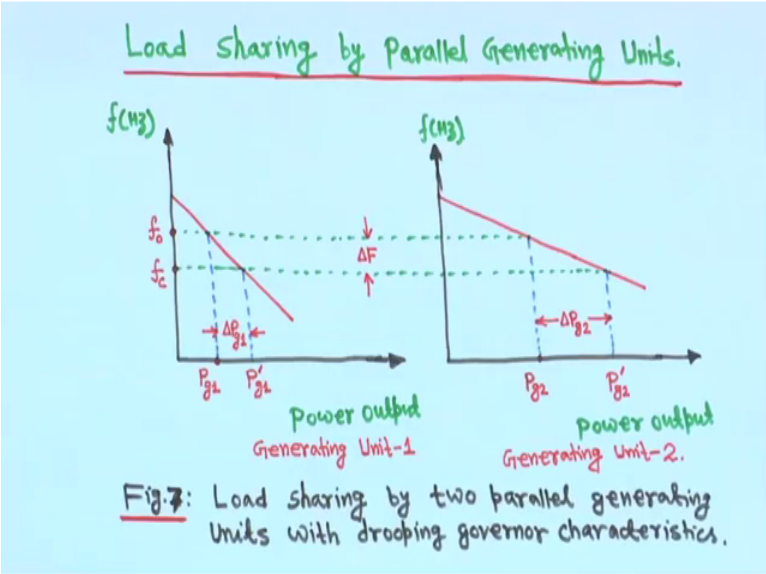

Now, suppose you have two generating units operating in parallel. First you understand then will write a other things are given suppose two generating units are operating in parallel this is the load sharing by parallel generating unit. Both having different speed droop characteristic, this generator has this kind of characteristic this generator has this kind of characteristic, but it is a linear, right.

So, initially suppose initially the generator it was operating at a nominal frequency f 0 right frequency; so you draw horizontal line this thing therefore, when it is operating a your at nominal frequency f 0 at that time it was generating power P g 1 this unit 1 generating power P g 1 at the same time this unit 2 or generating power P g 2. So, this is P g 1 per unit 1 and this is P g 2 per unit 2. When it was operating at nominal system frequency say f 0 F 0 may be 50 hertz 50 hertz system or 60 hertz per 60 hertz system, right.

Now, suppose, now suppose the load has increased suppose load as increased. So, both the generators have to share the load for example, for example, suppose demand was 200 megawatt right suppose suddenly load has increased from 200 to 210. So, 10 megawatt has increased and this 10 megawatt will be shared and according to the droop characteristic of this two generator. So, similarly suppose load demand has increased. So, frequency will fall suppose this is f c it is given right, change frequency f c. So, for that case you draw an horizontal line at that time according to droop characteristic these generating power P g 1 dash similarly generate two generating power P g 2 dash; that means, and because of this change in frequency delta F will be f 0 minus f c, right. So, f 0 minus F c, but in this case in this case delta P g 1 will be P g 1 dash minus P g 1, and delta P g 2 will be P g 2 dash minus P g 2 right.

Although delta F delta F remain same, but delta P g 2 and delta P g 1 there are same unless and until they are droop characteristic they are different unless and until they are speed droop characteristic is identical right; that means, this delta P g 2 will be different than delta P g 1 or vice versa right. So, in that case your what you call this if you try to take the speed droop in this case R will be delta F upon delta P g 2 that is R 2, and R 1 in this case will be your delta F upon delta P g 1 right. So, delta F will remain same, but this your generator sharing power sharing will be different. So, that is the load sharing by parallel generating units.

I hope this you understood, but one thing is there this side where you are making generally we make it your per unit. So, that is why this power output power output generating unit 1 and this is power output generating unit 2 and this side is frequency hertz, it is given in hertz, right. So, load sharing by two parallel generating units with drooping governor characteristic two different droop characteristic of the governor right. Now, all this thing this is actually figure 7 this is figure 7.

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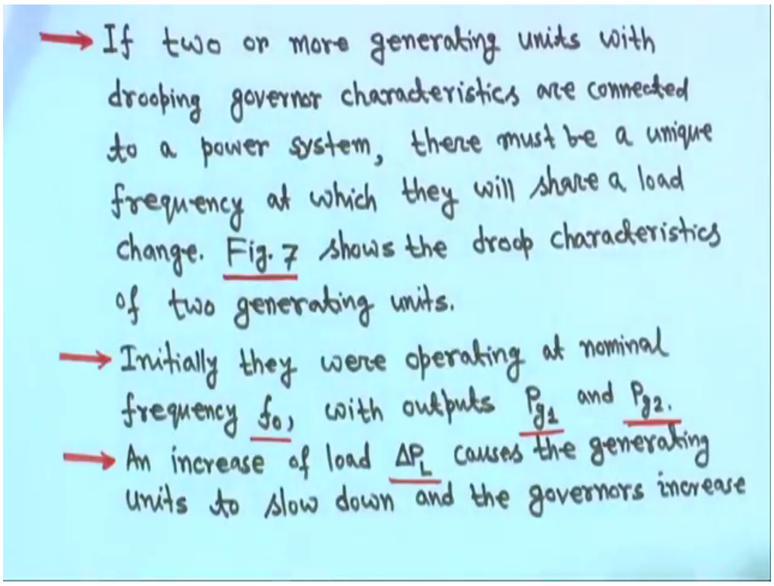

So, now, all this things I have written further I will tell you what exactly it is. If two or whatever I said I have written for you here, if two are generating units with drooping governor characteristic are connected to a power system there must be unique frequency at which they will share a load change. So, this is unit frequency the characteristics it is. Although they operating in parallel right and but their frequency is common that is f c they operate at a common frequency right. So, in this case and this is the figure 7 the droop characteristic what I told you this is the figure 7, this is figure 7, right.

Initially they are operating at nominal frequency f 0, this is at nominal frequency f 0 when this when they are operating load has increased. So, the operating another frequency you can say f c is a common frequency other than frequency change it is a common frequency. So, they are operating at common frequency. So, there is no there will be no tug of war between the generating units, but only generosen the power generosen will different for sudden increase of your sudden increase of your load, right.

So, what an increase in load delta P L causes the generating unit to slow down and the governor increase your what you call that your that in the case of your this thing the output until they reach a new common operating frequency that is f c.

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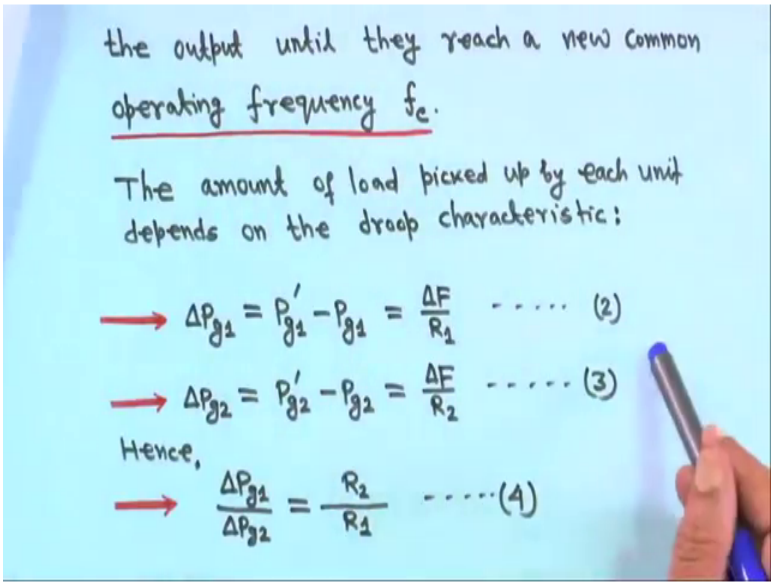

Actually, actually a power system that when load demand is increases I told you load demand increases the generators whatever power driven increases you have two or more generators that according to the droop characteristic that generator will share the power, whatever droop characteristic set for the what you call for the generating units, right. So, the amount of load picked up by each unit depends on the droop characteristic.

For example, just from this figure only I told you the delta P g 1 is equal to P g 1 minus P g 1 dash therefore, delta P g 1 is equal to P g 1 minus P g P g 1 dash minus P g 1 is equal to delta F upon R 1 right. So, this is your delta slope characteristic. That is your R 1 is equal to basically delta F upon your delta P g 1 other way we are writing delta P g 1 is equal to delta F of R 1. Similarly, for this one also R is equal to delta F upon delta P g 2 or other way we can write delta P g 2 is equal to delta F of R 2. This is equation 2 and this is equation 3. So, delta P g 2 is equal to your P g 2 dash minus P g 2 right is equal to delta F of R 2. So, this is equation 3.

Now, if you divide equation 2 by equation 3 then you will get delta P g 1 upon delta P g 2 is equal to R 2 upon R 1. That we look that this generator sharing actually it is inversely proportional because delta P g in general change in that delta P g is inversely proportional to speed regulation parameter delta P g 1 R 1 is equal to actually delta P g 2 R 2. So, this is equation 4, right.

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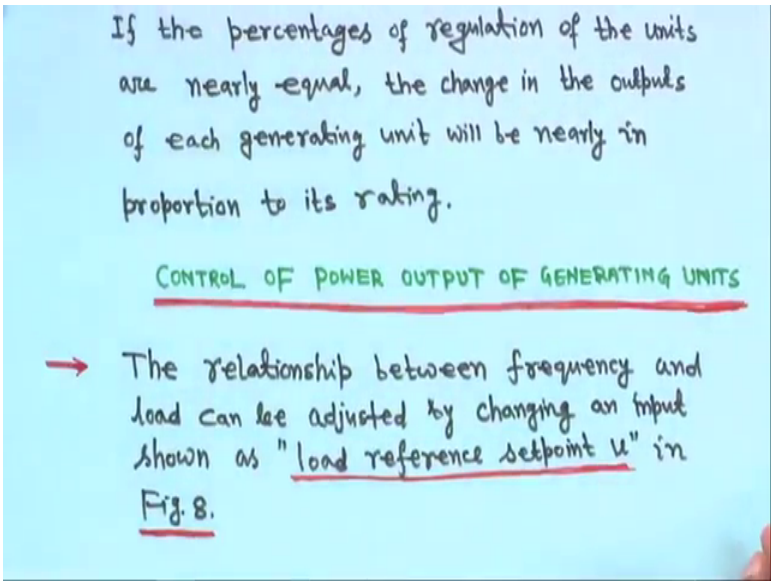

So, therefore, if the percentage of regulation of the units are nearly equal the change in the output of each generating unit will be nearly in the proportion to its rating; that means, if R 1 is equal to R 2 then delta P g 1 will be is equal to delta P g 2 otherwise not right. Now, this is one thing.

Next one is that you have control; I hope this droop characteristic why do they why do they use that droop characteristic for each governor I think it is it is now understandable to you, instead of instead of isochronous governor right and those mechanism. So, control of power output of generating units. Now, you have the generating will generate power, but you have to control the how to call output generating power.

So, the relationship between frequency and load can be adjusted right by changing the input as shown in load reference set point this is called u in the figure 8. So, we will come back to that.

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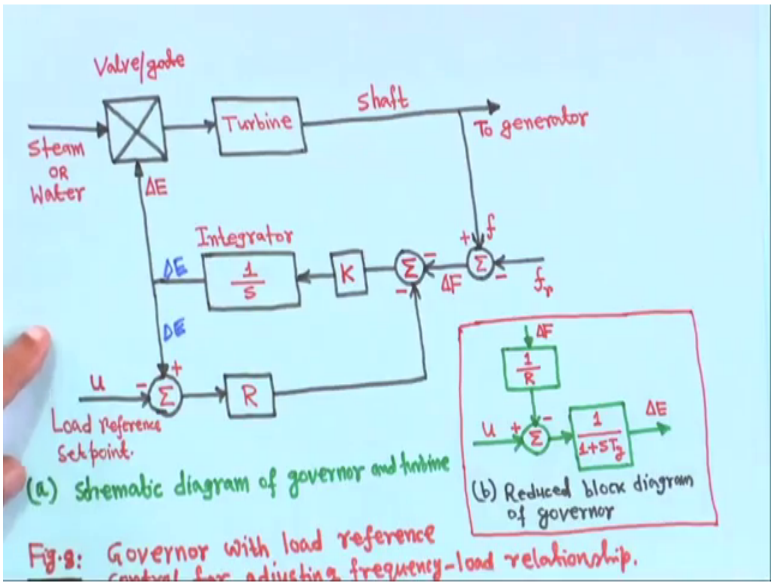

So, this is actually speed changer motto right, details will not go the schematically will show it will act as an integrator right this output of u actually it is output of an integrator different type of controller not only integrator different type of controller. So, this will load reference. So, same block diagram everything is same up to this as it was, up to this as it was if it is not there it was like that whole block diagram will same, but you have to what you call you have to control the output of the generating power, generating power output. Therefore you need a load reference set point this is we call u right.

So, this is the schematic diagram of governor and turbine with that load reference set point and governor with load reference control for adjusting frequency and load relationship and this is your what you call. If you already this portion if you not turbine or generator only this portion if you simplify it will become actually delta F that is one up on R u this u will become plus then 1 upon 1 plus ST g delta E. Now, how this your what you call this things are coming from this one.

If you if you have seen this diagram if you have just hold on from that I will I will make it for you just hold on right. From this diagram, just hold on from this is your schematic diagram without reference set point, without reference set point right schematic diagram and this is your what you call when u has being given, when u has this u has being given right. So, according you can make it. So, how I am made it from this diagram only I will not go for left and right that this portion of course, will come to this portion right, but it from here only we will try to make it look at that. So, only this u minus say what you simplify u plus will be here how things are look.

This is delta E actually this is your delta E so that means, this is going this way and this delta E is going this way right. So, if you if you try to simplify it will be your what you call this is your this side will be your, this is minus delta F and this is your what you call u it is minus u and this is your delta E. So, this is your minus delta E minus u into R will come here right, into R will come here that feedback will go there then if you simplify this then how things are, how things are just have a look.

So, this is your minus delta F and this side this side is coming R into to your delta E minus u are; here I am writing this is R, this is delta E minus u this feedback is coming here right so that means, this is your minus sign is there. So, it is minus delta F, this with minus delta F and this is minus R into delta E minus u delta this is R into delta E minus u then you close the bracket.

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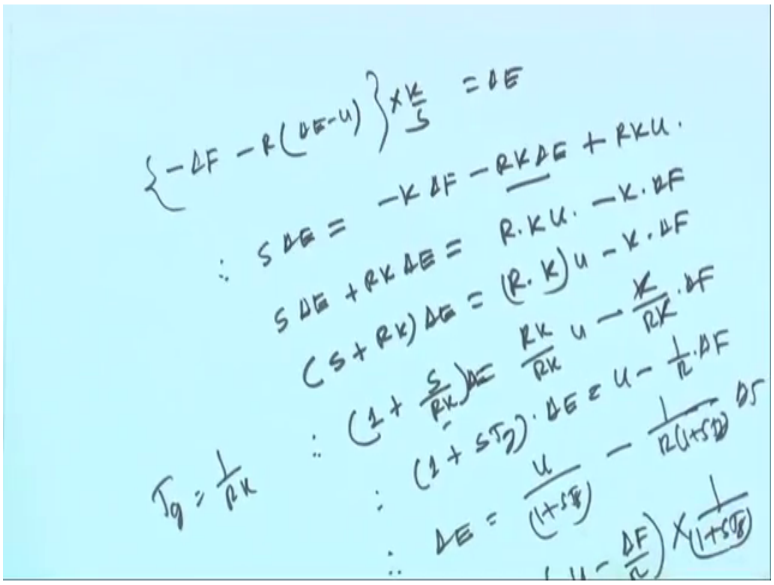

So, output here whatever is coming here it is actually minus delta F minus R into delta E minus u right, into your this K operation is there right, into K operation is there is equal to what; is equal to your this delta E. So, is equal to your delta E therefore, it is S delta E is equal to your minus K delta F then multiply this 1 minus RK delta E plus your minus minus it is plus RK into your u, right.

So, this one this one you bring to this side. So, S delta E plus RK delta E is equal to R into R into u minus K into delta F. Therefore, you take delta E common. So, it will be your S plus RK delta E is equal to RK into u minus K into delta F. So, divide both side by RK right. If you do so, I am making it like this RK if you divide it will be 1 plus S upon RK is equal to this RK will be cancelled. So, because this side will be RK by RK u and minus K upon RK into delta F that means, 1 upon RK is equal to T g that is a time constant that here I have missed delta E, right.

So, it is 1 plus ST g into your delta E is equal to u minus K K will be cancel 1 upon R into delta F, that means, your delta E and T g is equal to I have told you it is governor time constant 1 upon RK right. And delta E is equal to your u upon 1 plus ST g minus your 1 upon R into your 1 plus ST g delta F. This way or the way we have made the block diagram delta E is equal to you make u minus delta F upon R into 1 upon 1 plus ST g right. So, this is your what you call this is your this thing so that means, delta is equal to u minus delta F upon R into 1 upon 1 plus ST g. So, that we are making now.

Look here the diagram delta E is equal to u. This delta F is coming from somewhere you see u minus delta F upon R into 1 upon 1 plus ST g, it is coming know same thing right. So, from this side we are because will this is for the understanding purpose right. And when making the block diagram actually we are going from this right, right side we have bring it to left side and this one we have taken to only this portion only this portion only this portion this will see later, this part will see later right only this portion.

Thank you very much we will be bye.