Power System Generation, Transmission and Distribution

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Lecture No. # 24

Automatic Generation Control

Welcome to this lecture 24th this on automatic generation control.

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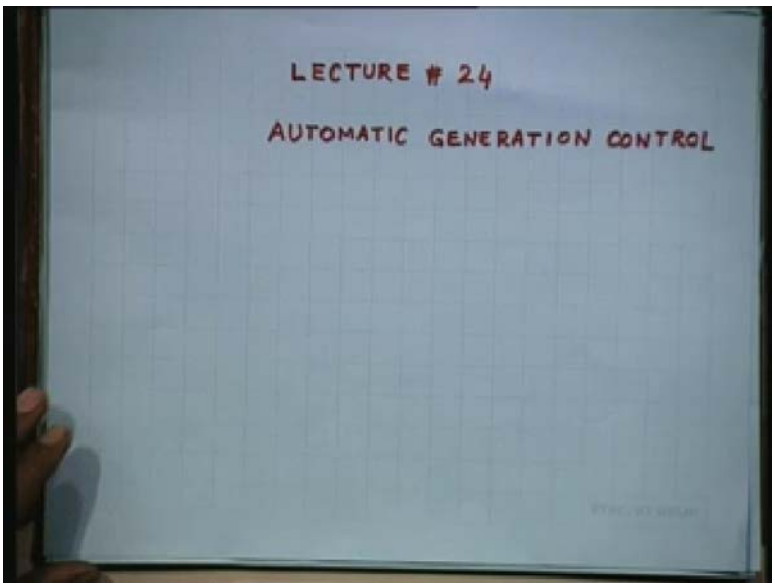

I am sure all of you are aware that frequency is as important as voltage if not more. We have been seeing in last many lectures how voltage is to be controlled. Now we also need the frequency control. Now, that is a different matter that frequency has to be controlled in a very narrow band, well voltage indeed was also in narrow band plus minus 5 percent. Here it is plus minus 0.5 hertz.

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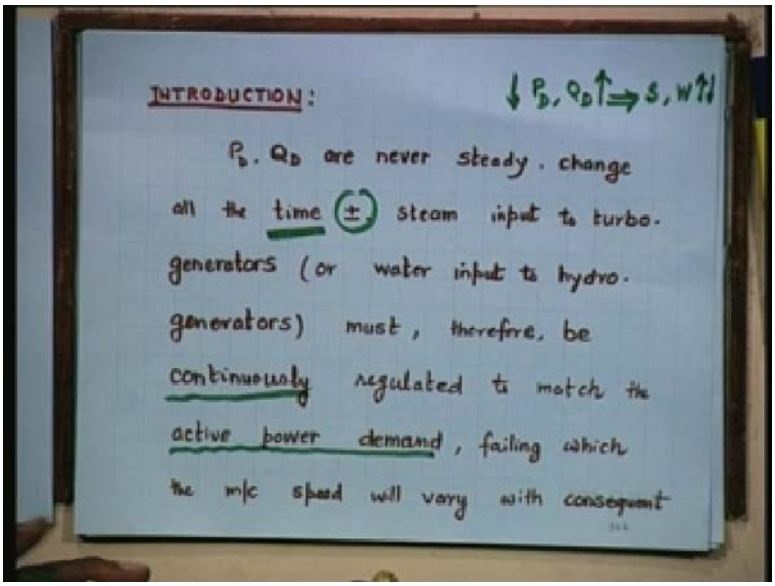

P D and Q D as I told you these are our load demands. D is demand, P is the real load and Q is the reactive load. Now unfortunately or fortunately they are never steady. They keep on changing all the time throughout 24 hours, 7 days, 30 days in a month and 12 months. Unfortunately the change is also random. You can predict load forecasting is a very important topic, but nobody can really forecast with complete certainty and that is why it is a random variable and this change is also unfortunately not in one direction. It can be plus minus any direction with time. It can go up, it can go down. At what time you will switch on your fan? Nobody knows. At what time you will switch off your fan? Nobody knows. How much you will operate the mixie for preparing chutney or anything or even the house wife does not know whenever she likes seems to be and switches are off. There is no fixed duration for which you will be running a particular device.

Steam input to turbo generators or water input to the hydro generators must therefore, be continuously regulated to match the active power demand. Since P D and Q D, the key point varying correspondingly your steam input or water input should also keep on varying up and down, it is also up and down. So, there is a constant matches going on between them to keep track of each of them right. Continuously constant, failing which suppose you do not do it, suppose you say I do not care then what will happen? Then machine speed will vary. Once the frequency varies the speed will vary, once the speed will vary the performance will vary, because motors are suppose to operate many applications constant speed applications.

For example, it is a flour mill. Now if that motor speed changes the auto will have a different variety in that 5 minutes. If you this speed keeps on changing or even that paper machine paper factory, the times of India each page will be of different width. How do you like it? Each book of each page if it is of different width, different length, different thickness, the book will look offer. So, speed has to be constant, but if frequency is varying naturally speed is link with frequency f is equal to p n by 120, so if p being constant number of poles, 120 being constant because it is number. So there is a direct relationship between frequency and speed. If there is a delta f corresponding delta n is bound to be there whether we like it or not. Change in frequency which may be highly undesirable. Think of the clocks the electric clocks, now if the frequency changes the time will also change. Now that will play (( )). How can you just keep on changing the time with speed going has to be absolutely constant frequency operation that is also synchronous machine is all about it operates at constant speed because frequency remains constant.

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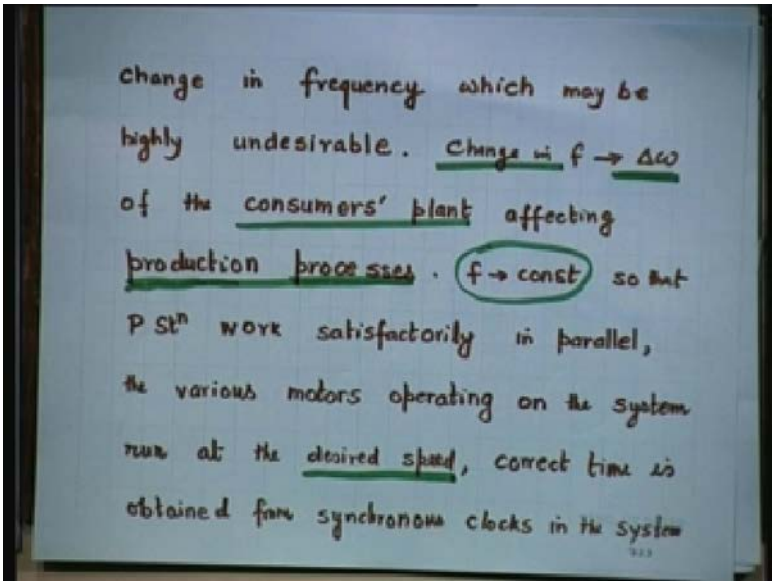

If there is a change in frequency, there is a change in speed again and again I am repeating of the consumer's plant affecting production processes. I have already explained you how different changes will affect different products be it paper be it clock be it atta in a flour mill anything. So, frequency constant is more important than voltage constant because voltage constant we have a certain voltage stabilizer the UPS, but frequency stabilizer is very rarely used we have frequency stabilizer. So, that power

station works satisfactorily in parallel, the various motors operating on the system run at the desired speed, at the rate cut speed for which it is design. So, design speed, related speed, desired speed, required speed which ever what you want to use, the idea is there is a fixed speed at which a particular motor particular device suppose to work.

Correct time is this is what I was telling you few minutes back, correct time is obtained from synchronous clocks in the system. They will be no correct time available and not only that it will then have an error and this error will be cumulative she has there is a someone says even the clock which is stop you shows correct time at least twice day in a day, twice in 24 hours, but the clock which is running you know behind it is never showing correct time. So, even the clock which is stopped is better than the clock which is not showing correct time. So that clock will atleast show twice the correct time. What about entertainment devices? TV,VCR, Home Theater, Cinema, all these you know if the voltage changes if you see a movie in a village, you will find that every (( )) there is a different you know because the power is coming of different quality.

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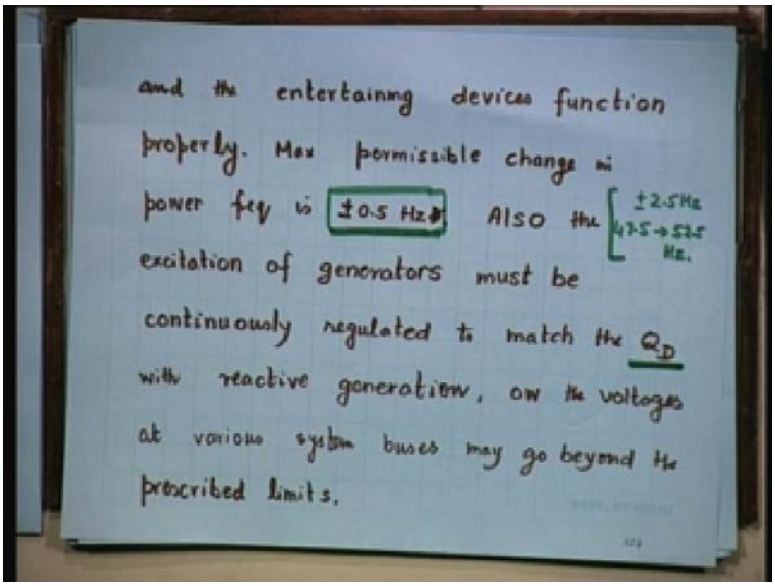

You can see even in your hostel indicate power from stand by generator. It is a different quality then you get power from BSNL or this DVB whatever is this name. Maximum permissible change I have already talked about in the beginning of the class is plus minus 0.5 hertz, but it in India we have a special country so we have special requirement we have minus plus 2.5 hertz; that means, it can go from 47 point 5 to 52 point 5 hertz. But

in world standard it is plus minus 0.5 hertz. If it is crossing beyond 49 point 5 or 50 point 5 or 59 point 5 and 60 (( )) state immediately AGC will come into play. AGC is Automatic Generation Control. Unfortunately we do not have any AGC in this country so far. Also the excitation of generators must be continuously regulated to match Q D.

We have in talking about P D so far real demand, but the reactive demand, the reactive generation we have to change; that means, we have to change excitation generators you want to keep the Q D constant. Otherwise the voltages at various system buses may go beyond the prescribed. This of course problem we are studied very well in fast in earlier lectures. If you do not do that, the voltage will go beyond limit either lower limit or upper limit. Now here is a schematic diagram of load frequency and excitation voltage regulators of a turbo-generator.

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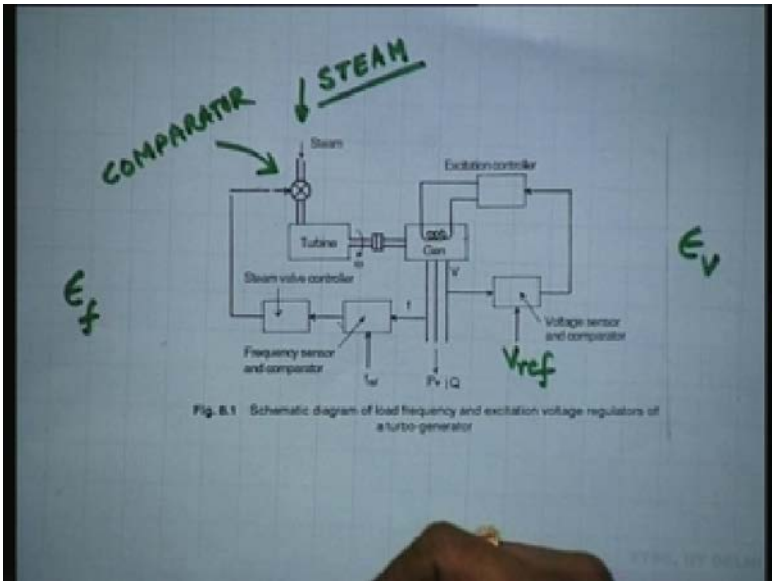

From here this P steam is coming. How steam is produced? A burning coal .Water getting heated up boiler then steam is passing through turbine. The fuel can be coal, fuel can be natural gas, fuel can be nuclear fuel, it can be uranium, it can be thorium, it can be plutonium, it can be anything, it can be multi fuel. Other told you now cars and buses are all multi fuel. Similarly here also there can be multiple fuels. Once the steam at a proper temperature and proper pressure and tills the turbine which is running at some speed are connected to generator, the power is generator and you take a sample from this power P plus j Q which is fit to the grid. All those transformers, circuit breakers, all things are

there it is not shown in the figure, but that you know, sample this frequency compare with the reference frequency, you must have the control system in your earlier lectures. So, you have to compare this whatever frequency comes, let us say it is 48 hertz, the reference frequency 50 hertz. So, there is a frequency sensor and comparator is there in this block. It will then control the steam wall controller because if frequency is low you have to increase the steam input, if frequency is high you have to decrease the steam input and likewise with the hydro, you have to open the gate or close the gate accordingly depending on what is a frequency.

A frequency is below 50 hertz gate opening will go up unless it is already it is full then you cannot do anything. But if it is not full, assuming that there is a scope for control then we will put it up. If it is frequency is higher which also happens then we have to put the water down. This is a steam valve controller and then the signal goes here, this is called comparator in control system language and then you control the steam it is a controller and turbine will then operative in such a way that you generate power of correct frequency till the time this feedback goes on. Right? Simultaneously there is a voltage controller loop you cannot separate them. P and Q this is (( )) you know there always in a hand in hand you cannot separate them up. You may lies them separately, you may control them separately, you may use them separately, but they are together whether you like it or not.

So, similarly you take a voltage sample and there is a voltage sensor and comparator this is again a v reference this like f reference this is the v reference and if there is a mismatch more than certain epsilon. What is the epsilon here? plus minus 5 percent. What was the epsilon there? plus minus 0.5 hertz. So, this is an epsilon frequency, this is epsilon voltage allowable permissible variation. Right? Then again a signal goes, excitation controller goes then this is a x field (( )) the excitation is controlled and then you get a proper voltage, till this happens we do that. Why these two loops? One is a voltage control loop another is frequency control loop do not interfere with each other. Why? You can ask me why these 2 guys when they are together do not interfere because the time constants are entirely different. This is a faster control, this is a slower control. So, they do not interfere with each of them. About this is now fully clear. You can always see the more explanation in the book any book whichever you want (( )) book also gives a easy very well, our book also gives easy and then there are so many books.

Now this is the turbine speed governing system, a very important system control in power system.

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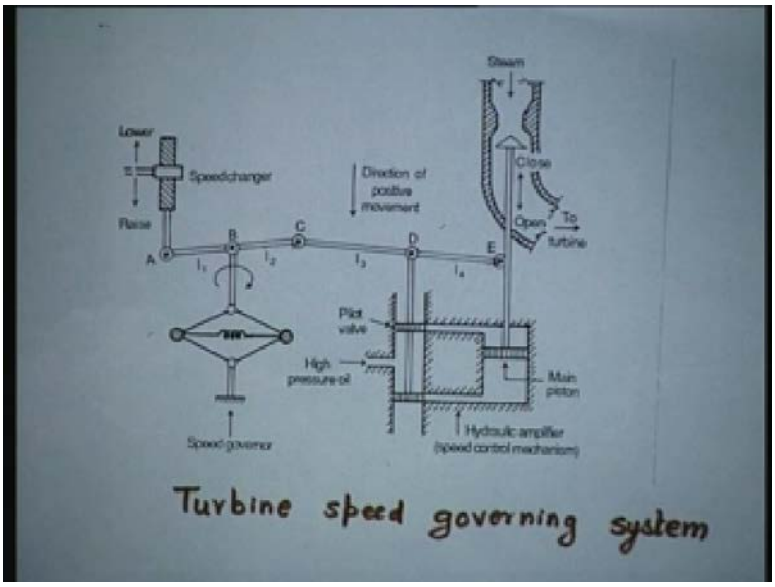

This is the speed changer. Right? If you lower it you want to lower the speed goes up, if you race it comes down. This governor you must be knowing for ages (( )) and if it collapses then crystal moves in one direction, if it is expands crystal moves in another direction and what will happen. The amount of steam input will get controlled that is all you are get. Now direction of positive moment is downwards. l 1, l 2, l 3, l 4 these are the lengths of mechanism the linkages. This is a rigidly pivoted at B and this is another rigidly pivoted at D. If just consider here pilot valve. This is the input for the high pressure oil. Now if D goes down these terms down and this gets open and the oil will enter like this and pushes this main system upwards at least you are closing this steam valve. So steam input will be restricted, minimized, decreased, lowered, oppose it happens, if this D goes up then this entry is not available, the oil will enter from here and will push piston down; that means, see open the steam wall that is all.

For there are, this is a complicated hydraulic amplifier is here, speed controlled mechanism, this is a main piston, this is the pilot wall, this is the high pressure oil which operates this whole governing system. So, if you ask that draw the speed turbine speed governing system, its plane, its function this is what (( )) explain depending on number of marks. It is 2 marks 4 lines, if it is 5 marks 10 lines, if it is 10 marks then 20 lines as

given in the book. In modern large interconnected systems, see other told you in spite of distributed power systems and disperse power systems the fact remain the individual power system is going to continue. They are not going to through away 1000 of kilo meters of transmission lines they have built in the country with lot of effort. They not going to through away, they not going to through any conventional power system power station just because a solar, a wind, a hydrogen, you have a tidal, you have a geo thermal, you have (( )). They are separate in axis. The main dish will continue to be [FL] (( )) and chappathi (( )). You may go an adding small some snacks, some sweet (( )), soup etcetera. So, they will be like that only distributor dispose power system.

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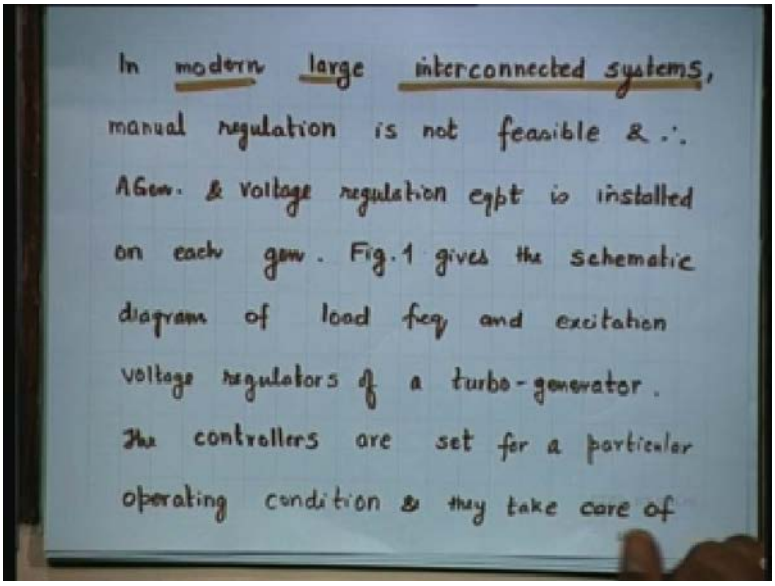

So, we will continue to have whether you like it or not this modern large interconnected systems in operation for force see will future that is 2050. Manual regulation is not feasible in such a big system. How can you regulate manually and therefore, automatic generation and voltage regulation equipment is installed on each generator and let me tell you generators are not many, there are only 10 percent of the total number of buses.

Figure one which you already seen gives a schematic diagram of load frequency and excitation voltage regulators of a turbo generator. The controllers are set for a particular operating condition. Initially you have to set when you go, when you start from your home you set a car to a particular speed then you manipulate it, control it depending on a some vehicle comes front of you or road is clear, you are driving it mid night to go to

Indira Gandhi airport then you can go faster, 20 minutes will be there. But if it is morning 9 am or evening 5 pm the rush hour you have to go in a slow mode. So, particular operating condition and they take care of small changes in load demand without frequency and voltage exceeding the prescribed limits.

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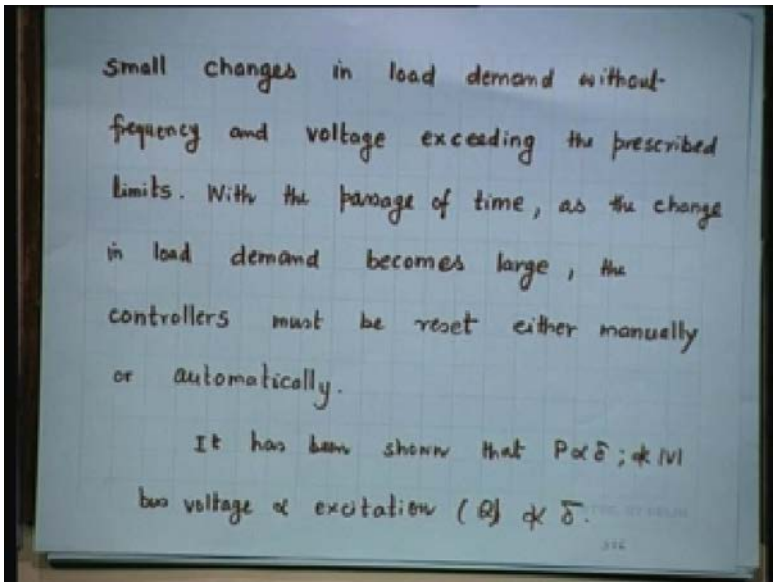

Those regulators with the passage of time, as the change in load demand becomes large. Right? If it is fever is around 99 nobody goes to doctor. You may take paracetamol, crocin or in olden days just tea with thulasi leafs you know will said you right. But it is 100 and 200 and 3 then because of dengue fever, fear etcetera, you will go on immediately get you all blood test and then. So, if load demand change as large then controllers must be reset. How you reset? Either manually or automatically depending what mechanism you have in your system. You remember those olden days TV when you use to control the voltage by actually getting up taking a trouble and going out to the TV set and now nobody wants to get up. If they want they can have a remote for wearing suite also. Do not no physical labor they want to do. So, for every damn thing there is a remote now, sitting and that is why you know there are problems health problems.

So, controllers must be reset either manually or automatically, this is the only 2 ways. It has been shown that at least 100 times you must have repeated a real power depends on delta and does not depend on voltage appreciably to be exit. After lot of approximation you can show you can remove delta also from delta Q equation and you can you cannot

remove v any way from P equation that E v by x into sin delta, but those E and v s are constant suppose early, but voltage is proportional to excitation and Q is not proportional to delta this we have shown if you recall that. delta Q is equal to del v r upon x into delta v, but delta v is delta v s minus delta sorry v s minus v r. Delta delta caused by momentary change in generator speed.

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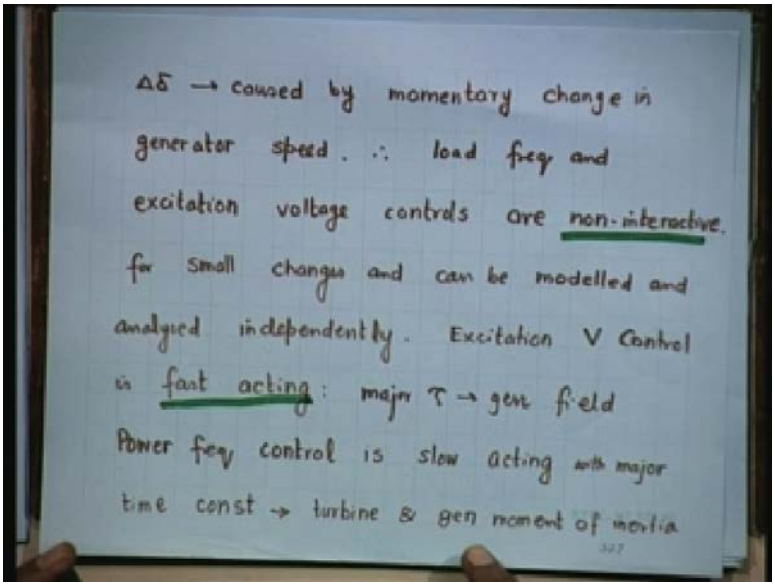

Therefore, load frequency, an excitation voltage controls are non iterative because they not depended on each other. When voltage loop is operating the angle or speed loop may not operate. They are non interactive, this word is very important. For small changes and can be modeled and analyzed independently that is the approximation. Excitation voltage control is fast acting, I told you earlier that loop is fast acting the time constant is small whereas, in that frequency loop, the time constant is large so, takes longer time. What is the time constant? You reaching 63.2 percent something like that takes more time. Major time constant is generator field which is larger and hence power frequency control is slow acting with major time constant is turbine and generator model moment of inertia. The book is the all various ideas of different time constant that you can read.

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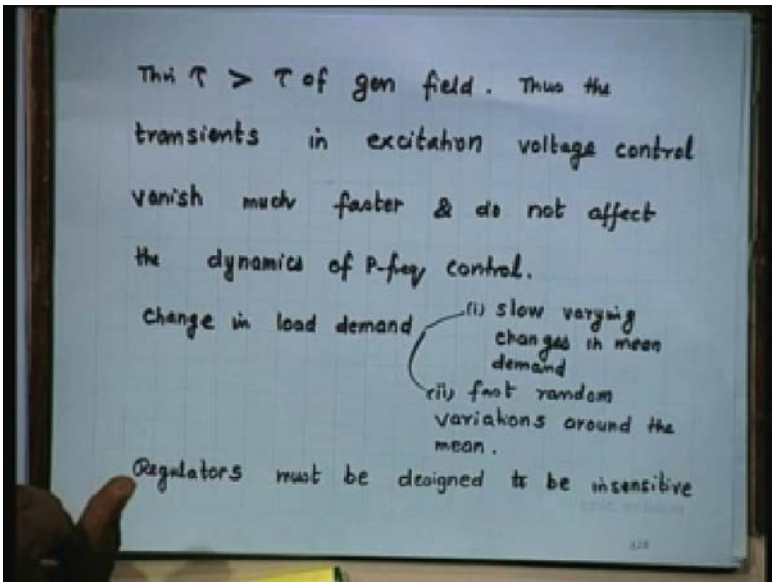

Thus the transients in excitation voltage control vanish much faster, thus it is the quick acting and do not affect the dynamics of this is very good thing that got as done that these two loops are non interactive. Otherwise there are (( )) be in a further complications, you try to correct frequency and voltage get corrected interactive where is not required to be corrected. Interactive get voltage control and frequency get corrected corrected means disturb, but luckily they leave together, but peacefully no interactions like nowadays in hostel our students leave 3 2 or whatever number without any interaction and decide interaction it desirable interaction should be there. So, these voltage control vanish much faster and do not affect the dynamics of p-f control.

So, change in load demand, slow varying changes in mean demand, fast random variation around the mean. These two things are entirely different. The mean may vary very slowly, but around mean, variation can be fast. Regulators must be designed to be insensitive to fast random changes should not act just it is 99 and 98.6 should not go and take (( )) to small allow it sometimes. So, that it may go of it zone like swings power swings in production must have red. Do not just get your relays operator unnecessarily it may be a just passing you know swing it will go. All pain here it is not heart attack you should not rush to the bypass surgery may be just a gastric pain or just like that. So, regulators must be designed to be insensitive to fast random changes because we do not intent to take note of them they will come and go, otherwise, the system will be prone to hunting.

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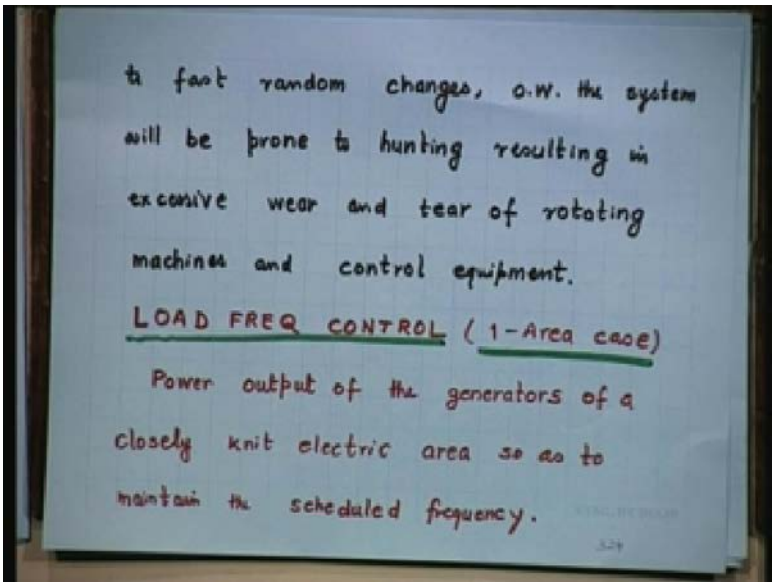

Hunting is a very important topic in synchronous machine and to avoid that we have damper winding and second order equations (( )) we can analyze hunting resulting in excessive wear and tear of rotating machines and control equipment like using brick. Brick should be use very sparingly gives you jerk, the fellow sitting back if he is not careful you made heat the top if the car is small or you may have a back pain.

Load frequency control now we will study in detail for a single area case. What is single area? Single area means Delhi state of Delhi. We do not consider Haryana, we do not consider Punjab, we do not consider UP, we do not consider Uttaranchal, neighboring states. So, only (( )) just your house, just your room not the whole hostel. So, power output of the generators of a closely knit electric area so as to maintain the scheduled frequency. At least you have to keep your room clean then only you have talk of hostel being clean. Right? If you maintain your frequency in your area naturally it will help the largest system also because this is called component to subsystem to system approach, this is system theory. System theory is another branch of electrical engineering. In fact, all engineering because there is a system everywhere except India there is no system. So, component to sub system to system approach you have to take care components then subsystem then system. As it is known that you will take care of (( )) bond will take care of itself. If you are not spending (( )) where is any question of (( )) point. All the generators is such an area constitute a coherent group.

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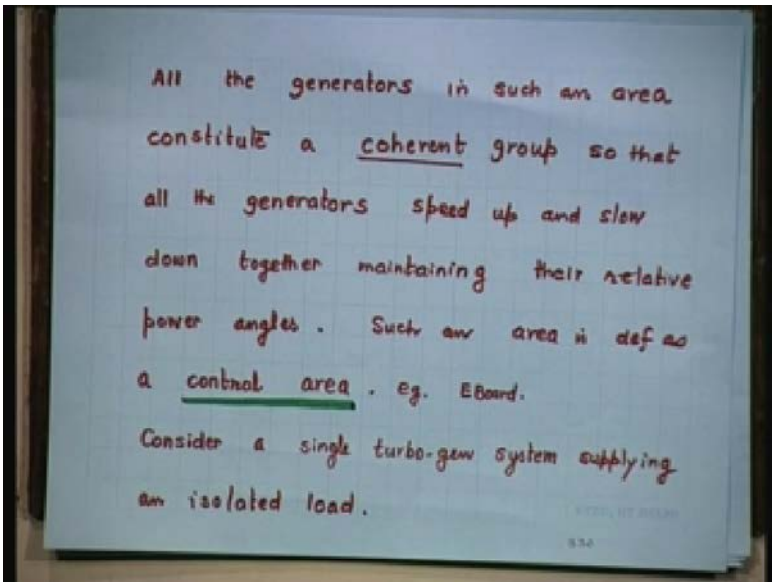

What is the meaning of coherent? Coherancy is a very important topic in Electrical Engineering. Yes, it is a larger meaning is not just same frequency. For example, two of you move together, you go and take tea together, you go and take breakfast together, you go and take lunch together, you live together, you want to die together, that type of thing and that is called coherency coherent group those (( )) a bran something like that always moving together. Similarly these all generators swing together if you plot the swingers. I am sure all of you know what is swinger delta versus time.

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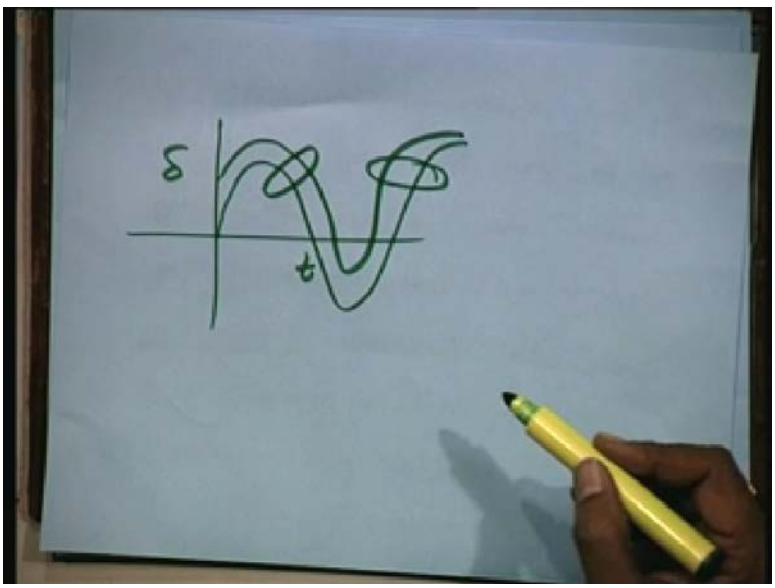

So, another will have similar, we can say they are swinging together. So, if you study the stability of one automatically where is the Ram it is a very very Sham is. So, if you know about Sham, Ram is noun normally found there are only let us a coherent group. So, all the generators is such an area constitute coherent group Delhi in the (( )) for house (( )) for house naturally whatever happens to (( )) will happen to because they are all interconnected and is small when it coherent group that is called (( )) or DVB or BSNL system or Tata power whatever is the name. So, that all the generators speed up and slow down together. This is (( )) sink together maintaining their relating power angles. So, delta 1 2 will be 0 delta 1 minus delta 2 because the values are same. Such an area is defined a coherent area. So, if you are ask in the exam define a coherent area. For example, given electricity board e board is not (( )) electronic board, it is electricity board. Here for a change e is stand for electricity.

Consider a single turbo- generator system applying an isolated load with distributed system and disperse system coming back they are not replacing the interconnected I told you sometime back, but they are very much they are now. Why? At every village every (( )) hutch (( )) you cannot take the grid. We are a poor country where is the money to I know build even it today's paper its same item, but (( )) to (( )) bus is failure because there are no person it is. So, such a link will be a failure where you need only 2 mega watt and that 2 mega watt is coming from Delhi to (( )). It is better to generate the two mega watt in (( )) itself and there where the importance of distributed power system and disperse power system there.

Even if the generation cost is fit higher, let us argue with those people who are against non conventional resources. Explain them how about the cost of transporting or transmitting or taking power from Delhi or even nearest let us say Punjab to lay, let us say (( )) on code or Jammu wherever your power station is going to late self is about 300, 400 kilo meters just for 2 mega watt because requirement is not much not many people stay there. So, consider a single turbo-generator system applying an isolated load like lay hutch there are all isolated loads. I will already shown that second figure, Turbines Speed Governing System.

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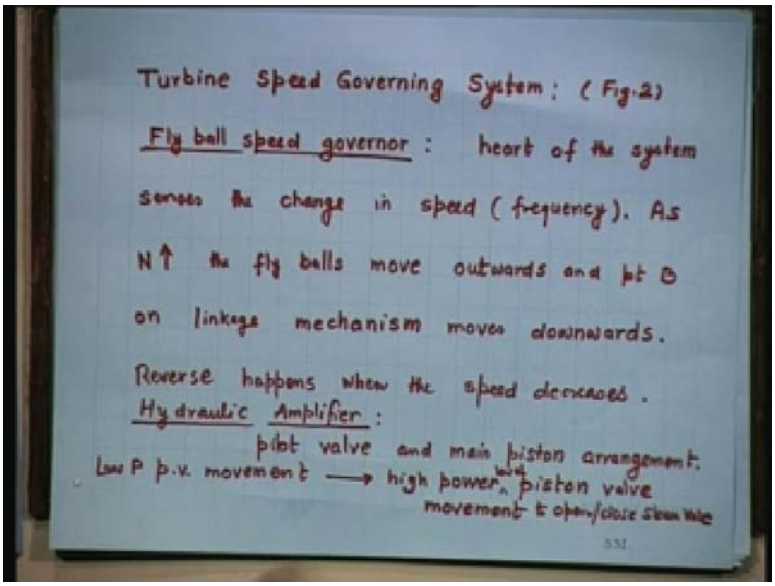

Now we were talking about this Fly ball speed governor, I showed you that picture. It is the heart of the system, it is senses the change in speed. Speed and frequency are same thing I have told you they are only differentiated by a constant P and by 120 is f. As I am goes up the fly ball move outwards and point B on linkage mechanism moves downwards. Reverse happens when the speed decreases and ultimately naturally it will operate those valves pilot valve and the amount of oil will be controlled, amount of oil will in turn controlled, the opening or speed steam valve so it will again controlled, input of steam to the turbine. As that increased or decreased depending on whether you want more generation power or less generation power.

What is Hydraulic Amplifier? Pilot valve and main piston arrangement, let P pilot valve movement low P. Low P means low real power, high power level piston valve movement to open and close system. So, the piston valve needs high power, this pilot valve needs low power low power can operate that. So, we are changing this low power piston valve movement into high power level piston main piston valve movement pilot to piston. What will do? It will movement will open and close steam valve I will explain with several times. So, now, it is should be clear to everybody. Linkage mechanism:

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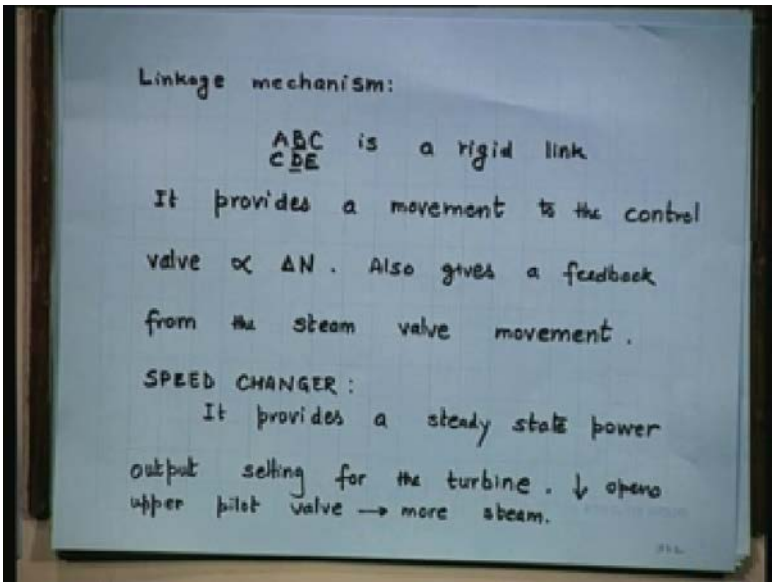

A B C I have already talked about and C D E there were rigid links. It provides and B (( )) D is a short cut language of use because of already explain you in the figure. It provides a movement to the control valve which is proportional to change in speed. Change in speed will trigger this, there is no change, this fellow will sit. Why? You have coffee break, tea break nothing, no piston valve movement, no men valve movement. What for? You are getting a constant speed is operating, constant power is being generated, no frequency beautiful 50 hertz, the voltage is accident 220 volts or 11 KB whatever and nothing no (( )) civil will operate, no voltage control mechanism will operate. What for? If you are find 80 to 120 blood pressure, temperature 98 point 4 degree per night, pulse is 80, why should you go to (( )) ? You should have no stop there, straight away come to institute. It provides a movement to the control valve proportional to change in speed also gives a feedback from the steam valve movement.

Speed changer: it provides a steady state power output setting for the turbine. If speed changer goes down opens the upper pilot valve more steam will come this also I have already explained the speed changer and more steady power output will be obtained once the speed power valve opens. Reverse will happen for upward movement of the speed changer, the speed valve get close, less steam will go and the less steady power output generator because the requirement is changed it is not required.

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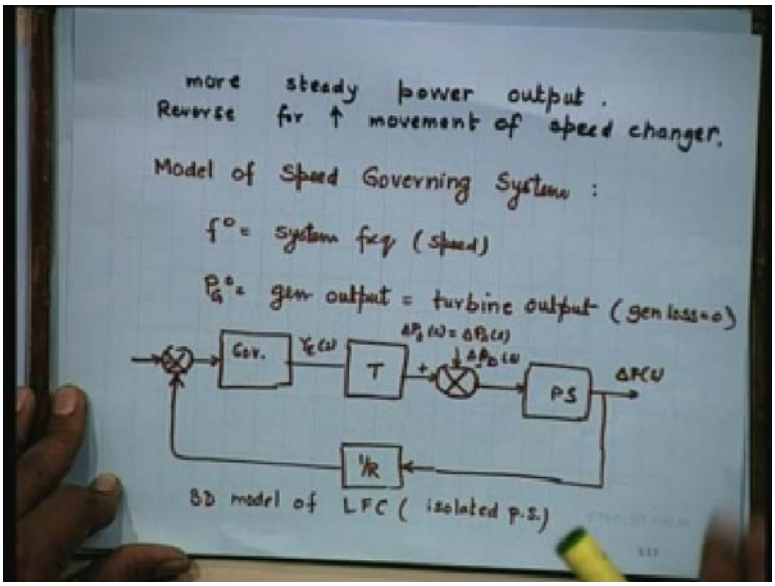

So, why should generate more power? It is not only that it will operate when frequency changes even if your power requirement goes down naturally you have to bring down the steam input. So, do not thing this mechanism will only operate if there is change in frequency or change in speed. Even if change in power requirement changes you have to generate less power. Why should you generate more power?

Model of the speed governing system: you must have thus solve this block diagram. You should drawn several times in doing your control system course. f 0 is a system frequency, P G 0 is generator output which is here and turbine output let us assume that they are equal. If you assume that the losses are not there, this is the governor block diagram, this is the turbine block diagram, this is the power system block diagram. All these diagrams are given in detailed in the book. Since there is a no time we have only one more lecture. So, kindly go through this in detail in the book.

Tomorrow will solve 2 problems also that will be tutorial type thing may be will solve here itself, whether they do this or not (( )) matters. This 1 by R is a controller regulation constant. This is the BD. BD means Block Diagram model of LFC. LFC means Load Frequency Controlled isolated power system just one power system, this is the change in frequency, this is the feedback. So, this gives the correction it compare with the schedule frequency. If there is a change in them, there is an error then it goes to governor. If there is nothing fine, no control is required. Let us do steady state analysis.

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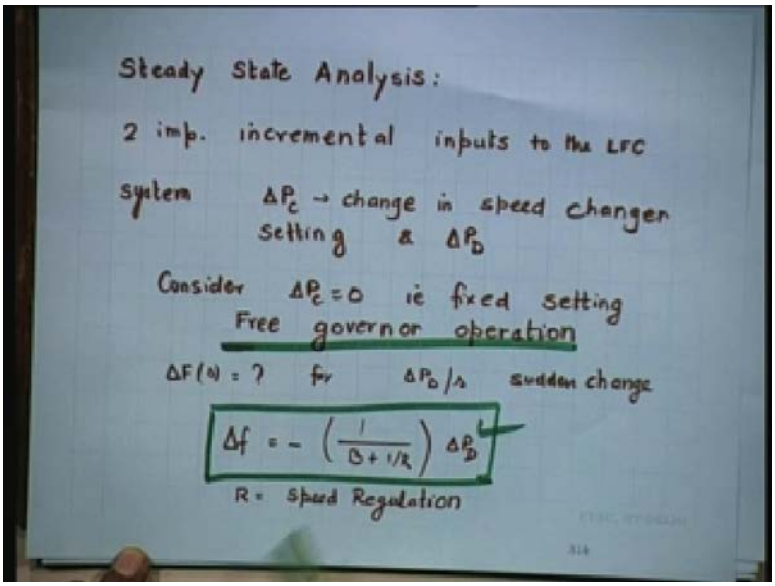

Two important incremental inputs to the LFC problem is change in speed changer setting and change in load. These are the only 2 inputs. Consider that speed changer is fixed. So, we get (( )) of 1 input. The only input is and such an operation is called Free Governor Operation, this is asked in many interviews. What is a Free Governor Operation? All IAS exam, all Engineering services exam, all NTPC (( )) anywhere, it only means you have fixed setting of speed changer and that is called free governor operation (( )) is free not control. So, find out the change in the frequency for change in sudden change in power demand. Sudden change means step in. Step means 1 by f is the sudden change and this equation is very important it relates the change required in delta frequency because of change in demand, where R is the speed regulation, B is a power system (( )). B can be ignored as we will see in next lecture.

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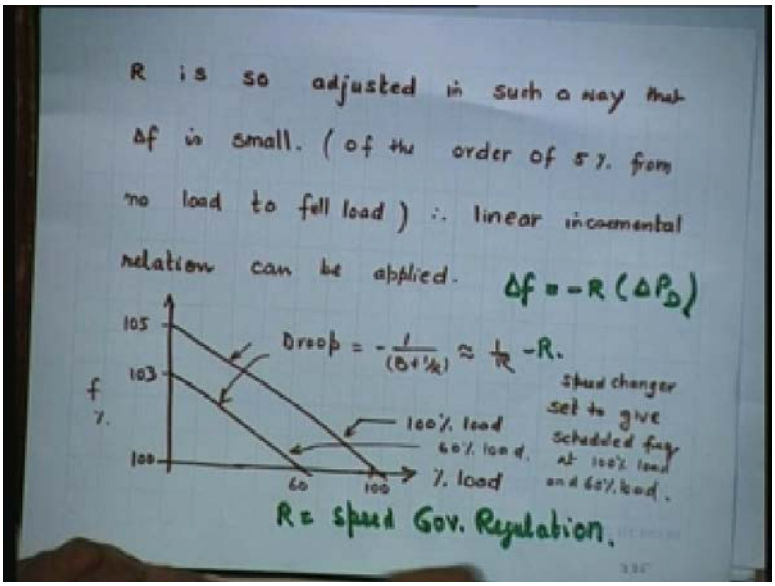

R is so adjusted in such a way the delta f is small (of the order of 5 percent from no load to full load) change in frequency. Therefore, linear incremental relation can be applied. This figure is very important. Study this figure carefully. y axis is frequency percentage starts with 100,103,105 stops at 105 because we do not allow more than 5 percent variation. What is x axis? Percentage load. 60 percent, 100 percent you may require just 60 percent of the load, it is a night time, all loads are switched off. A month of November neither heater is there nor fan is there, no cooler, no AC, no even fridge. So, the load drops. So, you may operate at 60 percent of the load. yet you need a frequency say 60 percent load does not mean you can reduce a frequency. The frequency is still required is 50 hertz. So, load can be 100 percent, the frequency is still required to be plus minus within 5 percent range and droop this is a droop characteristics. Why droop? The load goes up frequency drops. Though it is linear, but it is droop characteristic and this is the slope is given by 1 upon R, B is very small you can ignore. It will come minus R because the B goes 1 by R goes up.

Speed changer set to give scheduled frequency at 100 percent load and 60 percent load and that is why delta f then will become minus R delta P D and this R is a Speed Governor Regulation. With this will stop today. Tomorrow will solve couple of problems then will go for the and the AGC topic goes on it is not just one area. We are just consider one area then tend to be two area then both areas linked with the tie line like this and there is a tie line so interconnected.

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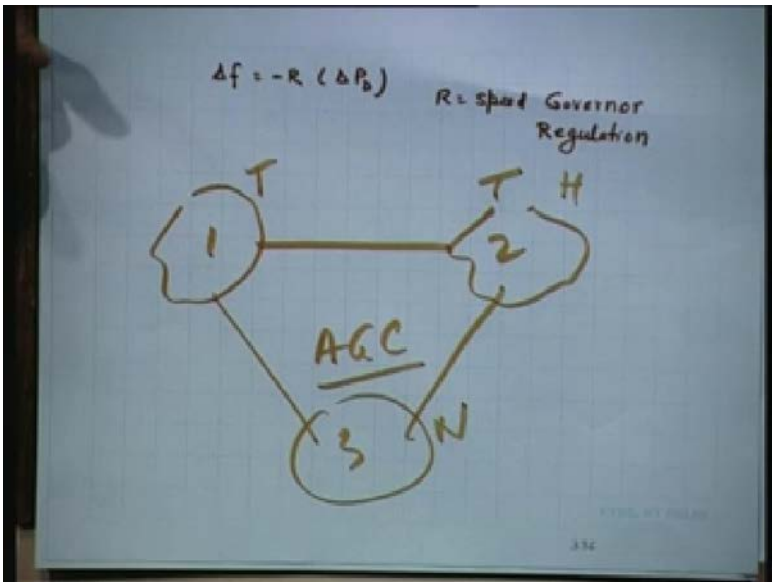

Now you have to have A G C of this 2 area control that will be third area. This can be thermal, this can be thermal hydro nuclear. It takes complicated involved dead band dead band control you to consider dead band also. What is dead band? Any idea? There is certain time for which control it does not operate takes time like certain effort is required to continue to run the machine at no load, there is no output, but still input is there because you have to supply losses then there is a generator rate constraint GRC. It takes time to increase the generation it is not no time. So, rate of generation increase which is 25 percent in hydro I told you in the first chapter, thermal it takes more time it is slow. So, with this ladies and gentle men to stop today, any questions we have today for lecture?

What is the voltage demand?

(( ))

That is right.

See the changes are small there will go to reset it will take care of itself, but changes are widen large and whole setting has to be rechanged. Any other thing?.