Power System Generation, Transmission and Distribution

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Lecture No # 25

A G C (contd.)

So, welcome to this lecture number 25, which will be last in this series and we will continue in the next semester, which lecture 26 on load flow studies. So, today we are talking last on automatic generation control; and yesterday, we have seen why it is required, why it is necessary to control the frequency. If you do not, the speed will vary, speed will vary the output will vary and the purpose would not be served for which the motor is being used. In fact, the time will be you know wrong, on all those synchronous clocks in the world or wherever the system is.

Now, we also seen, how do we derive the model for an isolated system? There is a governor model, there is a turbine model, and there is a power system model. Now, various researchers in past have given different models, a model will vary because of different assumptions. What is model? It depicts the real system to certain assumptions and the hopefully, the results obtained using that model is applicable to, or are applicable to the real system, that is the whole idea of doing any analysis or any simulation on computers.

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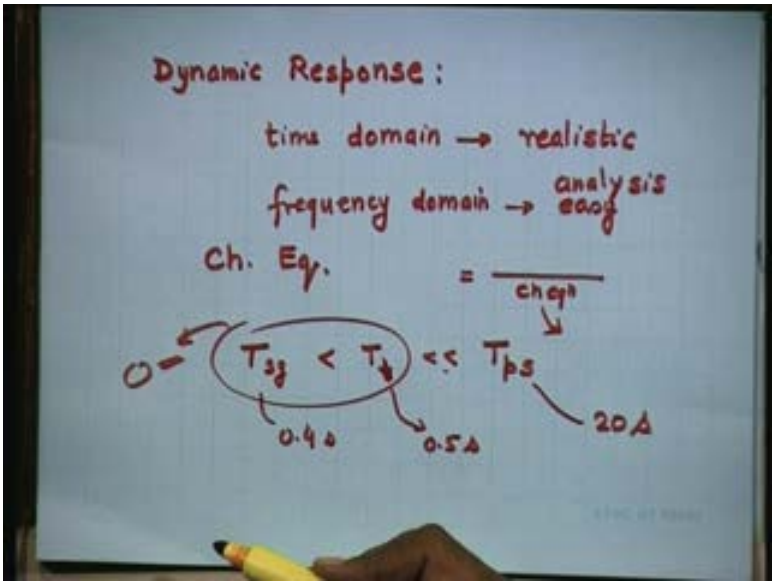

Now, today we will talk of dynamics response. Now, what is the dynamic response? The dynamic response is, if there is a perturbation; see, the system does not remain on steady state all the time, something or other keeps on happening in the system. So, if there is a perturbation, some change as I told you, the load keeps on changing all the time. So, let us consider a change in load which is very realistic delta p d.

And if you consider a step change which is a sudden change, I am sure all of you know what is step function u of t it is 0 up to origin or particular time instant, and then suddenly it gets you know, step up increases or decreases either direction by a particular amount a, then it becomes a u t. If a is 1, then it is a unit step function; otherwise it becomes a normal step function.

Now, take the Laplace inverse of the function and then you will get the time domain. See, the studies can be done in time domain as well as s domain, that is frequency domain; at times it is easy to work in frequency domain, at times it is easy to work in time domain.

Time domain gives you, let us write down this, time domain is realistic because things do happen in time. So, if you can work in time domain, it is wonderful. But if you cannot, because of mathematical convenience, then there is a frequency domain. For example, you know certain things are easy in frequency domain, what is the simple multiplication in frequency domain, becomes a convolution integral in time domain, which is not easy

to solve. So, it is easy, analysis is easy. analysis is easy Now, what is the characteristic equation? All of you must have studied control system; characteristic equation is the denominator of a transfer function. So, this characteristic equation, if you further analyze, you get the roots.

There may be poles or 0 and depending on that, you can say whether the system is stable or not. Now, if you obtain a characteristic equation and if it is can be approximated by a first order, by making certain assumptions. the For example, time constant T s g is less than T t is much much less than T p s. What is s g? speed governor, what is T? Turbine, what is T p s? The transfer, the time constant of power system, now a typical value if you want T s g is 0.4 seconds, T 1 or T t is 0.5 second and this is 20 seconds. That is why, much much less than, so we can put these two 0.

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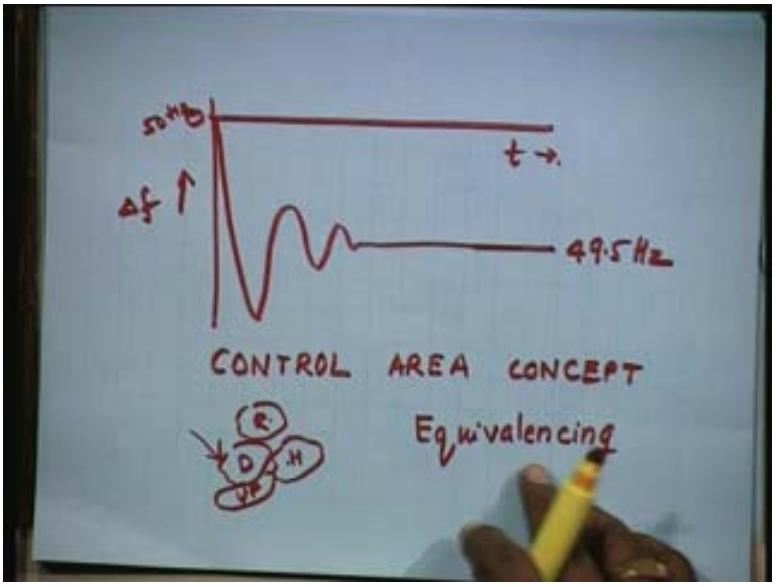

So, when you solve this and finally, if you plot the dynamic response for that isolated system whose block diagram we drew yesterday, then what you will get? This is a dynamic response, this is the time, and this is change in delta f frequency as we can see, it reaches a peak overshoot, comes back after some oscillations it settles down to new steady state.

So, if it is started with 50 hertz, and if it settles down to 49.5, then there is no problem, we are safe, and we say system is stable. Now, what is the control area concept? control area concept Yesterday, if you recall, we were talking about coherent system, that is a

system in which all the your generators swing together, move together, behave in similar way. So, if you can examine one, you as if you examine all. Similarly, there is one area that is a Delhi electricity board or DVB, what is that is our control area, we are really not bothered what is happening in Haryana, what is happening in Rajasthan, all neighboring states. But if you are interested in all those things, then what happens? This is Delhi, this is Haryana, this is Rajasthan, and this is UP.

These are the four or three neighboring states UP, Haryana Rajasthan. It is surrounded by these three states, but they are inter connected, you cannot say this Delhi is completely isolated, we do get power from Bakra we do get power from Haryana, we get water from Haryana, so it is all interconnected. But we can as well study Delhi system alone, if you want to, because that is our system. But in case, you want to study the whole big system, then you can use a principle of equivalency, this is being done in practice every day. What is equivalency? In order to reduce the order of the system, reduce order modeling is a very important technique in control system.

So, what you do? You reduce the number of buses in Rajasthan Haryana and UP and bring their effect to the boundary of Delhi. So, that becomes equalized system, reduced order system and then the number of buses is reduced from 100 to may be 20, and it is easier to analyze 20 bus system, why? Because, if something goes wrong drastically in Rajasthan, Haryana or UP; definitely, the effect will felt in Delhi, so you must analyze these three boundary states.

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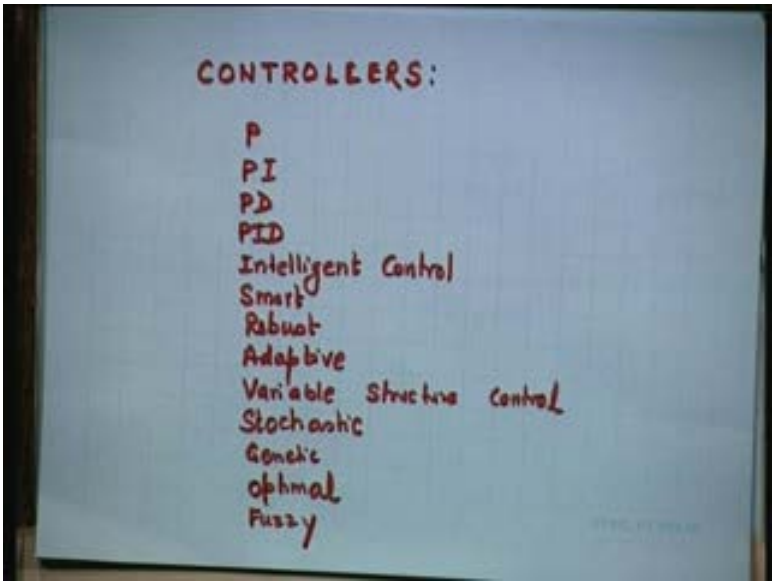

What are different controllers, this topic is very important. What are different controllers? One is proportional, P I P D P I D and then, let us let us say intelligent control intelligent intelligent control or we call it smart control, or robust control, adaptive control, and variable structure control variable structure control, so variable structure, a stochastic, and then we have evolutionary a genetic genetic optimal, these are the, you can have fuzzy control. These are the various controllers used in not only electrical engineering, in any system be it medical system, be it biomedical, be it air, earth, anything in life in the world, these controllers have to be used to control certain things. We have to control the direction of the missile, rather than going to enemy country, it should not land in the the friendly country.

So, your target has got to be hit you know, and that is why these controllers are very important in life. Now, each control has some positive point, some negative point. So, to choose a controller is not an easy task like choosing a medical you know, by a medical doctor, a medicine. Even if you have a cough, all of you may be given a different medicines, it depends whether you react to particular medicine, it depends what are other complications, it depends whether you are a diabetic, it depends whether you are a hyper tension, having hyper tension.

So, similarly in a system, we have to see system is used for what? What is that we control, Is it a (( )) control? Are you on local optima? You want universal optima? You

want global optima? What are the different constraints? What are the efforts required? What is the time in which you have to control it? So, all these factors make life very very complicated and choosing a control, that is why no single control can be said is an optimal, is the best for all situations. And that is why, all these controllers are equally important, because it depends on circumstances, which one, there is no neither a time nor necessary to study all of them in detail, because, you must have studied them in your control course. However in this particular topic, we will talk about proportional and proportional integral, only two controls.

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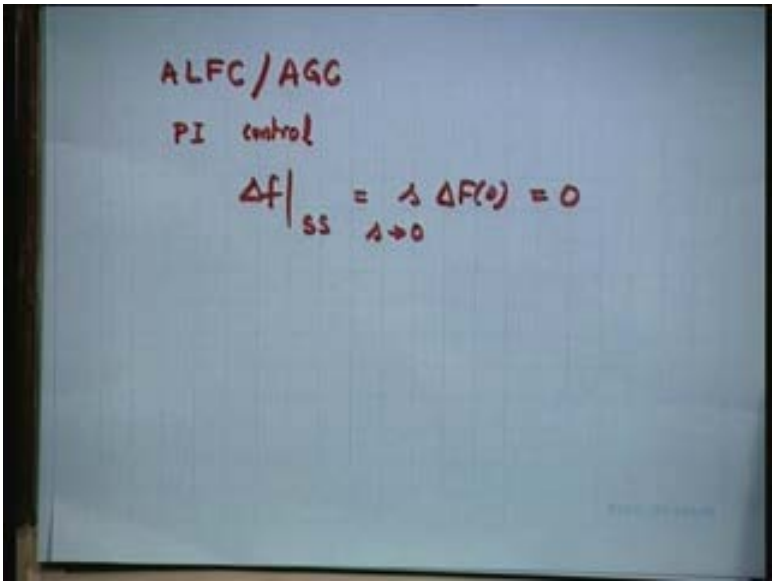

So, for LFC, that is load frequency control or AGC, that is automatic generation control, both are used interchangeably. Some people use ALFC also, automatic load frequency control. If you use P I control, what is the advantage? Delta f steady state s times delta F s as s tends to 0 is 0. I am sure you must be recalling your initial value theorem and final vale theorem, this is what we are using to find out the final value of deviation and this must becomes 0.

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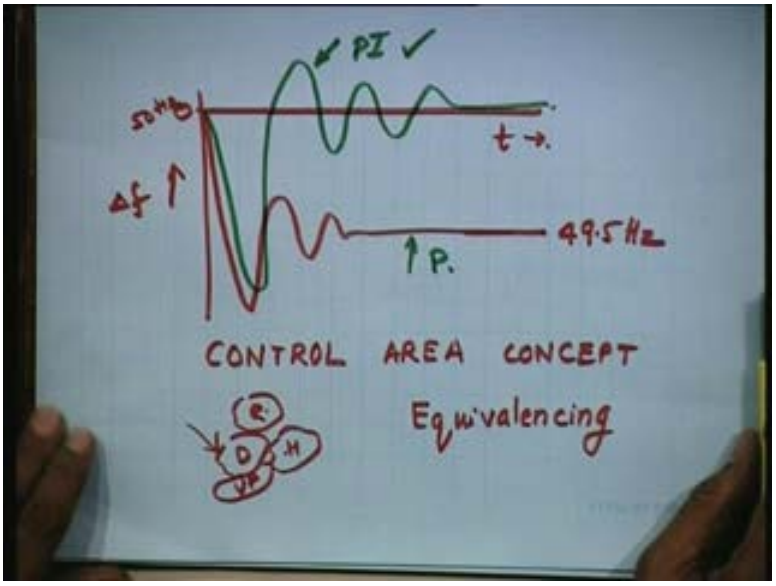

Unlike the diagram I have drawn earlier, it is not becoming 0, it is settling to a new steady state. What I want, I want it to be like this, this is P I control, and this is without integral control, it is only P. I am interested in, then I want the steady state error to be 0, in this case it is 0.5 hertz. So, this 0 is only possible if you use P I control.

Now, I have mentioned to you the, in one of the earlier lectures regarding load despatch centre or energy control centre or power system control centre. What is going on in the centre? Different studies are taking place and different time frame. For example, load forecasting; it is not load frequency control, this is load forecasting, is going on all the time, very short term, short term, middle term, long term, very long term. What will be the load in India in 2050? I am interested, what will be the load in 2010? I am interested, what will be load in 2004 end? There is 13 14 months and I will be interested, what will be load tomorrow? I will be interested, what will be the load at 11.30 p m today? now it is 11.26 not a m not p m, 11.30 am, I am interested, that is very short term.

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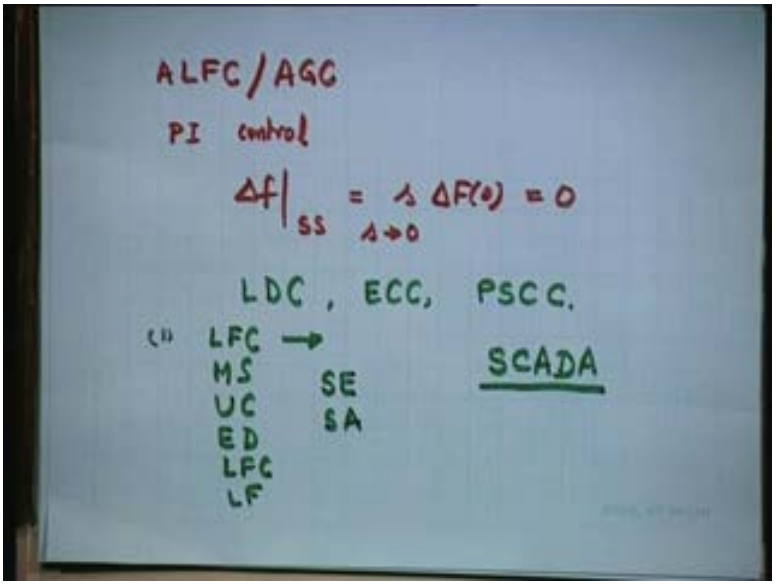

So, I have to run maintaining scheduling program, unit commitment program, economic dispatch program and LFC load flow, all these various functions are being solved all the time by engineers sitting in load dispatch centre. Here, you can get a information from all; whole country, whole system and we use SCADA. What is SCADA? Supervisory control and data acquisition system using modern computer knowledge. If you feel straight estimation, you can add to this least, can also add security analysis SA. Now, what is state estimation? The data may be spurious may be corrupted. Now, how do you remove the corruption in the data? How do you made data pure? That is called again a filtering, suppression of spurious data and getting the correct data that is a estimation, news; news comes, the government has to filter out what is the correct news and what is the rumors, same thing happens in power system. The methods used are least square estimation technique; we want to minimize the error.

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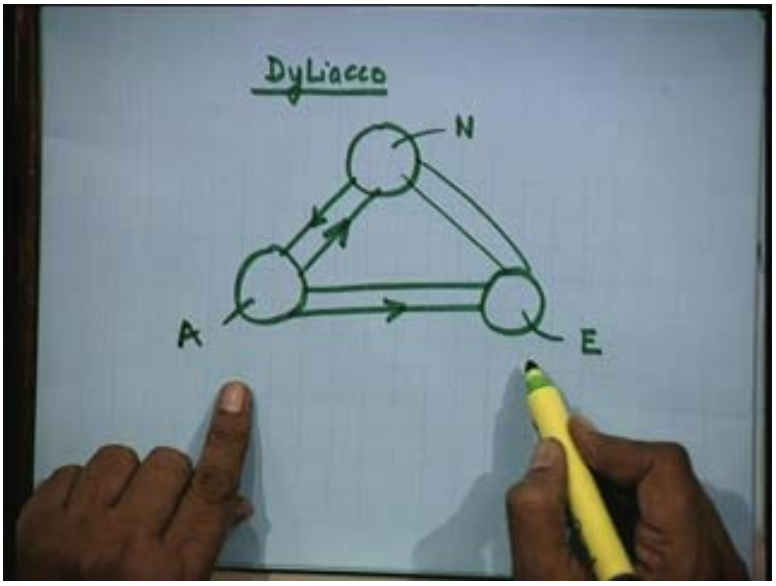

Now, what is security analysis? Security analysis was started for the first time by a gentleman called DyLiacco. What does he do or what did he do? He divided the system into three parts, this is the normal state, this is the alert state, this is an emergency state. Now, from normal to alert you can go, suppose you are normal, your temperature is perfectly alright, blood pressure is, pulse is, and suddenly you feel there is a cough and cold.

So, cough and cold is alert, you immediately go to doctor or to a nearest, you know medical shop, purchase some, you know tablets, some novagen, or action 500, depending what you are use to, or jandu balm and you try to apply yourself (( )) correct reaction and you try to go back to normal state. But if you happen to take a wrong medicine or if you happen to go on eating chola batura and you know samosas dirty oil, then we land up in emergency rather than going to normal.

So, cough and cold get converted into fever, high fever, lot of cough, bronchitis. And maybe there is a problem, if you do not properly take precautions something will happen. What will happen? Break out, collapse, system collapse and then 18 hours; there is no power in Unites States, Canada, France, India. In order that not to happen is, still there is a time a load despatch control people do something and they try to go back to normal, even without going to alert, special injections, ICU, operation and you come back to normal. And sometimes you go from directly to fever, so normal to emergency, without

coming from cough and cold route, or you can go back from emergency to alert and an alert to normal.

The Tata electric company is the best private electric companies in India, there was one doctor, R K Pandit. He was the director general of that company, he was delivering one key note address and there he said, in India the power system lies in normal state, only 28 percent of the time, this was a shocking statement. how do you feel if you remain healthy only 28 percent of time of the year and remaining 72 percent of time you are sick? Do you have that much sick leave? Do you have that much medical leave? What will happen to lectures? You will miss the lectures, or miss the minus. So, how do you have mechanism, some strategy, so that it remains in normal state 72 percent rather than 28 percent? And for that, you need to carry out all those studies and this is a very serious affair, because now our install capacity is 100 (( )) 5000 mega watt, multiply by 40000000. How much money is involved in this operation? No power, no industry will run, no production, no production; the economy will be down.

So, our job is to keep the wheels of the industry running all the time, how can that happen? Provided you supply the power, forget about quality supply, have to supply some power and then the quality can be improved by the consumer, that is the era which is come, it depends on you how much you want to boil the milk to make it rabri, it is up to you. So, that expense is yours, that gas expense, or time expenses, the house lady he has to stand there or whatever. So, that quality power supply is a distant dream, when it will be absolutely 50 hertz, 220 volts, no harmonics, THD is less than 5 percent; total harmonic distortion less than 5 percent, so that is the quality, power quality or energy quality.

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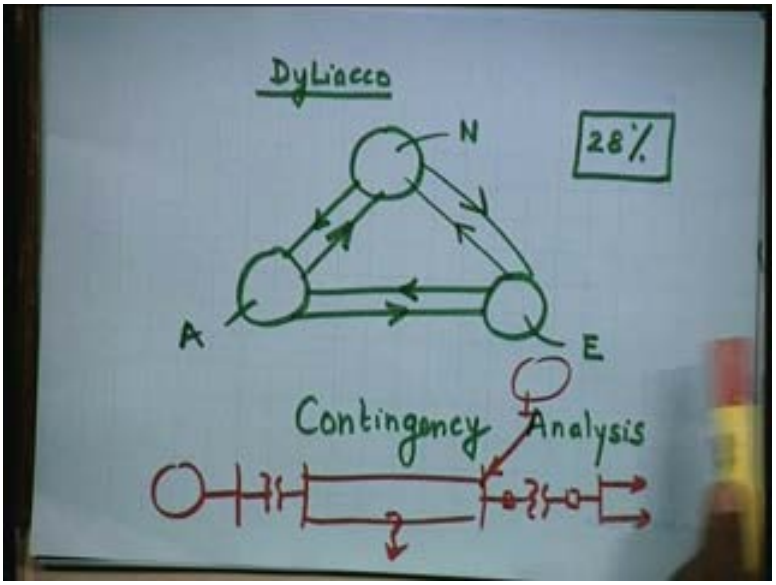

Now, this is the security analysis, now security analysis you do contingency studies, this is not contingency which you get your scholarship, 10000 or 30000 or 20000 or 5000 or whatever you get, I do not know. Contingency analysis is another important topic in power systems, contingency is nothing but, what is contingency? In fact, that is same meaning here also, you have given that money to provide for any typing, any xeroxing, that is a contingency which is has a reason. Here, contingency means fault, series fault, shunt fault, open conductor, line to ground, line to line, line to line to ground, all line grounded. So, assume different type of faults and see whether your system remains in normal state or not. Suppose, there is a power system, now there is a fault here, will this line be strong enough to carry the requisite amount of power to supply the loads, at least temporarily, till you clear out this contingency, this is contingency analysis. Can you bring in some power from somewhere else here to compensate the loss here? This is what you do in contingency analysis.

Now, if you consider all contingencies, you will go mad, because a 100 bus system, a 1000 line system, permutation and combination you must have studied in your sixth class or seventh class or whatever class, and n p r n c r, you know you have several permutation and combination. So, contingencies can occur in a different fashion. Anyway, so contingency can occur in a different way, they have to announce that, hey, I coming tomorrow fever, I am fever speaking, you suddenly get up in the morning and you feel you are not well. So, there is no warning given by them, right. So, what we do,

we run the contingences, the the most hopeless, most critical contingencies, number one, examine that and if you feel you are safe, then naturally you will be safe for remaining contingences. If you can have 1000 rupees and you have your spouse or your brother needs 100 rupees, there is no problem; once you taken care of 1000 rupees, 100 rupees, there is no problem. So, that is called contingency or ranking problem, which is very important in power systems.

The last resort is load shedding; suppose, you cannot get power from any source, then you have to shed the load, load shedding is a genuine control mechanism to circumference any fault, any contingency. But which load to be shed, not the way it is done in India close those park, close green park, this is done in a ad hoc manner, this is the only country where the traffic control is the open loop control, red light and green light is closed after two minutes round in a round fashion, without bothering whether somebody is there or not, it should be a function of the traffic. Suppose, there is no traffic there, then why should we have a green light, nobody to go, you have red here and if that road is having lot of traffic, have green there rather than having green here for two minutes, it happens, it may not happen in Delhi, but it happens in so many places.

So, you have to have a load shedding also in a style by some mechanism, by some algorithm, by some formula. How much load to be shed, and for how long, this is the very important optimization problem and which someone of you should take it as a M. Tech thesis, because it is very much relevant to our country, thus we have load shedding all the time. There is no city in India where you get power for 24 hours, not even Delhi, no Bombay, except Bombay, Bombay is a different world, Bangalore, Hyderabad, Calcutta, everywhere there is a load shedding varying from few minutes to few hours to whole day.

Now, the dynamic response should be fast, how do you make this dynamic response fast? If you get 49.5 hertz after one hour, what is the use. I want it to achieve that figure, I do not want to go through again back to that figure that zero state steady error should be achieved less than 20 milli seconds, less than 20 milli seconds, then it is called fast, a second is a very big time in power system, so it should be in milli seconds. Now, it is a era of nano; nano technology, nano materials, nano physics, and a bio, of course.

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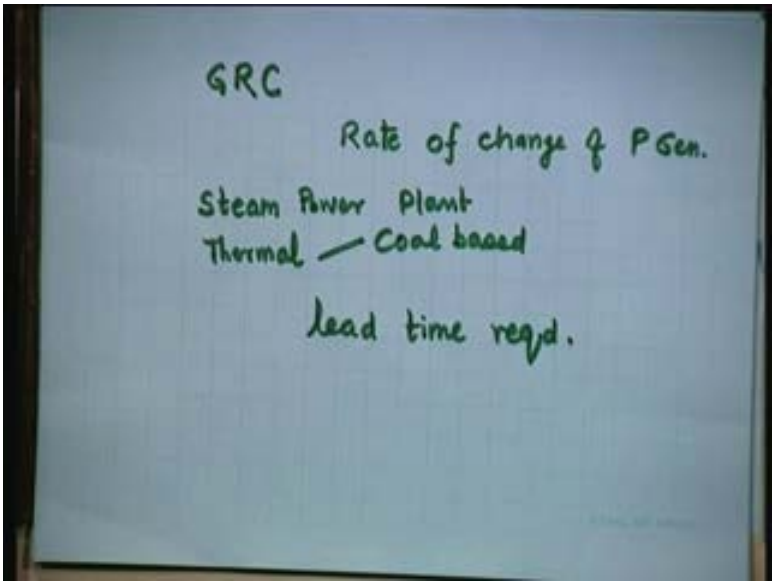

I was talking about yesterday, if you recall GRC, generator rate constraint. The load frequency control problem discussed so far, does not consider the effect of restrictions on the rate of change of power generation. You cannot make it any you know like a gyn, in a second change, you want 50 mega watt 50 mega watt, you want 30 mega watt 30 mega watt, if that would have been the case, no control is required. If you can switch on and switch off any amount of mega watts, where is the problem? Unfortunately, the reality is not so accommodating, it is different.

So, rate of change of power generation, suppose we have a steam plants, as you know we have 72 (( )) 2 percent is steam power plant, thermal, they are also called thermal, may be coal based, mostly. Now, you take always a considerable amount of time to start a thermal power plant and that is called lead time required. If you ask your driver to bring car, he would not bring it in second, yes, sir I am going to the garage, wherever the garage, even if it is in your house, used to go, open the lock, open the car.

Nowadays, there are 3 4 locks in the car, you too open all those locks, you too sit there to start, come on the road next 5 to 10 minutes, it cannot be instantaneous. Similarly, if somebody wants power in the afternoon, then only you to start running the thermal power plant right now 11.42, then you get power (( )) 5 p m or 4 p m, depending on when it was shut off last, Suppose, it is absolutely cold, and even coal is also not pulverized, then god is the answer, you also cannot do anything. So, it depends, what is

the current situation, is it a cold start up, is it a hot start up, or is already spinning (( )), where you can do it, perhaps as early as possible. The generation rate from safety considerations of the equipment for re heat units is quite low, most of the re heat units have a generation rate around 3 percent per minute.

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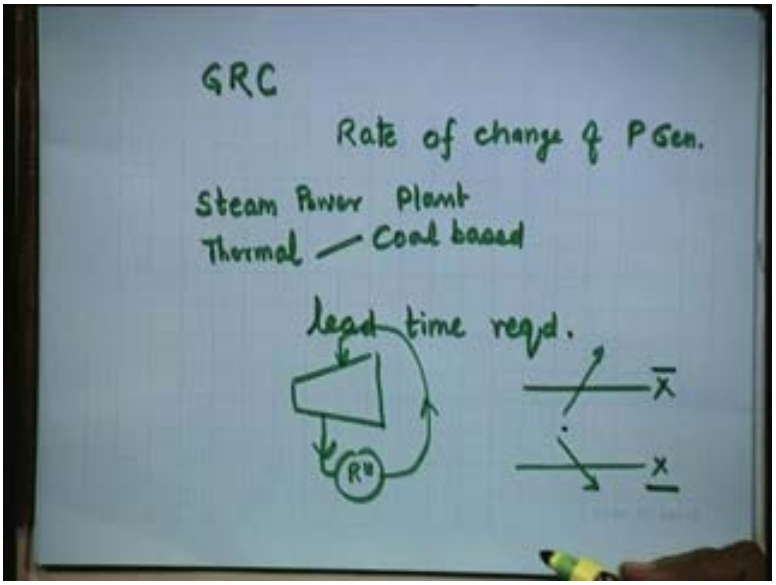

What is re heat unit? There what you do you have, a turbine. I explained you earlier also; you take out steam power to re heater and again bring it back. So, it is a recharging the battery, your say, your super heated steam has lost some of the, you know steam as we call it and then again is a re heater pass through that and, so this generation rate constant is 3 percent per minute. Somehow, a generation rate between 5 to 10 percent power per minute, not more than that. If this (( )) are not considered, system is likely to chase large momentary disturbances, which you should avoid. This result in undue wear and tear of the controller, I have told you earlier also, in power swing.

Several methods have been proposed to consider the effects of GRC's for the design of automatic generation controllers, when GRC is considered, the system dynamic model becomes non-linear. Whenever the model becomes non-linear, people get worried because the non-linear analysis is not easy; a linear analysis is lot easier. And so, people always linearize the system and get the results, and this should be fairly valid, otherwise is no point in linearizing the model, if you cannot linearize. And linear control techniques cannot be applied, once it is a non-linear for optimization or control setting or

anything, naturally the system order will go up, from second order to third order, third order to fourth order, the higher the order more difficult to solve the system. Sometimes, it is better to consider it as a constraint rather than a variable. For example, water storage in a reservoir, once you get a answer, see whether it is more than x max or x min, if it is more or less. Fortunately, it cannot cross both the constraints simultaneously; either you are inside the studio or you are outside, you cannot be both, only god is only present.

So, at a given point of time, any variable either can cross upper limit or lower limit, not both, we are saved, if it have been possible to do both, then we have been (( )). Fortunately, no variable can cross its limits, upper and lower simultaneously, so it is better to check this algorithmically rather than bring this assumption in the formulation. So, what you will see, you will see that whether the generation rate constraint is obeyed, then there is no problem, then you do not have have to alter the order of the system.

What is dead band? I talked to you yesterday about dead band, the effect of the speed govern a dead band is that, for a given position of the governor control valves, an increase and decrease in speed can occur before the position of the valve changes. It is not able to keep track, there is a time delay. The governor dead band can (( )) affect the system response, the dead band effect indeed can be significant since relatively small signals are under considerations, a speed governor characteristics is of course, non-linear. You have seen that diagram and we definitely approximate them by linear analysis, so this is another non-linear analysis is introduced if you consider dead band.

Mechanical friction and backlash can also valve overlaps in the hydraulic relays cause governor dead band speed governor may not immediately react until the input reaches a particular value, it is like a no load current which you have to supply to keep a motor running at no load. If you talking on your scooter, or your bike, and this is on, it is not moving yet it is consuming the petrol, because you thought you will finish your talk in a minute, but you have been there for five minutes, Indians anyway talk too much. So, it is better to put it off, but then who will kick it again, that is the problem, people do not want to do any hard labour.

So, they keep on continuing, have it on, which is very bad against the principle of energy conservations. So, dead band can be also considered in the model make it as complicated as you can and that becomes a very important and complete model, if you consider GRC

as well as dead band. Well, many people have already considered there have been five PHD thesis in this institute on load frequency control; one is the (( )) one is (( )) one is B.L.Paul, B.L.Paul is the principal of a private college in Noida, you can go and have a job with him if you want and (( )) one is in n r e b Prabat Mohan and so on.

So, you can have go at their introduction or summary of those PHD thesis, I do not want you to read the whole thesis, you just read the synopsis to get a feel, how those guys have done improving the LFC model, digital load flow control, now everything is digital now, digital camera, all digital, there is nothing analog. In recent years, more attention is been payed to the question of digital implementation of AGC algorithm, digital control turns out to be more accurate, more reliable, more robust, compact, small, less sensitivity noise, drift and more flexible, all plus points.

It may also been implemented in a time sheared fashion, a time shearing, multi tasking, parallel possessing, these are the mantras of present day. You have to do it, you go and opening windows on your PC's, you go and see naukri dot com and etcetera etcetera, so many sites which are not supposed to see also you see, etcetera etcetera.

The ACE is automatic control error, a signal which is used for AGC is available in a discrete form, they occur sampling theorem, you must have read sampling theorem, at what rate you should sample, that is very important in anything digital. In fact, in practice you cannot judge in a factory all the coco cola bottles that are coming, you take sample and feel satisfied, oh quality is excellent, so sampling is got to be done. The digital control process is inherently a discontinuous process and the designer has thus to resort with the discrete time analysis for optimization of AGC's techniques. That means, instead of differential equation x dot is equal to a x plus b u, you have to use difference equations which you must be aware, you must have studied in your earlier classes and you will have x k plus 1 is equal to phi or pi times x k plus psi times u k plus gamma times p k, disturbance variables are also there, besides state variables, besides control variables, besides your independent variables, you have disturbance variables as well.

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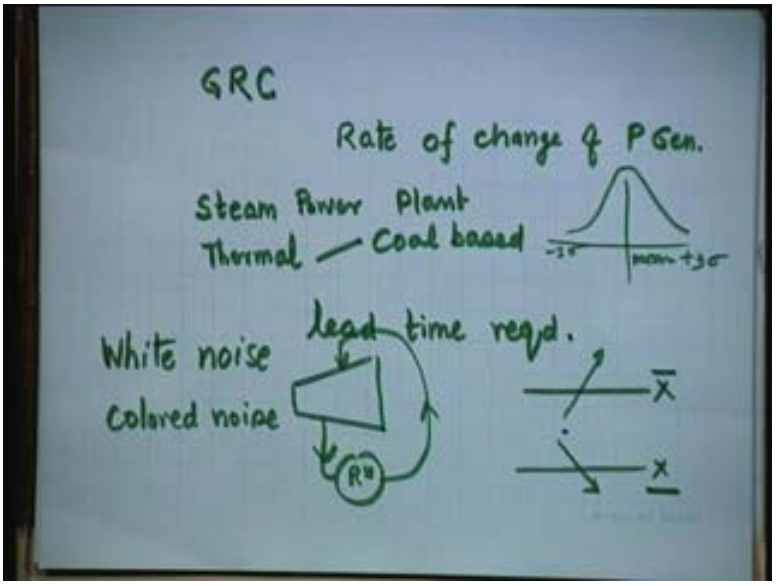

Then you can bring stochastic by having either the white noise or color noise. I do not know whether you have studied these things, the white noise has zero mean and it varies around that normal distribution. I am sure you must have studied the normal or Gaussian distributions, this is minus 3 sigma to plus 3 sigma, and this is a mean value, what is decentralized control? So far, we have been talking about digital load flow control, now let us talk of, let us change the color, change the color as different connotations, this is very faint, have to see this.

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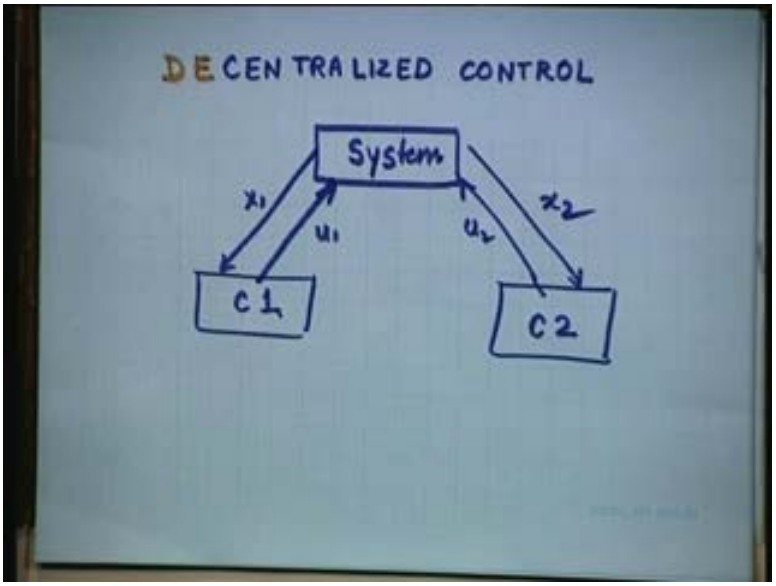

This is decentralized control, now they talk of transparencies, they talk of openness in life, and they also talk of decentralization, all powers need not be with the boss, the power should be decentralized, some to d d, some to d e, some to hertz, some to in chargers so that decisions can be taken fast, without any interference in the talk; TQM, total quality management, what we have in India is NQM, no quality management, and no more, not even LQM, low quality management, it is a no quality management.

Anyway, in view of the large size of the modern power system, right from you know Srinagar to Kanyakumari and Kutch to Agarthala or whatever is the last point in north east, it is virtually impossible to implement either the classical or modern ellipsial algorithm in a centralized manner. You cannot have a ellipse in the whole India, a decentralized control scheme is always preferred as I said, let us only control Delhi and if you want to include the neighboring states, because you are connected to them, the reality is Delhi is not in islanding, power system islanding you may be knowing.

So, you cannot create islands, it has to be inter connected with the, in fact now we are going for international grade, what is the advantage? When India sleeps US works, US sleeps India works. So, that all that power can be transmitted to India from US, when they are having night and all power from India can be transmitted through satellite, through whatever link, through whatever may be wireless, or whatever less, you know it is possible, it is no more a fiction, it is going to be a reality.

There are already their offices are operating in India and US round the clock, they have a office in Gudgeon, all US forms, the Gudgeon secretary speaks English again in an American accent, you will never know from where she is talking, she is sitting in New York or in Gudgeon, the client will not know. And so, there now US foroums are operating round the clock, there is only two hours in time which is overlapping in US and India, otherwise it is night there day here, day there night here. And so, imagine they are they are they are on the pulse of the world for round the clock, for them it is and the payment is one third of US and the work is perhaps better than US. So, most of the US now are going to have offices, work done, outsourcing, another mantra of today's era, and they want to work in India, anyway this is nothing to (( ))

So, if there is a system, may be it is whole country, or whole world, or whole Europe, whole continent, or SAARC or whatever this is controller 1, this is u 1, this is x 1.

Similarly, you have, you can have more than two, I am just explaining you the principle, controller 2, this is decentralized control, these two are not in talking turns directly, this may be France and England, but there is a, sorry the this system is been controlled independently by c 1 and c 2, the information is fair to well c 1, c 1 gives you control, information is fair to c 2, c 2 gives you control, this is u 2 and x 2. So, it is decent, the c 1 c 2 are not at one place and this is now being operated, now other techniques of model simplification are available in literature, alternative tools have decentralized control are also available, aggression analysis.

I do not know you heard about it, singular perturbation, moment matching and so many other techniques are given in the literature, if you have a time, if you can unless until if you only want to download everything, no you have not only download, you have to go to library and read literature, downloading you may not get everything this can only be a help it is not the only way of learning sitting in front of the PC. I think with this, we finish today's lecture, any difficulties, any clarifications or anything? If not, then will see you on 26 for the final, I am immensely enjoyed your company for the whole semester, we had a very pleasant time and I wish you all the best for all the exams that you have in this semester.