Power System Generation, Transmission and Distribution

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Lecture No. # 35

Optimal Load Flow (Contd.) & Hydro Thermal Scheduling

This is our last class lecture 35, Optimal Load Flow we continue, and we introduce and finish Hydro Thermal Scheduling. Last time we did out with equality constraints if you recall the optimal load flow. Today, we are doing with inequality constraints.

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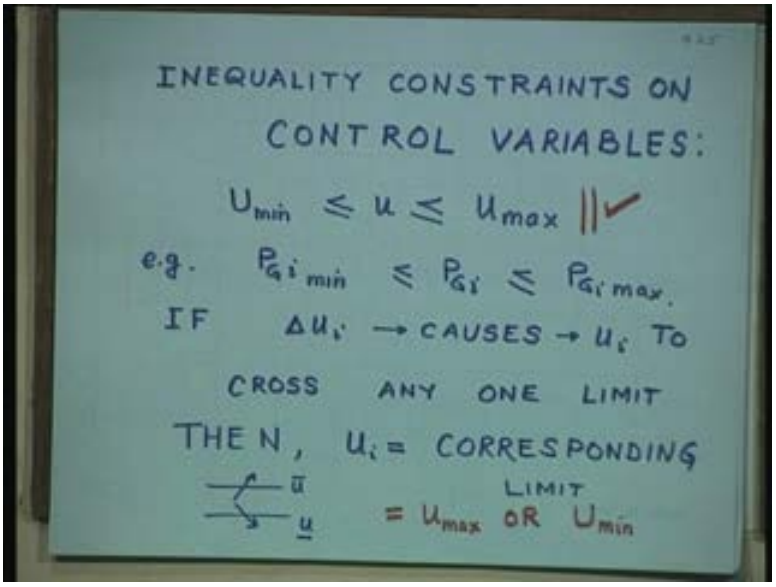

Now, inequality constraints all of you understand, what is the meaning of inequality constraints, it is less than equal to… Now, inequality constraints can be there on control variables, it can be there on dependent variables. Now, these two inequality constraints have to be tackle in two different ways. Let us first consider, the inequality constraints on control variable: control variables is normally specified in control systems by u, so U min less than equal to u less than equal to u max. For example, power generation that can be control variable, you can control power generation by controlling the water gate opening or steam input.

So, P G i min less than equal to P G i less than equal to P G i max. Now, when you add delta u i to get the latest value of control variable, you check whether this mu, new mu is within this limits or not this is what you have to check, this must be always satisfied. If this delta u causes u i to cross any one limit, you can other cross the upper limit or lower limit not both simultaneously.

As I have been always saying either you are in inside the hall or you are outside. You cannot be both only God is only present. So, then what you do, if this happens then put u i equal to corresponding limit; that means, either it will be u max or it will be u min, it cannot be both and proceed, because you cannot have gate opening more than the gate. Suppose you have a 10 rupees, you cannot spend more than 10 rupees that is upper limit, so spent 10 rupees only.

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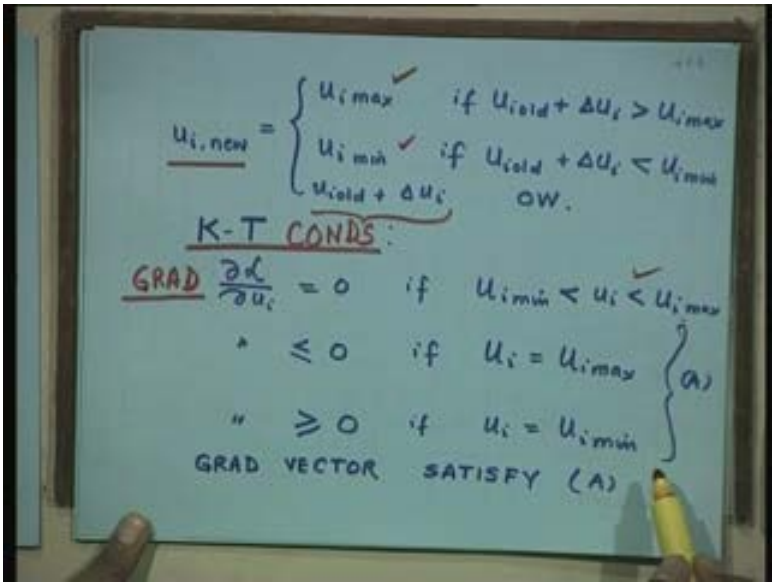

So that means, u new will be either equal to u max, if the upper limit is crossed, u old plus delta u i is greater than u max or it will be u i min, if lower limit is crossed. If the u new is between the limits, then put equal to whatever is the value you are getting, otherwise OW is otherwise, this should be clear to you. So, u new u will take one of the three values, when there is inequality constraint either it will take the upper limit or lower limit or actual value which lies between the two limits.

Now, K-T is Kool-Tooker conditions, I hope you have by now, master this K-T conditions, because we are applying them again and again and again, what do this

condition tell, please read them in appendix e of anyone of the books, they say these are only necessary condition not sufficient, I already explained you, what is necessary condition and what is sufficient condition, for you to pass the course it is necessary to appear in exam not sufficient, you are to do well, you have to get certain amount of performance. So, this is the meaning of necessary and sufficient conditions.

So, the necessary conditions are the first order partial derivatives of lagrangien with reference to all the dependent variables should be 0 after that than using those necessary conditions, you write gradient and these are… that is why, I am not repeating K-T conditions here, now this is a gradient, because after all those gone to the conditions you get the values that we have seen last time, you substitute jacobian, put the value of lamda, ultimately you get the value of the gradient. And get it to be 0, but that was a case when there are no constraints, no inequality constraints, but with inequality constraints gradient get modified into three parts, it should be 0 if everything is within limit, like last time, but if you have put u i is equal to u i max then gradient should be negative less than equal to 0 or if u i you are put u min then gradient should be either positive or 0, this is called semi positive definite and semi negative definite, which you must done out in control system, I do not know whether you read control system or you forgotten.

So, gradient vector should satisfy this A, three conditions as an when there are constraints on inequality constraints on control variables. It is, so it was easy to handle inequality constraints on control variables.

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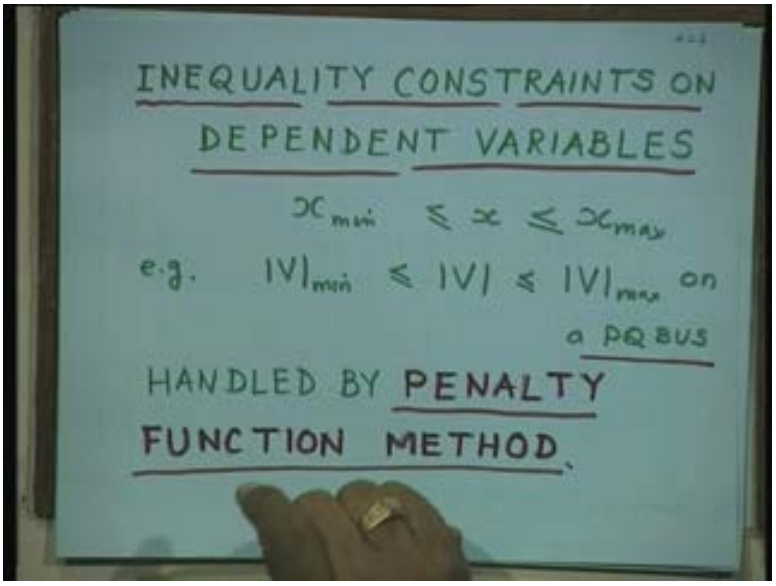

But if you have inequality constraints on dependent variables, then what you do, you cannot do the same thing, you cannot put that equal to x max and x min, you have to do something else, what we are talk about it now, x has to be between x min and x max, what is x, lets a voltage on a PQ BUS, which is not a control variable, because it is dependent variable on a PQ BUS, what are control variables P and Q that is given to you, what is not given to you is V and delta.

So, V becomes a dependent variable, so V must lie at each bus between a given minimum value and given maximum value, handled by penalty function method, this saying one of the ways. In this class I cannot talk about all the different ways, the best way to handle constraints on inequality constraints on dependent variables is by using penalty function method.

Now, what is a penalty function; that means, I am treating them as a soft constraints, it is not like a gate opening, you cannot open the gate beyond the limit, it is a soft constraint like class, I can always finish beyond one 5 minutes, you won not mind, if I take extra 5 minutes, but exam, no extra 5 minutes are normally given, you have to submit your… Specially in IAS exam in Indian engineering services or any important Gate exam, Je exam, nobody say ,take extra 5 minutes, nobody he will be hanged, tomorrow it will be a headlines particular centers 5 extra minutes were given, so cancel the exam. So, that is the hard constraints.

That means when I say penalty, it means I allowed certain deviation, but I penalized it is like a book, if you want to… if you are not… If you failed to give back to library on that upper date, I do not know whether now a days in hi-tech thing is there in a ours a days is to be a tapper, tapper means 15th December. So, you have to whether it is delivered the book back before the time or at the most 15th December, but suppose you have exam on 16th, you give the book on 17 th or 16 th, he will make the most charges you some penalty of some 1 rupee fine or he will give you some piece of advice, do not do it again that is a penalty.

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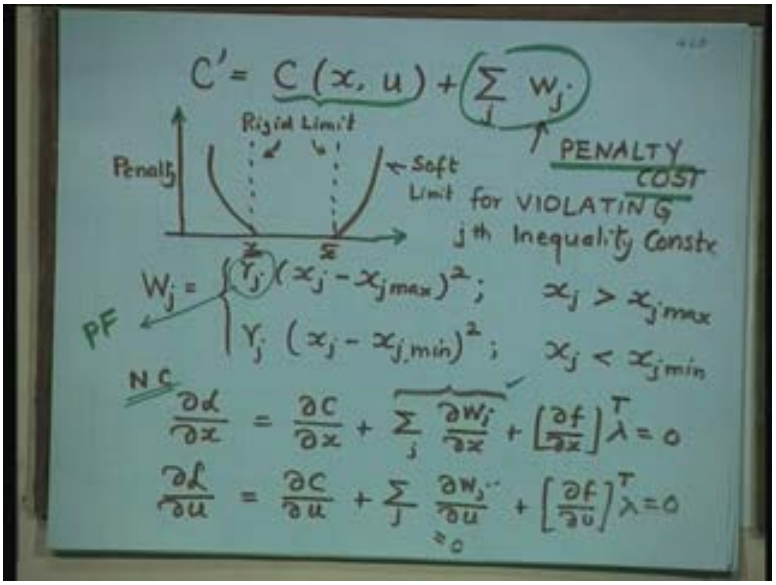

Now that means the original cost C (x, u) now get modified by adding the penalty cost, this is called penalty cost. So, now you have to minimize, original cost, fuel cost plus penalty cost, you cannot give penalty as much as you want, can you deliver the book after 1 year, no he may take the penalty almost the cost of the book, it is better to purchase the book rather give penalty for 1 year. So, this penalty does not mean, you can have any amount of penalty cost; no this has to be a part of minimization process. So, C dash is the new modified objective function, original objective function plus cost function.

For violating j th inequality constraints, this is the cost W j all such constraints summation j. So, total penalty cost is sigma j W j all variables will not cross limits, otherwise is something wrong with your definition of limits. Suppose, you put your

limits so stringent 0.99 per unit to 1.01 per unit all the PQ was voltages will cross the limit, because you foolishly kept such a limit which is not possible in India, because voltages go minus infinity to plus infinity. So, you have to at least put 0.9 per unit to 1.1 per unit then it is likely that some of the variables, voltage variables will not cross the limits. So that is why, I have put it here j, otherwise I put all j.

This is the graph which is very important to understand Y axis is penalty cost, x axis is the x variables, if It is between x lower bar means, x min there was no place to write min. So, I have to written x lower bar, x upper bar means, x max why upper bar and lower bar are not normally used, because it can be misunderstood by vector sign and even lower bar some people write for some special meaning.

So, I write x min x max with no confusion, but here, because of the space constraints, let me use the word constraint, I put x lower bar and x upper bar, if there between this two limits, no problem this dotted line which is the Rigid Limit no penalty, penalty is 0. The moment x crosses either the upper bar or lower bar this quality curve is there. So, penalty starts increasing moment x crosses limit and as it moves away from the limit, the Rigid Limit, the penalty also increases, the penalty cost characteristics you can choose, it can be quadratic, it can be cubic, it can be exponential, suppose they are very strict, if you give book after 10 days, you can see you are suspended or 1000 rupees that is various stringent penalty.

This is the model, I have chosen W j is equal to gamma j x j minus x j max whole square, gamma j x j minus x j min whole square, luckily one of the two will be there, as I have been repeatedly telling you, either it crosses upper limit or it crosses lower limit, you cannot have both, so it crosses upper limit this equation, if it crosses lower limit this equation and gamma j is called Penalty Factor, not power factor, but penalty factor.

It is up to you to choose, what penalty factor you want, I will talk, I will comment on this selection of gamma j after some time, why have put square here, penalty cost should be positive, you cannot have negative penalty, you cannot given award for someone for not giving book in proper time, no problem, well done, here 1000 rupees for you, I think no where no library will give you reward or award for depositing book late, no appreciations for that hence we had to have positive penalty cost, so square.

Now, the necessary condition are Kool Tooker conditions gets modified, you get the W j also terms here, which is quite understandable, because W j is definitely a function of x x, because W j is on x, naturally u which is 0 is no penalty on u. So, whenever u is constant it will be 0. So, these are the modified Kool Tooker condition equation, now you have to solve them and again same gradient vector, consider your that necessary condition gradient should be 0 within certain limits, within epsilon is 0, optimization is reached, if not use this gradient to find out u new, u new is equal to u old plus alpha times gradient, alpha is gain is a Keller, we already commented on alpha, how do you select alpha.

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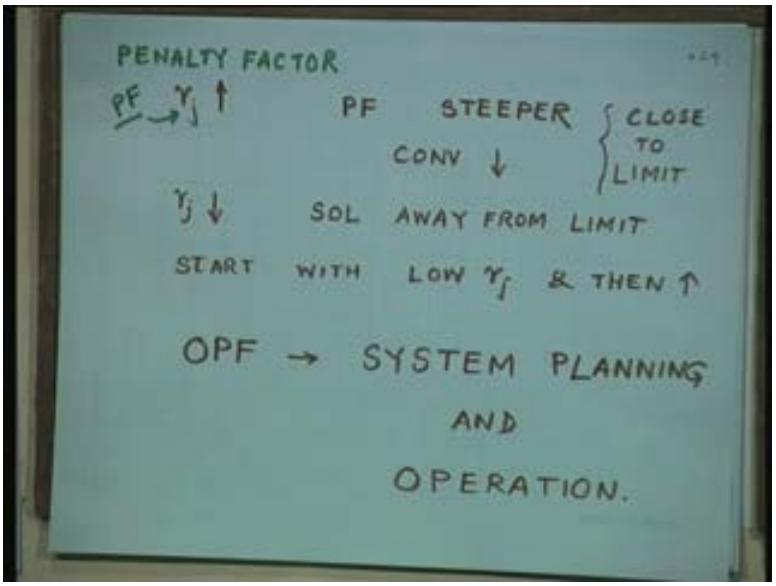

I promised to you that I will comment on gamma j, what is gamma j, gamma j is nothing but Penalty Factor, if you want full name.

I given you that beautiful example of IIT Delhi coming from aims to Gudhupinar, but oscillation, I will explain you. Similarly, this penalty factor, it is for an analyst for a control engineer, for a energy engineer to choose the value from past experience, past experience always helps you a doctor, he must have taken such patient several times he must operated the Siddhartha heart operation number one in the country must operated some several 1000 bypass surgeries. So, he has a vast experience behind him. So he knows how to take corrective action in real time, if something goes wrong that why everybody wants to be operated by him only which is not possible.

So, everybody cannot we taught by lets a professor Siddhart Roy, he may be the best teacher, but then he has own limitation, constraints. Everybody, may like to go USA, but there is a constraint on H 1 be visa, everybody wants to go and do some job there, but there is somebody should be willing to take you, you can just cannot land in JFK airport will say give me a job, they say go back.

So Penalty Factor if you choose a, varies steeper value. So what will happen, it will very stringent value. It will remain close to limit, the rigid limit have plotted that vertical lines. So, it will remain close to them, but convergence there are problem, convergent down, you know, share market the news it shows share are gone up, shares are come down, even in chemistry you must use this arrow, if there is a precipitate then down arrow, if it is a gas it is I do not know, whether you remember chemistry, I remember, I read read chemistry in 61, it is more than 44 years back, the year when will have to first to release in black and white version. So, my chemistry teacher is to took show me, tell me advantage H 2 hydrogen show arrow, it will give extra mark teacher, because that means, you are telling him look I know H 2 is a gas. So gas means… Or precipitates then down. So, this down shows, the convergence becomes poor.

If I choose a lower value of gamma j, not a higher value, then what happens, solution is away from the limit? Suppose, I convergent 1.5 per unit voltage, what the help, what certain solution you have got, how can I have a 50 percent extra voltage over voltage. So, what is then what one should do, the remedy is the prescription is start with lower value and slowly increase it, if you are not getting convergence and there are several methods available in literature, as an when you do your master thesis for doctoral thesis involving choosing the penalty factor, then I can tell you.

Even if I am not your guide to which paper you should refer to and remember these can be used in any area biotechnology, nanotechnology, biology, physics, because optimization is everywhere, constraints are everywhere medical so, you have this this topic is universal like reliability, everybody needs a reliable operation whether is a engineer, doctor, manager or lawyer you choose a lawyer which will win you the case nobody chooses the lawyer which you will lose the case. So you always ask, what is the record, take record, how many cases you won.

OPF we have just finished, Optimal Power Flow or Optimal Load Flow where do use it, you use it in all system planning and operation, all the time you need this data and optimal data, you just do not need values of P, Q, V delta, you need d values of P, Q, V delta which are the best as per some given condition, as per some given situation. So look optimal load flow, you need to run all the time, whether it is a planning operation, whether it is a system operation real time online. So, you have to have a software ready, in any power utility, whether it is power grade or NTPC or it is the EPRI in US - Electric Power Research Institute where you can all go or BBA or department of energy various institution, you need to have this software.

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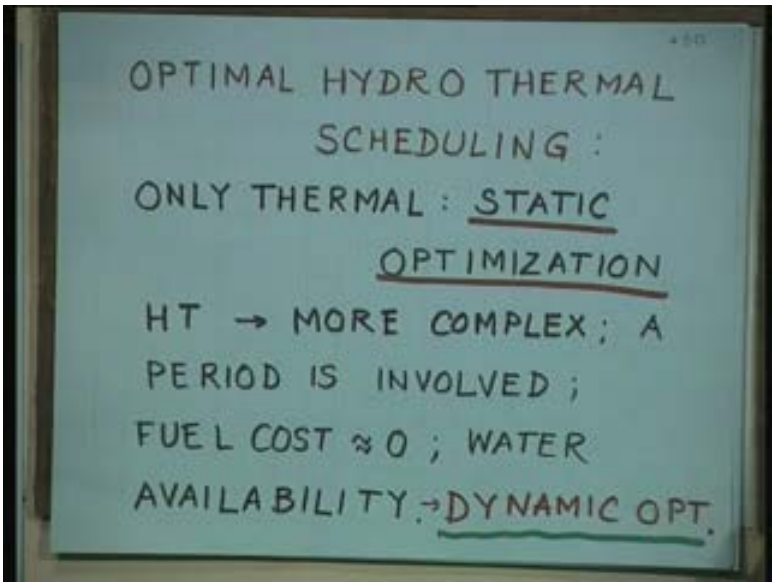

Well gentleman, Now we come to the last topic of the last day and it is very important for our country and for several countries where there is a mix, hydro thermal mix if you are pure thermal, no problem, if you are pure hydro like Norway and Sweden no problem, but if you have a mix like India, Australia, Japan even US there is bit of hydro, then you need to find out, how much hydro and how much thermal, scheduling means you to schedule the amount of hydro power generation and amount of thermal power generation to satisfy a given load.

As I have been telling you, right from the first day in India, we have 72 percent thermal, 24 percent hydro, 3 percent nuclear and 1 percent renewable, for which you are doing your M. Tech, it is largely in renewable energy sources, but that one percent is very

important, because that is what one percent is we should become 10 percent by 2020 and it is the hope of all villages, where there is no grid.

Even nuclear can be modeled as thermal. So, you have to find out only fuel cost is different, it may be uranium, it may be thorium, it may be plutonium. Even in thermal it can be coal, it can be oil, it can be gas, if it was always only thermal then it is what, it is very easy to optimize, why it is very easy to optimize, because it is a static optimization, what is static optimization, it is irrespective of the time you are optimizing. Suppose, I am carrying out optimization in Indhraprasth power station or Badharpur power station, how many units are there 5 units.

As long as coal is same, the coal cost is same, the labor cost is same, no pay commission has come your scales are same, your salaries are same, your maintenance cost is same, whether you solve this problem in January, October or November the answer will be same. So, it is a static optimization, the period does not affect the final outcome, but if it is a hydro thermal problem, it is more complex, why it is more complex, a period is involved; why period is involved, you are using a water and water availability over a given time period, it can be a day, it can be a week, it can be a month, it can be a year.

You do not go beyond year for operational problem, planning problem yes, we can go 10 years, 20 years, very short term planning, short term, midterm, long term and very long term, see we are already started saying that 2020 will be a developed country. So, for that we have to work, it do not become automatically 2020 first January has come, today onwards we are developed country, it would not become like that we all of us have to strive, we have to work our GDP should improve, our per capital energy consumption should improve and so on.

What are the parameters to be called oneself developed countries like Singapore is a developed country now. So fuel cost is 0 as per the water is constraints. So, availability water consideration makes it a dynamic optimization; that means, you working for a given period and dynamic optimization problem is always more complex then static optimization.

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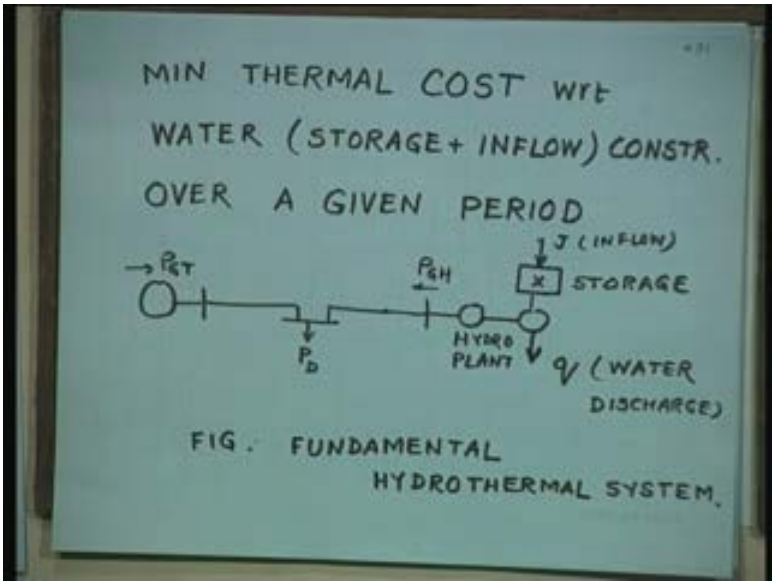

We still try to minimize thermal cost with respective to constraints, what are the constraints, main constraint is water constraint. Two types of water constraints storage, (( )) reservoirs, inflow, how much inflow is available; that is a data of course, so depending on this, they we have to minimize over a given period. Period either said can be day week, month, year. Here is the simplest possible hydrothermal system drawn, why simplest possible, he has to at least one hydro station, one thermal system to justify calling it hydro thermal system; that is why it is called Fundamental Hydrothermal System, because you cannot go below this, here is the thermal power station, here is the hydro power station, here is the load, this is a P G T power generation by thermal plant, P GH power generation by hydro plant, this will…

You will now learn, how to specify suffix, prefix, subscripts, you know, why G, G generation, why T, T is thermal, you cannot write anyone of the A, B, C, D here. So, this make sense, P is power, so power generation by thermal plant, this is a hydro power plant, this is J is inflow universally J is used as inflow, X is a storage and this is the water discharge q and here is turbine we generates power and power goes to the grid water discharge, the control variable here is water discharge gate opening, we should know anyway, because of AGC he must have done hydro thermal system in AGC.

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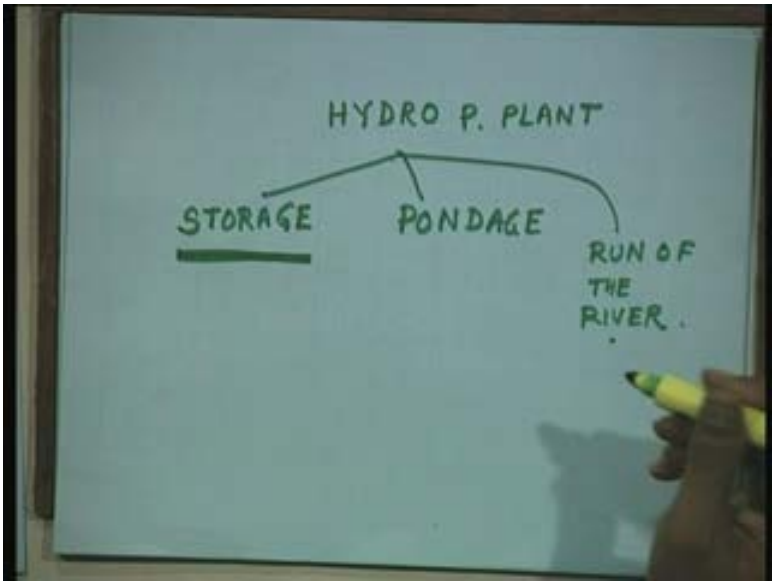

Let me tell you one more thing, hydro power plants are of three types, we are interested in storage types, because optimization is only possible in storage tank. The second one is pondage type and third one is run of the river. Here, we are not considering small hydro, which is renewable, no this hydro is also renewable, but small hydro is normally considered in our non conventional energy sources below 15 megawatt, 1 to 5 megawatt is min Hydro Power Plant, below 1 megawatt is Micro and below few kilo watts is Nano and now a days is a area of Nano, everything Nanotechnology.

Idea is whatever power you can generate, it is welcome, it is power is a commodity which is in short supply at least in developing world; storage is something where you can really apply optimization, what is pondage, what is coming all the time, but you cannot control it, why you cannot control it, you cannot store it, it is coming, so put a turbine and generate power and feed it to grid, but there is no control, there is no optimization, this is a bonus, it is not a salary, you get a bonus once in a year and use it way you want to use it, it helps to improve your you know, condition, lifestyle.

Run of the river is as an when water comes use it, like a deleverage as an when he gets offer to come, he comes to IIT everyday at 8 o clock or today are not required sorry he goes back go somewhere else, so as an when there is snow melts, water comes use it, if it is not there, do not use it.

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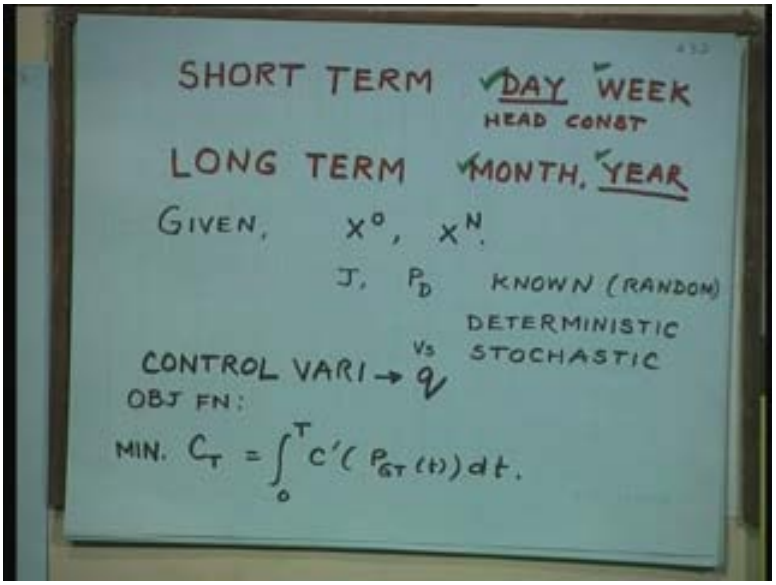

The hydro thermal optimization problem is divided into two parts, short term, long term. Short term is a day or a week; long term is a month or a year, as I told you operational problem cannot we consider more than year, there is no sense, like we give a time table semester wise, tomorrow somebody will ask what about 2007, what will be the time table like is that referred you fool 2007 is per half.

Even 2005 first semester time table is not at given, why we want to divide into two parts, somebody may ask, normally you do not ask question, but suppose you ask me question, what is the grade to show what, why do not you call it same, whether it is a day or week or month or year, it is a hydro thermal optimization? No, the constraints change. If it is a daylong problem you are solving, the head is likely to remain same, you treat a constant head (( )) head will not change drastically today the 23 of November, what is 23, it 5 am whatever was head, it is likely to remain same more or less, it is so huge reservoir, but for a month, head can change. So, head variation must be taken into account if you are solving long term problem, you have perhaps ignore losses, when you solve a day long problem, but in a month long, yearlong problem, you cannot ignore losses.

Here I not talking about only PL that is transmission line losses, I am also talking about seepage loss, what is seepage, in your hostel room may be in better room, but in some of our houses there is always a (( )), the walls are always wet, given data initial water storage, suppose you are solving year long problem. So first January, what is the water

storage you know, end of the year what should be water storage you also know, 0th is beginning, N is final. Initial water storage and final water storage is given to you.

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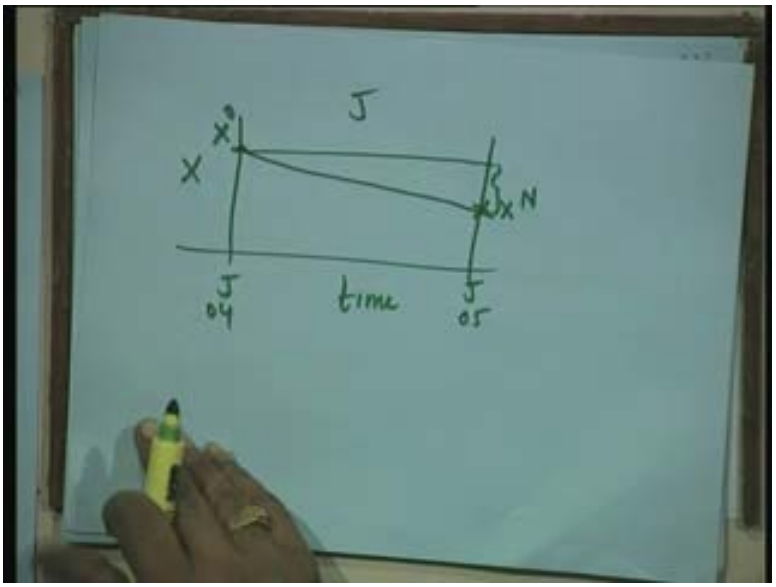

So, within that what I am specify, I am specifying the water availability, how much water you are entered to use. For example, storage is shown by X this is time, January this is the water storage X 0, this is the water storage in the January of 5; that means, this is the water, I can use provided there is no inflow, because inflow you have to consider that also; that is additional bonus water availability.

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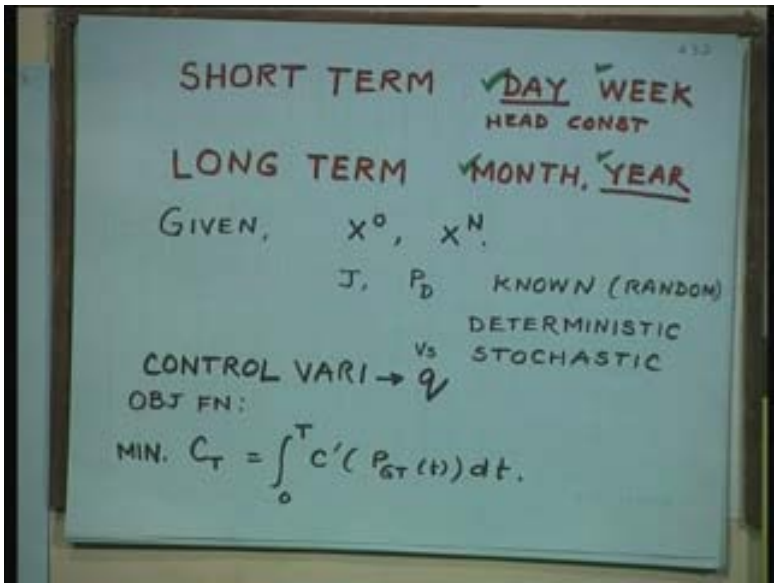

Of course, you are given inflows and power demand, they are known, out of these 4 these 2 chaps are random variables, I hope you must have done enough of stochastic control In your under graduate and post graduate, at least you are done it, which is very important topic, truly speaking in life nothing is known with certainty, which grades you are going to get in this semesters, nobody knows you only make a guess, may be correct guess, because you know, minor one marks you know, minor two marks and you are likely to perform, but again is a function of type of paper, it is a type of examiner, the examiners mood on the particular day and so on. So, it is a random variable.

When you get a telephone call nobody knows, suddenly tring, tring, of course, now a day's cell phone means all the time it is on. So, you can predict everyone minute you can get a call, but the land line call, you really do not know when it will come, customer in a shop, when customer will come, nobody knows a death, though it is a certainty, but when it is going to come, I do not think anybody knows.

So, water inflow and load these two are random variables and if you consider the random variables then the problem becomes stochastic scheduling of hydro thermal system, but I am going to consider only Deterministic, Stochastic may be next time, because it is very interesting and very fascinating to deal with stochastic problem, because then you have to minimize expected cost, standard deviation, the moments, they all coming to play, the best book in this case if you want to learn random variables is populous and that is the wonderful book random variable and stochastic processes.

Control variable you have chosen is q. Objective function is minimization of C T integral 0 to T C dash P G T t dt, t is a total period day, month, week.

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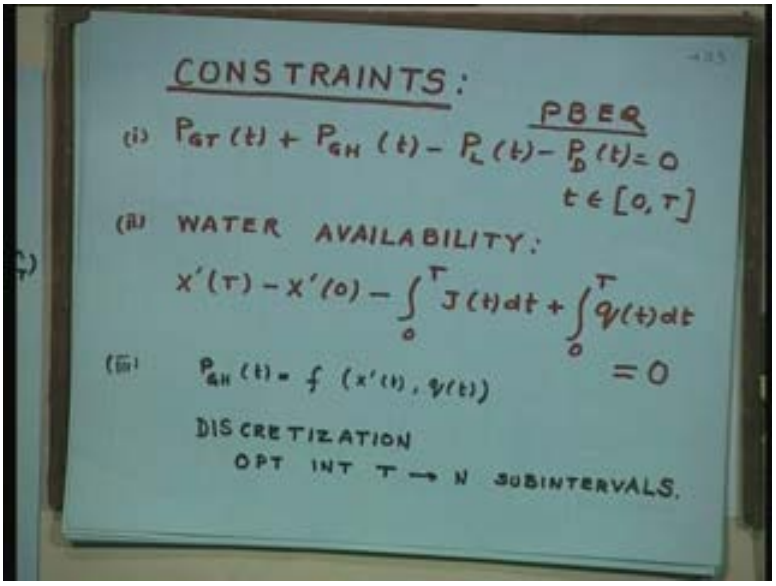

What are the other constraints: total Power Generation Thermal plus total Power Generation Hydro minus loss minus demand should be 0 within this time period 0 to T, I think you know, this thing if it is square bracket including 0 and T, if it is a small bracket leaving that final point, both small 0 and T both are not considered. So you know these things. Water Availability: the final water storage minus initial water storage must be equal to total input minus total output, I hope this is clear to you.

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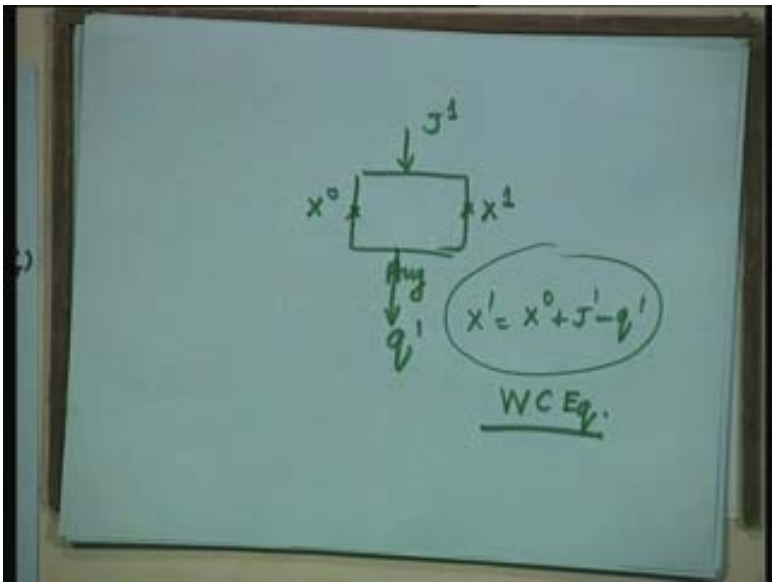

This is the reservoir, lets a month of August, in the beginning of August this is the water storage, at the end of August this is the water storage, during August this is the inflow and outflow is or discharge is q 1. So, X 1 is equal to X 0 plus input minus output, this is called Water Continuity Equation, Water Continuity Equation wish you must have done in control system plant equation

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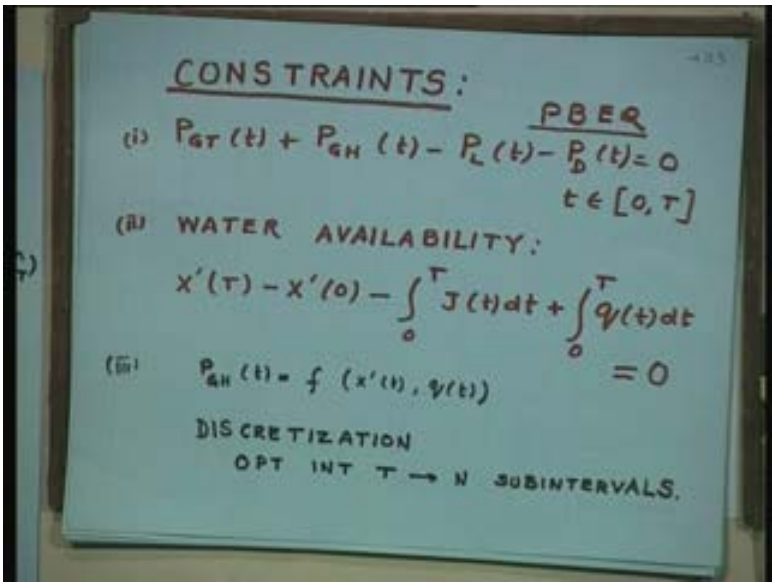

So water availability is this and hydro power is defined as head into water discharge, but if you want total equation, it is a function of storage and water discharge, I will give exact equation after 2 minutes, but nobody solves now problem in continuous time variables, all of you must be intelligence enough to understand by now, see you are using computers, we discretize the problem.

So, computer won't take continuous values, it you have discretize; that means you have to have a subinterval, if it is a day 24 hours divide into 8 parts, 3 hours each. If you have more for see 24 hour, 1 hour each. So, optimization interval T is divided into N subintervals. Week 7 days, month 30 days, year 12 months or 365 days or 52 weeks depending on what you want.

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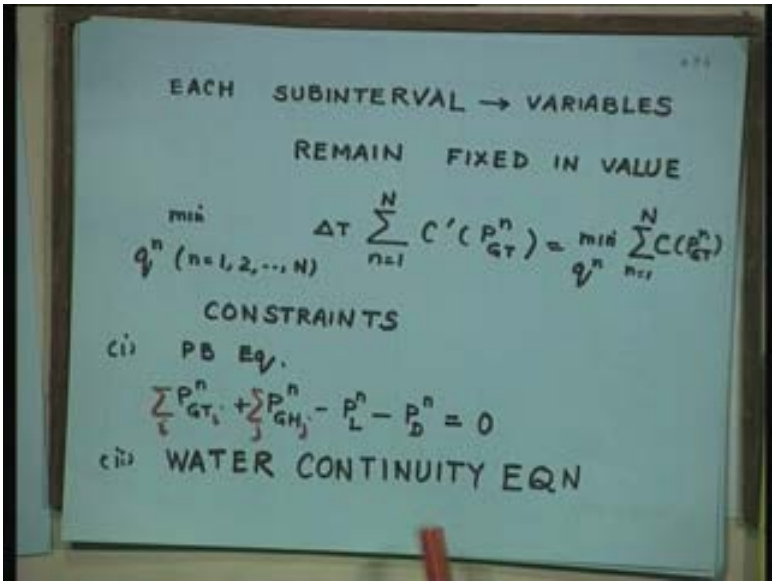

We assume that in each subinterval variables remain fixed in value, otherwise it is very difficult to handle the problem, if I am considering 1month as a sub interval during that month inflow is constant, outflow is given, the water storages are given anyway in the beginning and the end of the period otherwise there will be caves.

So, now the problem is you want to minimize delta t times the cost with reference to the control variables q n and this can be, delta T can be observed with C dash C P G T n, n is during nth interval, thermal power generation during nth subintervals, maybe a day maybe a hour, maybe a week, maybe a month and so on.

What are the constraints, power balance, these is our old (( )) total power generation, why there is no sigma here you are just talking about one thermal power station, one hydro power station, if you say what is this, this is not practical, you have there i, you have here j, as many hydro stations, as many thermal power station, so without loss of generality, I have written here power balance equation. Water continuity equation, I have just explained you, using that plant equation model.

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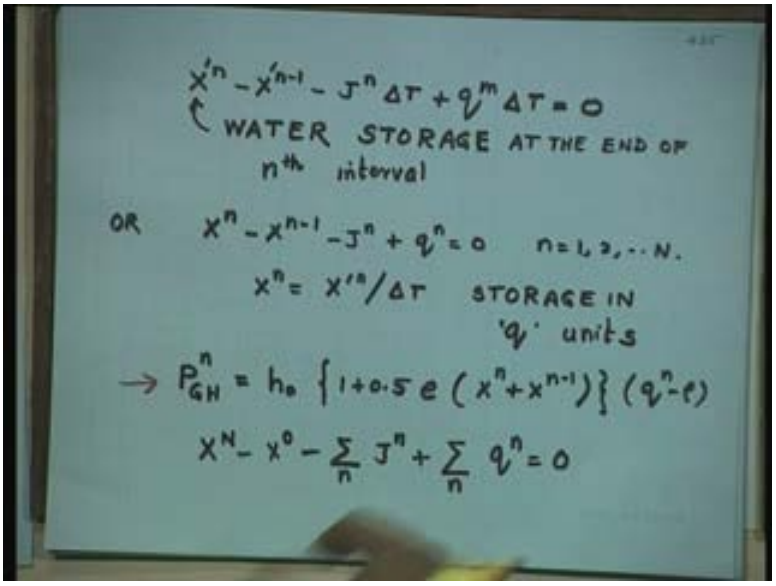

So, water storage at the end of nth sub interval minus at the end of the n minus interval is equal to J minus q, if you transfer it to left hand side then you will get this. Now, if you convert the unit of storage into discharge unit, then you get read of this delta T, because if you divide by delta T, X meter cube becomes meter cube per second, q max. So, they all become in the same units and hence, I written this x n minus x n minus 1 minus J and plus q n is equal to 0, n is equal to 1, 2, N. And P G H n this is the equation, I promised you that I gave you a hydro power equation.

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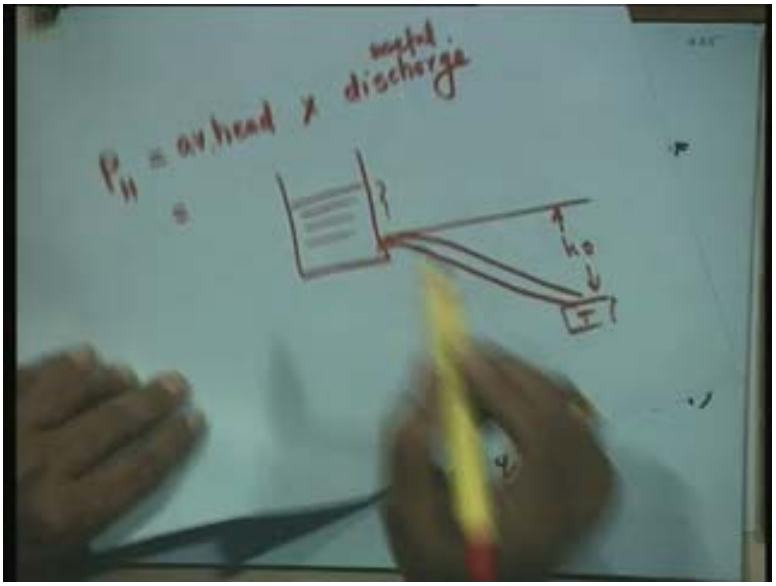

So, what is this hydro power equation, it needs slight explanation, hydro power generation is equal to head into discharge, head is an average head and discharge is useful water discharge. So average head is this, if the storage varies convert into the head unit, take average add to one, this is average head and 0 is the basic head. What is basic head, if this is reservoir, this is pen stock, this is your turbine, then this is your basic head as 0 and then depending on the water storage head varies, this what I have done.

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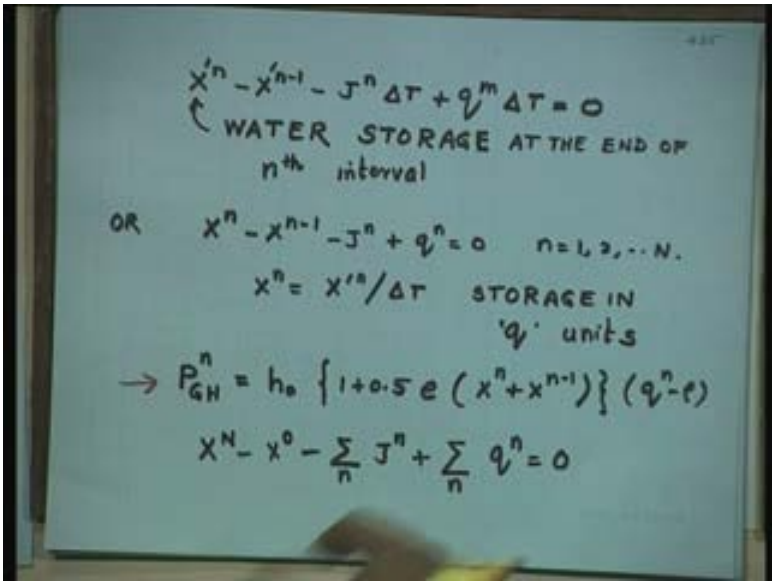

h 0 is basic head, one is a convergent unit this explained in the book also, you can see the book and q n minus rho is effective water discharge, this rho is non effective water discharge means it includes what, seepage evaporation, you cannot stop water evaporating, because sun is there. In some countries, where water is scarcity like Middle East, they have developed a substance solid, which you put in water the evaporation rate gets slow down to shown on TV, Tablet Phone for, but still it cannot be 0.

If I eat anything, I am definitely adding calories even if it is a diet coke, even if it is a low salt, low calories, stuff, only bread no butter no bread pakkoda, still the bread itself is a food and I am adding it to eat, if I it. So, this subtract non effective your discharge. So, this is the equation which is used throughout the world for hydro power generation; that proof of this, derivation of this is given in the book, since time is limited, I am not able to take it up here; however, you are free to read it if you so desire, this is again water availability equation, final storage minus initial storage minus summation of all

inflows plus summation of all discharges must be 0, final minus initial input minus output. So, this is water availability equation.

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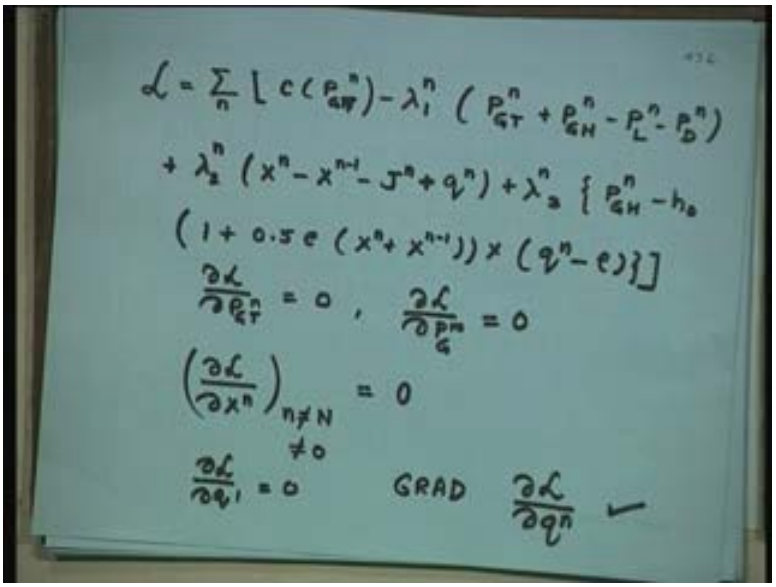

Now, as usual you formulate your lagrangian, how do you formulate your lagrangian, I have been talking last several lectures, original objective function augmented by all the constraints multiplied by dual variables, (( )) variables, lagrange variables, lamdas.

So, first constraint is power balance equation lamda 1 n, second constraint is water continuity equation lamda 2 n, third constraint is water power generation, hydro power generation and then apply your Kool Tooker conditions, differentiate it with all the dual variables P G all dependent variables rather and then calculate gradient, gradient means control variables, what are the control variables here, only water discharge and then see if it is zero if it is zero you converged, you optimized print out data, what is hydro generation, thermal generation, loss, storage, discharge for your benefit, this is what is happening all the time, where hydro thermal operation DVB - Dhamodhar Valley Corporation (( )) you know, authority there wherever there is TATA, TATA have hydro station also near Kohinoor and others.

Now if there are constraints, inequality constraints on control variables treat them in the same way, as you have treated in the optimal load flow, what we do we, equate it equal to q max or q min, q is a control variable. So, if q crosses certain limit equate it, because who will cannot get water gate opening beyond a limit.

So, you have to equate it equal to q max or if there is a minimum water discharge, limit crossed then you have to equate it equal to minimum, why? You may need water for something else irrigation, flood control, navigation, drinking, washing, water is a multipurpose job it does and continue and gradient vector does not become only 0, it becomes more than equal to 0, if it is crossing a lower limit, it becomes less than equal to 0, if it crosses the upper limit like we did it today itself.

Now if there are constraints on dependent variable, storage, well penalty function method, now there will be several penalty function here, because several dependent variables, water storage is a dependent variable, thermal generation itself is a dependent variable, so you have as many penalty function.

Now that terms will appear in this Kool Tooker condition, calculate the gradient again see whether you satisfy the optimality conditions are not that is the three conditions, gradient 0, gradient positive or 0 for lower limit, gradient negative or 0 for upper limit and then that is the problem is solved, you can instruct your operator a look operator this value, operator that value and you get optimal hydro thermal solution.

If there is a nuclear also well that is again you can model it like a thermal power plant, again it is a cost equation and normally nuclear is used as base power plant. So, it really does not participate in the optimization, what you do you subtract that nuclear power generation from load and then load the modified load is to be supplied by hydro and thermal, but if you are fuzzy, if you are very sticky no no no I want optimization.

So, include it in this cost function here plus C of P G n nuclear, then you may change this n to n, as I have done in the book, you will wonder why I am use here super script as m, because n may be used as a sub script for nuclear power generation. So, to avoid confusion in both ways m super script n and sub script also n, what is this going on, so to avoid that confusion, in fact I use in that book not n, but m as a super script, m means during m x sub intervals.

So, gentlemen we come to an end here, all good things come to an end though will like to continue, but then constraint, this is the hard constraint, today is for our last lecture. So, I enjoyed talking to you all this semester, hope you would also enjoyed it and I wish you all the best for your exam on 27th and this is not the end, this is only the beginning we continue it our association, where ever your through email or whatever IT technology

any difficulty you have so far in any lectures, whatever you have delivered, you are most well get them to ask now there are 3 minutes or you are welcome to contact me wherever I am either, I am in this office or house or wherever. And if you have anything, please let me know right now, otherwise…

Regarding numerical, there is one numerical solved in the book, you can read it, and normally you need a computer to solve a hydro thermal power problem, even if you want hydro and one thermal. So, I will appreciate someone can develop a program on mat lab and see whatever I have solve the problem is ok or not, whether it converges or not.

So, one of you can do that if you feel there is no time here, you can do it after the exam just for your satisfaction, the algorithm works or not, you feel happy, if you get the same results which I have got it.

Anything you want to say, you are our guest, no, no questions, no queries, exam will be my thirteen marks question the it may be (( )) two questions or one big question, the main thing is marks will be 13. And the time required will be one third of 2 hours that is 40 minutes, but you do not have to it is not a rigid constraints, you can do my portion in 30 minutes, save those 10 minutes and put it into other teachers questions, then All the Best.