Power System Analysis
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 37
Optimal system operation

So, we have just now this thing discuss regarding incorporation of P and PQV buses in the load flow algorithm right.

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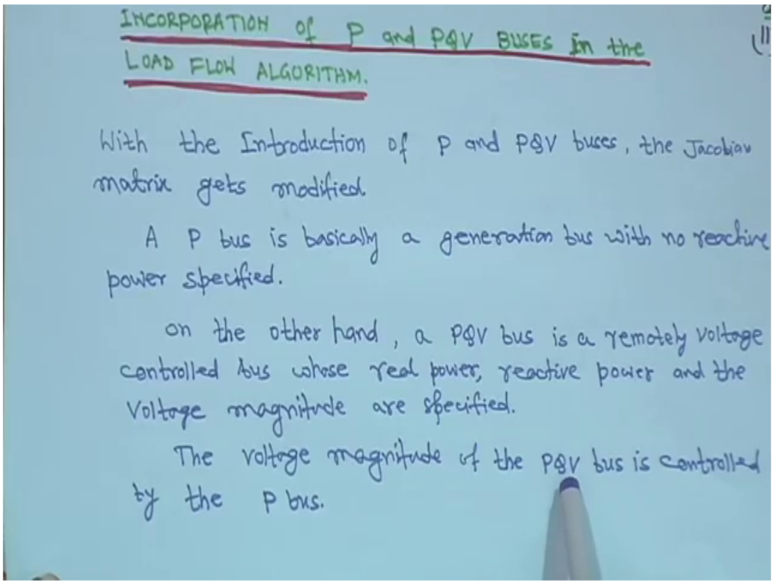

INCORPORATION of P and PQV BUSES in the LOAD FLOW ALGORITHM.

With the Introduction of P and PQV buses, the Jacobian matrix gets modified.

A P bus is basically a generation bus with no reactive power specified.

On the other hand, a PQV bus is a remotely voltage controlled bus whose real power, reactive power and the voltage magnitude are specified.

The voltage magnitude of the PQV bus is controlled by the P bus.

So, just we have told that a that remotely located bus voltage can be control from another bus that is called that is called P bus from P bus 1 can control that voltage magnitude of your what you call that PQV bus right.

So, P bus is basically a generation bus right with no reactive power specified right. So, at P bus only P is specified that is known; unknown is that voltage magnitude angle and the reactive power right. So, on the other hand in the PQV bus is a remotely voltage control bus right whose real power reactive power and voltage magnitude all 3 quantities are specified at PQV bus, but delta is unknown at PQV bus right.

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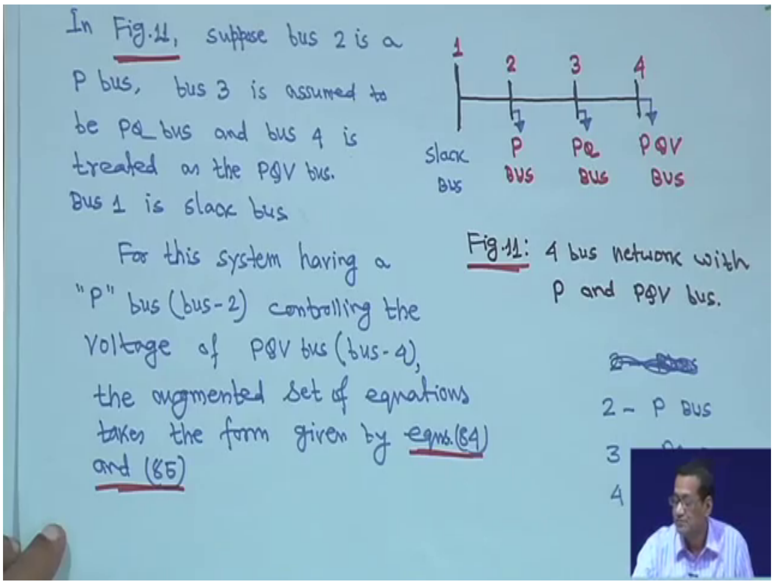

In Fig.11, suppose bus 2 is a P bus, bus 3 is assumed to be PQ bus and bus 4 is treated as the PQV bus. Bus 1 is slack bus.

For this system having a "P" bus (bus-2) controlling the voltage of PQV bus (bus-4), the augmented set of equations takes the form given by eqns.(84) and (85)

Fig.11: 4 bus network with P and PQV bus.

2 – P BUS

3

4

So, the voltage magnitude of PQ bus is controlled by the PV bus. So, what will do in that in this is class room excise. So, just will explain that regarding the formation of Jacobian matrix for this kind of consideration of P and PQV bus we will take a small example and with that we will see that Jacobian will be form right for example, you consider a simple redial network that you have 4 bus one 2 3 4 there are 4 buses right.

This bus 1 is a slack bus this is slack bus then this bus 2 we have assume is a P bus right bus 3 we have assumed it is a PQ bus and bus 4 it is a PQV bus right. So, it is a small example to show that how Jacobian can be form right. So, bus 4 that voltage magnitude is specified it is not a PV bus it is PQV bus PQV all the 3 quantities are specified and from these bus. So, it is a remotely look it is bus for example, say by you from these bus you are controlling the voltage magnitude of these bus then we have P is known Q is unknown; that means, you have to inject sufficient Q at these bus such that these voltage magnitude can be maintained right; that means, we have to see the how Jacobian can be form.

So, bus 2 is a P bus here I have written here I have written here bus 2 is a P bus; bus 3 is a PQ bus and bus 4 is PQV bus right. So, for this system having a P bus right you are controlling the voltage of PQV bus that is bus 4 the augmented set of equation takes the form given by equation 84 and 85 right; that means, if you if you see the delta V.

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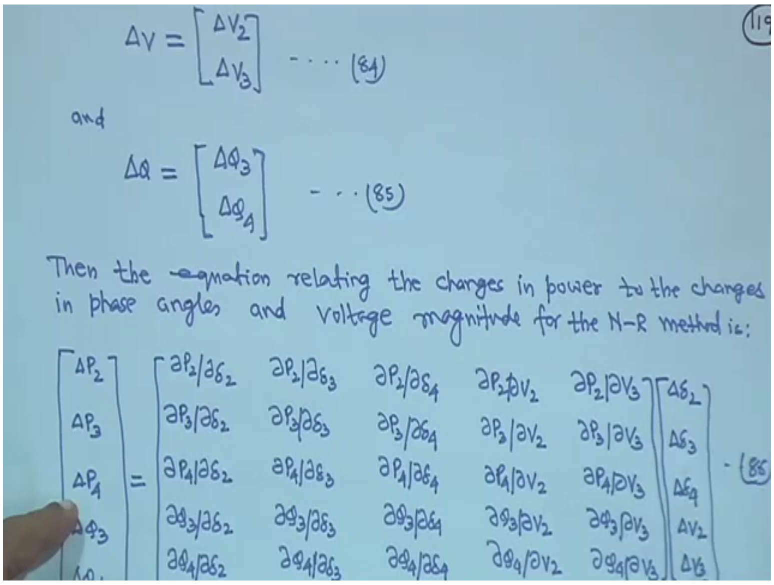

$$\Delta V = \begin{bmatrix} \Delta V_2 \\ \Delta V_3 \end{bmatrix} \quad \cdots (84)$$

and

$$\Delta Q = \begin{bmatrix} \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} \quad \cdots (85)$$

Then the equation relating the changes in power to the changes in phase angles and voltage magnitude for the N-R method is:

$$\begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} = \begin{bmatrix} \partial P_2/\partial \delta_2 & \partial P_2/\partial \delta_3 & \partial P_2/\partial \delta_4 & \partial P_2/\partial V_2 & \partial P_2/\partial V_3 \\ \partial P_3/\partial \delta_2 & \partial P_3/\partial \delta_3 & \partial P_3/\partial \delta_4 & \partial P_3/\partial V_2 & \partial P_3/\partial V_3 \\ \partial P_4/\partial \delta_2 & \partial P_4/\partial \delta_3 & \partial P_4/\partial \delta_4 & \partial P_4/\partial V_2 & \partial P_4/\partial V_3 \\ \partial Q_3/\partial \delta_2 & \partial Q_3/\partial \delta_3 & \partial Q_3/\partial \delta_4 & \partial Q_3/\partial V_2 & \partial Q_3/\partial V_3 \\ \partial Q_4/\partial \delta_2 & \partial Q_4/\partial \delta_3 & \partial Q_4/\partial \delta_4 & \partial Q_4/\partial V_2 & \partial Q_4/\partial V_3 \end{bmatrix} \begin{bmatrix} \Delta \delta_2 \\ \Delta \delta_3 \\ \Delta \delta_4 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix} \quad \cdot (86$$

Delta V will be delta V 2 delta V 3 right and in this because your PQV bus slack bus voltage is known you know and for PQV bus voltage magnitude will also known. So, delta V actually comes under 2 quantities delta V 2 and delta V 3 right this is equation 84 similarly delta Q if you see right at P bus it is is a slack bus right.

So, but P bus there your Q are known right, but bus 3 and bus 4 both are both cases your Q are known. So, delta Q actually delta Q 3 delta Q 4 right, so, 2 variables. So, this is say equation 85 then, but all the cases 2 3 and 4 P bus PQ all cases delta unknown. So, you have to obtain the delta also. So, delta is unknown therefore, if you form these Jacobian matrix of this one then all the cases P is known at 2 3 and 4 there P is known that mean delta P 2 delta P 3 delta P delta P 4 right iteratively you have to see you have to check these miss match.

So, delta P 2 delta P 3 delta P 4 this thing be there on the left hand side and this delta Q 3 and delta Q 4 also will be there. So, delta Q 3 and delta Q 4 right this is your delta Q 4 and then this column will be delta delta 2 delta delta 3 delta delta 4 and then delta V 2 and delta V 3 delta V 4 will not come because voltage magnitude at bus 4 is specified because it is a PQV bus right . So, this that is why is delta V 2 delta V 3 right therefore, this is your Jacobian matrix delta P 2 upon delta delta delta P 2 delta delta delta P 2 delta delta delta 2 delta P 2 delta delta 3 and so on delta P 2 delta V 3 right.

Similarly all these you have seen how to find out Jacobian matrix. So, right similarly delta P 3 delta delta 2 delta P 3 delta delta 3 and so on up to delta P 3 delta V 2 delta P 3 and delta V 3 this way this way the Jacobian matrix will forms. So, in this case the if you look in to that this matrix actually order is 5 in to a 5 right.

So, this is actually; that means, Jacobian is form right and if the iteration your trying to find out what is the miss match and automatically from that your trying to compute this right hand side delta delta 2 delta delta 3 delta delta 4 then delta V 2 and delta V 3 and you are updating iteratively right therefore, your this thing what you call then.

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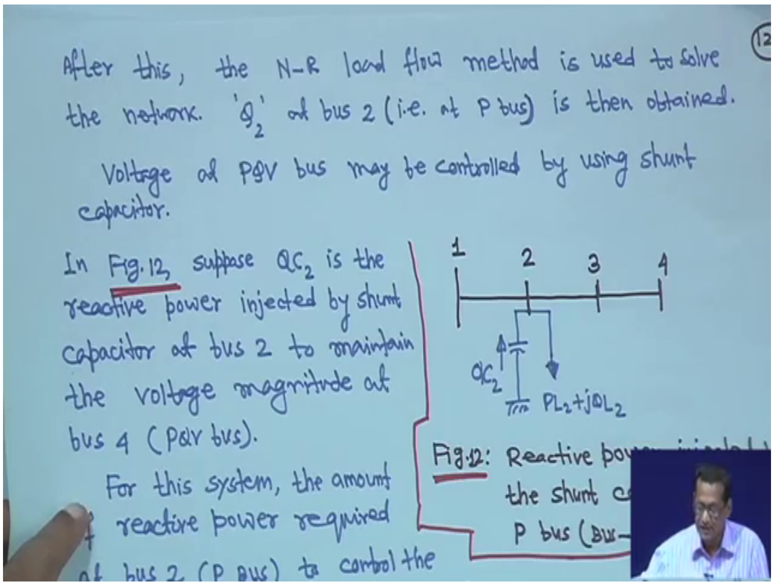

After this, the N-R load flow method is used to solve the network. 'Q_2' of bus 2 (i.e. at P bus) is then obtained.

Voltage of P&V bus may be controlled by using shunt capacitor.

In Fig.12, suppose QC_2 is the reactive power injected by shunt capacitor at bus 2 to maintain the voltage magnitude at bus 4 (P&V bus).

For this system, the amount of reactive power required at bus 2 (P bus) to control the

Fig.12: Reactive po
the shunt c
P bus (Bus–

After this; that means, after the Newton (Refer Time: 06:11) the Raphson method when your this thing loop for method is used to solve right one network is solved; that means, you have you have solve this network right you have solve these you have what you call that that your this network points of solve this all the bus voltage. I mean here these 2 buses voltage magnitudes angles are known here also angles are known at the same time will load flow you have solve the load flow after solving the load flow right you find out what is the reactive power injection at this bus that is Q 2 right that you can easily find out because all the real power and reactive power injections of the load flow studies have been given.

So, automatically you can find out your what is the reactive power injection that is Q 2 after the load flow studies when load flow is converts right; that means; that means, your . So, when may be controlled suppose reactive power whatever it is power injection right. So, for example, suppose I want to control this is your; this is your PQV bus this bus code is a PQV bus and bus 3 is your PQ bus. So, load flow load flow your has converts actually your got the load flow solution then had bus 2 what will be your this thing what you call that reactive power Q 2 you have to find out for example.

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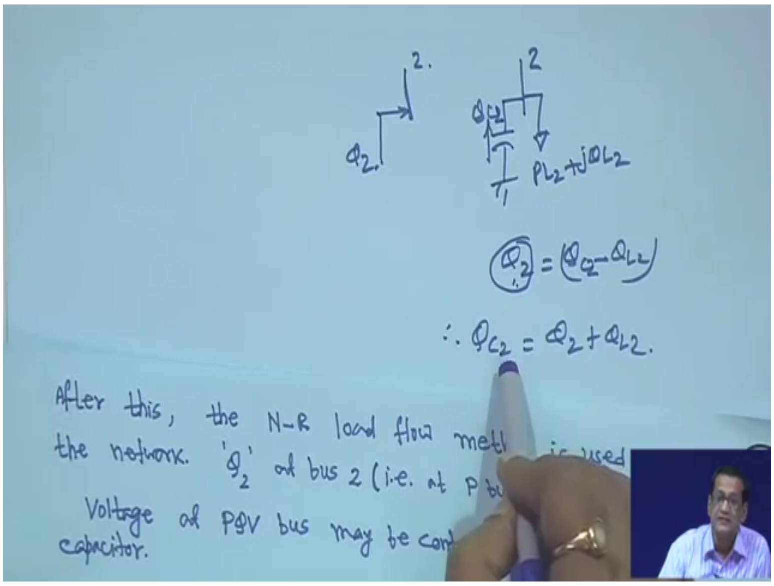

$$\boxed{Q_2} = (Q_{C2} - Q_{L2})$$

$$\therefore Q_{C2} = Q_2 + Q_{L2}.$$

After this, the N-R load flow meth is used
the network. 'Q_2' of bus 2 (i.e. at P bu
Voltage of PQV bus may be con
capacitor.

Suppose this is your bus 2 this is your bus 2 right so, reactive power you have to find out what is your reactive power injection right suppose this is your Q 2 right this is your Q two, but if you see that if you want to control this voltage using a shunt capacitor. For example, say then this bus 2 actually you have a load this is bus 2 you have a load PL 2 plus jQL 2 you have a load right then here suppose if I put shunt capacitor here. So, this is your QC right then what will be this then if you see that this is QC it is qc. So, I can put it is QC 2 because it is a bus 2 say QC 2 right.

Then what will be Q 2 Q 2 will be is equal to QC 2 minus QL 2 right; that means, from the load flow studies this you have obtain Q 2 you have got it and load flow has convert Q 2 you have got it; that means, your this is actually QC 2 right; that means, my QC 2 will be Q 2 plus QL 2; that means, ; that means, this after the load flow studies right you have got the load flow right and after these this much this much of your what you call shunt capacitor. For example, is require that is whatever reactive power injection after the load flow studies you got in addition to that if you have any reactive load here you add that from that only from that concept only right and that amount of reactive power you have to connect here right then you can see you can maintain the voltage magnitude of your what you call that is your PQV bus voltage magnitude right.

Then once you get this value QC 2 got it then what you do take a normal load flow forget our PQV bus anything whatever your network is that take that one and there you connect that these amount of your what you call that capacitor value right you connect it then what you will see that you will see this voltage magnitude is maintained right; that means, the voltage magnitude have remotely locate bus bar can be control from a totally different from another bus right.

So, and this a how to how to select your what you call P bus basically one bus at that day I was this thing previously I was telling that every your what you call you have to chose every bus along these as a P bus and you have to see how loss is minimum. So, you have to find out whose bus is giving the minimum loss of the network this one criteria right and accordingly you find out that what will be the Q 2 injection after the load flow studies and then you find out this amount of your what you call QC 2 that is why right that is why, but your what you call Q 2 is equal to I just told you Q 2 is equal to QC 2 minus your what you call Q QL 2 right ; that means, your QC 2 is equal to Q 2 plus Q l 2 just now we said that QC 2 is equal to Q 2 plus Q l 2 right.

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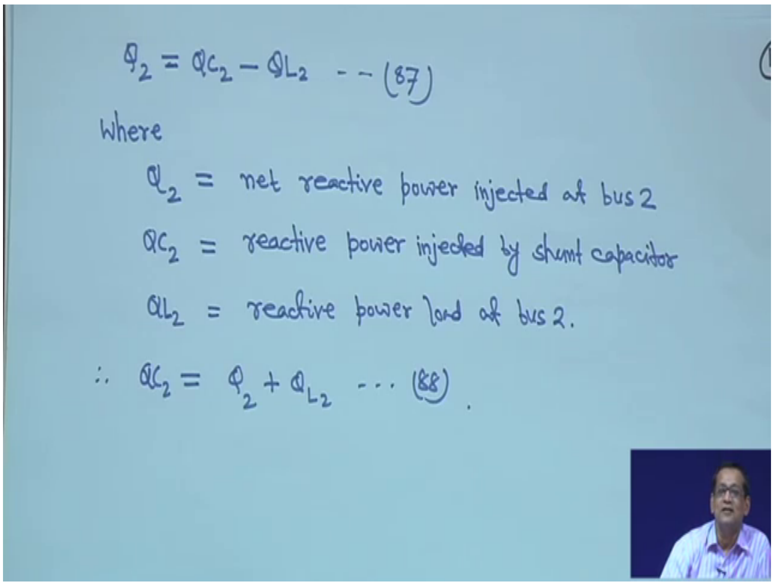

$Q_2 = QC_2 - QL_2$ - - (87)

Where

Q_2 = net reactive power injected at bus 2

QC_2 = reactive power injected by shunt capacitor

QL_2 = reactive power load at bus 2.

$\therefore$ $QC_2 = Q_2 + Q_{L_2}$ . . . (88).

So, this much of reactive injection require for your; what you call for that bus bar right then this is that a actually new concepts are coming in power system. So, this concept of P bus and PQV bus are also coming. So, that is why I thought at list Jacobian matrix formation I should tell you. So, for the load flow studies part your [co/completely] completely I mean more or less completed here. So, in this you have tried to see the Gauss Seidel method then Newton Raphson method and all the your necessary your derivation for law like line flows ride and your what you call line branch losses at the trying that pi equivalent model for a tap changing transformers right and this P and PQV bus. And we have also studied that example how to solve those networks right iteratively at few steps have been maintained step by step such that you have a way your better criteria right better idea right and second thing is that large problem are for this class room study it is not possible for Newton Raphson method because you need computer and you have to this go for coding right, but we have gone up to 3 bus problem and accordingly we have tried to solve right.

So, load flow study is a now over next what we will do that will go for optimal system operation right that is your economic load dispatch just hold for a few for few second.

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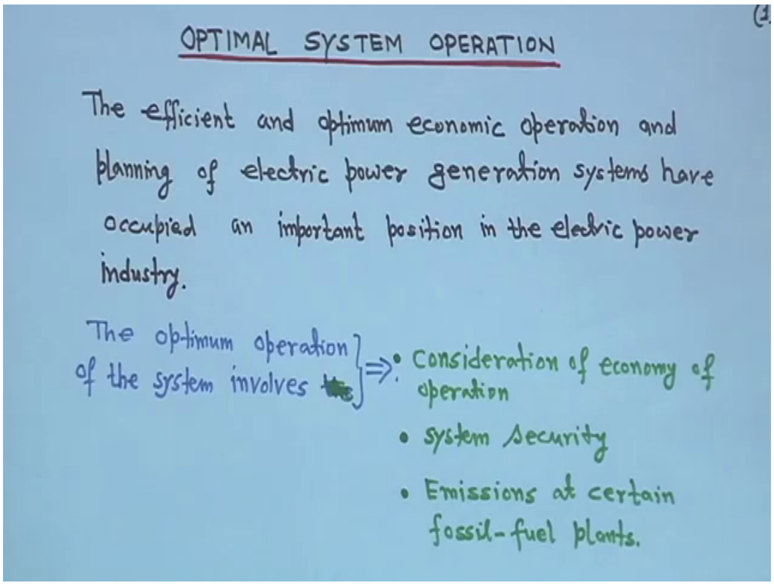

OPTIMAL SYSTEM OPERATION

The efficient and optimum economic operation and planning of electric power generation systems have occupied an important position in the electric power industry.

The optimum operation of the system involves ~~the~~ ⇒

- Consideration of economy of operation
- System Security
- Emissions at certain fossil-fuel plants.

Just hold for few second right. So, now this optimal system operation right is also is you know many things are there many things are there, but to the extend I will go right whatever possible as far as the class room study is concerned right. So, that the efficient and optimum economic operation right and planning of eclectic power generation system have occupied the important position in the eclectic power industry because this optimal system operation an economical economic load dispatch is very important your part of the power system right.

So, the optimum operation of the system involves like consideration of economic operation system security and emissions at certain fossil fuel plants. So, so many things are there. So, we will we will already considered the basic thing right we in this it is a class room excise. So, system security or a emissions of certain fossil fuel plant all this things cannot be covered right it will this will go up to then post graduate level right or even research level right.

So, we will see that all the basic thing that how we can go for optimal a system operation and economic your what you call load dispatch. So, in this way right, so, what we will do it that basically your what you call that a optimum system operation this thing optimum system operation case basically you know when you have that thermal power point is there nuclear power point.

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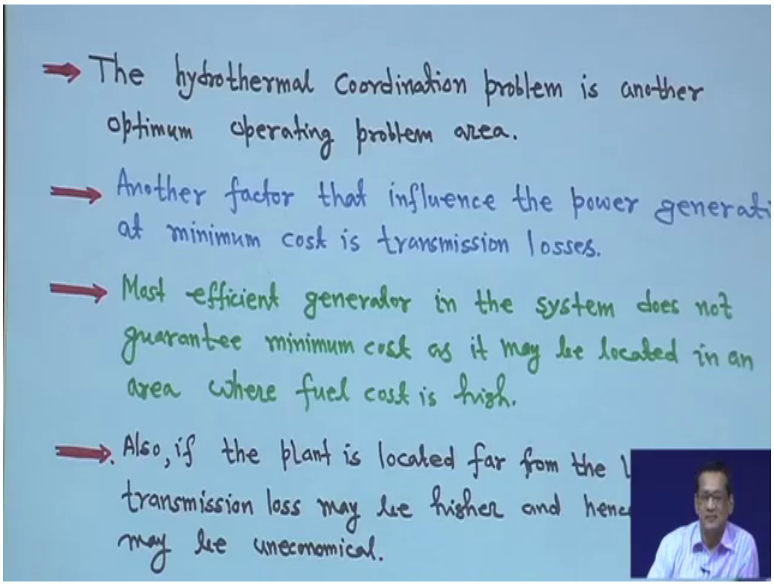

- The hydrothermal coordination problem is another optimum operating problem area.
- Another factor that influence the power generati at minimum cost is transmission losses.
- Most efficient generator in the system does not guarantee minimum cost as it may be located in an area where fuel cost is high.
- Also, if the plant is located far from the l transmission loss may be higher and hen may be uneconomical.

Is also there and sometime that hydrothermal coordination problem is another optimum operating problem area right; that means, you have to your what you call this hydrothermal system also as far as this course is concerned hydrothermal coordination also we are not considering with because this also goes to the P g level post graduation level right.

So, another factor that influence the power generation at minimum cost is a transmission loss right. So, that is another factor right because for a power network that transmission loss minimization subject to several constant right. So, that is also another factor that influence the power generation. So, most a for example, most efficient generator system does not guarantee the minimum cost suppose most efficient generator is located somewhere right where fuel cost is very high.

So, in that case it does not guarantee that is minimum cost similarly if the plant is located far from the load center transmission loss may be higher suppose your power plant is located far away at from there your transmitting power. So, in that case also for your what you call power loss of the network that is the transmission loss will be high right when is the plant may be are economical right.

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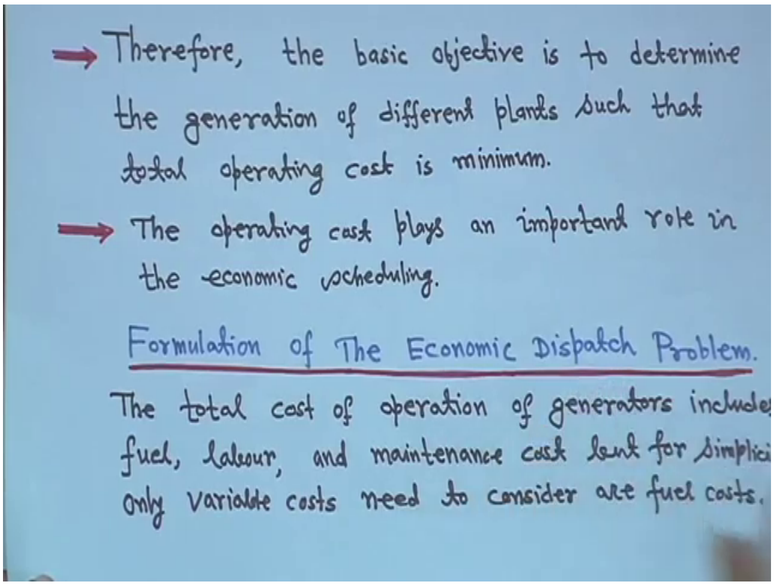

→ Therefore, the basic objective is to determine the generation of different plants such that total operating cost is minimum.

→ The operating cost plays an important role in the economic scheduling.

Formulation of The Economic Dispatch Problem.

The total cost of operation of generators include fuel, labour, and maintenance cost but for simplici only variable costs need to consider are fuel costs.

So, many issues many issues are there right many issues are there. So, therefore, you are the basic objective is to determine the generation of different plants such that that total operating cost is minimum you have a your different your take the your differ your determine the generation for different plants right for example, every you have for example, if you take thermal power plant say that manufacturer they give the your cost characteristics of those your flop your of those generating units right.

So, accordingly an total load is known. So, so in say you the; your what you call distribute the generation level your among the generators right because that load has generation has to match if the load plus loses right. So, such that your fuel cost will be minimum right. So, this is that the operating cost. So, what will what will try to see it here that is basically that your minimization of the fuel cost right that is the that is the objective of this what you call of your optimum system operation.

So, the formulation of the economic dispatch problem right for example, the total cost of operation of generators includes the fuel cost labor cost and maintenance cost, but for simplicity only variable cost need to consider are fuel cost. So, what will do this labor and maintenance cost will not considered for our this excises will only considered the variable cost that is the fuel cost right that will considered.

Now so, fuel cost is very important for thermal and nuclear power plant right.

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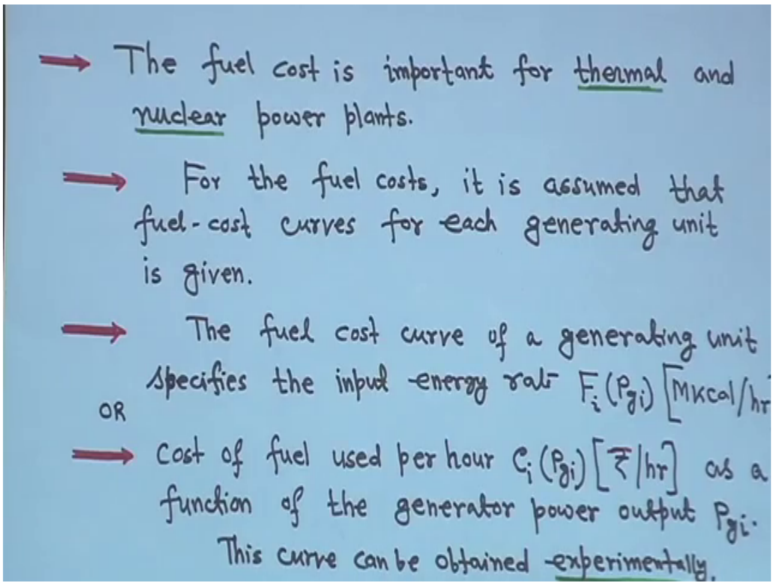

→ The fuel cost is important for thermal and nuclear power plants.

→ For the fuel costs, it is assumed that fuel-cost curves for each generating unit is given.

→ The fuel cost curve of a generating unit specifies the input energy rate $F_i(P_{gi})$ [MKcal/hr

OR

→ Cost of fuel used per hour $C_i(P_{gi})$ [₹/hr] as a function of the generator power output P_{gi}. This curve can be obtained experimentally.

So, the fuel cost is important thermal and nuclear power plants right for the fuel cost it is assumed that fuel cost curves for each generating unit is given because manufacturer they actually provide these right. So, will also assumed this cost characteristic is known to us right. So, the fuel cost curve of a generating unit right specifies the input energy rate that is F i function of P gi right its unit is mega kilo calorie per hour right. So, input energy rate is mega kilo calorie per hour right or cost of fuel used per hour that we used

C i function of P gi in bracket it is rupees per hour right as a function of the generator power output right this way you have to altimetry you will come to C i P gi right.

So, as a function of the generator per output P gi this curve can be obtained experimentally that is manufacturer you will get this curve right and will as we assumed that this is known to us right.

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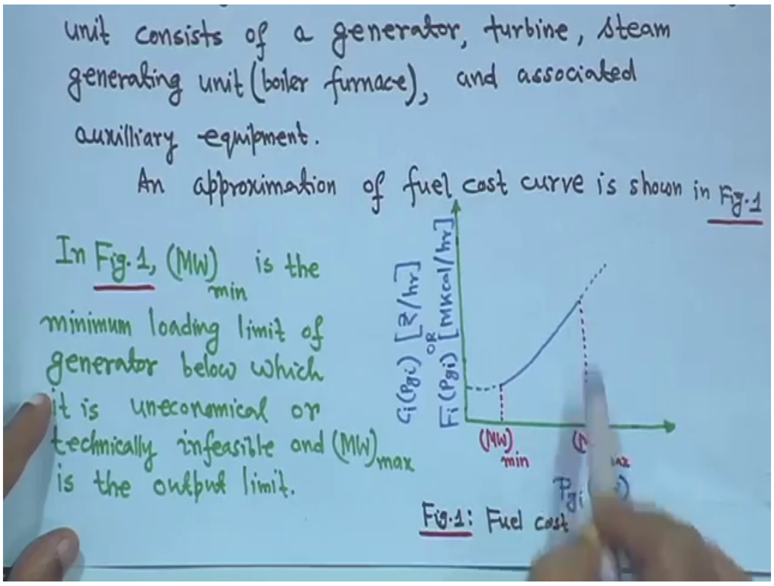

unit consists of a generator, turbine, steam generating unit (boiler furnace), and associated auxilliary equipment.

An approximation of fuel cost curve is shown in Fig.1

In Fig.1, $(MW)_{min}$ is the minimum loading limit of generator below which it is uneconomical or technically infeasible and $(MW)_{max}$ is the output limit.

Fig.1: Fuel cost

For simplicity it is assumed that is generating unit consist of generator turbine steam generating unit right in bracket is written boiler furnace and associated auxiliary equipment.

So, an approximation of fuel cost is shown in your fuel cost curve is shown in figure one right this is figure one this is your C i P gi that is rupees per hour or it is F i P gi that is mega kilo calorie per hour right this way you that is input it energy rate right either you put C i P gi rupees per hour or F i P gi mega kilo calorie per hour. But later will see that will use C i P gi frequently right and this is that mega watt minimum that generator can generate below minimum beyond billow that it cannot go right or this is the maximum mega watt maximum. So, this is P g this xx is a P gi mega watt and this is this one right.

So, mega watt minimum I mean this one is the minimum loading limit of generator bellow it is uneconomical right and or technical infeasible and mega watt max is the output limit it is the output limit of this right. So, next is that your; what you call the shape of the fuel cost curve; so, this one.

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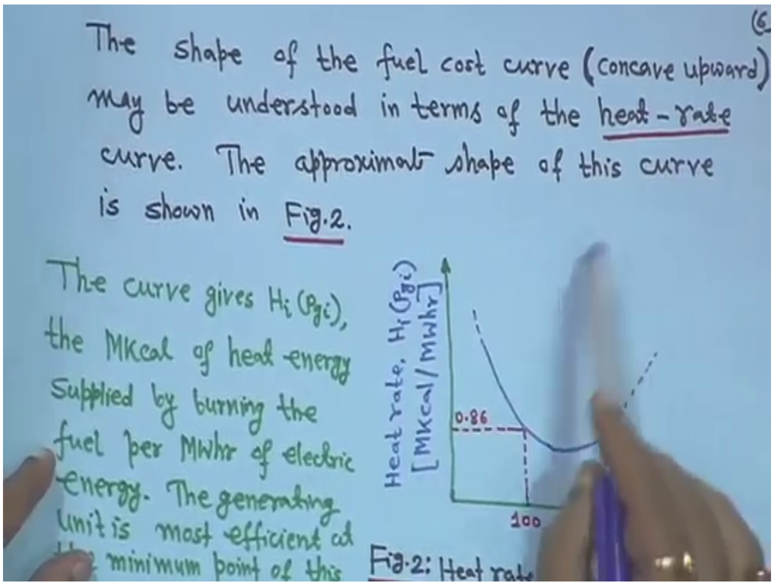

The shape of the fuel cost curve (concave upward) may be understood in terms of the heat-rate curve. The approximate shape of this curve is shown in Fig.2.

The curve gives $H_i(P_{gi})$, the MKcal of heat-energy supplied by burning the fuel per MWhr of electric energy. The generating unit is most efficient at the minimum point of this

Fig.2: Heat rate

The shape of the fuel cost curve that is concave upward may be understood in terms of the heat rate curve the approximate shape of this curve shown in figure 2 this is the heat rate curve meaning here it is written 0.86 per 100 I will explain right.

So, this is P gi mega watt and this is heat rate that is we call H i P gi that is mega kilo calorie per mega watt hour this is mega kilo calorie per mega watt hour right. So, the curve gives this is H i P gi right this is H i P gi the mega kilo calorie of heat energy supplied by burning the fuel per mega watt hour of electrical electric energy right the generating unit is most efficient at the minimum point of this curve I mean this point this minimum point at this curve right for example, keep it here let it be here.

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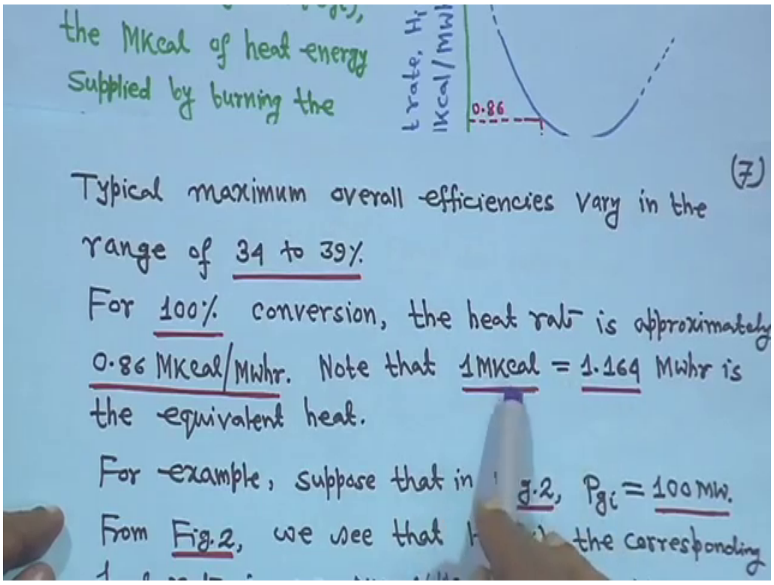

the MKcal of heat energy
Supplied by burning the

(7)

Typical maximum overall efficiencies vary in the range of 34 to 39%.

For 100% conversion, the heat rate is approximately 0.86 MKcal/MWhr. Note that 1MKcal = 1.164 MWhr is the equivalent heat.

For example, suppose that in g.2, P_{gi} = 100 MW.

From Fig.2, we see that the corresponding

The maximum typical maximum overall efficiency vary in the range of thirty 4 to thirty nine percent this you know right.

Now for 100 percent conversion the heat rate approximately 0.86 mega kilo calorie per mega watt hour right this is the 100 percent conversion note that one mega kilo calorie is equal to 1.164 mega watt hour is the equivalent heat right this you can transform of your own right for example, in figure 2 right. For example, in figure 2 suppose if you say that for 100 mega watt suppose it is generating 100 mega watt right and it is running for 1 hour. So, 100 mega watt in to 1, so, 100 mega watt hour right for that how much heat will be generated that is it is a your by it is 0.86 mega kilo calorie per mega watt hour right.

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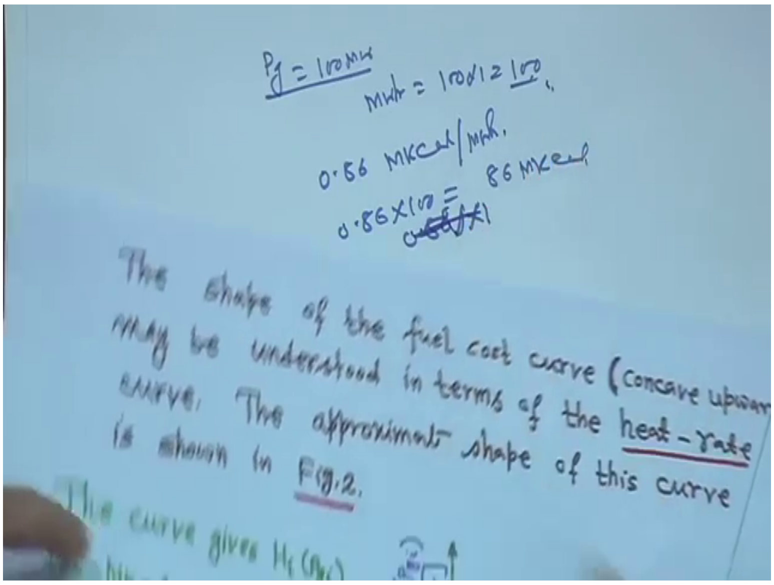

$P_g = 100\,MW$

$MWh = 100 \times 1 = \underline{100}$.

$0.86\ MKcal/MWh$.

$0.86 \times 100 = 86\ MKcal$

~~0.86×1~~

The shape of the fuel cost curve (concave upwar may be understood in terms of the heat-rate curve. The approximate shape of this curve is shown in Fig.2.

The curve gives $H_i(P_{gi})$

So, this one your this one that is if it P g is one 100 mega watt say if P g is equal to 100 mega watt right and for one hour it is generating therefore, your mega watt hour is equal to 100 in to 1 is equal to 100 this much of mega watt hour right and this heat rate is given 0.866, sorry 0.86 mega kilo calorie per mega watt hour. That means, for this 100 mega watts hour generation it has to give it will be 0.86 into sorry 0.86 into 100 is equal to 86 mega kilo calorie right.

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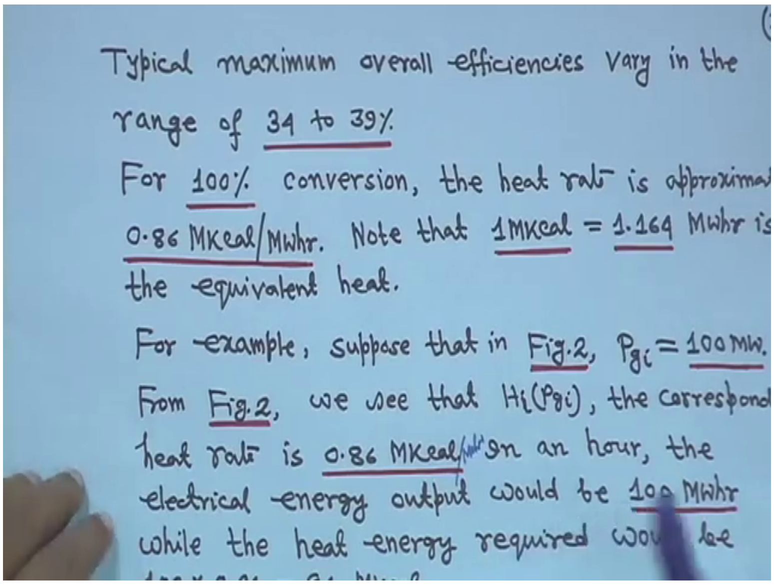

Typical maximum overall efficiencies vary in the range of 34 to 39%.

For 100% conversion, the heat rate is approxima 0.86 MKcal/MWhr. Note that 1 MKcal = 1.164 MWhr is the equivalent heat.

For example, suppose that in Fig.2, $P_{gi} = 100\,MW$. From Fig.2, we see that $H_i(P_{gi})$, the correspond heat rate is 0.86 MKcal/MWh. In an hour, the electrical energy output would be 100 MWhr while the heat energy required wou[illegible] be

So, that is the meaning; that means, that your figure 2 the P g is 100 mega watt right P g is 100 mega watt then H i P gi the corresponding heat rate is 0.86 mega kilo calorie per mega watt hour right here I written mega watt hour per this thing right. So, in an hour electrical energy would be one 100 mega watt hour because 100 into one right while the heat energy required would be 100 in to 0.86 that is 86 mega watt kilo calorie right.

So, if this is; so, this is; so that means, a heat input energy rate.

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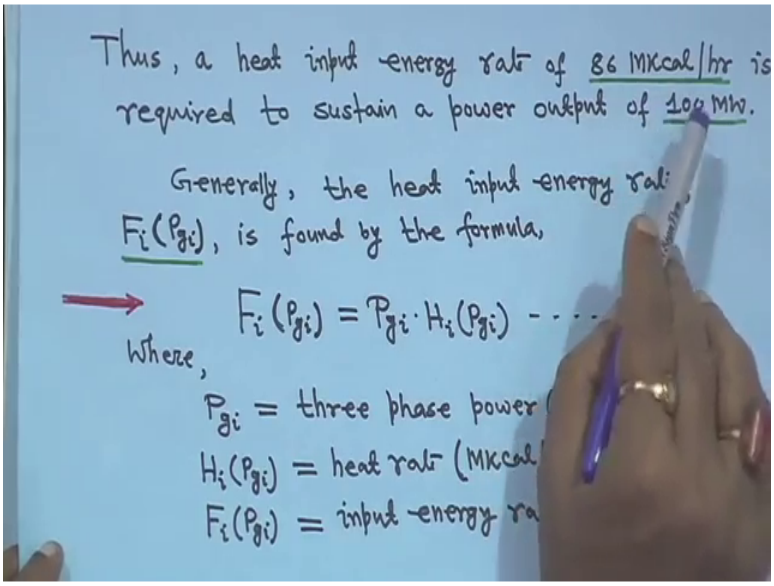

Thus, a heat input energy rate of 86 MKcal/hr is required to sustain a power output of 100 MW.

Generally, the heat input energy rat
$F_i(P_{gi})$, is found by the formula,

$$F_i(P_{gi}) = P_{gi} \cdot H_i(P_{gi}) \quad \cdots$$

Where,

P_{gi} = three phase power (
$H_i(P_{gi})$ = heat rate (MKcal
$F_i(P_{gi})$ = input energy ra

Of just 1 mint that there thus a heat input energy rate of 86 mega kilo calorie per hour is required to sustain a power of 100 mega watt right that is the thing that is the meaning. Now generally the heat input energy rate that is F i P gi is found by the this formula that is F i P gi if F i is a function of P gi is equal to P gi in to H i P gi capital H i function of P gi this is 1 P gi actually 3 phase power mega watt H i P gi I told you heat rate mega kilo calorie per mega watt hour and F i P gi input energy rate that is mega kilo calorie per hour right.

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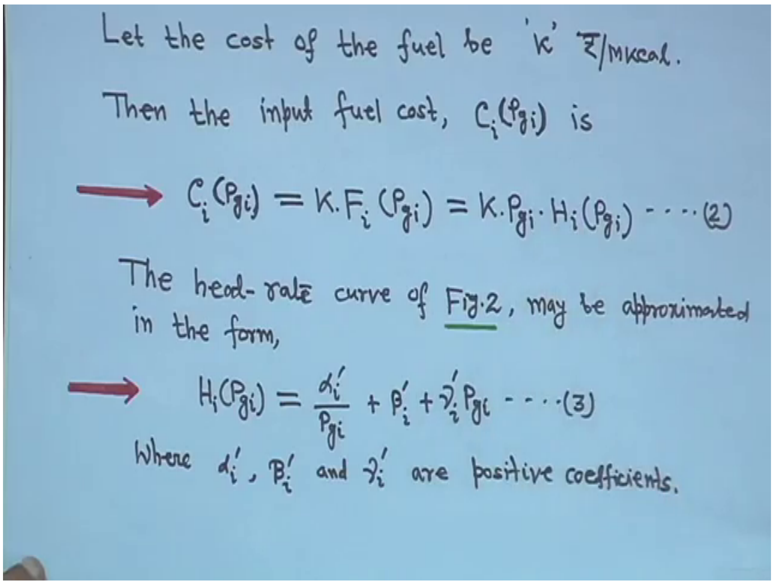

Let the cost of the fuel be 'k' ₹/Mkcal.

Then the input fuel cost, $C_i(P_{gi})$ is

→ $C_i(P_{gi}) = K.F_i(P_{gi}) = K.P_{gi}.H_i(P_{gi})$ ....(2)

The head-rate curve of Fig.2, may be approximated in the form,

→ $H_i(P_{gi}) = \frac{\alpha_i'}{P_{gi}} + \beta_i' + \gamma_i' P_{gi}$ ....(3)

Where α_i', β_i' and γ_i' are positive coefficients.

So, this is that this is the function of F i P gi is equal to P gi in to H i P gi right now. Now let the cost of the fuel we say k rupees per mega kilo calorie right then the input fuel cost C i function of P gi is C i P gi is equal to k in to F i P gi and F i P gi is equal to your P gi into H i P gi that is from equation one right. You put it here you put it I mean this one this one F i P gi is equal to P gi into H i P gi you put it there right therefore, heat rate curve of figure 2 this is your this is the equation. So, heat rate curve of figure 2 may be approximated in the form.

So, we are for assuming are approximating that H i P gi is equal to say alpha I dash upon P gi plus beta I dash plus gamma I dash P gi this is equation this is equation 3 right where alpha I dash beta I the gamma I dash are positive coefficients you have to find out what is the value of alpha I dash beta I dash and gamma I dash right now this H i P gi this equation 3 this H i P gi what you can do it you substitute here it is H i P gi expression from 3 you substitute here in equation 2 right.

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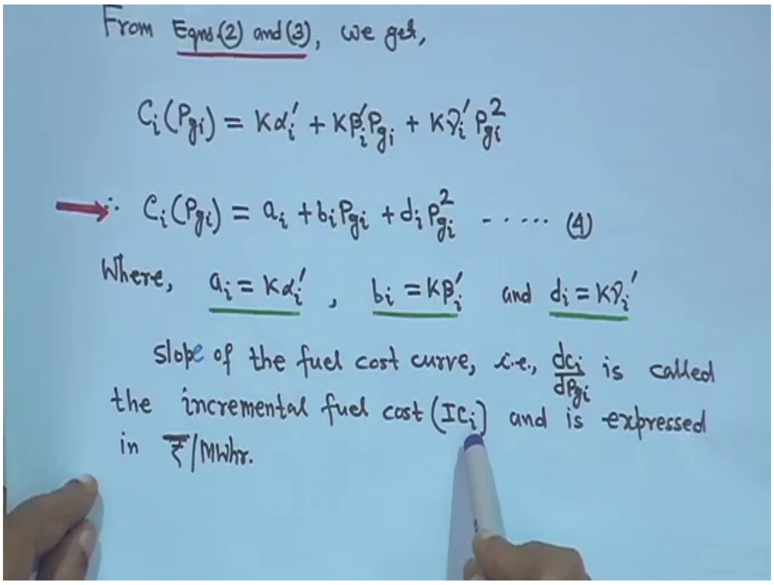

From Eqns (2) and (3), we get,

$$C_i(P_{gi}) = K\alpha_i' + K\beta_i' P_{gi} + K\gamma_i' P_{gi}^2$$

$$\therefore C_i(P_{gi}) = a_i + b_i P_{gi} + d_i P_{gi}^2 \quad \ldots\ldots (4)$$

Where, $\underline{a_i = K\alpha_i'}$, $\underline{b_i = K\beta_i'}$ and $\underline{d_i = K\gamma_i'}$

slope of the fuel cost curve, i.e., $\frac{dc_i}{dP_{gi}}$ is called the incremental fuel cost (IC_i) and is expressed in ₹/MWhr.

Then just for one then that is I am writing from equation 2 and 3 will become C i P gi become k alpha I dash plus k beta I dash P gi plus k gamma I dash P gi square right or you can write C i function of P gi equal to A i plus B i P gi plus D i P gi square right this is equation 4 where A i is equal to that is your k alpha I dash B i is equal to k beta I dash and D i is equal to k gamma I dash right.

So, slope of the fuel cost curve I mean for this one I mean; that means, your C i P gi d C i P gi upon D P gi right that is d C i D P gi is called the incremental fuel cost i C i right and is expressed in rupees per mega watt hour right. That means that means, that equation 4 if you take the derivative of it equation 4 right then You will get d C i upon D g D P gi is equal to i C i is equal to B i plus 2 D g D i P gi this is equation 5 right.

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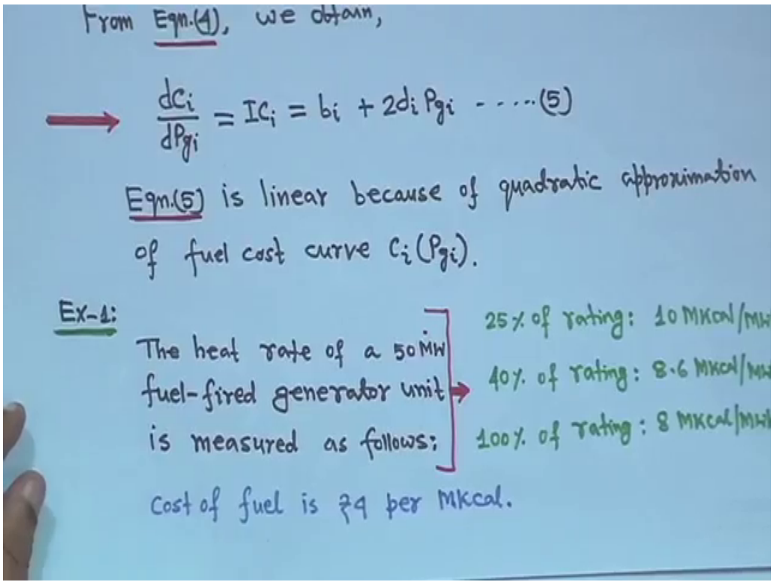

From Eqn.(4), we obtain,

$$\longrightarrow \frac{dc_i}{dP_{gi}} = IC_i = b_i + 2d_i P_{gi} \quad \text{....(5)}$$

Eqn.(5) is linear because of quadratic approximation of fuel cost curve $C_i(P_{gi})$.

Ex-1:

The heat rate of a 50 MW fuel-fired generator unit is measured as follows: →

25% of rating: 10 MKcal/MW

40% of rating: 8.6 MKcal/MW

100% of rating: 8 MKcal/MW

Cost of fuel is ₹4 per MKcal.

So, equation 5 is linear because of quadratic approximation of fuel cost curve C i P gi right so, but if you take the curve approximation then this will be quadratic C i P gi, but generally linear approximation is correct C i quadratic approximation of C i P gi is correct enough right, so, next will start with a small example right.

So, it is given heat rate of a 50 mega watt fuel fired generating unit is measured as follows right it is 25 percent of rating it is ten mega calorie per mega watt hour is required 40 percent of the rating 8.6 mega kilo calorie per mega watt hour and 100 percent of percent of rating 8 mega kilo calorie per mega watt hour and your taken this cost of fuel is rupees 4 per mega kilo calorie reality it will be much higher, but it is a class room excises, so, some value here taken rupees 4 per mega kilo calorie right you have to find out you have to you have to find out that your one is the c P g.

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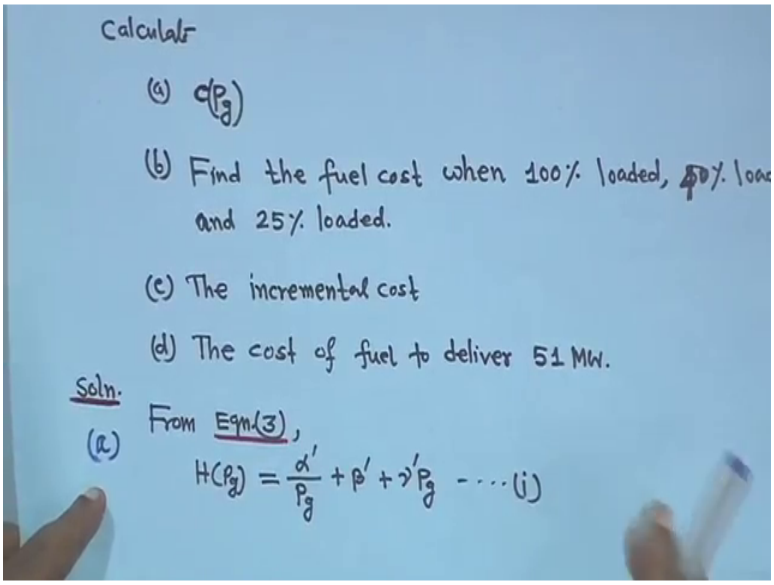

Calculate

(a) $C(P_g)$

(b) Find the fuel cost when 100% loaded, 40% loa
and 25% loaded.

(c) The incremental cost

(d) The cost of fuel to deliver 51 MW.

Soln.

(a) From Eqn.(3),

$$H(P_g) = \frac{\alpha'}{P_g} + \beta' + \gamma' P_g \quad \cdots (i)$$

Right b is find the fuel cost when 100 percent loaded forty percent loaded and 25 percent loaded c the incremental cost that is dc d d C i d P gi and d the cost of fuel to deliver 51 mega watt right. So, these are the things you have to do it.

Thank you.