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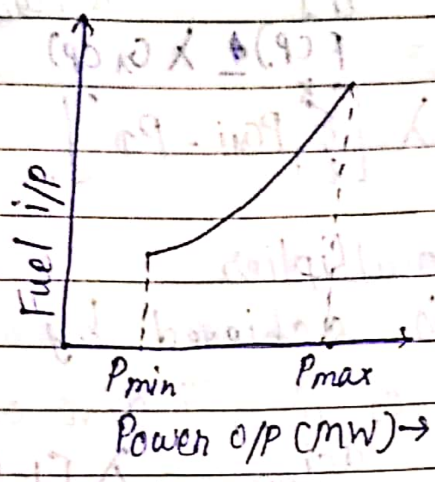
CH: 2 Economic Load Dispatch.



Incremental fuel rate = $\frac{\Delta \text{input}}{\Delta \text{output}}$

$= \frac{dF}{dP}$

where F is the fuel i/p in million Btu/hr and P is the power output in MW.

* ~~Economic Dispatch Neglecting Losses:~~

Optimal Operation: (~~Non~~ Inequality Constraints)

gen: $\sum P_{Gimax} \geq P_D$

P_{Gimax} is rated real power capacity.

$P_{Gimin} \leq P_{Gi} \leq P_{Gimax}$. max. P of source is limited by thermal consideration & min P limited by the flame instability

Considering Spinning reserve

$\sum P_{Gimax} > P_D$

Reactive power Qmin is limited by stability limit of ... /C.

operating cost $C = \sum_{i=1}^{k} C_i P_{Gi}$.

Voltage, $|V_{pmin}| \leq |V_p| \leq |V_{pmax}|$, $\delta_{pmin} \leq \delta_p \leq \delta_{pmax}$ δ lies bet 30 to 40

under the equality constraint

$$\boxed{\sum_{i=1}^{k} P_{Gi} - P_D = 0}$$

X'mission line constraints : $C_p \leq C_{pmax}$

Active & reactive power through X'mission line is limited by thermal capability of ckt.

Economic dispatch Neglecting losses:

Take Lagrangian as $\quad \text{Min } P_{Gi} = \sum_{i=1}^{n} P_{Gi}$

$$L = F(P) - \lambda\, G(P)$$

$$\therefore L = \sum_{i=1}^{k} C_i P_{Gi} - \lambda \left[\sum_{i=1}^{k} P_{Gi} - P_D \right]$$

λ = lagrange multiplier

Minimization is achieved by

$$\frac{\partial L}{\partial P_{Gi}} = 0 \quad \text{so it will give optimal operation}$$

$$dc_i / dP_{Gi} - \lambda [1-0] = 0.$$

$$\therefore \frac{dc_i}{dP_{Gi}} = \lambda$$

So, $\dfrac{dc_1}{dP_{G1}} = \dfrac{dc_2}{dP_{G2}} \cdots\cdots = \lambda.$

above eq^n is called coordination eq^n

Ex: Incremental fuel cost in rupees per MWh for a plant consisting of two units are:

$$\frac{dc_1}{dP_{G1}} = 0.20 P_{G1} + 40$$

$$\frac{dc_2}{dP_{G2}} = 0.25 P_{G2} + 30$$

Assume that both units are operating at all times, and total load varies from 40 MW to 250 MW, and the maximum and min. loads on each unit are to be 125 and 20 MW. How will the load 150 MW be shared between the two units as the sys. load varies over the full range? what r the corresponding values of the plant incremental cost.

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Ex: 2 gen of 100 MW each with incremental charge $\frac{dF_1}{dP_1} = 2 + 0.012 P_1$, $\frac{dF_2}{dP_2} = 1.5 + 0.015 P_2$; min load on each unit is 10 MW total load to be supplied is 150 MW. Find economic operation schedule

Ans: $\lambda = 2.78$

Sol^n: For 20 MW: $\frac{dC_1}{dP_{G1}} = 44$ Rs/MWh

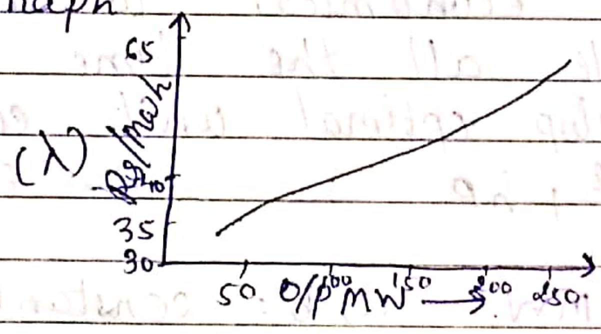
$$\frac{dC_2}{dP_{G2}} = 35 \text{ Rs/MWh}$$

So additional load should be taken by unit 2 until $dC_2/dP_{G2} = 44$

For $dC_2/dP_{G2} = 44$ $\quad P_{G2} = 56$.

λ	P_{G1}	P_{G2}	$P_{G1} + P_{G2}$
35	20	20	
44	20	56	
50	50	80	
55	75	100	
60	100	120	
61.25	106.25	125	
65	125	125	

Draw graph



From above graph for total load 150 MW $\lambda = 52.22$ for this λ.

$P_{G1} = 61.11$

$P_{G2} = 88.89$ Draw 2 sep. graph for 2 units

Ex: For the plant described in above example find the saving in fuel cost in Rs/hr for optimal scheduling of a total load of 130 MW as compared to equal distribution of the same load betn 2 units.

Ex: A constant load of 300 MW is supplied by 2 gen. for which $\frac{dC_1}{dP_{G1}}$ ... $\frac{dC_2}{dP_{G2}} = 0.12P_2 + 15$ Rs/MWh find a) the most economical division b) saving in Rs/day compared with equal load sharing. Ans: $0.1P_1 + 20 = 0.12P_2 + 15$ So, $P_1 = 140.9$, $P_2 = 159.1$, $\lambda = 34.09$, saving $= 9.09$/, $= 218$/.

From table in example one for 130 MW. $P_{G1} = 50$, $P_{G2} = 80$.
If we take equal distribution of 65 MW.

then $\int_{50}^{65} (0.2P_{G1} + 40)\, dP_{G1} = 0.1P_{G1}^2 + 40P_{G1}\Big|_{50}^{65} = 772.5$

for unit-2

$\int_{80}^{65} (0.25P_{G2} + 30)\, dP_{G2} = -721.875$ Rs/hr

Net saving $772.5 - 721.875 = 50.625$ Rs/hr.

assuming continuous operation
$=$ Rs. 4,43,475.~~000~~

* Optimal unit commitment (UC)

it is not economical to run all the units available all the time. So we have to develop optimal unit commitment

e.g. $f = \frac{1}{2}ap^2 + bP$ (Ans: $F_2(2) + F_1(7)$)

P: Power in MW, a, b = constant

plant no:	capacity (MW)	a	b
1	1-12	0.77	23.5
2	1-12	1.6	26.5
3	1-12	2	30
4	1-12	2.5	32

find optimal cost.
Take combinations of plant - 1-2, 1-3, 1-4, 2-3, 2-4, 3-4. ~~For load of~~ 9 MW.

Determine the most economical units to be commited for a load of 9 MW. Let the load changes in steps of

* Dynamic Programming method
It the load is assumed to increase in small but finite size steps, dynamic programming (DP) can be used.
- The total no. of units available, their individual cost characteristics and load cycle on the s^{th} are assumed to be known.
- It shall be assumed that the load on each unit or combination of units changes in suitably small but uniform steps of size ΔMW
* Starting with any 2 units, the most economical combination is determined for all the discrete load levels of the combined O/P of the two units.
* At each load level the most economic answer may be to run either unit or both units with certain load sharing betn the two.
* The third unit is now added and the procedure repeated to find the cost curve of the three combined units.
* This process is repeated till all available units are consider.

Let a cost f^n $F_N(x)$ be defined as follows:
$F_N(x)$ = the minimum cost in Rs/hr of generating x MW by N^{th} units.
$F_{(N)}y$ = the minimum cost in Rs/hr for generating y MW by N^{th} unit.

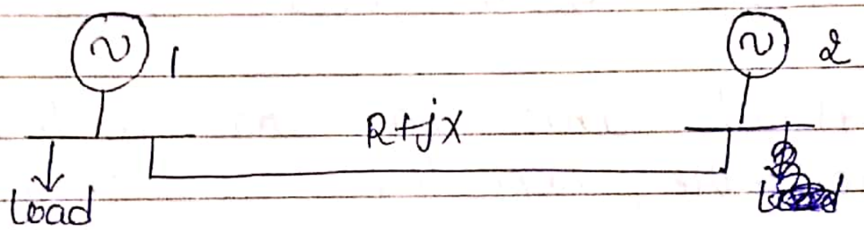
$F_{(N-1)}(x-y)$ = the minimum cost of generating $(x-y)$ MW by remaining $(N-1)$ units.

Application of DP results in the following eqn.

$$F_N(x) = \min_y \{ F_N(y) + F_{N-1}(x-y) \}$$

Using the above relation, we can easily determine the combination of units for minimum operating costs of loads ranging in convenient steps from the minimum permissible load of the smallest unit to the sum of the capacities of all available units.

* Optimum Load Dispatch including X'mission losses.



X'mission losses may vary from 5 to 15% of the total load, so it is essential to account for losses while developing economic load dispatch policy.

- Consider a two bus system with identical gen. at each bus
- Assume that the load is located near plant 1 and plant 2 has to deliver power via a lossy line.

- In this section, we shall investigate how the load should be shared among various plants, when line losses are accounted for. The objective is to minimize the overall cost of generation

$$C = \sum_{i=1}^{K} C_i P_{Gi}.$$

at any time under equality constraint of meeting the load demand with x'mission losses.

$$\sum_{i=1}^{K} P_{Gi} - P_D - P_L = 0.$$

K = total no. of generating plants
P_{Gi} = generation of i^{th} plant.
P_D = Sum of load demand at all buses
P_L = total sys. x'mission losses.
To, solve the prob. we write as

$$F = \sum_{i=1}^{K} C_i P_{Gi} - \lambda \left[\sum_{i=1}^{K} P_{Gi} - P_D - P_L \right]$$

If power factor of load at each bus is assumed to remain constant, the sys loss P_L can be shown to be a f^n of active power generation at each plant i.e.

$$P_L = P_L(P_{G1}, P_{G2} \dots P_{GK})$$

So for optimization P_{Gi} $(i = 1, 2 \dots k)$ are the only control variables.

- For optimum real power dispatch

$$\frac{dF}{dP_{Gi}} = \frac{dC_i}{dP_{Gi}} - \lambda + \lambda \frac{\partial P_L}{\partial P_{Gi}} = 0. \quad (1)$$

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Ex: On the sys. consisting of 2 plants the IC in Rs/mwh with ... sys. is operating on economic dispatch
$dc_1/dP_1 = 0.15P_1 + 150$, $dc_2/dP_2 = 0.25P_2 + 175$.
with $P_1 = P_2 = 200$ MW and $\partial P_L/\partial P_2 = 0.2$ find L_i.
Ans: $L_1 \, dc_1/dP_1 = L_2 \, dc_2/dP_2 = \lambda$, $L_2 = \frac{1}{1-\partial P_L/\partial P_2} = 1.25$, $L_1(0.15P_1+150) = 1.25(0.25P_2+175)$, $L_1 = 1.56$

Rearranging the eq^n.

$$\frac{\frac{dC_i}{dP_{Gi}}}{\left(1 - \partial P_L/\partial P_{Gi}\right)} = \lambda$$

or $\frac{dc_i}{dP_{Gi}} L_i = \lambda$.

where $L_i = \frac{1}{(1 - \partial P_L/\partial P_{Gi})}$

is called the penalty factor of ith plant.

- From above discussion we observe that minimum fuel cost is obtained, when the incremental fuel cost of each plant multiplied by it's penalty factor is same for all the plants.
- The partial derivative $\partial P_L/\partial P_{Gi}$ is ref. to as the incremental transmission loss $(ITL)_i$, for ith generating plant.

and $dc_i/dP_{Gi} = (IC)_i$

So $(IC)_i = \lambda[1 - (ITL)_i]$ $i = 1, 2 \ldots k$

This eq^n is known as exact coordination eq^n

Th: 1 →

* Simple but approximate methods of expressing x'mission loss as a f^n of gen powers is through B-coefficients. The general form of loss formula is

$$P_L = \sum_{m=1}^{k} \sum_{n=1}^{k} P_{Gm} B_{mn} P_{Gn} \quad (1)$$