KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

ELECTRICAL ENGINEERING DEPARTMENT

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EE-463

Key Solution

Quiz # 4 Serial # Name: I.D.#

The fuel-cost functions in $/h for three thermal plants are given by

$C_1 = 350 + 7.2\,P_1 + 0.0040\,P_1^2$

$C_2 = 350 + 7.2\,P_2 + 0.0040\,P_2^2$

$C_3 = 350 + 7.2\,P_3 + 0.0040\,P_3^2$

where $P1$, $P2$, and $P3$ are in MW. The governors are set such that generators share the load equally. Neglecting line losses and generator limits,

a) find the total cost in $/h when the total load is 745 MW

b) determine the optimal scheduling of generation for each loading condition by analytical technique,

c) find the savings in $/h for each case compared to the costs in part (a) when the generators shared load equally.

Solution

a)

(i) For $P_D = 450$ MW, $P_1 = P_2 = P_3 = \frac{450}{3} = 150$ MW. The total fuel cost is

$$C_t = 350 + 7.20(150) + 0.004(150)^2 + 500 + 7.3(150) + 0.0025(150)^2 + 600 + 6.74(150) + 0.003(150)^2 = 4,849.75 \quad \$/\text{h}$$

(ii) For $P_D = 745$ MW, $P_1 = P_2 = P_3 = \frac{745}{3}$ MW. The total fuel cost is

$$C_t = 350 + 7.20\left(\frac{745}{3}\right) + 0.004\left(\frac{745}{3}\right)^2 + 500 + 7.3\left(\frac{745}{3}\right) + 0.0025\left(\frac{745}{3}\right)^2 + 600 + 6.74\left(\frac{745}{3}\right) + 0.003\left(\frac{745}{3}\right)^2 = 7,310.46 \quad \$/\text{h}$$

(iii) For $P_D = 1335$ MW, $P_1 = P_2 = P_3 = 445$ MW. The total fuel cost is

$$C_t = 350 + 7.20(445) + 0.004(445)^2 + 500 + 7.3(445) + 0.0025(445)^2 + 600 + 6.74(445) + 0.003(445)^2 = 12,783.04 \quad \$/\text{h}$$

b)

(i) For $P_D = 450$ MW, from (7.33), λ is found to be

$$\lambda = \frac{450 + \frac{7.2}{0.008} + \frac{7.3}{0.005} + \frac{6.74}{0.006}}{\frac{1}{0.008} + \frac{1}{0.005} + \frac{1}{0.006}}$$
$$= \frac{450 + 3483.333}{491.666} = 8.0 \ \$/\text{MWh}$$

Substituting for ¸ in the coordination equation, the optimal dispatch is

$$P_1 = \frac{8.0 - 7.2}{2(0.004)} = 100$$
$$P_2 = \frac{8.0 - 7.3}{2(0.0025)} = 140$$
$$P_3 = \frac{8.0 - 6.74}{2(0.003)} = 210$$

(ii) For $P_D = 745$ MW, from (7.33), λ is found to be

$$\lambda = \frac{745 + 3483.333}{491.666} = 8.6 \ \$/\text{MWh}$$

Substituting for ¸ in the coordination equation, the optimal dispatch is

$$P_1 = \frac{8.6 - 7.2}{2(0.004)} = 175$$
$$P_2 = \frac{8.6 - 7.3}{2(0.0025)} = 260$$
$$P_3 = \frac{8.6 - 6.74}{2(0.003)} = 310$$

(iii) For $P_D = 1335$ MW, from (7.33), λ is found to be

$$\lambda = \frac{1335 + 3483.333}{491.666} = 9.8 \ \$/\text{MWh}$$

Substituting for ¸ in the coordination equation, the optimal dispatch is

$$P_1 = \frac{9.8 - 7.2}{2(0.004)} = 325$$
$$P_2 = \frac{9.8 - 7.3}{2(0.0025)} = 500$$
$$P_3 = \frac{9.8 - 6.74}{2(0.003)} = 510$$

(c)(i) For $P_1 = 100$ MW, $P_2 = 140$ MW, and $P_3 = 210$ MW, the total fuel cost is

$$C_t = 350 + 7.20(100) + 0.004(100)^2 + 500 + 7.3(140) + 0.0025(140)^2 + 600 + 6.74(210) + 0.003(210)^2 = 4,828.70 \ \ \$/\mathrm{h}$$

Compared to part (a) (i), when the generators shared load equally, the saving is 4,849.75 - 4,828,70 = 21.05 $/h.

(c)(ii) For $P_1 = 175$ MW, $P_2 = 260$ MW, and $P_3 = 310$ MW, the total fuel cost is

$$C_t = 350 + 7.20(175) + 0.004(175)^2 + 500 + 7.3(260) + 0.0025(260)^2 + 600 + 6.74(310) + 0.003(310)^2 = 7,277.20 \ \ \$/\mathrm{h}$$

Compared to part (a) (ii), when the generators shared load equally, the saving is 7,310.46 - 7,277.20 = 33.26 $/h.

(c)(iii) For $P_1 = 325$ MW, $P_2 = 500$ MW, and $P_3 = 510$ MW, the total fuel cost is

$$C_t = 350 + 7.20(325) + 0.004(325)^2 + 500 + 7.3(500) + 0.0025(500)^2 + 600 + 6.74(510) + 0.003(510)^2 = 12,705.20 \ \ \$/\mathrm{h}$$

Compared to part (a) (iii), when the generators shared load equally, the saving is 12,783.04 - 12,705.20 = 77.84 $/h.