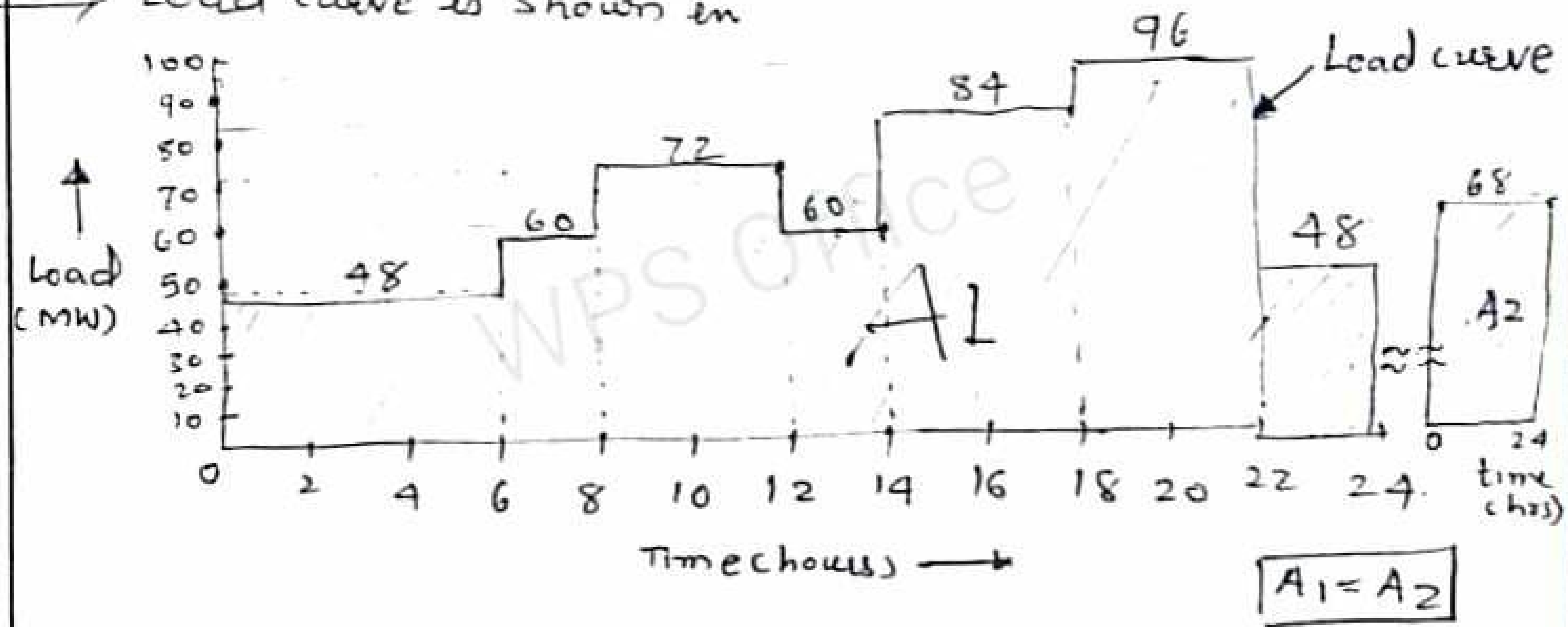
The maximum demand of a power station is 96000 kW and daily load curve is described as follows:

| Time (hours) | 0 - 6 | 6 - 8 | 8 - 12 | 12 - 14 | 14 - 18 | 18 - 22 | 22 - 24 |
|---|---|---|---|---|---|---|---|
| Load (MW) | 48 | 60 | 72 | 60 | 84 | 96 | 48 |

i) Determine the load factor of power station.

ii) What is the load factor of standby equipment rated at 30 MW that takes up all load in excess of 72 MW. Also calculate its use factor.

⟹ Load curve is shown in




Energy generated = area under the load curve

" " $= \underline{48 \times 6} + \underline{60 \times 2} + \underline{72 \times 4} + \underline{60 \times 2} + \underline{84 \times 4}$ $\underline{96 \times 4} + 48 \times 2$

" " $= 1632 \text{ MWh} = 1632 \times 10^3 \text{ kWh}$

To Find Load factor

(i) Load ~~factor~~ Average (kW) $= \dfrac{\text{Energy generated (kWh)}}{\text{Total time (hr)}} = \dfrac{1632 \times 10^3}{24} = 68000 \text{ kW}$

ii) Maximum demand = 96000 kW

$\therefore$ Load factor $= \dfrac{\text{Average Load}}{\text{Maximum demand}} = \dfrac{68\text{ MW}}{96\text{ MW}}$

" " $= 0.71$ (Ans)

(ii) To find load factor of standby equipment:

The standby equipment supplies

$84 - 72 = 12$ MW for 4 hours (14-18)

$96 - 72 = \underline{24\text{ MW}}$ for 4 hours (18-22).

Max Demand

$\therefore$ Energy generated by standby equipment

$= (12 \times 4 + 24 \times 4) \times 10^3 = 144 \times 10^3$ kWh

Time for which standby equipment remains in operation (from the load curve)

$= 4 + 4 = 8$ hours

$\therefore$ Average $= \dfrac{144 \times 10^3 \text{ kWh}}{8 \text{ hr}} = 18 \times 10^3$ kW.

Load factor $= \dfrac{\text{Average load}}{\text{Max Demand}} = \dfrac{18 \times 10^3}{24 \times 10^3}$

" " $= 0.75$ (Ans)

Use factor $= \dfrac{E}{C \times t'}$ where E = Energy generated

C = Capacity of the standby equipment, &

t' = Actual number of hours the plant has been in operation

$= \dfrac{144 \times 10^3}{30 \times 10^3 \times 8}$

$= 0.6$ (Ans)

Rs/KW

Annual interest & depreciation (fixed cost) $= 0.12 \times 18000 \times 210 \times 10^3$

" $= Rs\ 453.6 \times 10^6$

Total annual cost $=$ Total fixed cost $+$ Total running cost

" $= 453.6 \times 10^6 + 200 \times 10^6$

" $= Rs\ 653.6 \times 10^6$

Cost of power generation $= \dfrac{\text{Total cost per annum}}{\text{Total units (Net) generated (or delivered)}}$

" $= \dfrac{653.6 \times 10^6}{933.781 \times 10^6} = 0.7$

" $= 70$ paise/KWh.

Date: 28/12/2017

Insem exam March 2016

A power plant of 210 MW installed capacity has the following particulars:

capital cost = Rs. 18000/kW installed

Interest and depreciation = 12 %

Annual load factor = 60 %

Annual capacity factor = 54 %

Annual running charges = Rs $200 \times 10^6$.

Energy consumed by power plant auxiliaries = 6 %

Calculate i) cost of power generation per kWh

ii) The reserve capacity.

1) ~~Average load~~ = To find reserve capacity.

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum demand}} \quad \text{--- (1)}$$

$$\text{capacity factor} = \frac{\text{Average load}}{\text{plant capacity}} \quad \text{--- (2)}$$

$$eq^n \frac{(1)}{(2)} \quad \frac{\text{Load factor}}{\text{capacity factor}} = \frac{\cancel{\text{Avg. Load}}}{\text{Max. demand}} \times \frac{\text{Plant capacity}}{\cancel{\text{Max. demand}}\ \text{Avg. Load}}$$

$$\frac{0.6}{0.54} = \frac{\text{Plant capacity}}{\text{Max. demand}} = \frac{210}{M.D}$$

$\therefore$ Maximum demand = 189 MW

Reserve capacity = plant capacity − Max. demand.

= 210 − 189 = 21 MW.

2) To find cost of power generation per kWh.

Units generated per annum = Avg. Load (kW) × 8760 kWh

" = Load factor × Max. demand (kW) × 8760 (hr)

" = $0.6 \times 189 \times 10^3 \times 8760$ kWh

" = $993.384 \times 10^6$ kWh

Net units delivered = Units generated − Units consumed by power plant

" " " = $993.384 \times 10^6 - 0.06 \times 993.384 \times 10^6$

" " " = $933.781 \times 10^6$ kWh.

Insem exam - March 2016.

A power plant has the following annual factors : Load factor = 0.75, capacity factor = 0.6, use factor = 0.65, Maximum demand is 60 MW. Estimate i) Annual energy production ii) The reserve capacity over & above the peak load iii) The hours during which the plant is not in service, per year.

(i) Load factor $= \dfrac{\text{Avg load}}{\text{Max. demand}} = 0.75.$

Average load $= 0.75 \times$ Max. demand

$= 0.75 \times 60\,(\text{MW}) = \underline{45\ \text{MW}}$

Annual energy production $=$ Avg. load (kW) $\times$ hours in year

$= 45000 \times 8760$ kWh.

$= 394.2 \times 10^{6}$ kWh.

(2) Capacity factor $= \frac{\text{Average load}}{\text{plant capacity}} = \frac{45}{\text{plant capacity}} = 0.6$

$\therefore$ plant capacity $= \frac{45}{0.6} = \underline{\underline{75 \text{ MW}}}$

Reserved capacity over & above peak load

$= \cancel{75}$ plant capacity − maximum demand

$= 75 - 60 = 15 \ \underline{\underline{\text{MW}}}$

(3) Use factor $= \frac{\text{Energy generation per year}}{\text{plant capacity} \times \text{hours in use (in operation)}}$

Hours in use (in operation) in hours $= \frac{\text{Energy generation per year}}{\text{plant capacity (kW)} \times \text{use factor}}$

" $= \frac{394.2 \times 10^6 \ (\text{kWh})}{75 \times 10^3 \times 0.65}$

" $= 8086 \ \underline{\underline{\text{hours}}}$

$\therefore$ ~~plant~~ Hours not in service in year $= 8760 - 8086.$

$= \underline{\underline{674}}$ hours//

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**Q.1 b.** In a power station annual factors are as under
Load factor = 60%, capacity factor = 50% &
use factor = 60%, the power plant has a
maximum demand of 45000 kW, find:

i) Annual energy production.

ii) Reserve capacity above peak load

iii) Hours per year the plant is not in use.

**Sol$^n$** →

i) Annual energy production = Avg. load × Hours in Year

" = L.F × M.D. × 8760

" = 0.6 × 45000 × 8760

" = $236.52 \times 10^6$ kWh. ANS

ii) Reserve capacity = plant capacity − Max. demand — (1)

plant capacity factor (PCF) (0.5) = $\frac{A.L \times \cancel{t}}{P.C \times \cancel{t}}$ — (2)

plant capacity (P.C.) = $\frac{L.F \times M.D}{P.C.F.}$

" = $\frac{0.6 \times 45000}{0.5}$

" = 54000 kW

∴ Reserve capacity = plant capacity − Max. Demand

= 54000 − 45000

= 9000 kW ANS

iii) Use factor (0.6) = $\frac{A.L \times t}{P.C. \times t_{use}}$ = $\frac{27000 \times 8760}{54000 \times t_{use}}$

∴ $t_{use}$ (Hrs) = 7300

∴ Hours per year the plant is not in use = 8760 − 7300

= 1460 Hrs. ANS

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Q.1. b) Determine the annual cost of water softening plant from the following data:

cost = Rs. $2.56 \times 10^5$

Salvage value = 6 %

Life = 10 years.

annual cost of chemicals = Rs. 15000

Annual repair cost = Rs. 1000

Labour cost per month = Rs. 3000

Rate of interest by sinking fund method = 11 %

⇒ ~~L = 350~~ Life, n = 10 years.

Capital cost P = Rs 256000

Salvage value S = 6 % of capital cost

" " $= \frac{6}{100} \times 256000$ = Rs $\underline{\underline{15,360}}$

Annual interest = A

" $= \left[\frac{r}{(1+r)^n - 1}\right](P-S)$

" $= \left[\frac{0.11}{(1+0.11)^{10} - 1}\right]\left[256000 - 15360\right]$

" = Rs. $\underline{\underline{14390.6}}$

Total cost per year = cost of (chemical + repairs + Labour + interest)

" = 15000 + 1000 + 3000 × 12 + 14390.6

" = $\underline{\underline{66390.6}}$ Rs.

Total cost = Fixed cost + Running cost.

" $= 453.6 \times 10^6 + 200 \times 10^6$

" $= \underline{\underline{653.6 \times 10^6}}$ Rs

Total energy generated $= 993.384 \times 10^6$ kWh

Net energy delivered $= 0.94 \times 993.384 \times 10^6$ kWh

$\because$ 6 % of total units generated is used to run the plant

$\therefore$ Net energy delivered $= \underline{\underline{933.781 \times 10^6}}$ kWh



$\therefore$ cost of power generation $= \dfrac{\text{Total cost}}{\text{Net units generated}}$

" $= \dfrac{653.6 \times 10^6}{933.781 \times 10^6} = 0.699$ Rs/kWh.

" $\simeq$ 70 paise/kWh.

Reserve capacity = (plant capacity − max. demand)

$= 210 - 189 = \underline{\underline{21 \text{ MW}}}$

Q.2 b

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Q.1 b) A power plant of 210 MW installed capacity has the following particulars : ~~Capacity cost~~
Capacity cost = Rs. 18000/KW installed
interest and depreciation = 12 %.
Annual load factor = 60 %.
Annual capacity factor = 54 %.
Annual running charges = Rs 200×10^6
Energy consumed by power plant auxiliaries = 6 % Calculate
i) cost of power generation per KWh
ii) The reserve capacity.

i) Load factor = $\frac{\text{Avg. Load.}}{\text{Max. demand}}$  Capacity factor = $\frac{\text{Avg. load.}}{\text{plant capacity}}$

$$\frac{\text{Load factor}}{\text{Capacity factor}} = \frac{\text{Avg. Load.}}{\text{Max. demand}} \times \frac{\text{plant capacity}}{\text{Avg. Load}}$$

$$\frac{0.6}{0.54} = \frac{210 \text{ MW}}{\text{Max. demand}}$$

$$\text{Maximum demand} = \frac{210 \times 0.54}{0.6} = 189 \text{ MW}$$

$\therefore$ KWh generated = L.F × M.D. × 8760
" " $= 0.6 \times 189 \times 10^3 \times 8760$
" " $= 993.384 \times 10^6$

Capital investment = plant capacity (KW) × Rs/KW
" $= 210 \times 10^3 \text{ (KW)} \times 18000 \text{ (Rs/KW)}$
" $= 3.78 \times 10^9$ Rs.

Running cost = Rs $200 \times 10^6$.
Fixed cost $= 0.12 \times 3.78 \times 10^9 = 453.6 \times 10^6$.

Q. 2 b) A thermal power plant consists of two units of 30 MW each running for 8200 Hours and one unit of 10 MW running for 2000 Hours in a year. The energy produced by plant $400 \times 10^6$ KWh per annum. Determine the plant load factor and plant use factor. The maximum demand is equal to the plant capacity.

$\Rightarrow$

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum demand}} \quad \text{— (1)}$$

Given plant capacity = maximum demand.

$$(30 + 30 + 10)\,MW = 70\ MW$$

Energy produced per annum $= 400 \times 10^6$ KWh

$$400 \times 10^6 = A.L \times 8760$$

$$\therefore A.L. = \frac{400 \times 10^6}{8760} = 45662.1\ (KW)$$

$$\therefore \text{Load factor} = \frac{45662.1}{70 \times 10^3}\frac{KW}{KW} = 0.6523$$

$$\text{plant use factor} = \frac{A.L. \times t \quad \cancel{\text{Actual KWh generated}}}{\text{Plant capacity} \times \text{Hours used}}$$

$$" = \frac{400 \times 10^6\ KWh}{[2 \times 30 \times 10^3 (KW) \times (8200)] + [2000 \times 10 \times 10^3]}$$

MW (Hrs) (Hrs) MW

$$" = \cancel{0.3106} \quad 0.781$$

Q. 2b)

The daily load for a power plant is given by the following equation:

$L = 350 + 10t - t^2$

where t is time in hours from 0 to 24 Hrs. and L in MW calculate

i) value of max. load & when it occurs, &

ii) plant load factor.

$\Longrightarrow$ $L = 350 + 10t - t^2$

| t | L | t | L | t | L |
|---|---|---|---|---|---|
| 0 | 350 | 5 | 375 | 9 | |
| 1 | | 6 | | 10 | |
| 2 | | 7 | | 11 | |
| 3 | | | | 12 | 326 |
| 4 | 374 | 8 | 366 | | |

$\therefore$ value of max. Load = 375 MW ANS

Time when it occurs $t = 5$ Hrs.

ii) plant load factor = $\dfrac{\text{Avg. Load}}{\text{max. demand}}$.

Total units generated $= \int_0^{24} (350 + 10t - t^2)\,dt$

$= \left[350t + 10\frac{t^2}{2} - \frac{t^3}{3}\right]_0^{24}$

$= 8400 + 2880 - 4608 = 6672$ MWh

Avg. load = $\dfrac{\text{KWh generated}}{\text{time in Hrs in a day}}$

" " $= \dfrac{6672}{24} = 278$

$\therefore$ L.F. $= \dfrac{A.L}{M.D} = \dfrac{278}{375} = 0.7413$ ANS

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