TUTORIAL PROBLEMS

1. A generating station has an overall efficiency of 15% and 0·75 kg of coal is burnt per kWh by the station. Determine the calorific value of coal in kilocalories per kilogram. **[7644 kcal/kg]**

Tutorial set 1

Tutorial # 1

$\eta_{overall} = 15\% = 0.15$

Coal Consumption per kwh $= 0.75$ kg

We have to determine calorific value of Coal

Let x be the calorific value of coal

Heat produce by 0.75 kg of Coal $= 0.75 \times x$ kcal

Heat equivalent of 1 kwh $= 860$ kcal

$$\eta_{overall} = \frac{\text{Electrical output in heat units}}{\text{Heat of combustion}}$$

$$0.15 = \frac{860}{0.75\,x}$$

$$\Rightarrow \boxed{x = 7644.4 \text{ kcal/kg}}$$

2. A 75 MW steam power station uses coal of calorific value of 6400 kcal/kg. Thermal efficiency of the station is 30% while electrical efficiency is 80%. Calculate the coal consumption per hour when the station is delivering its full output. **[42 tons]**

Tutorial # 2

Generation / Calorific value $= 6400$ Kcal/kg

Max demand $= 75000$ KW

$\eta_{thermal} = 0.3$

$\eta_{electrical} = 0.8$

Assume load factor is 1

$$\eta_{overall} = \eta_{thermal} \times \eta_{electrical}$$
$$= 0.3 \times 0.8$$
$$= 0.24$$

Units generated per hour $= 75000 \times 1 \times 1$ Kwh

$= 75000$ Kwh

Heat equivalent of 1 kwh $= 860$ Kcal

Heat equivalent of 75000 kwh $= 860 \times 75000$

$= 64500000$ Kcal

$$\text{Heat produce per hour} = \frac{\text{Electrical output in heat units}}{\eta_{overall}}$$
$$= \frac{64500000}{0.24}$$
$$= 268750000 \text{ Kcal}$$

$$\text{Coal Consumption per hour} = \frac{268750000}{6400}$$
$$= 41992.2 \text{ kg}$$
$$\approx 42 \text{ tons}$$

3. A 65,000 kW steam power station uses coal of calorific value 15,000 kcal per kg. If the coal consumption per kWh is 0·5 kg and the load factor of the station is 40%, calculate (*i*) the overall efficiency (*ii*) coal consumption per day. **[(*i*) 28·7% (*ii*) 312 tons]**

Tutorial # 3

Electricity generation = 65000 kW
Calorific value = 15000 kcal/kg
Coal consumption per kWh = 0.5 kg
load factor = 40% = 0.4

(i) overall efficiency (ii) Coal consumption per day

units generated per hour = 65000 × 0.4 × 1
= 26000 kWh

units generated per day = 26000 × 24 = 624000 kWh

Coal consumed for 1 kWh = 0.5 kg
Coal consumed for 624000 kWh = 312000 kg

Daily coal consumption $\boxed{= 312 \text{ tons}}$

$$\text{Heat produce per day} = \frac{\text{Electrical output in heat units} \times 24}{\eta_{overall}}$$

$$\eta_{overall} = \frac{65000 \times 24 \times 860}{312000 \times 15000}$$

$$= \frac{1341600000}{4680000000}$$

$$= 0.287$$

$$\boxed{\eta_{overall} = 28.7\%}$$

4. A 60 MW steam power station has a thermal efficiency of 30%. If the coal burnt has a calorific value of 6950 kcal/kg, calculate :

(*i*) the coal consumption per kWh,

(*ii*)the coal consumption per day. **[(*i*) 0·413 kg (*ii*) 238 tons]**

Tutorial #4

output power = 60 MW

$\eta_{thermal} = 30\% = 0.3$

$$\text{input power} = \frac{60}{0.3} = 200\,\text{MW}$$

As we know

$$1\,\text{Kcal} = 4184\,\text{J}$$

$$6950\,\text{Kcal} = 29.0788 \times 10^6\,\text{J}$$

Clear that

1 Kg coal produce 29.0788 MJ

Also

$$1\,\text{Kwh} = 1 \times 10^3\,\text{W} \times 3600\,\text{s}$$

$$= 3600 \times 10^3\,\text{Ws}$$

$$= 3.6 \times 10^6\,\text{J}$$

$$1\,\text{kg coal} \longrightarrow 29.0788\,\text{MJ}$$

$$x\,\text{kg coal} \longrightarrow 3.6 \times 10^6\,\text{J}$$

$$x \times 29.0788\,\text{MJ} = 3.6\,\text{MJ}$$

$$\boxed{x = 0.124\,\text{kg}}$$

$$\text{Energy consumed per day} = 200 \times 10^3 \times 24\,\text{kwh}$$

$$= 4800 \times 10^3\,\text{Kwh}$$

$$1\,\text{kwh} \longrightarrow 0.124\,\text{kg}$$

$$4800 \times 10^3\,\text{kwh} \longrightarrow x\,\text{kg}$$

$$\Rightarrow \boxed{x = 595.2 \times 10^3\,\text{kg}}$$

5. A 25 MVA turbo-alternator is working on full load at a power factor of 0·8 and efficiency of 97%. Find the quantity of cooling air required per minute at full load, assuming that 90% of the total losses are dissipated by the internally circulating air. The inlet air temperature is 20º C and the temperature rise is 30º C. Given that specific heat of air is 0·24 and that 1 kg of air occupies 0·8 m^3. **[890 m^3/minute]**

Tutorial #5

Rating of alternator = 25 MVA

p.f = 0.8

η = 97% = 0.97

Intel air temp = 20°c

Temp rise ΔT = 30°c

Specific heat = C = 0.24 BTU = 1 KJ/kg°C

1 kg occupies 0.8 m^3

Output power = P = S cosϕ = 25(0.8) = 20 MW

Input power = $\frac{20}{0.97}$ = 20.62 MW

Power losses = Input power − Output power

= 0.61855 MW

90% of total loss are dissipated by internal circulating air

so heat transfer

$Q = 0.9 \times 0.61855$

= 556.695 KW or KJ/s

Also

$Q = mC\Delta t$

$556.7 = m(1\ KJ/Kg°c)(30°c)$

$m = 18.56$ kg/s =

1 kg occupies 0.8 m^3

18.56 kg occupies = (0.8)(18.56) = 14.848 m^3/s

$\boxed{= 890.4\ m^3/min}$

6. A thermal station has an efficiency of 15% and 1·0 kg of coal burnt for every kWh generated. Determine the calorific value of coal. **[5733 kcal/kg]**

Tutorial # 6

$\eta_{overall} = 15\% = 0.15$

Coal burn per Kwh = 1 Kg

We have to determine calorific value of coal

let x be the calorific value of Coal

Heat produce by 1 kg of coal $= 1 \cdot x$ Kcal

Heat equivalent of 1Kwh = 860 Kcal

$$\eta_{overall} = \frac{\text{Electrical output in heat units}}{\text{Heat of Combustion}}$$

$$0.15 = \frac{860}{x}$$

$$x = \frac{860}{0.15}$$

$$\boxed{x = 5733.3 \text{ kcal/kg}}$$

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SET 2

TUTORIAL PROBLEMS

1. A hydro-electric station has an average available head of 100 metres and reservoir capacity of 50 million cubic metres. Calculate the total energy in kWh that can be generated, assuming hydraulic efficiency of 85% and electrical efficiency of 90%. **[$10{\cdot}423 \times 10^6$ kWh]**

Tutorial set 2

Tutorial #1

$H = 100\,m$

Reservoir capacity $= 50 \times 10^6\ m^3$

$\eta_{hydraulic} = 85\% = 0.85$

$\eta_{electrical} = 90\% = 0.9$

$\eta_{overall} = 0.85 \times 0.9 = 0.765$

weight of water (available) $= W =$ Volume of water $\times$ density

$= (50 \times 10^6) \times 1000\ kg$

$= 50 \times 10^9\ kg$

$1\ kg = 9.81\ N$

$W = 490.5 \times 10^9\ N$

Electrical energy generated $= (490.5 \times 10^9)(100)(0.765)$

$= 3752325 \times 10^7$ watt sec

$= 3752325 \times 10^4$ kW sec

$= \dfrac{3752325 \times 10^4}{3600}$ kWh

$$\boxed{= 10.423 \times 10^6\ kWh}$$

2. Calculate the continuous power that will be available from hydroelectric plant having an available head of 300 meters, catchment area of 150 sq. km, annual rainfall 1·25 m and yield factor of 50%. Assume penstock, turbine and generator efficiencies to be 96%, 86% and 97% respectively. If the load factor is 40% what should be the rating of the generators installed ? **[7065 kW, 17662 kW]**

Tutorial #2

$H = 300\,m$

Catchment area $= 150\,Km^2 = 150\,(1000)^2\,m^2$

$= 1.5\times10^8\,m^2$

Annual rainfall $= 1.25\,m$

yield factor $= 50\% = 0.5$

$\eta_{penstock} = 96\% = 0.96$

$\eta_{turbine} = 86\% = 0.86$

$\eta_{generator} = 97\% = 0.97$

$\Rightarrow \eta_{overall} = 0.96 \times 0.86 \times 0.97 = 0.800832$

load factor $= 40\% = 0.4$

volume of water $= (1.5\times10^8 \times 1.25 \times 0.5) = 9.375\times10^7\,m^3$

weight of water (available) $= W = 9.375\times10^7 \times 1000$

$W = 9.375\times10^{10}\,Kg$

$W = 9.375\times10^{10} \times 9.81\,N$

$W = 9.196875\times10^{11}\,N$

Electrical energy available $= 9.196875\times10^{11} \times 300 \times 0.800832$

$= 2.20954554\times10^{14}\,Nm$ or watt sec

$= \dfrac{2.20954554\times10^{14}}{1000\times3600}\,Kwh$

$= 61376265\,kwh$

Average Power $= \dfrac{61376265}{8760}$

$\boxed{= 7006.4\,Kwh}$

max demand $= \dfrac{\text{Average load}}{\text{load factor}} = \dfrac{7006.4}{0.4}$

$= 17516.1\,Kw$

Rating of generator must be $\boxed{17516.1\,Kw}$

3. A hydroelectric plant has a reservoir of area 2 sq. kilometres and of capacity 5 million cubic meters. The net head of water at the turbine is 50 m. If the efficiencies of turbine and generator are 85% and 95% respectively, calculate the total energy in kWh that can be generated from this station. If a load of 15000 kW has been supplied for 4 hours, find the fall in reservoir. **[$5 \cdot 5 \times 10^5$ kWh ; 27·8 cm]**

Tutorial # 3

$$Area = 2\,Km^2 = 2000000\,m^2$$

$$Volume = 5\times10^6\,m^3$$

$$H = 50\,m$$

$$\eta_{turbine} = 85\% = 0.85$$

$$\eta_{generator} = 95\% = 0.95$$

$$\eta_{overall} = 0.85\times0.95 = 0.8075$$

$$W = 5\times10^6\times1000\times9.81 \quad N$$

$$= 4.905\times10^{10}\,N$$

$$\text{Electric energy available} = 4.905\times10^{10}\times50\times0.8075$$

$$= 1.98039375\times10^{12}\text{ watt sec}$$

$$= \frac{1.98039375\times10^{12}}{1000\times3600}\ Kwh$$

$$\boxed{= 5.5\times10^5\ Kwh}$$

Let reservoir fall $= x$ meter

$$Q = \frac{Area \times x}{time} = \frac{2\times10^6 \cdot x}{4\times60\times60} = 138.89x \quad m^3/s$$

$$\text{Weight of water available} = 138.89x\times1000\times9.81 \quad N$$

$$= 1362510.9x$$

$$\text{Power produce} = WH\eta_{overall}$$

$$15000\times10^3 = 1362510.9x\times50\times0.8075$$

$$\Rightarrow x = 0.273\,m$$

$$\boxed{x = 27.3\,cm}$$

4. It has been estimated that a minimum run-off of approximately 94 m^3/sec will be available at a hydraulic project with a head of 39 m. Determine the firm capacity and yearly gross output.

[3600 kW, 315·36 × 10^6 kWh]

Hint. Wt. of water flowing/sec $= \dfrac{94 \times (100)^3}{1000}$ kg

5. A hydroelectric power station is supplied from a reservoir having an area of 50 km^2 and a head of 50 m. If overall efficiency of the plant is 60%, find the rate at which the water level will fall when the station is generating 30,000 kW. **[7·337 mm/hour]**

Tutorial #4

Weight of water available $= W = 94 \times 1000 \times 9.81$ N

$W = 922140\,N$

$H = 39\,m$

Work done / sec $= WH = 922140 \times 39$ Watt

$= 35963.460$ KW $\Rightarrow$ Gross plant capacity

Firm capacity for 100% efficiency $\boxed{= 35963.460 \text{ KW}}$

Yearly gross o/p = Firm Capacity × Hours in year

$= 35963.460 \times 8760$

$\boxed{= 315.04 \times 10^6 \text{ kWh}}$

Tutorial #5

$Area = 50\,Km^2 = 50 \times 10^6\,m^2$

$H = 50\,m$

$\eta_{overall} = 60\% = 0.6$

output power = 30,000 KW

input power $= \dfrac{30,000}{0.6} = 50,000$ KW

let x be the rate; when water level goes down in one sec

$Q = x \times A = 50 \times 10^6 x \;\; m^3/s$

$P = \rho g H Q$

$50 \times 10^6 = 1000 \times 9.81 \times 50 \times 50 \times 10^6 x$

$\Rightarrow x = 2.04 \times 10^{-6}\; m/s$

$x = 2.04\; \mu m/s$

$\boxed{x = 7.334 \text{ mm/h}}$

6. A hydro-electric plant has a catchment are of 120 square km. The available run off is 50% with annual rainfall of 100 cm. A head of 250 m is available on the average. Efficiency of the power plant is 70%. Find (*i*) average power produced (*ii*) capacity of the power plant. Assume a load factor of 0.6.

[(*i*) 3266 kW (*ii*) 5443 kW]

Suggested: Solution of all tutorial problems Chapter no.3 || Princi...

Tutorial #6

catchement area $= 120\ km^2 = 120 \times 10^6\ m^2$

Coefficient of runoff $= 50\% = 0.5$

Annual rainfall $= 100\ cm = 1\ m$

$H = 250\ m$

$\eta_{overall} = 70\% = 0.7$

(i)

$$V = (120 \times 10^6)(1)(0.5) = 6 \times 10^7\ m^3$$

$$W = (6 \times 10^7)(1000)(9.81)\ N$$

$$= 5.886 \times 10^{11}\ N$$

$$\text{Energy available} = (5.886 \times 10^{11})(250)(0.7)$$

$$= 1.03 \times 10^{14}\ \text{Watt sec}$$

$$= 28612500\ \text{Kwh}$$

$$\text{Average power} = \frac{28612500}{8760}$$

$$\boxed{= 3266.3\ KW}$$

(ii)

$$\text{Max demand} = \frac{\text{Average power}}{\text{load factor}} = \frac{3266.3}{0.6}$$

$$= 5443.8\ KW$$

capacity of plant must be $\boxed{5443.8\ KW}$