1. The estimated mean monthly flow in a river is as follows (in $10^6 m^3$)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Inflow(10^6Mm^3)	7.65	19.6	17.3	10.5	5.95	6.79	10.7	13	19.3	17.3	10.5	6.79

The available fall is 42.7 m. what size of reservoir is necessary to give the greatest continuous power output and what would this power be if the plant efficiency is 70%?

Solution

Plot the mass curve for given river inflow as cumulative inflow Vs months

Months	**Inflow ($10^6 Mm^3$**	**Cumulative Inflow**
Jan.	7.65	7.65
Feb.	19.6	27.25
Mar.	17.3	44.55
Apr.	10.5	55.05
May	5.95	61
June	679	67.79
Jul.	10.7	78.49
Aug.	13	91.49
Sep.	19.3	110.79
Oct.	17.3	128.09
Nov.	10.5	138.59
Dec.	6.79	145.38

Therefore, the capacity of the reservoir will be

$$\boldsymbol{Size\ of\ the\ reservoir} = 9 * 10^6 m^3 + 12 * 10^6 m^3 = \mathbf{21 * 10^6 m^3}$$

$$Discharge(Q) = \frac{159 * 10^6 m^3}{(12 * 30 * 24 * 60 * 60)} = \mathbf{5.11 \frac{m^3}{s}}$$

$$\boldsymbol{Power\ Output} = 9.81 * 0.7 * 5.11 * 42.7 = \mathbf{1498KW}$$

2. The power demand for a town is as follows:

6-8 AM ------- 1200KW, 8-9AM --------- 2000KW, 9-12 AM ------ 3000KW

12-2 PM ------ 1500KW, 2-6 PM ----------1200KW, 6-8 PM -------- 2500KW

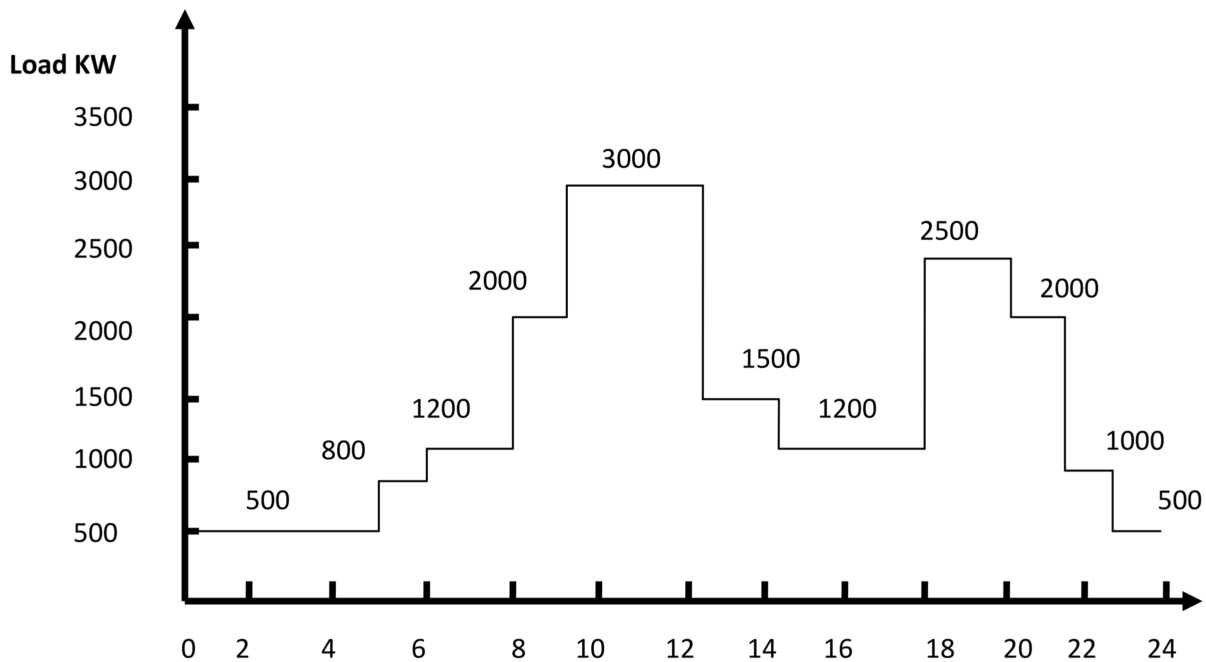
8-9 PM -------- 2000KW, 9-11 PM ------ 1000KW, 11-5 AM ------- 500KW

5-6 AM -------- 800KW

a. Draw the load curve and find the load factor
b. Chose proper capacity and number of turbine
c. Find the reserve capacity and plant capacity factor
d. Prepare operating schedule for the selected turbines

Solution: The load curve of the power station can be drawn as shown below.

a.



$$Load\ Factor = \frac{Average\ Load}{Max.demand}$$

$But, Average\ Load$

$$= \frac{(500*5) + (800*1)1200*2) + (2000*1) + (3000*3) + (1500*2) + (1200*4) + (2500*2) + (2000*1) + (1000*2) + (500*1)KWh}{24\ hr}$$

$$Average\ Load = \mathbf{1416.7\ KW}$$

Therefore,

$$Load\ Factor = \frac{Average\ Load}{Max.demand}$$

$$L.F = \frac{1416.67KW}{3000\ KW} = \mathbf{47.2\%}$$

b. In order to select the size and number of units,

- provision of one set of highest capacity as a stand by unit
- the units capacity to meet the maximum demand and
- Overall economy are must be considered.

Therefore, depending on these criteria, we select **four set** of turbines each having the capacity of 1000 kw.

Three sets will serve to meet the maximum demand i.e. 3000kw and one unit may serve as a standby.

c. Find the reserve capacity and plant capacity factor

$$Plant\ capacity\ factor\ = \frac{Actual\ energy\ produced}{Max.energy\ that\ could\ have\ been\ produced}$$

$$Plant\ capacity\ factor = \frac{(500*5)+(800*1)1200*2)+(2000*1)+(3000*3)+(1500*2)+(1200*4)+(2500*2) + (2000*1)+(1000*2)+(500*1)KWh}{3000*24}$$

$$Plant\ capacity\ factor\ = \frac{34000KWh}{72000KWh}$$

$$\mathbf{Plant\ capacity\ factor\ =\ 0.47}$$

$$Plant\ capacity\ factor\ = \frac{Average\ Load}{Plant\ Capacity}$$

$$Plant\ Capacity\ = \frac{Average\ Load}{Plant\ capacity\ factor}$$

$$Plant\ Capacity\ = \frac{34000KWh}{0.47}$$

$$Plant\ Capacity\ =\ 72340KWh$$

$$reserve\ Capacity = Plant\ Capacity - maximum\ Demand\ =\ 72340KWh$$

$$Reserve\ Capacity = 72340KWh - 72000KWh = \mathbf{340KWh}$$

d. Prepare operating schedule for the selected turbines

Operational schedule:

- Set No. 1 will run for 24 hrs
- Set no. 2 will run from 6:00 am to 23:00 night for 17 hrs.
- Set no. 3 will run from 9:00to 12:00 am and again from 18 PM to 22PM for five hrs

3. Given

- Elevation of the head water level: 500 m
- Elevation of the tail water level: 200m
- Tunnel: Length = 4000 m; Diameter = 8 m; f = 0.028
- Penstocks: Length = 500 m; Diameter = 2 m; f = 0.016
- The maximum reservoir storage which can be utilized continuously for 48 hrs: 15x10^6 m^3
- Efficiency of the turbine: 90%
- Efficiency of the generator: 90% (number of poles = 16, f = 50 Hz)

a. Determine the maximum power output from the installation

b. Estimate the specific speed and the type of turbine

Solution

The available discharge from the river storages

$$= \frac{15 * 10^6 m^3}{(48 * 60 * 60)s} = 86.8\frac{m^3}{s}$$

Then, in order to calculate the power output, first we have to calculate the velocity in tunnel. Therefore, tunnel velocity,

$$V_t = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4}D^2} = \frac{86.8\frac{m^3}{s}}{\frac{\pi}{4} * (8m)^2} = 1.73\frac{m^2}{s}$$

The head loss in tunnel would be

$$h_f = \frac{fLV^2}{2gD} = \frac{0.028 * 4000m * (1.73\frac{m}{s})^2}{2 * 9.81\frac{m}{s^2} * 8m} = \mathbf{2.13m}$$

Discharge per penstock: - since we have four turbines

$$= \frac{Q}{4} = \frac{86.8\frac{m^3}{s}}{4} = 21.7\frac{m^3}{s}$$

Velocity per penstock,

$$V_t = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4}D^2} = \frac{21.7\frac{m^3}{s}}{\frac{\pi}{4} * (2m)^2} = 6.9\frac{m^2}{s}$$

$$h_f = \frac{fLV^2}{2gD} = \frac{0.016 * 500m * (6.9\frac{m}{s})^2}{2 * 9.81\frac{m}{s^2} * 2m} = \mathbf{9.73m}$$

Gross head at the turbine

$$= Head\ water\ level - Tail\ water\ level$$

$$= 500m - 200m = 300m$$

$$\text{Net Head} = Gross\ head - Head\ loss$$

$$= 300m - (2.13m + 9.73m) = \mathbf{288.14m}$$

Thus, power output per turbine can be calculated as

$$P =$$

$$Total\ power\ output = \eta\gamma QH\ KW$$

$$Total\ power\ output = 0.9 * 9.81 * 21.7 \frac{m^3}{s} * 288.14m = \mathbf{55\ MW}$$

$$Total\ power\ output = 4 * 55MW = \mathbf{220MW}$$

The net output of the generator

$$= 0.9 * 220MW = 198MW$$

b. The specific Speed (N_s) and type of turbine

$$N_s = \frac{NP^{0.5}}{H^{1.25}}, but N = \frac{120f}{p} = \frac{120 * 50}{8} = 375rpm$$

$$N_s = \frac{375rpm * (55 * 10^3 KW}{(288.14m)^{1.25}}$$

$$N_s = \frac{375rpm * (55 * 10^3 KW}{(288.14m)^{1.25}} = \mathbf{76}$$

4. The amount of flow of water from a certain catchment is shown below (in $10^6\ m^3$)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Inflow(10^6Mm^3)	2.83	3.4	5.66	18.4	23.75	23.75	20.4	9.34	7.36	6.79	6.23	5.95

Determine:

a. The maximum capacity of the reservoir without spill over for maximum possible uniform withdrawal

b. Initial storage

c. If the initial storage is 14x106 m3what will be the maximum uniform draw off?

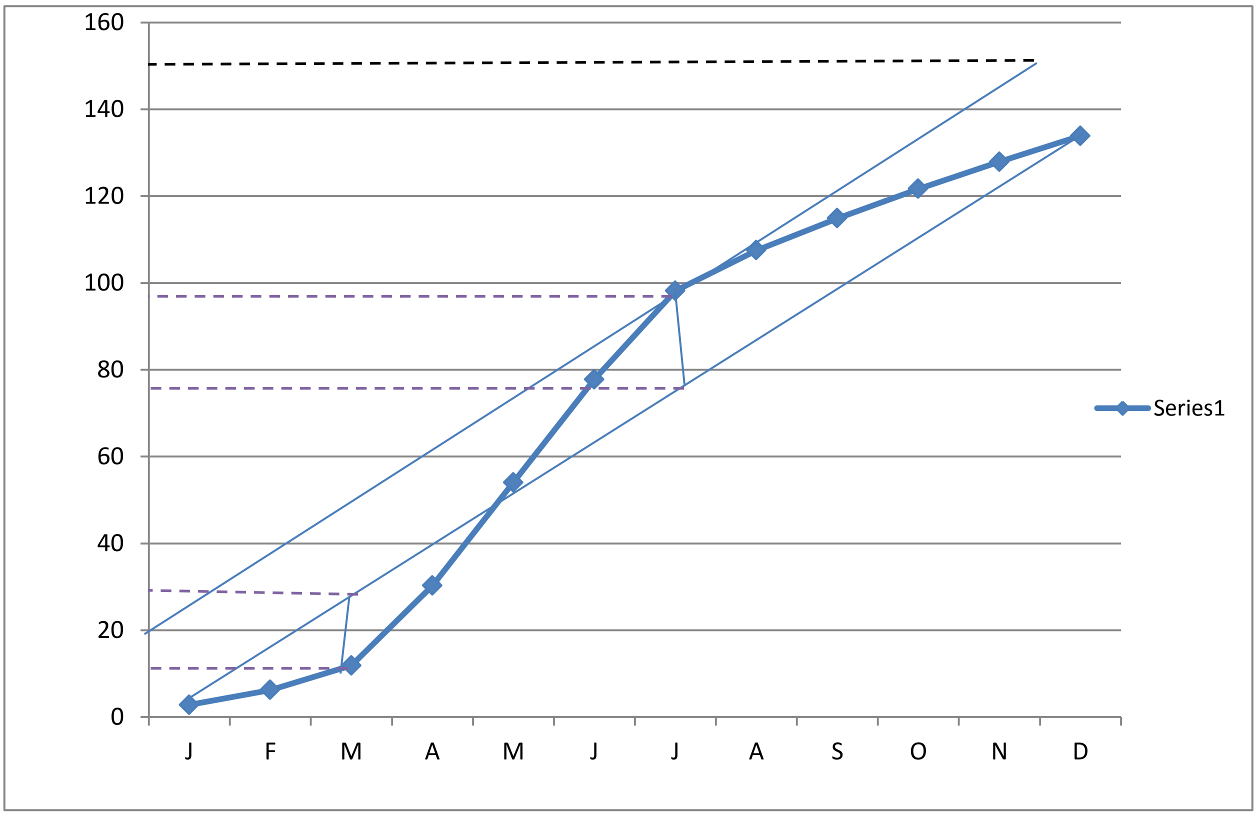
d. If the reservoir capacity is unaltered, what will be the amount of spillover?

e. If the available head is 55m and the overall efficiency is 87%, how much power can be generated in the two cases, (without spill over and with spill over) and the number of units of turbine in the two cases?

Solution

Months	Inflow (10^6 Mm^3	Cumulative Inflow
Jan.	2.83	2.83
Feb.	3.4	6.28
Mar.	5.66	11.89
Apr.	18.4	30.29

May	23.75	54.04
June	23.75	77.79
Jul.	20.4	98.19
Aug.	9.34	107.53
Sep.	7.36	114.89
Oct.	6.79	121.68
Nov.	6.23	127.91
Dec.	5.95	133.86



a. The maximum capacity of the reservoir without spill over for maximum possible uniform withdrawal

$$Maximun\ Capacity = \mathbf{14 * 10^6 m^3 + 20 * 10^6 m^3 = 34 * 10^6 m^3}$$

b. Initial storage= $\mathbf{14 * 10^6 m^3}$

c. If the initial storage is 14x106 m3what will be the maximum uniform draw off?

$$maximum\ uniform\ draw\ off(Q) = \frac{133.86 * 10^6 m^3 - 0 * 10^6 m^3}{(12 * 30 * 2 * 60 * 60)s}$$

$$maximum\ uniform\ draw\ off(Q) = \mathbf{4.3 \frac{m^3}{s}}$$

d. If the reservoir capacity is unaltered, what will be the amount of spillover?

$$Amount\ of\ Overspill = 20 - 14 = \mathbf{6}\frac{\boldsymbol{m^3}}{\boldsymbol{s}}$$

e. If the available head is 55m and the overall efficiency is 87%, how much power can be generated in the two cases, (without spill over and with spill over) and the number of units of turbine in the two cases?

For first case (without over spill)

$$P = \gamma * \eta * Q * H$$

$$\boldsymbol{P} = 9.81 * 0.87 * 4.3 * 55 = \mathbf{2018}\boldsymbol{KW}$$

For first case (wit over spill)

$$P = \gamma * \eta * Q * H$$

But,

$$\boldsymbol{Q} = \frac{130 * 10^6 m^3}{(12 * 30 * 24 * 60 * 60)s} = \mathbf{4.18}\frac{\boldsymbol{m^3}}{\boldsymbol{s}}$$

Therefore,

$$P = \gamma * \eta * Q * H$$

$$\boldsymbol{P} = 9.81 * 0.87 * 4.18 * 55 = \mathbf{1962}\boldsymbol{KW}$$

5. The amount of flow, head and efficiency to be used in power production is shown below

Time	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Flow (m^3/s)	0.04	0.19	0.4	0.78	0.83	0.78	0.87	1.7	1.04	0.68	0.07	0.03
Head (m)	16.7	16.7	16.7	16.7	16.7	16.7	16	16.32	16.6	16.7	16.7	16.7
Efficiency	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87

Design life of the project 50 years

a. Determine the design discharge capacity
b. Select the type and number of turbines for the design discharge capacity selected
   There by estimate the load factor, capacity factor of the project. The generator speed to be used is 100 rpm.

Solution

Table 5.1 FDC and PDC analysis

Month	sorted flow	Head(m)	Efficiency	rank	Q for P	Exce%	p(kw)	sorted p	Rank	Exce%
Aug	1.7	16.32	0.87	1	0.87	8.33	121.18	123.26	1	8.33

Month	sorted flow	Head(m)	Efficiency	rank	Q for P	Exce%	p(kw)	sorted p	Rank	Exce%
Sep	1.04	16.6	0.87	2	0.87	16.67	123.26	121.18	2	16.67
Jul	0.87	16	0.87	3	0.87	25.00	118.80	118.80	3	25.00
May	0.83	16.7	0.87	4	0.83	33.33	118.30	118.30	4	33.33
Apr	0.78	16.7	0.87	6	0.78	50.00	111.17	111.17	6	50.00
Jun	0.78	16.7	0.87	6	0.78	50.00	111.17	111.17	6	50.00
Oct	0.68	16.7	0.87	7	0.68	58.33	96.92	96.92	7	58.33
Mar	0.4	16.7	0.87	8	0.4	66.67	57.01	57.01	8	66.67
Feb	0.19	16.7	0.87	9	0.19	75.00	27.08	27.08	9	75.00
Nov	0.07	16.7	0.87	10	0.07	83.33	9.98	9.98	10	83.33
Jan	0.04	16.7	0.87	11	0.04	91.67	5.70	5.70	11	91.67
Dec	0.03	16.7	0.87	12	0.03	100.00	**4.28**	**4.28**	12	100.00

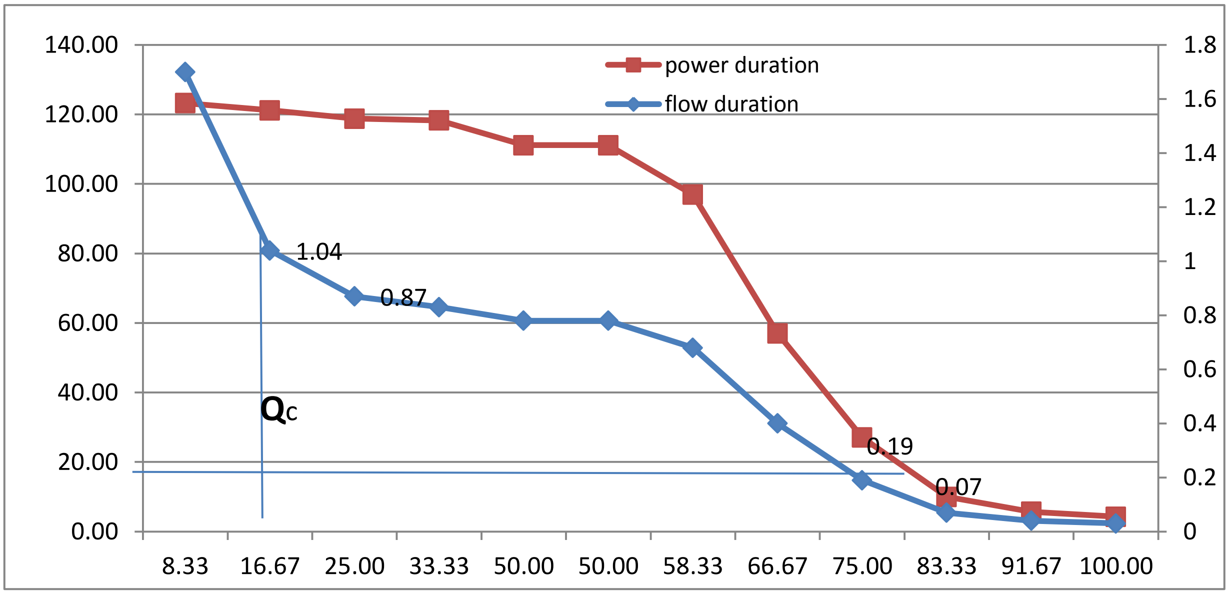


Fig 5.1 FDC and PDC

A) From the FDC Qc is take 0.87 m^3/s

B) For the above selected Discharge $N_s = \frac{N(P)^{0.5}}{(H)^{1.25}}$: (100*123.26^.5)/16.32^1.25 = 33.8 appropriate turbine type is pelton wheel with150 kw

LF = average load/peak load =111.7/123.26 = 90%

CF = average load/ rated capacity of the plant 111.7/150 =74.5%