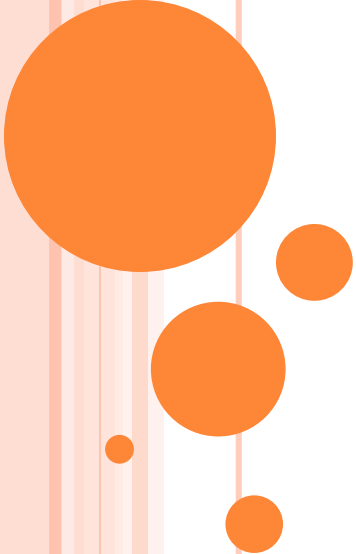




HYDROPOWER ENGINEERING

Chapter 3

Estimation of Water Power Potential

Chap. 3. Water Power Potential

- It is essential to assess the inherent power available from the discharge of a river and the head available at the site before any power plant is contemplated.
- The gross head of any proposed scheme can be assessed by simple surveying techniques, where as hydrological data on rainfall and runoff are essential in order to assess the available water quantities.

The following hydrological data are necessary:

- a) the daily, weakly or monthly flow over a period of several years, to determine the plant capacity & estimated output.
- b) low flows, to asses the primary, firm, or dependable power.

The potential or theoretical power in any river stretch with a difference in elevation H is computed from:

$$P_p = \gamma \cdot Q \cdot H$$



where

H = head in m

Q = discharge of streams in m^3/s

P_p = Potential (theoretical) power of the stream in KW

From the above relationship:

$$P_p = \gamma \cdot Q \cdot H \text{ (KW)} = 9.81 Q \cdot H \text{ (KW)}$$

Since

$$1 \text{ hp} = 736 \text{ Watts} \text{ -----hp (horse power)}$$

$$P_p = 13.33 Q \cdot H \text{ (hp)}$$

The hydraulic power P is given by

$$P = \eta \cdot \gamma \cdot Q \cdot H = 9.81 \eta \cdot Q \cdot H \text{ (KW)}$$

Where η = is the total efficiency



From the available stream flow data, one can obtain *flow duration curve* of the stream for a given site by plotting the discharge against the percentage duration of the time for which it is available.

Similarly, *power duration curve* can be plotted since power is directly proportional to the discharge and available head.

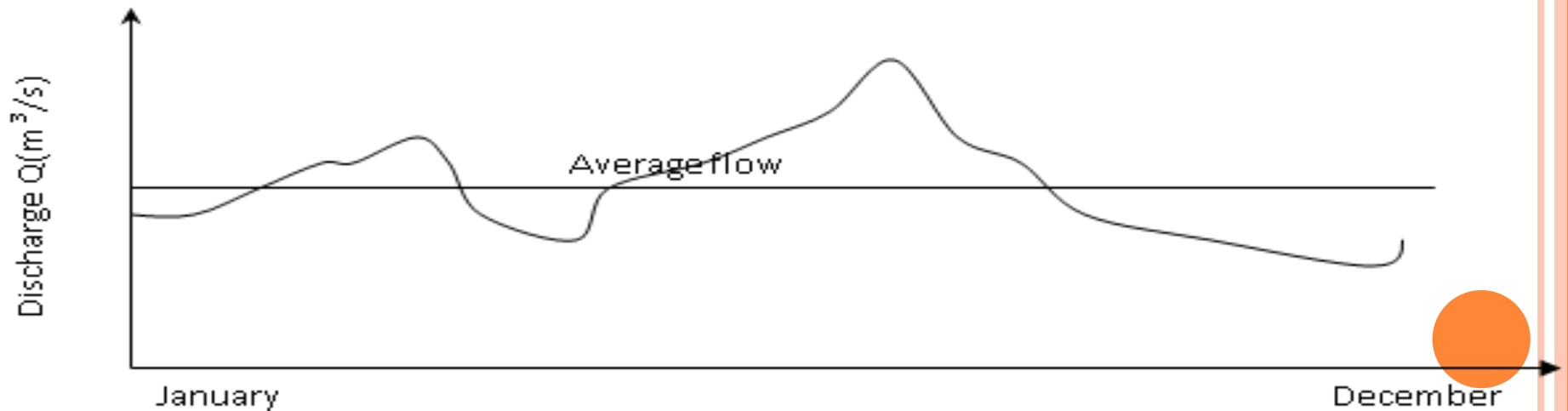


Fig.3.1: Stream flow hydrograph

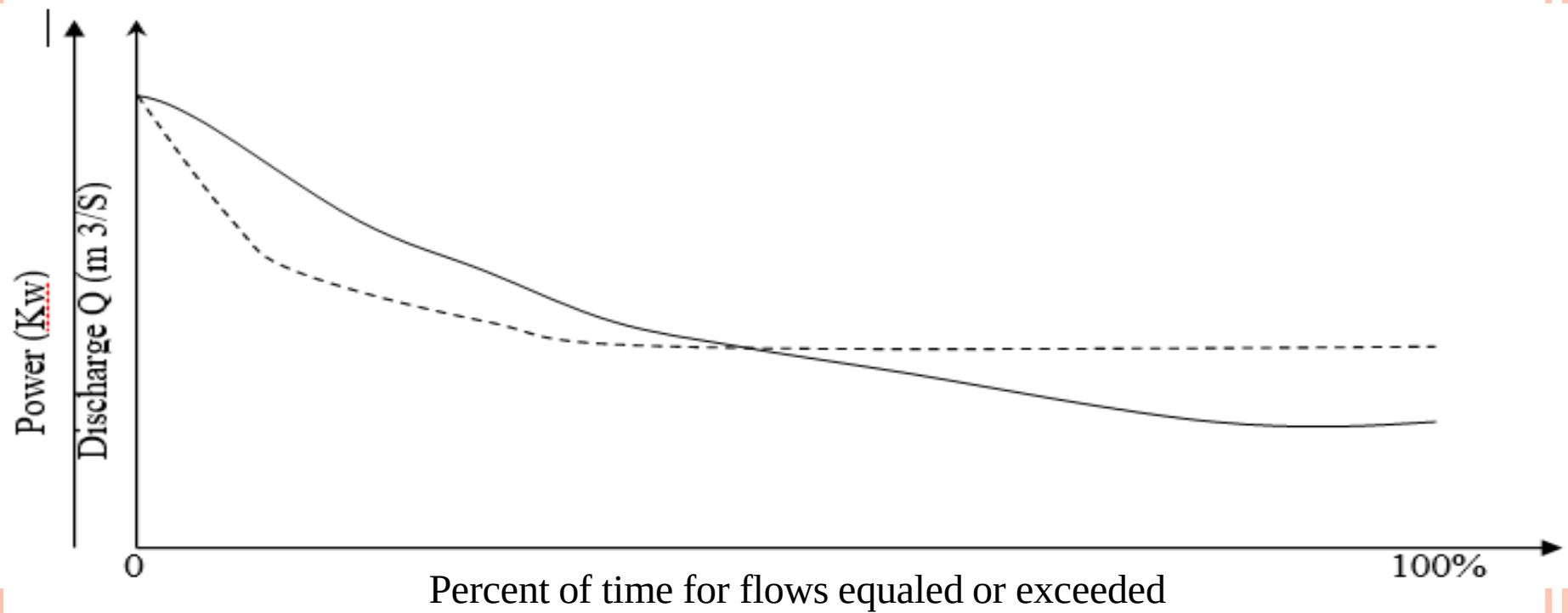
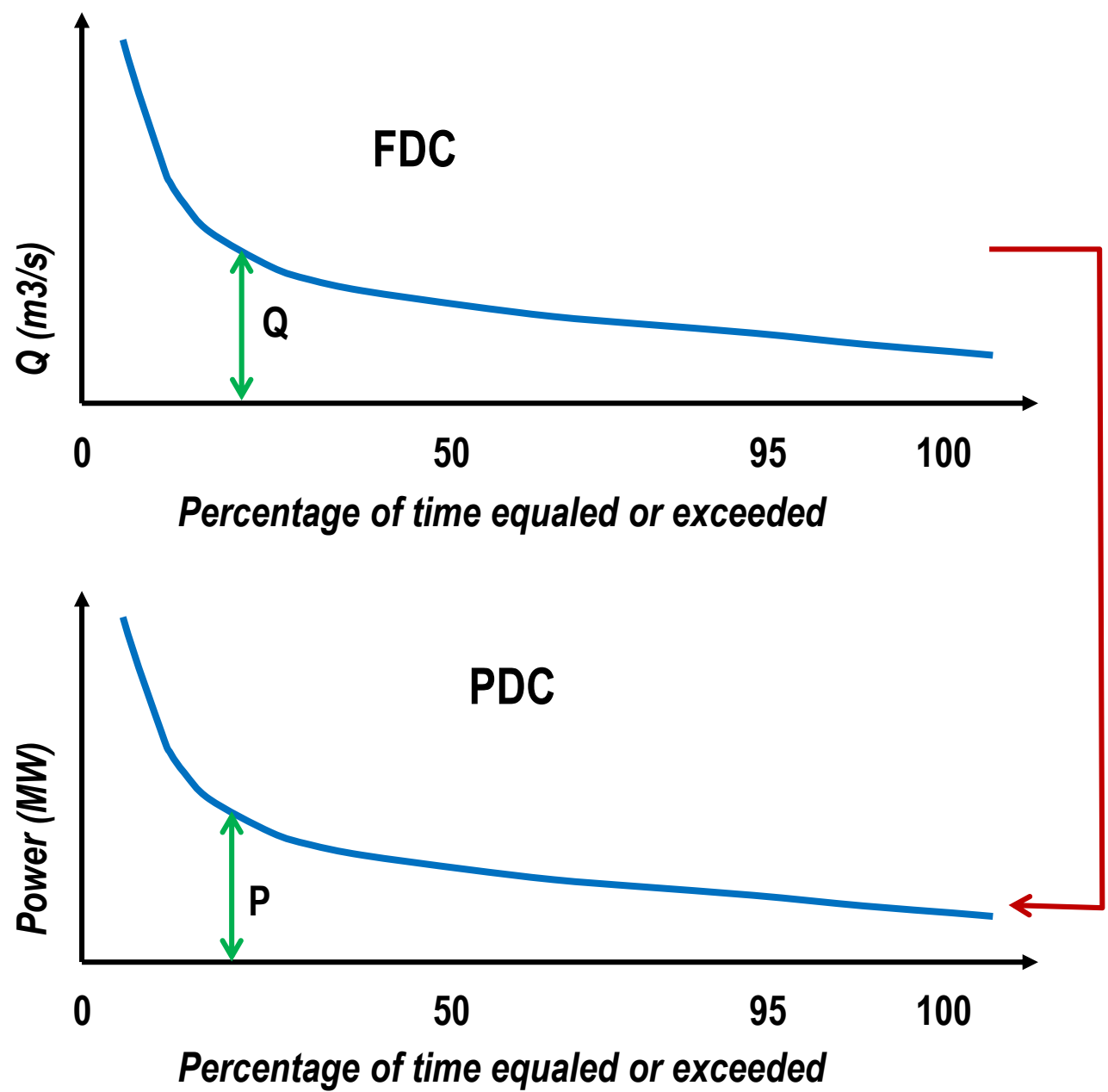


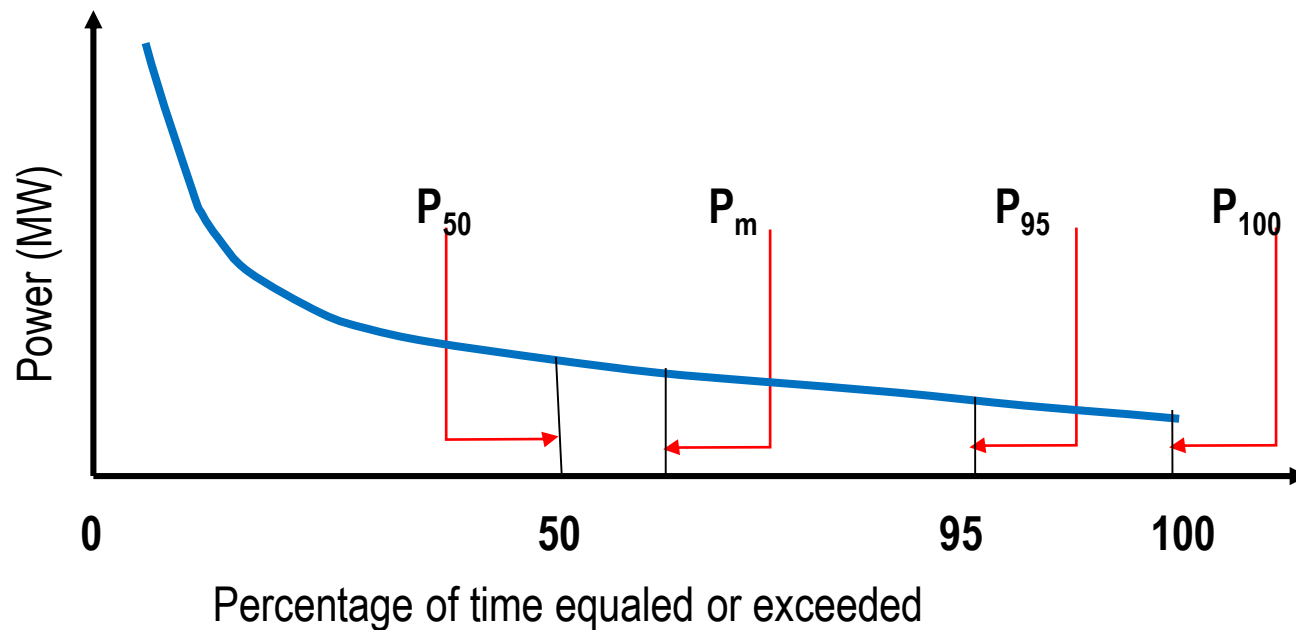
Figure 3.2 Flow\Power duration curve (Power scale multiplying factor = $9.81 \eta.H$)

Potential power resources can be characterized by values according to the discharge taken as a basis of computation. The conventional discharges are Q_{100} , Q_{95} , Q_{50} , Q_m .



❑ A relationship between FDC and PDC is shown below





- ❑ **Minimum potential power** computed from the minimum flow available for 100 % of the time (365 days or 8760 hours). This is represented as **P100**;
- ❑ **Small potential power** computed from the flow available for 95 % of time (flow available for 8322 hours). This is represented as **P95**;
- ❑ **Average potential power** computed from the flow available for 50% of the time (flow available for 6 months or 4380 hours). This is represented as **P50**;
- ❑ **Mean potential power** computed from the average of mean yearly flows for a period of 10 to 30 years, which is equal to the area of the flow-duration curve corresponding to this mean year. This is known as 'Gross river power potential' and is represented as P_m .

Technically Available Power

- ❖ Evaluation of technically available power from the available power is significance. According to Mossony the losses subtracted from the P_p values represents an upper limit of utilization.

Losses = Conveyance loss + plant losses

(entrance, rack, generator, turbine)

- ❖ According to F.I. Nestruck

Conveyance efficiency = 70%

Overall plant efficiency = 80%

Total multiplying factor = 0.56 to be used with average potential power P_{p50} .

- ❖ Therefore, technically available power $P_a = 0.56 P_{p50}$.

- ❖ The multiplying factor depends up on the type of development.
i.e. run-of-river plant, high head plant, etc.

❑ It would be more significant to find out the **technically available power** from the potential power;
According to Mosonyi, the losses subtracted from the P values present an upper limit of utilization;

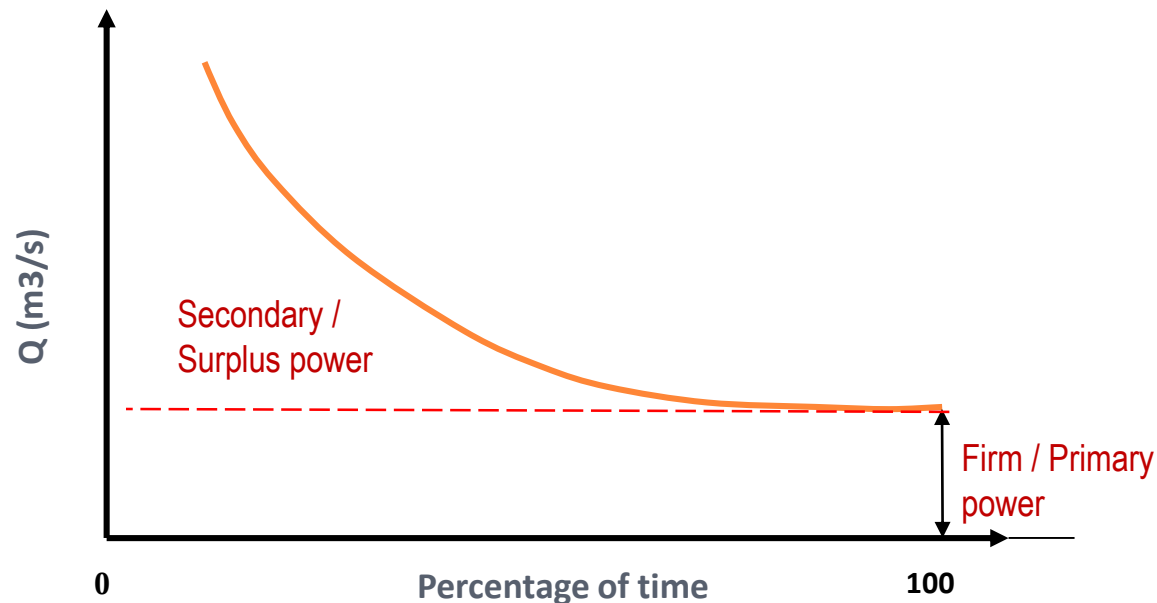
❑ **Technically available power:** With conveyance efficiency of 70% and overall efficiency of the plant as 80%, a combined multiplying factor of 0.56 should be used with the average potential power, P₅₀;

$$P_a = 0.56P_{50}$$

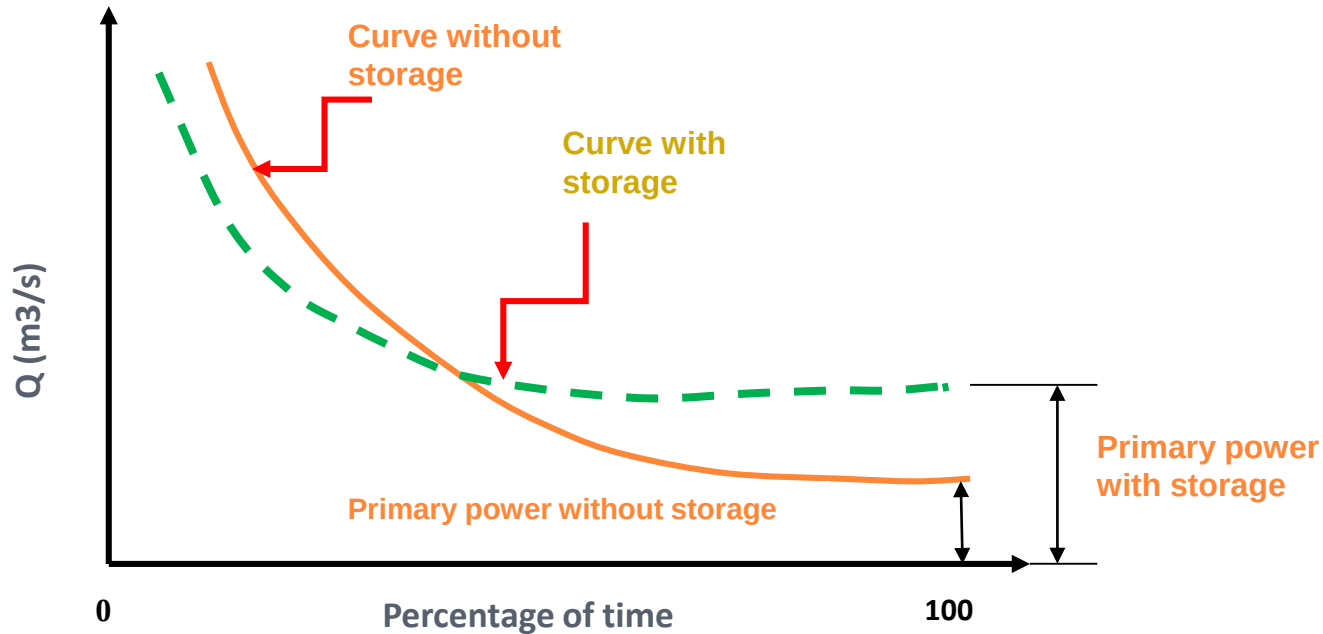
❑ **Firm Power (primary power)**

✓ is the power which is always ensured to a consumer at any hour of the day and is, thus, completely dependable power.

✓ Firm power would correspond to the minimum stream flow and is available for all the times;



- The firm power could be increased by the use of pondage (storage).



□ Secondary power (surplus or non-firm power),

- Is the power other than the primary power and is, thus, comparatively less valuable
- The secondary power is useful in an interconnected system of power plants.
- At off-peak hours, the secondary power may be called upon to relieve the interconnected stations.
- The secondary power may also be used to take care of the current demand by following a load-duration plan

Example 3. For the example 1 given in chapter 2, construct the power duration curve if the available head is 15 m. Calculate the average potential power and the technically available power with conveyance efficiency of 70% and overall efficiency of 80%.

Year	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Flow (m³/s)	905	865	1050	1105	675	715	850	775	590	625	810	885	1025	1150	925

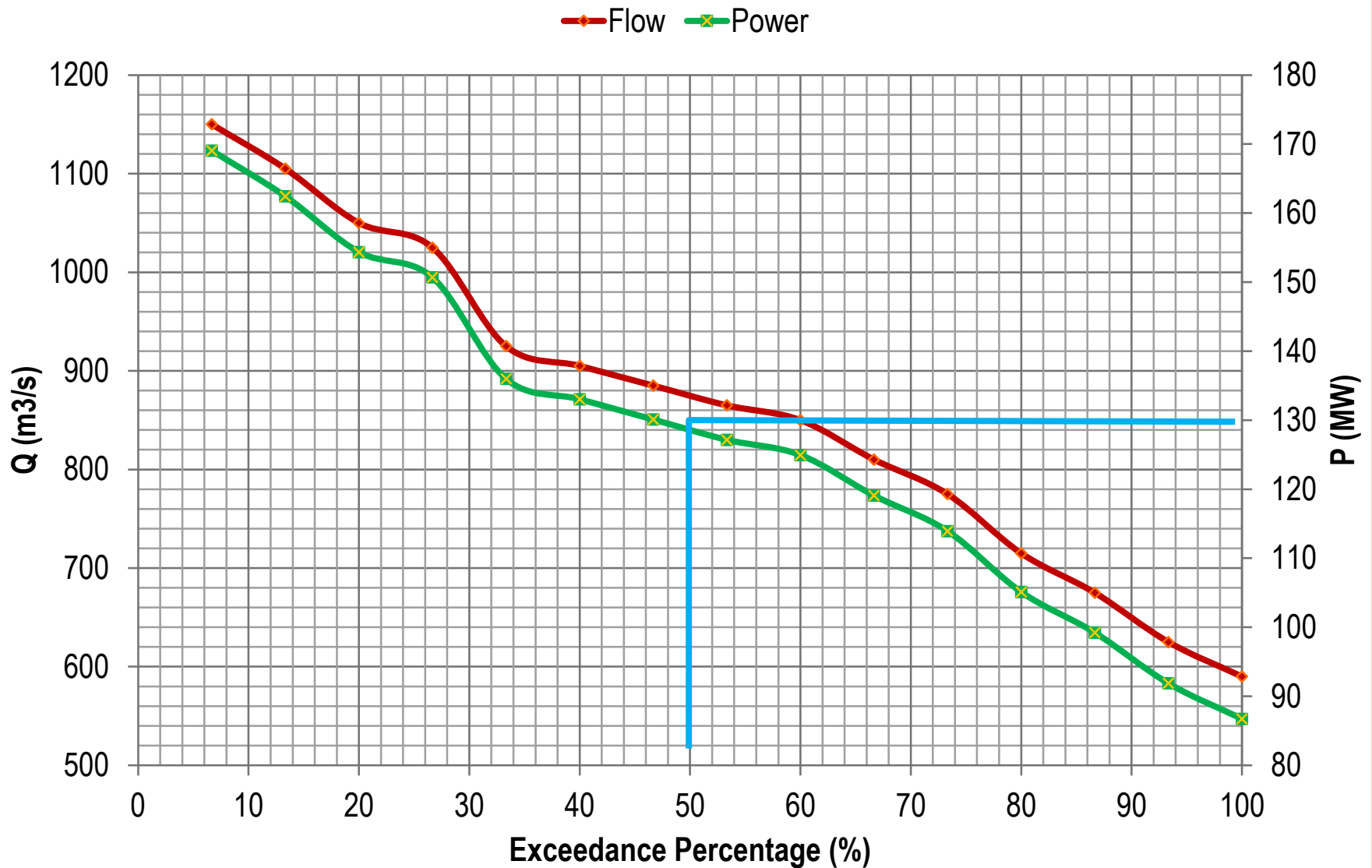
- A. Construct the Flow Duration Curve
- B. Using the Power equation, calculate the theoretical power from the FDC for constant head = 15 m

$$P = \rho \, g \, Q \, h$$

$\rho = 1000 \text{ kg/m}^3$;
 $g = 9.81 \text{ m/s}^2$
 $h = 15\text{m}$

Year	Q	Order No	Q	Excedence Probability	P = ρ gQh; (MW)
1956	905	1	1150	6.67	169.05
1957	865	2	1105	13.33	162.435
1958	1050	3	1050	20.00	154.35
1959	1105	4	1025	26.67	150.675
1960	675	5	925	33.33	135.975
1961	715	6	905	40.00	133.035
1962	850	7	885	46.67	130.095
1963	775	8	865	53.33	127.155
1964	590	9	850	60.00	124.95
1965	625	10	810	66.67	119.07
1966	810	11	775	73.33	113.925
1967	885	12	715	80.00	105.105
1968	1025	13	675	86.67	99.225
1969	1150	14	625	93.33	91.875
1970	925	15	590	100.00	86.73





- C. Average power = $P_{50} = 128.6$ MW
- D. Technically available power = $0.7 \times 0.8 \times 128 = 72.03$ MW

3.2 Load Terminologies

3.2.1 Load and Demand

❑ Power is needed for a variety of purposes such as

- ✓ domestic,
- ✓ commercial,
- ✓ industrial,
- ✓ municipal,
- ✓ agricultural,
- ✓ public transport etc.

❑ The terms load and demand are used synonymously

❑ Load

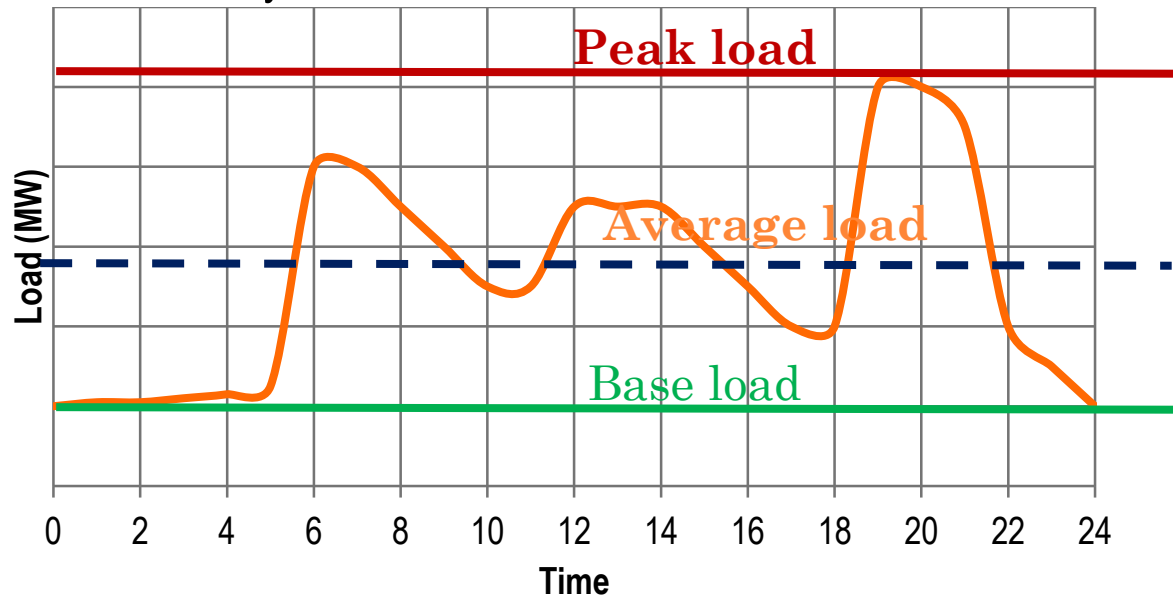
- ✓ the amount of power that is actually **delivered to or received by consumers** at any instant.

❑ Demand

- ✓ refers to the amount of **power needed or desired by consumer** at any instant;

3.2.2 Load Curve

- ❑ The amount of load that is used at various hours of the day may vary depending up on the requirement of consumption.
- ❑ A curve that displays load against time is known as **the load curve**
- ❑ A **Daily Load Curve** is a curve drawn between load as the ordinate and time in hours as the abscissa for one day.



Note: The area under the load curve represents the energy consumed in kWh;

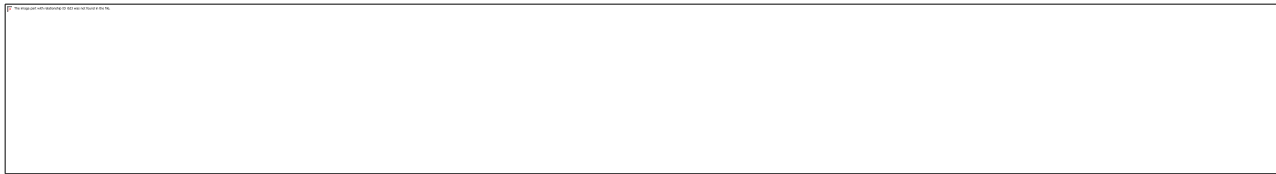
1. **Base load:** the total load that is continuously exceeded;
2. **Average load:** the area under the curve divided by time.
3. **Peak load:** the highest instantaneous load. Generally, peak load is defined as that part of the load carried at intensity greater than $\frac{4}{3}$ times the average load intensity. The peak load determines the size of the hydro plant and its cost.

❑ **Load Factor:**

- The degree of variation of the load over a period of time is measured by the load factor,
- It is given by the ratio of the average load to the peak load



- A **daily load factor** may also be defined as the ratio of the actual energy consumed during 24 hours to the peak demand assumed to continue for 24 hours, i.e.

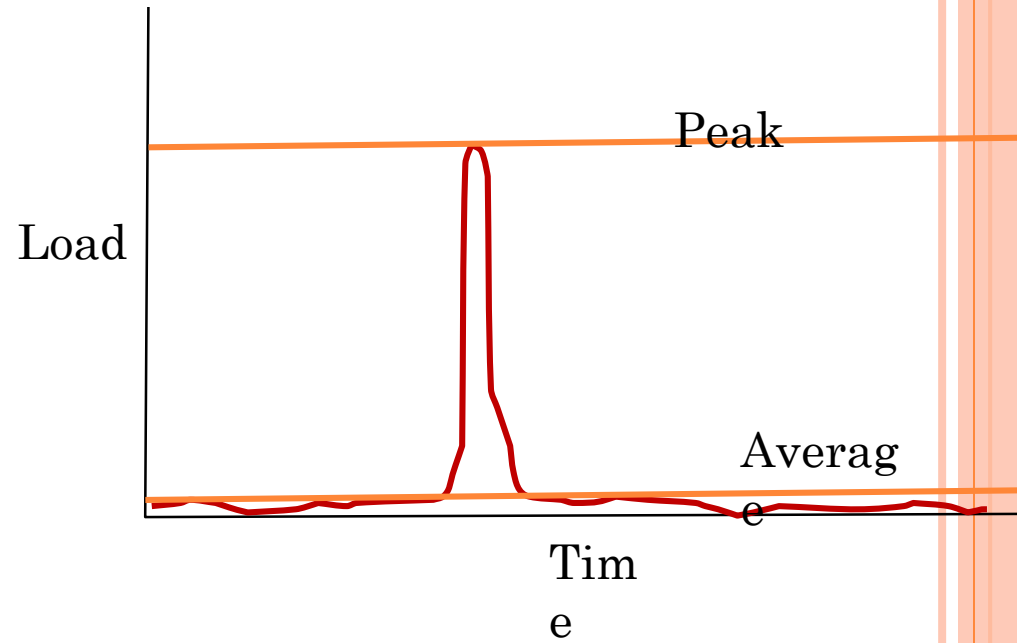


- Load factor gives an idea of degree of utilization of capacity;
- Thus, an annual load factor of 0.45 indicates that the machines are producing only 45% of their yearly production capacity.



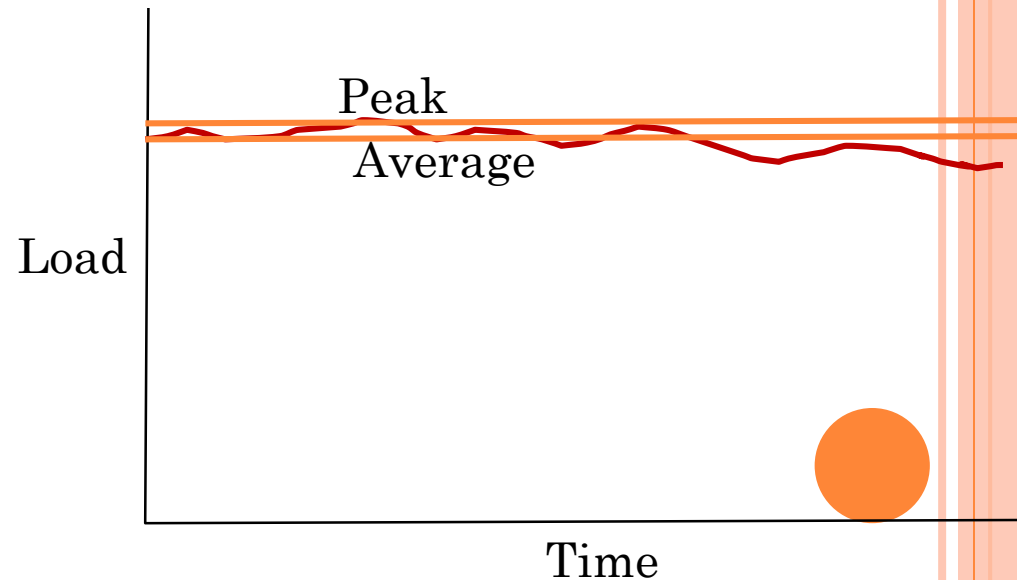
- **Load factor approaching zero.**

The load curve will approach a narrow spike, i.e., a peak load of very short duration with very low or no load during the major portion of the time.



Load factor approaching one.

The load curve will be somewhat rectangular in appearance, indicating high sustained loads.



❑ **Capacity Factor.** (*plant use factor* or *plant factor*)

- The extent of use of the full generating capacity of a plant is measured by the capacity factor,



Example:

If a plant with a capacity of 100MW produces 6,000,000 kWh operating for 100 hours, what is its capacity factor,

Energy actually produced in 100 hrs = 6,000,000 KWh

Energy that the plant is capable of producing at full capacity =

$100 \text{ MW} * 100 \text{ hrs} = 10,000 \text{ MWh} = 10,000,000 \text{ KWh}$



- ❑ The capacity factor for hydroelectric plants generally varies between **0.25 and 0.75**.
- ❑ The **capacity factor** would be identical with **load factor** if the **peak load** were equal to the **plant capacity**. However, the load factor would be different if the plant were not used to its full capacity.
- ❑ Thus, in the above example, if the peak load was 75 MW instead of 100 MW, then
 - ✓ Energy actually produced in 100 hrs = 6,000,000 KWh
 - ✓ Average load = $6,000,000 / 100 = 60,000 \text{ KW} = 60 \text{ MW}$
 - ✓ Peak load = 75 MW



□ **Utilization Factor:**

- The utilization factor measures the use made of the total installed capacity of the plant. It is defined as the ratio of **the peak load** and **the rated capacity** of the plant.



- If the **head is assumed to be constant**,



- The value of utilization factor varies between **0.4 and 0.9** depending on the plant capacity, load factor and storage.
- The utilization factor for a plant depends upon the type of system of which it is a part of.
 - ✓ **A low utilization factor** may mean that
 - ❖ the plant is used only for **stand-by purposes** on a system comprised of several stations or
 - ❖ that capacity has been installed well in advance of need

✓ **A High utilization factor** indicates that

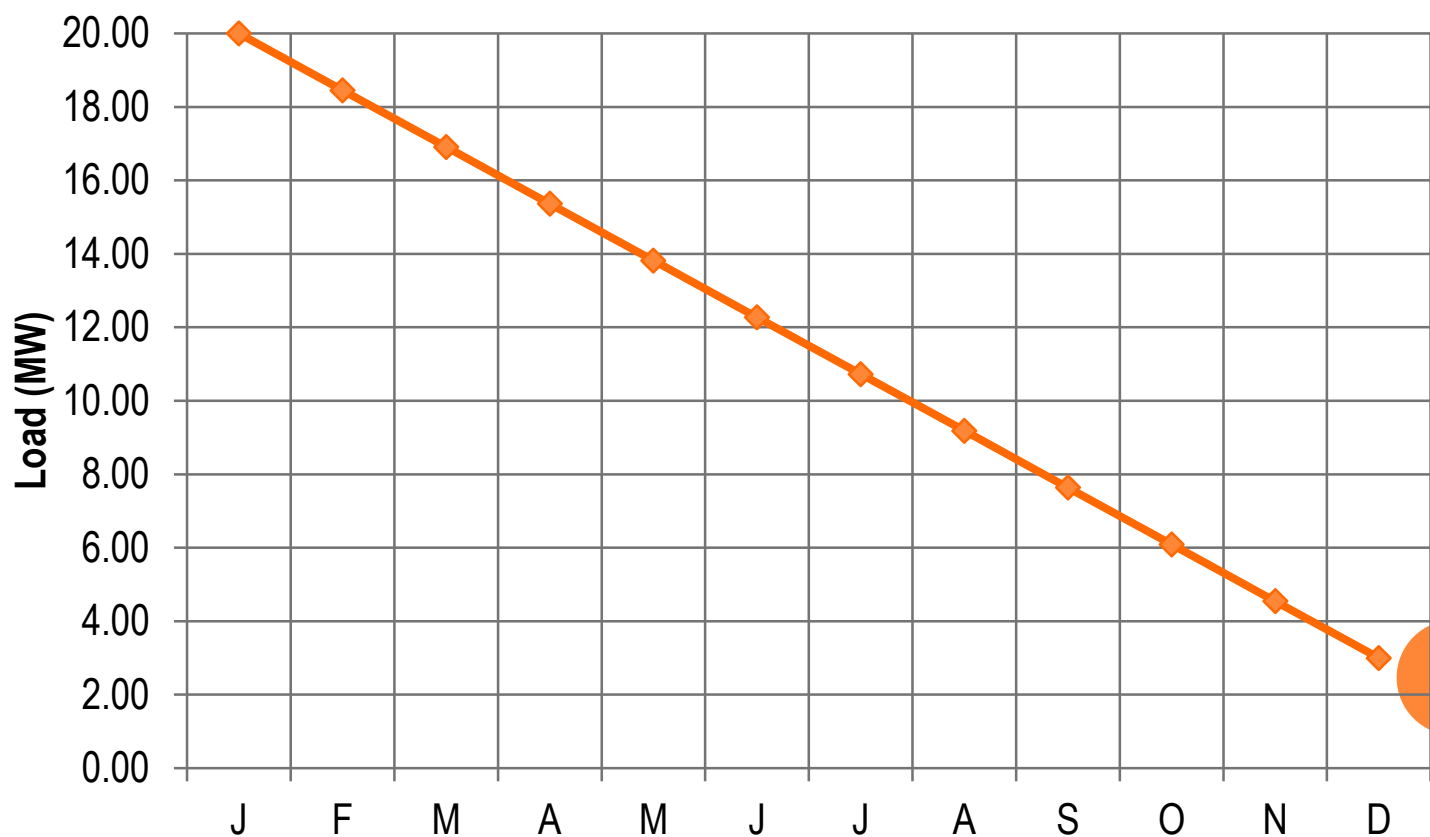
- ❖ the plant is probably the most efficient in the system.
- ❖ In the case of isolated plants a high value means the likelihood of **good design** with some reserve-capacity allowance.



□ Example 5

Consider the yearly load curve for a certain load center to be a straight line from 20 to 3 MW. To meet this load, three turbine units, two rated at 10 MW each and one at 5 MW are installed. Determine:

- a. Load factor (LF)
- b. Capacity factor (CF)
- c. Utilization factor (UF)



A. Load Factor

Energy produced during the year = $(20+3)/2 \times 365 \times 24 = 100,740$ MWh

Average Load = $100,740 \text{ MWh} / (365 \times 24) = 11.5$ MW

Peak Load = 20 MW

$$\text{Load Factor} = 11.5 / 20 = 0.575 = 57.5\%$$

B. Capacity Factor

Energy produced during the year = $(20+3)/2 \times 365 \times 24 = 100,740$ MWh

Energy that can be produced at full capacity = $(10+10+5) \times 365 \times 24$
= 219,000 MWh

$$\text{Capacity Factor} = 100,740 / 219,000 = 0.46 = 46\%$$

C. Utilization Factor

Power Utilized = 20 MW

Power Available = $(10+10+5) = 25$ MW

$$\text{Utilization Factor} = 20/25 = 0.8 = 80\%$$



THANK YOU



Any Questions?

