# UNIT 1

## LOAD MODELLING AND CHARACTERISTICS

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### DEFINITIONS

***Load*** Electrical power needed in kW or kVA

***Demand*** The power requirement (in kVA or kW) at the load averaged over a specified interval (15 min or 30 min). Sometimes it is given in amperes at a specified voltage level.

***Demand Intervals*** The time interval specified for demand ($D_i$), usually 15 min or 30 min. This is obtained from daily demand curves or load duration curves.

***Maximum Demand*** The maximum load (or the greatest if a unit or group of units) that occurred in a period of time as specified. This can be daily, weekly, seasonal or on annual basis (for billing purpose in India it is monthly and in kVA).

***Demand Factor*** The ratio of maximum demand to the total load connected to the system

***Connected Load*** The sum total of the continuous rating of all the apparatus, equipment, etc., Connected to the system.

***Utilization Factor*** The ratio of maximum demand to the rated capacity of the system.

***Load Factor*** The ratio of average load in given interval of time to the peak during that interval.

***Annual Load Factor*** The ratio of total energy supplied in an year to annual peek load multiplied by 8760.

***Diversity Factor ($D_f$)*** The ratio of sum of the individual maximum demands of various sub-divisions of the system to the maximum demand of the entire or complete system.

***Coincident Maximum Demand ($D_g$)*** Any demand that occurs simultaneously with any other demand and also the sum of any set of coincident demands.

***Coincidence factor ($C_f$)*** This is usually referred to a group of consumers or loads. It is defined as the ratio of coincident maximum demand $D_g$ to sum total of maximum demands of individual or group of loads.

Generally, it is taken as the reciprocal of the diversity factor.

***Load Diversity*** The difference between the sum of peaks of two or more individual loads and the peak of combined load.

$$\text{Load diversity} = \Sigma D_i - D_g \tag{2.1}$$

$D_i$ = individual maximum demand

$D_g$ = coincident maximum demand

***Contribution Factor*** This is a factor that is usually referred in distribution systems regarding the importance of weighted effect of a particular load.

If $C_1, C_2 \ldots C_n$ are the contribution factors of each of the n individual loads and $D_1, D_2, D_3 \ldots\ldots\ldots\ldots D_n$ are their maximum demands.

$D_g$ = coincident maximum demand is taken as

$$D_g = C_1D_1 + C_2D_2 + \ldots\ldots\ldots\ldots C_nD_n = \sum_{i=1}^{n} C_iD_i \quad \text{.... (2.2)}$$

$$\text{Hence } c_f = \text{coincidence factor is} = \frac{\sum C_iD_i}{\sum D_i} \quad \text{.... (2.3)}$$

The contribution factor $C_i = C_f$ when all the demands equally affect or influence the maximum demand.

***Loss Factors*** This is the ratio of average power loss in the system to power loss during peak load period and referred to the variable power losses, i.e., copper losses or power loss in conductors or windings but not to no load losses in transformers, etc.

## LOADS AND LOAD CHARACTERISTICS

A broad classification of loads are

(i) Domestic and residential loads
(ii) Only lighting loads (such as for street lights etc.)

(iii) Commercial loads (shops, business establishments, hospitals)
(iv) Industrial loads
(v) Agricultural loads and other rural loads

### 1 Domestic and Residential Loads

The important part in the distribution system is domestic and residential loads as they are highly variable and erotic. These consist of lighting loads, domestic appliances such as water heaters, washing machines, grinders and mixes, TV and electronic gadgets etc. The duration of these loads will be few minutes to few hours in a day. The power factor of these loads in less and may vary between 0.5 to 0.7. In residential flats and bigger buildings, the diversity between each residence will be less typically between 1.1 to 1.15. The load factor for domestic loads will be usually 0.5 to 0.6.

### .2 Industrial Loads

Industrial loads are of greater importance in distribution systems with demand factor 0.7 to 0.8 and load factor 0.6 to 0.7. For heavy industries demand factor may be 0.9 and load factor 0.7 to 0.8

Typical power range for various loads

Cottage and small-scale industries: 3 to 20 kW.

Medium industries (like rice mills, oil mills, workshops, etc.) : 25 to 100 kW

Large industries connected to distribution feeders (33 kV and below): 100 to 500 kW.

### .3 Water supply and Agricultural Loads

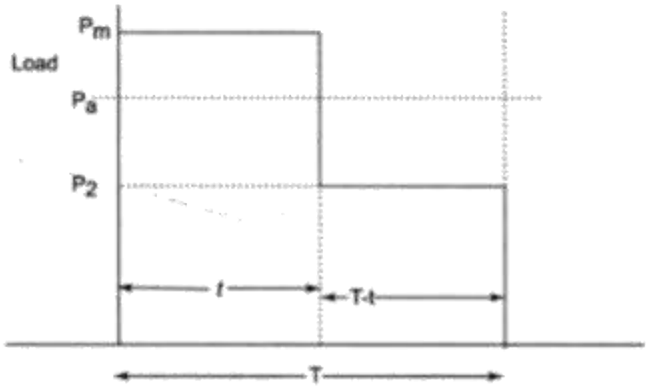
Most of the panchayats, small and medium municipalities have protected water system which use pumping stations. They normally operate in off peak time and use water pumps ranging from 10 h.p to 50 h.p or more, depending on the population and area.

### .4 Agricultural and Irrigation Loads

Most of the rural irrigation in India depends on ground water pumping or lifting water from tanks or nearby canals. In most cases design and pump selection is very poor with efficiencies of the order of 25%. Single phase motors are used (up to 10 h.p.) for ground water level 15 m in depth or less with discharge of about 20 l/sec while multi stage submersible pumps with discharge of 800 to 1000 l/m may require motors of 15 to 20 h.p.

## RELATION BETWEEN LOAD AND LOSS FACTOR:

In general, load changes occur continuously for any type of load and the load pattern on any feeder or distributor can be idealized and simplified approach for load on a feeder can be taken as shown in Fig.




Let a peak load $P_m$ exist for duration of '$t$' and $p_2$ be the off peak load during any interval '$T$' considered. Let $P_a$ be the average load during the period '$T$'.

$$P_a = \frac{P_m \times t + P_2(T-t)}{T} \quad \text{.... (2.4)}$$

But load factor $= \dfrac{P_{av}}{P_{peak}} = \dfrac{P_a}{P_m}$

For the duration '$T$' considered

$$\text{Load factor} = \frac{P_m \times t + P_2(T-t)}{P_m \times T}$$

$$= \frac{t}{T} + \frac{P_2}{P_m}\frac{(T-t)}{T} \quad \text{.... (2.5)}$$

and loss factor $= \dfrac{(Power\ loss(avg)\ in\ given\ time\ period)}{powoer\ loss(max.\ loss) \times the\ total\ duration}$

This can be extended to the whole duration of 24 hours by considering $P_1, P_2 \ldots\ P_k$ as the loads occurring over a duration of $t_1, t_2 \ldots\ldots t_k$ with $P_m$ as the peak load. If $P_{LS}$ is average power loss and $P_{Lm}$ power loss corresponding to peak load $P_m$.

$$\text{Loss factor} = \frac{P_{LS}}{P_{lm}} = \frac{P_{LS}\,t + P_m(T-t)}{P_{lm} \times T} \quad \text{...(2.6)}$$

Since losses are proportional to $I^2 \times P^2$

($\because$ voltage is constant)

$$\text{Loss factor} = \frac{t}{T} + \left(\frac{P_{avg}}{P_m}\right)^2\left(\frac{T-t}{T}\right) \quad \text{... (2.7)}$$

(a) This is $= t/T$ if off peak load i.e $P_2 \times 0$,(same as load factor)

(b) For short time peak $t << T$ loss factor $\approx \left(\frac{P_{avg}}{P_m}\right) = (load\ factor)^2$ (2.8)

(c) In general for variable industrial loads loss factor, is taken as

$= 0.3(\text{load factor}) + 0.7\ (\text{load factor})^2$ ... (2.9)

**Example 2.7** *Find the annual load factor and average demand, given that peak load is 3.5 MW and energy supplied is 10 million units ($10^7$ kwh). Peak demand was recorded during April – June.*

**Solution** Average demand $= \frac{10^7 \text{ kWh}}{8760} = 1141 \text{ kW}$

Peak load = 3500 kW

Annual load factor $= \frac{1141}{3500} = 0.326$

**Example 2.8** *A feeder supplies 2 MW to an area. The total losses at peak load are 100 kW and units supplied to that area during an year are 5.61 million. Calculate the loss factor.*

**Solution** Load factor $= \frac{5.61 \times 10^6}{200 \times 8760} = 0.32$ (unit supplied/ peak load × 8760)

Loss factor = 0.3 (*load factor*) + 0.7 (*load factor*)$^2$

$= 0.3 \times 0.32 + 0.7 \times (0.32)^2 = 0.168$

Average power loss = 0.168 × (100 kW) = 16.8 kW

The above examples illustrate how the average power loss and loss factor can be estimated from the peak load occurring and units supplied. The estimates give gross idea regarding power losses and hence the revenue lost in a distribution system. The loss factor should be as low as possible so that the energy efficiency will be high. In general, loss factor will be such that

$(\text{load factor})^2 < (\text{loss factor}) < (\text{load factor})$

# UNIT 2

# CLASSIFICATION OF DISTRUBUTION SYSTEMS