Course Title: 19EEE341- Electrical Distribution Systems
Topic for the class: EDS Unit 1 part1

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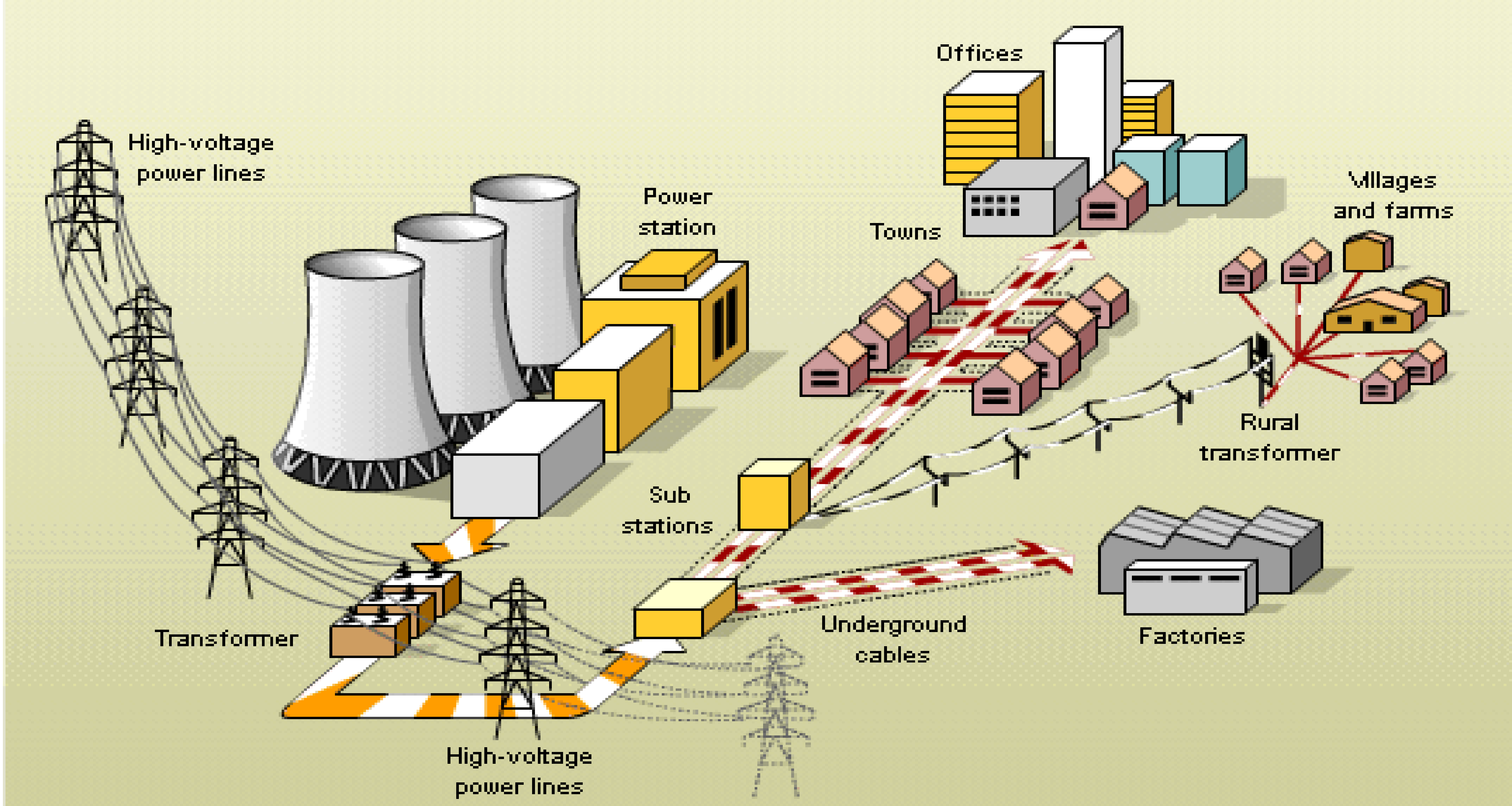
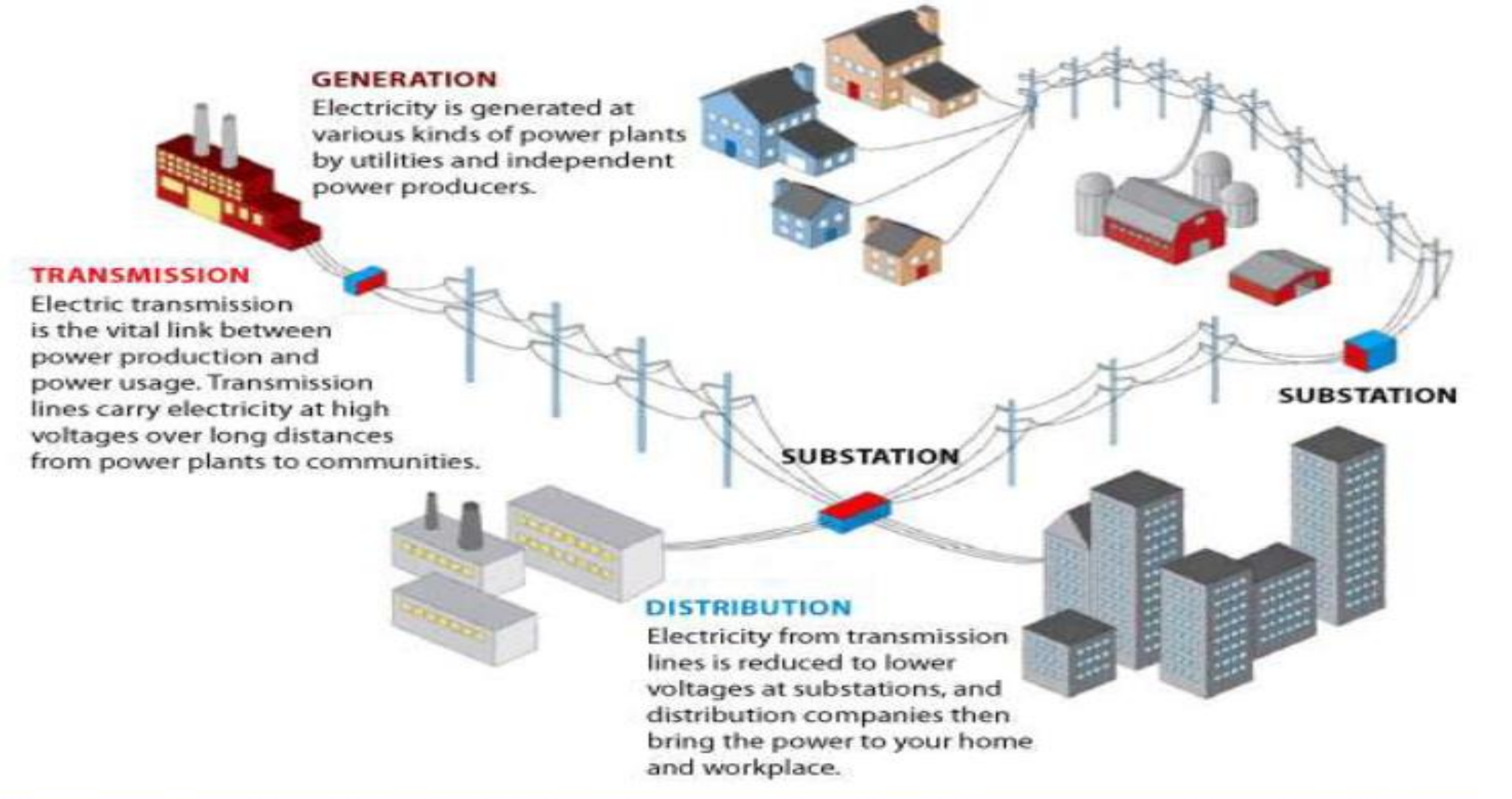

High-voltage power lines
Power station
Offices
Towns
Villages and farms
Rural transformer
Sub stations
Transformer
Underground cables
Factories
High-voltage power lines

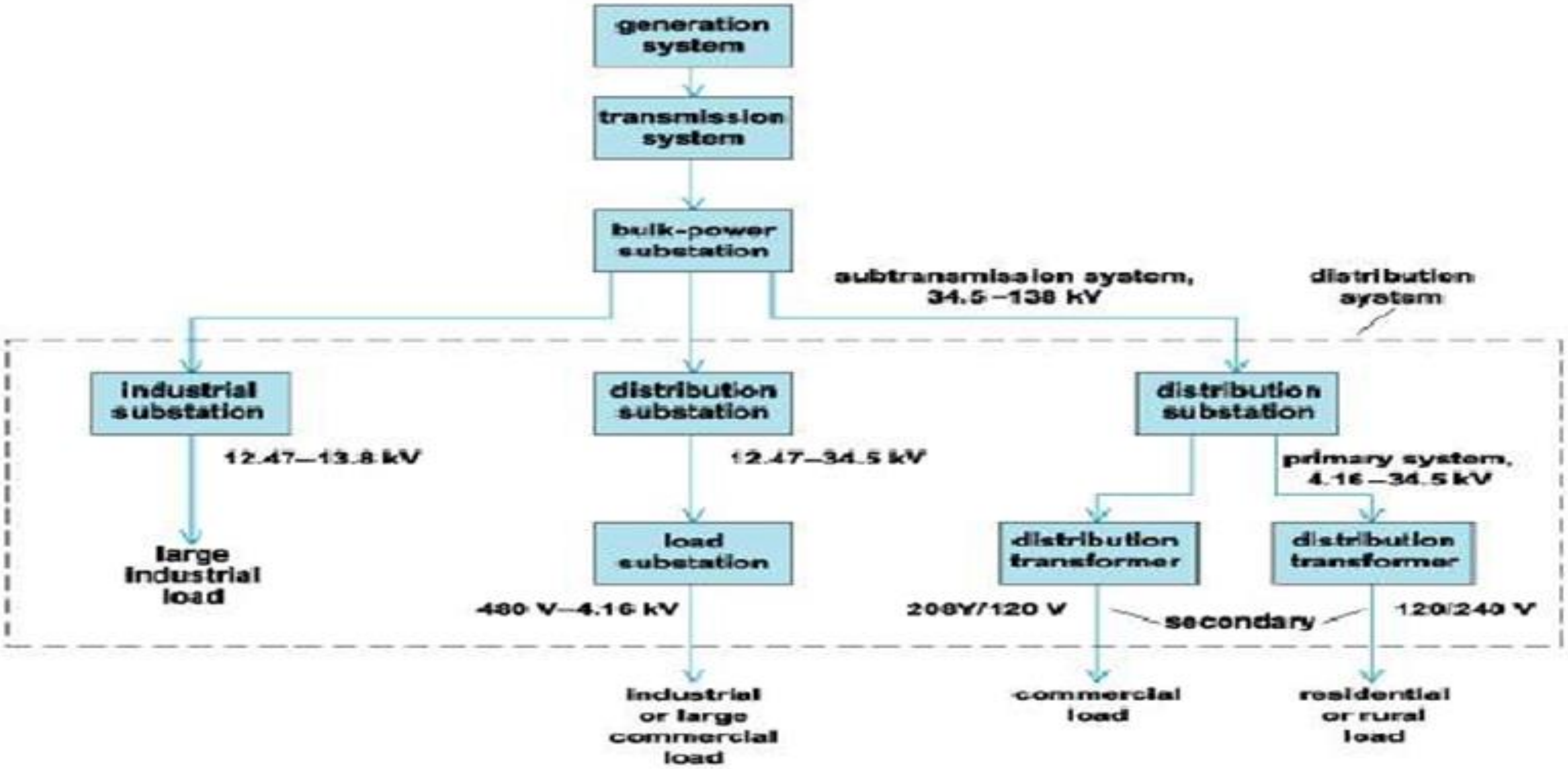

GENERATION
Electricity is generated at various kinds of power plants by utilities and independent power producers.
TRANSMISSION
Electric transmission is the vital link between power production and power usage. Transmission lines carry electricity at high voltages over long distances from power plants to communities.
SUBSTATION
SUBSTATION
DISTRIBUTION
Electricity from transmission lines is reduced to lower voltages at substations, and distribution companies then bring the power to your home and workplace.

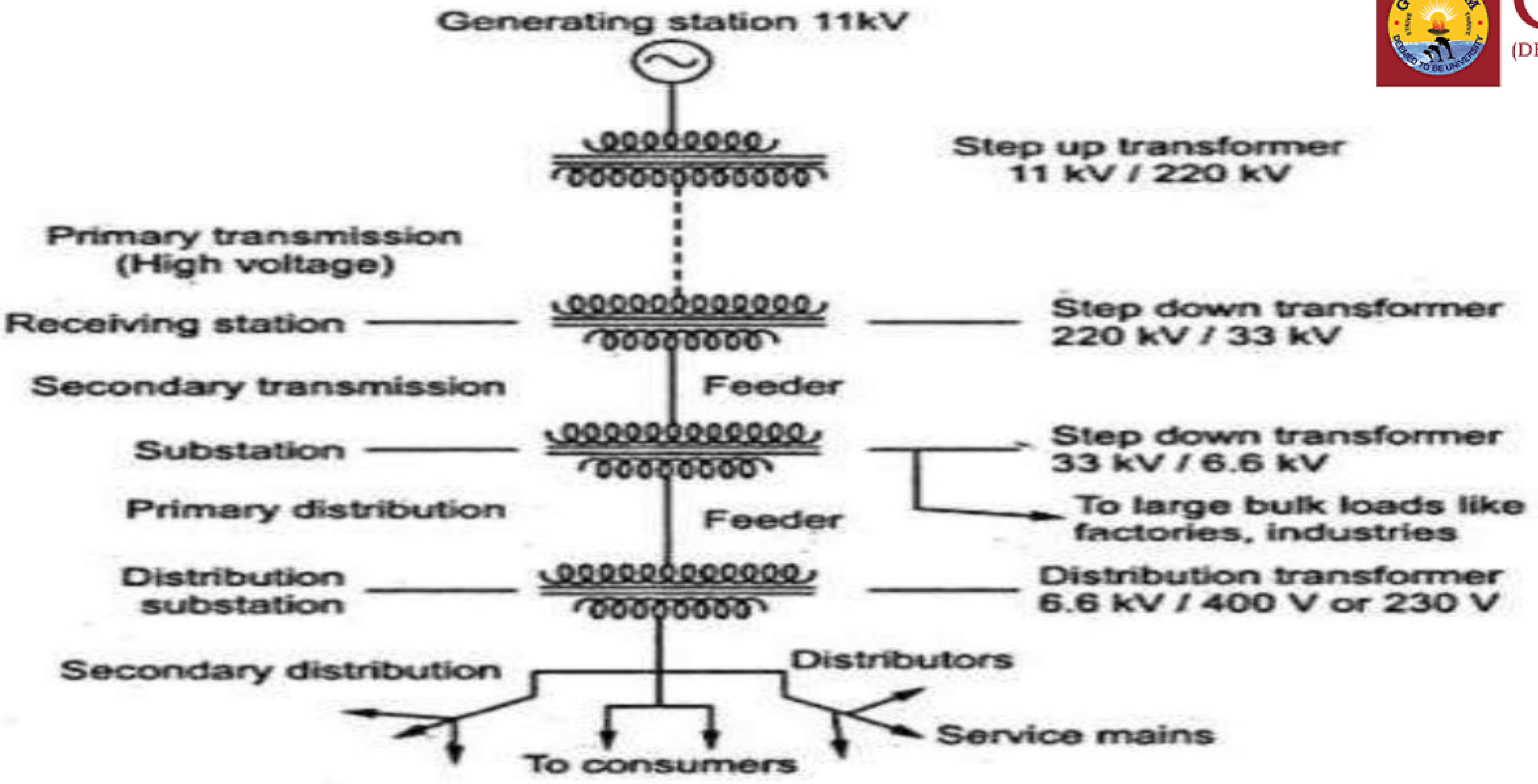
PREREQUISITES

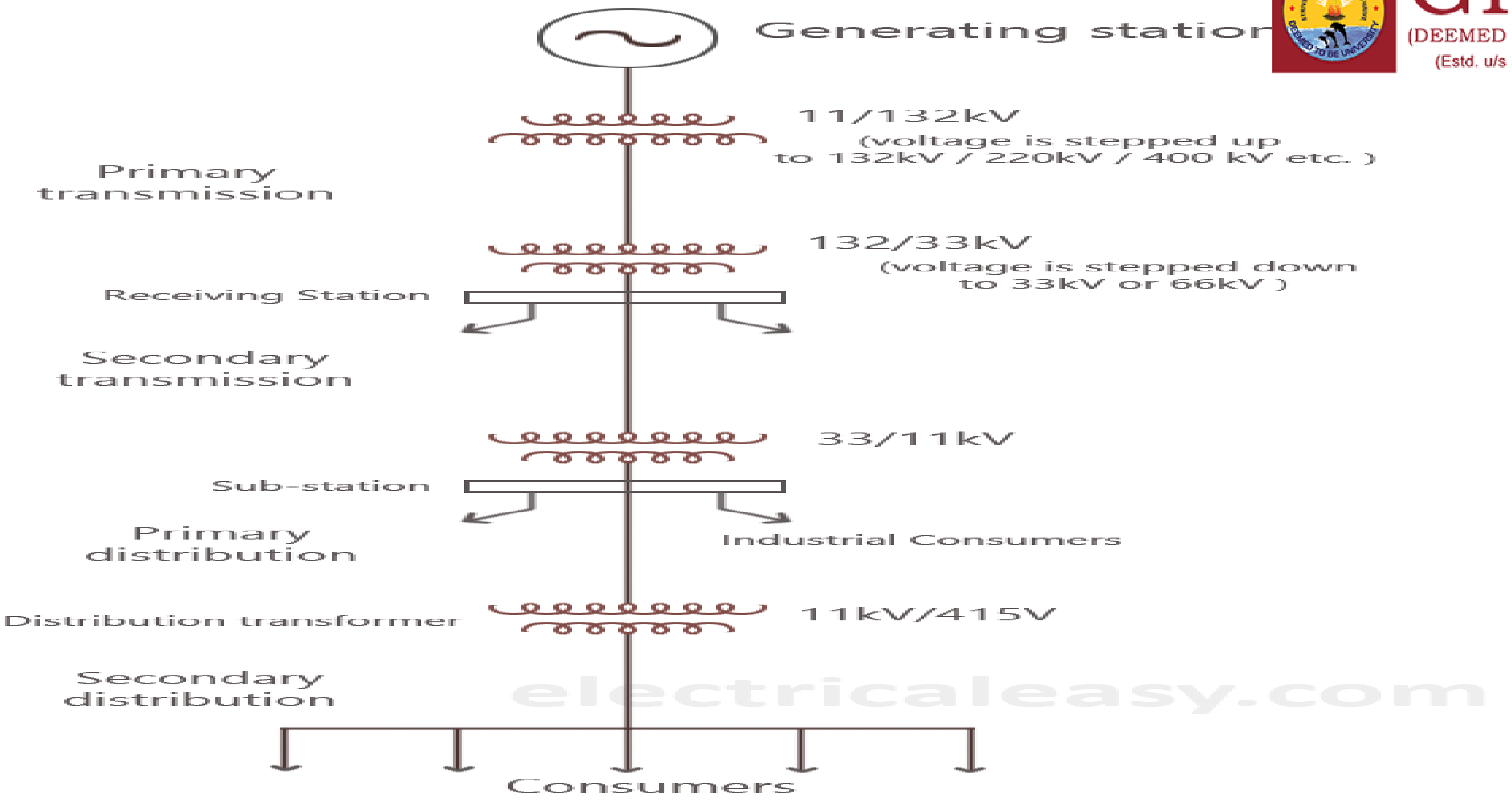
A basic knowledge on these subjects would be beneficiary

(i) Power Systems-I

Distribution system layout




Generating station 11kV
Step up transformer
11 kV / 220 kV
Primary transmission
(High voltage)
Receiving station
Step down transformer
220 kV / 33 kV
Secondary transmission
Feeder
Substation
Step down transformer
33 kV / 6.6 kV
Primary distribution
Feeder
To large bulk loads like
factories, industries
Distribution
substation
Distribution transformer
6.6 kV / 400 V or 230 V
Secondary distribution
Distributors
Service mains
To consumers


Generating station
11/132kV
(voltage is stepped up
to 132kV / 220kV / 400 kV etc.)
Primary
transmission
132/33kV
(voltage is stepped down
to 33kV or 66kV)
Receiving Station
Secondary
transmission
33/11kV
Sub-station
Primary
distribution
Industrial Consumers
Distribution transformer
11kV/415V
Secondary
distribution
electricaleasy.com
Consumers

Definition

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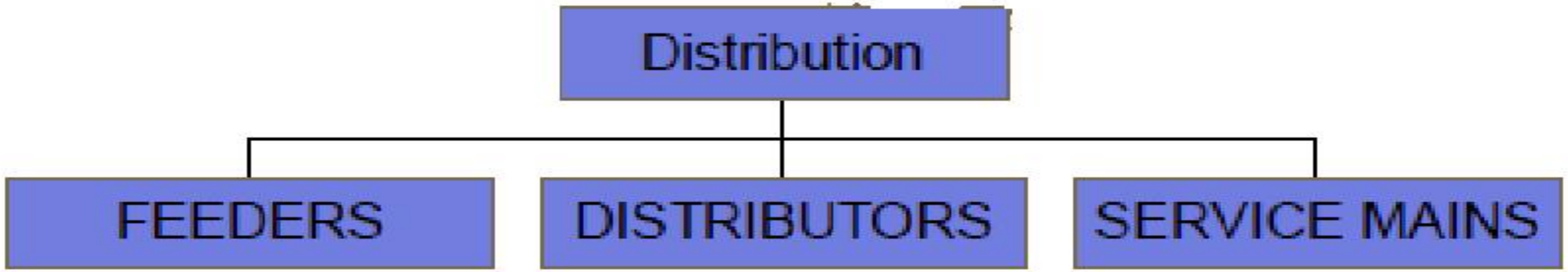
(Estd. u/s 3 of the UGC Act, 1956)

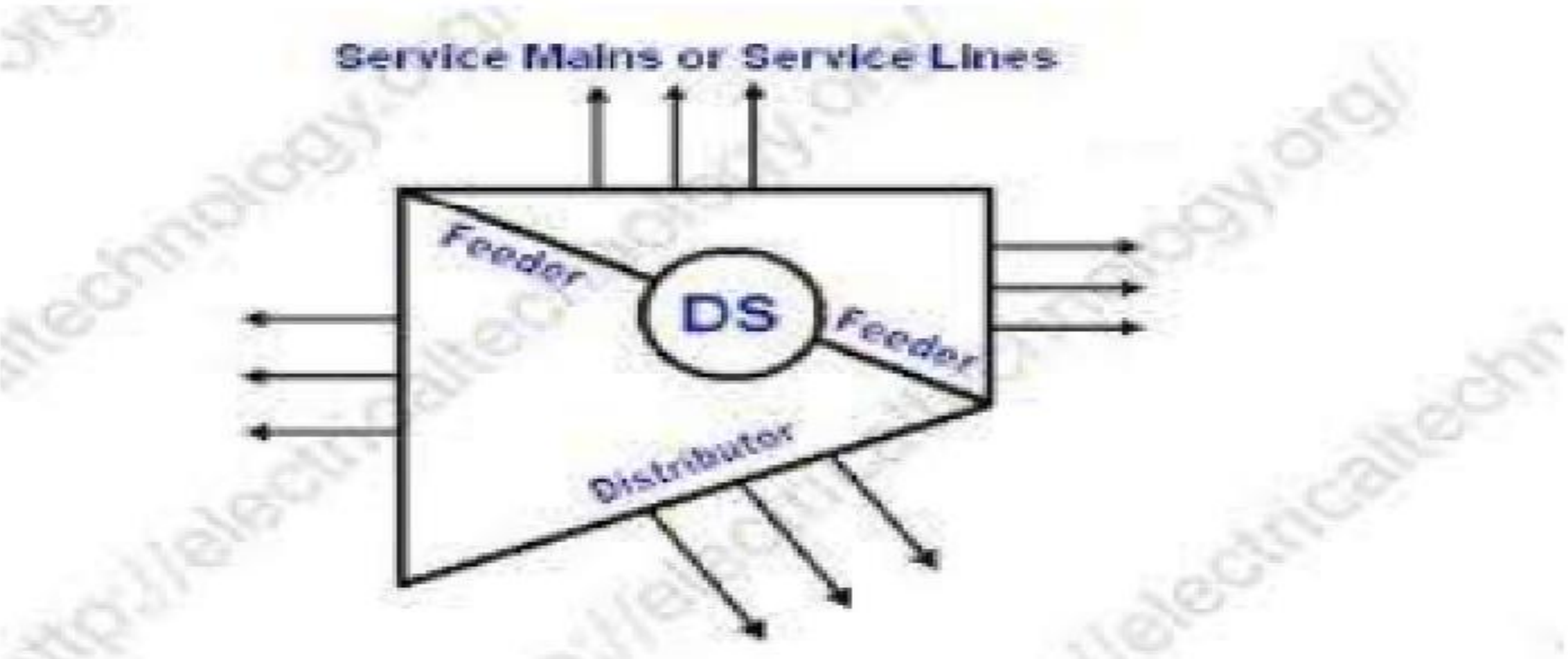
The Part of Power system which distributes electrical power for local use is known as "Electrical Distribution System".

This system is the electrical system between the substation fed by the transmission system and consumer meter.

Distribution line generally consists of

- **FEEDERS**
- **DISTRIBUTERS**
- **SERVICE MAINS**





Elements of a Distribution System

Feeder

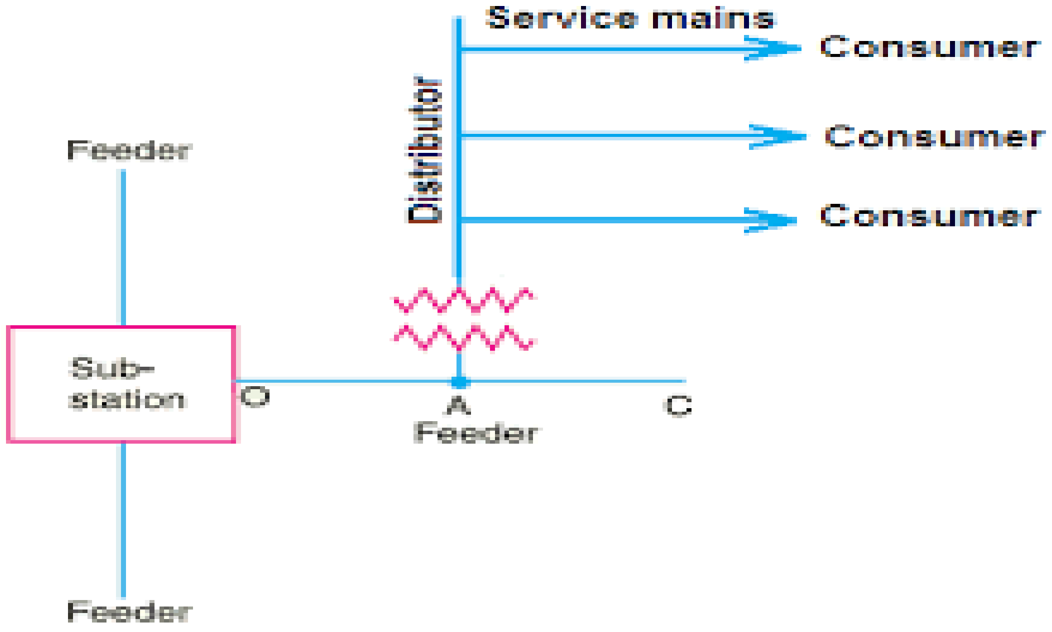
- A feeder is conductor which connects the substation to the area where power is to be distributed.
- Feeder are used to feed the electrical power from the generating station to the substation
- No tapings are taken from the feeder
- So the current in it remains the same throughout
- Main consideration in the design of feeder is the current carrying capacity

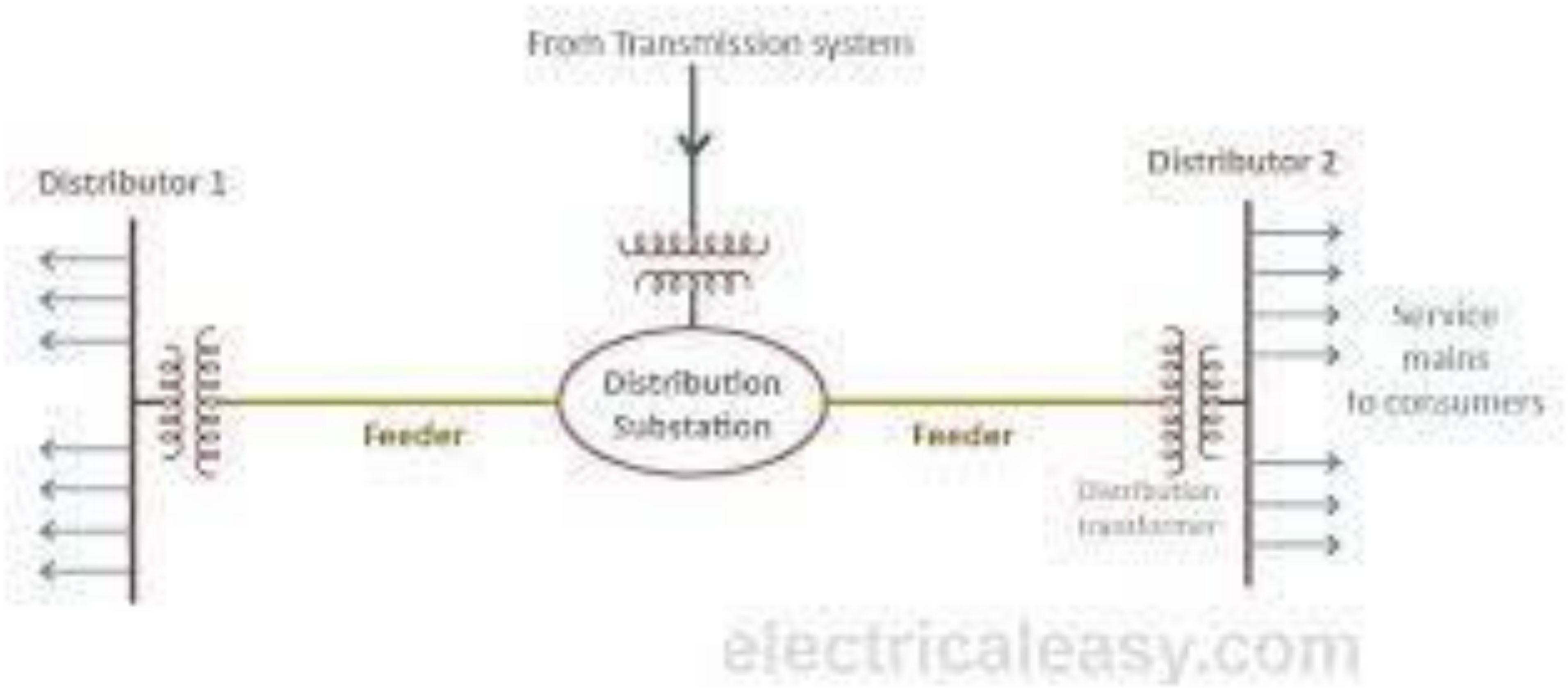
Distributer

- A distributer is a conductor from which tapings are taken from pole mounted transformer to the consumer
- The current through a distributer is not constant because tapings are taken at various places along its length
- Voltage drop is main consideration

Service mains

- A service mains is a generally a small cable which connects the distributer to the consumer‘s meter.
- The connecting links between the distributor and the consumer terminals




From Transmission system
Distributor 1
Distributor 2
Service
mains
to consumers
Distribution
Substation
Feeder
Feeder
Distribution
transformer
electricaleasy.com

Introduction to Distribution System

- Distribution system is a part of power system, existing between distribution substations and consumers.
- It is further classified on the basis of voltage
  - ✓Primary distribution system- **11 KV or 6.6 KV or 3.3 KV**
  - ✓Secondary distribution system- **415 V or 230 V**

Primary Distribution System

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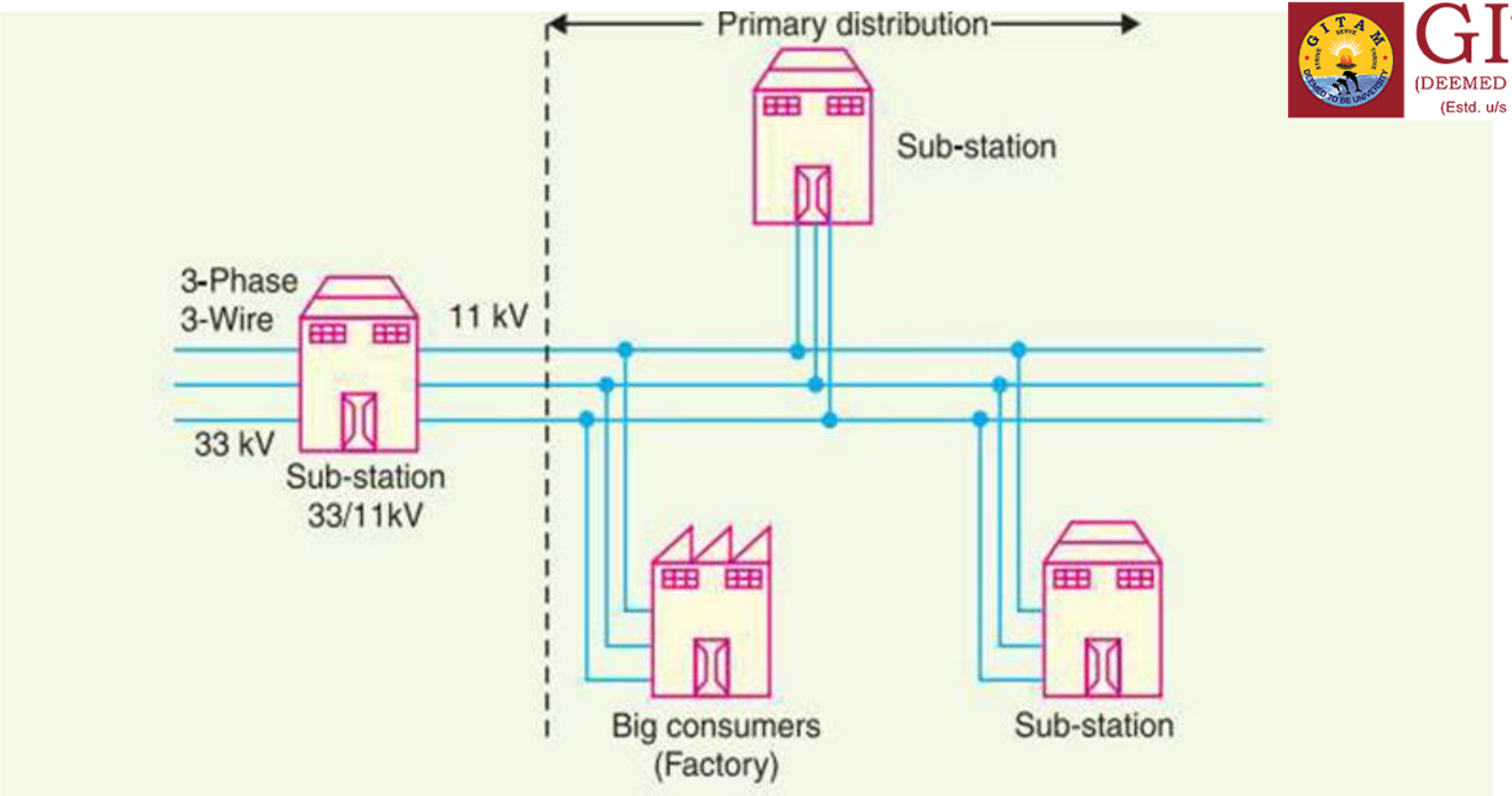
(Estd. u/s 3 of the UGC Act, 1956)

- Voltages somewhat higher than general utilization and handles large blocks of electrical energy than the average low-voltage consumer uses.
- Commonly used primary distribution voltage 11KV, 6.6 KV,3.3 KV.
- Electric power from the generating station is transmitted at high voltage to the substation located in or near the city.
- At this substation, voltage is stepped down to 11 kV with the help of step-down transformer.
- Power is supplied to various substations for distribution or to big consumers at this voltage.
- This forms the high voltage distribution or primary distribution.


Primary distribution
Sub-station
3-Phase
3-Wire
11 kV
33 kV
Sub-station
33/11kV
Big consumers
(Factory)
Sub-station

Secondary Distribution System

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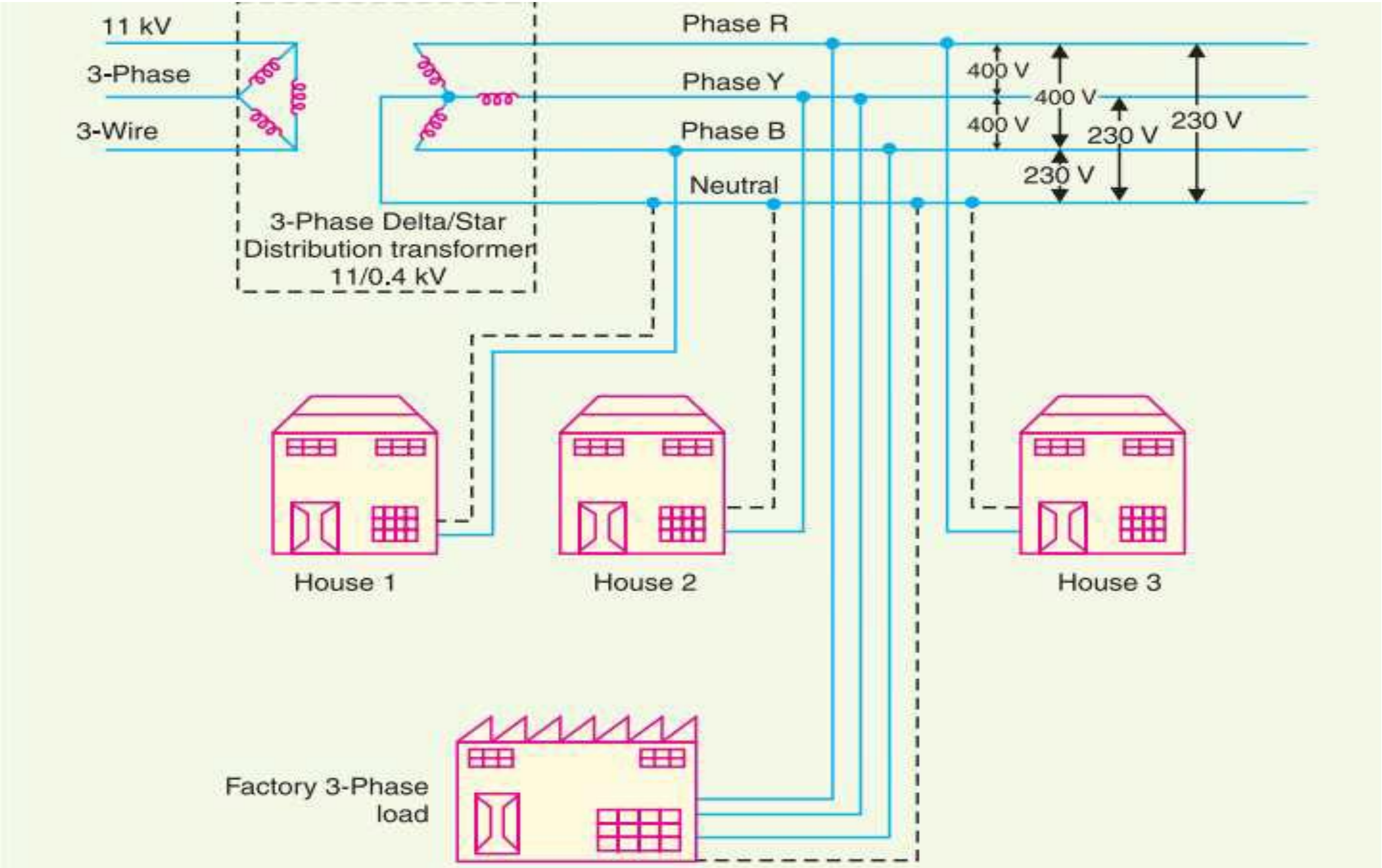
- It is that part of a.c. distribution system which includes the range of voltages at which the ultimate consumer utilizes the electrical energy delivered to him.
- The secondary distribution employs 400/230 V, 3-phase, 4-wire system.


11 kV
3-Phase
3-Wire
Phase R
Phase Y
Phase B
Neutral
400 V
400 V
400 V
230 V
230 V
230 V
3-Phase Delta/Star
Distribution transformer
11/0.4 kV
House 1
House 2
House 3
Factory 3-Phase
load

Radial Distribution System

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- Separate feeders radiate from a single substation and feed the distributors at one end only.
- Only one path is connected between each customer and substation.
- Electrical power flows along a single path.
- If interrupted, results in complete loss of power to the customer.

Advantages:

✓ Low cost .

✓ Simple planning.

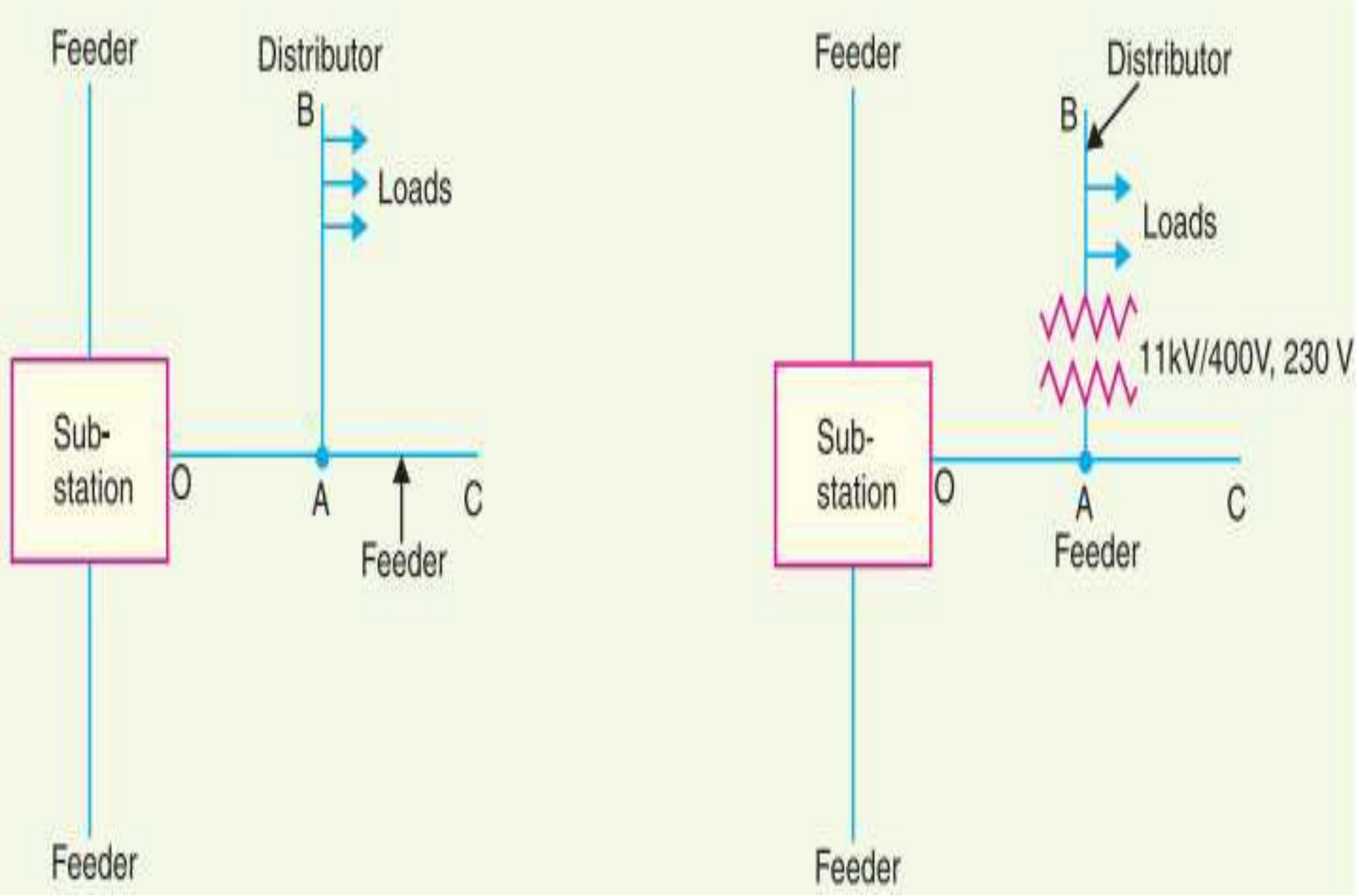
Disadvantages :

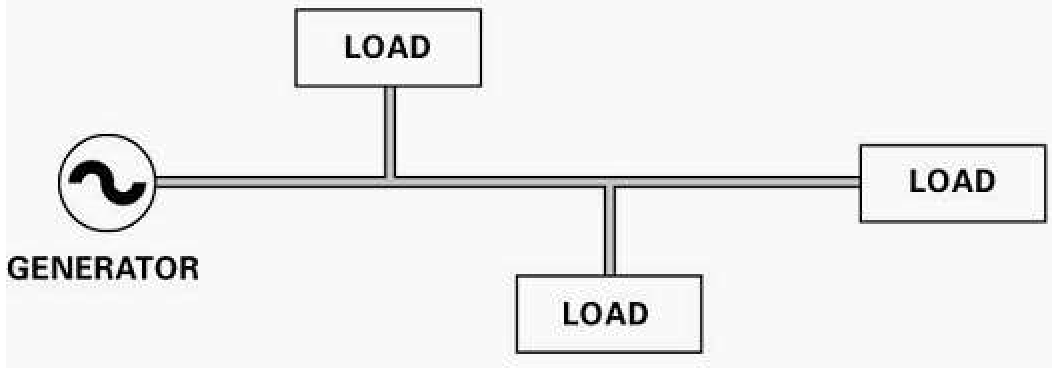
✓ The radial system is employed only when power is generated at low voltage and the substation is located at the centre of the load.

✓ Distributor nearer to feeding end is heavily loaded.

✓ Consumers at far end of feeder would be subjected to serious voltage fluctuations.

Radial Distribution System





Ring main Distribution System

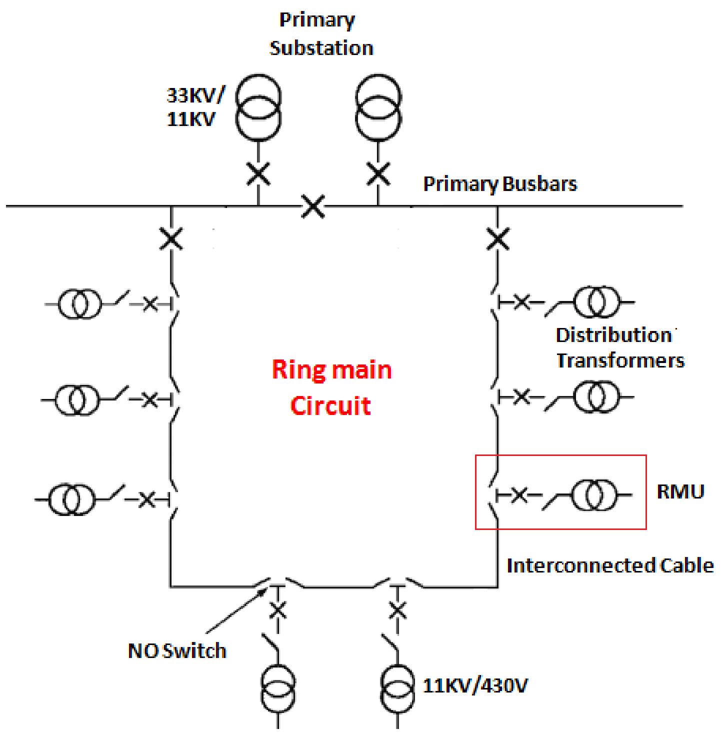
- It consists of two or more paths between power sources and the customer.
- The loop circuit starts from the substation bus-bars, makes a loop through the area to be served, and returns to the substation

Advantages:

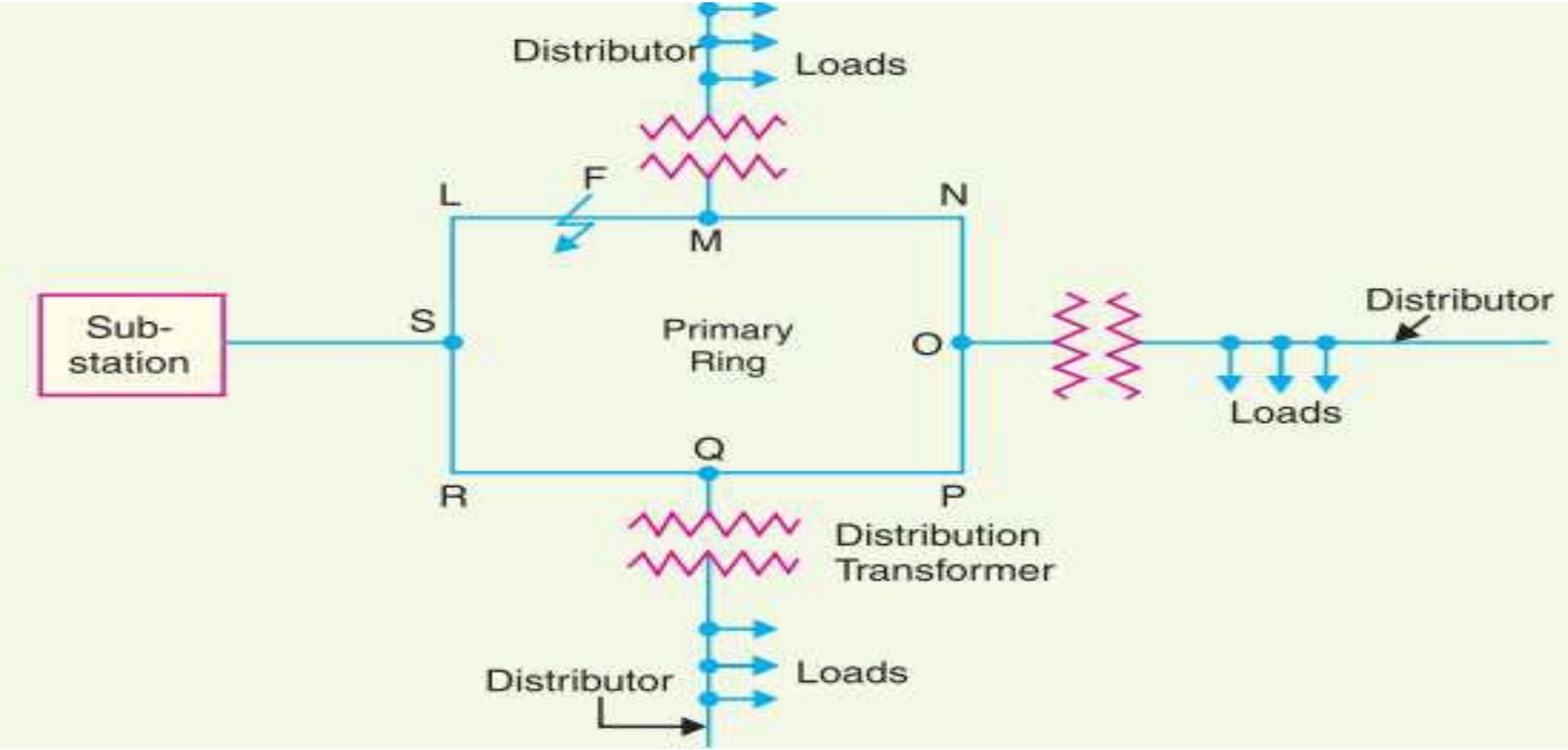
- ✓ Less conductor material is required.
- ✓ Less voltage fluctuations.
- ✓ More reliable.

Disadvantages:

- ✓ It is difficult to design as compared to the design of radial system.



Ring main Distribution System



https://www.youtube.com/watch?v=VxxrElzziW4

Terms used in Distribution System

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- **Load –** Electric Power needed in KW or KVA
- **Demand** – It is the load at the receiving terminals averaged over a specified interval of time
- **Demand interval** – It is the period over which the load is averaged. 15 min, 30 min.
- **Maximum demand** – It is the greatest of all demands which have occurred during the specified period of time.

- **Demand factor** – The ratio of max. demand to total load connected to the system.

$$DF = \frac{\text{Max demand}}{\text{Total load connected}}$$

- **Connected load** – Sum of continuous rating of all the apparatus, equipment, etc., connected to the system.

- **Diversified Demand(coincident demand) -** It is the demand of the composite group, as a whole, of somewhat unrelated loads over a specified period.

- **Non coincident demand -** Sum of the demands of a group of loads with no restrictions on the interval to which each demand is applicable.

Assume 4 Customers Connected to a Transformer

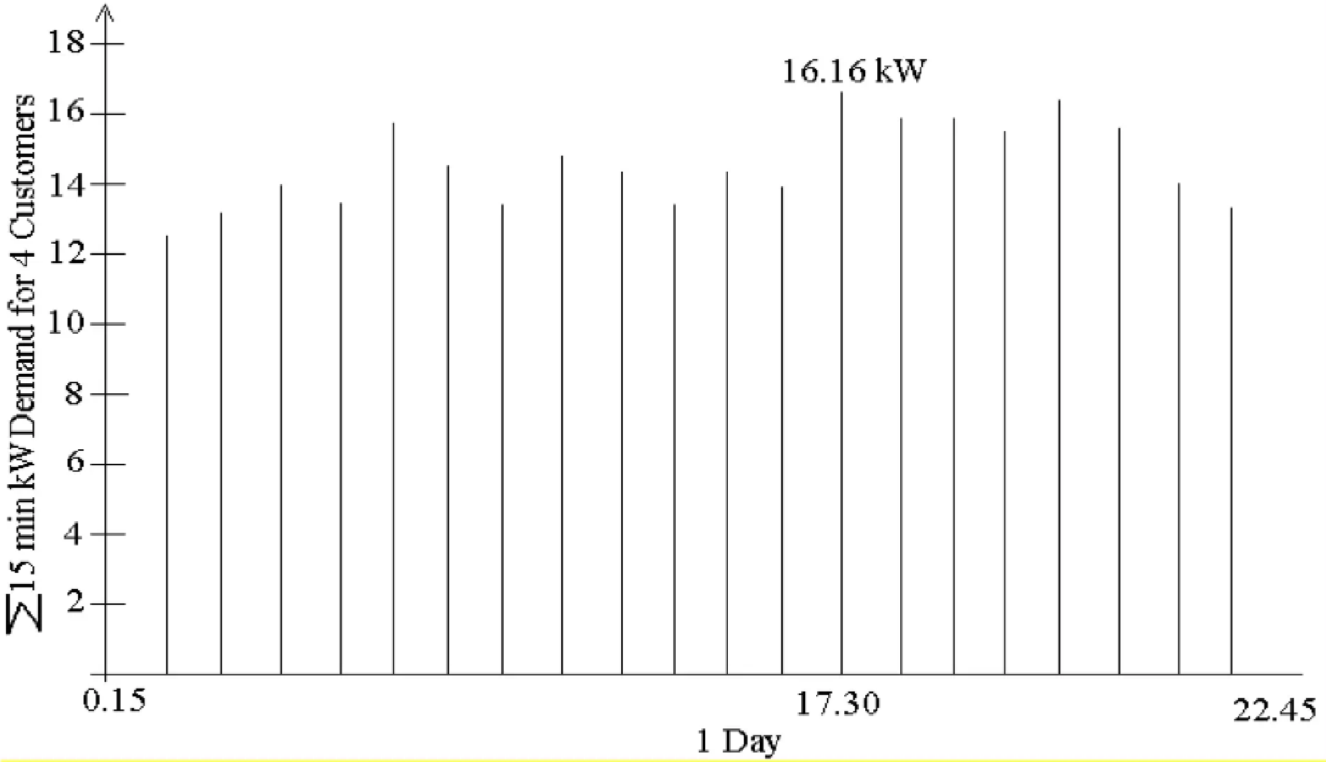
Given: Individual Customer Load Characteristics

	Cust # 1	Cust # 2	Cust # 3	Cust # 4
Energy Usage (kWH)	58.57	36.46	95.64	42.75
Max. kW Demand	6.18	6.82	4.93	7.05
Time of Max. kW Demand	13.15	11.30	6.45	20.30
Load Factor	0.40	0.22	0.81	0.25
Avg. kW Demand	2.44	1.52	3.98	1.78

And Given also the 4 (24 hr/15 min) demand curves for the customers.

Diversified Demand

- The sum of the four individual 15 min. kW Demand over the 24 hour period gives the diversified Demand for the transformer.



- *Note as you sum the loads, the resulting curve starts to smooth out.*

Maximum Diversified Demand

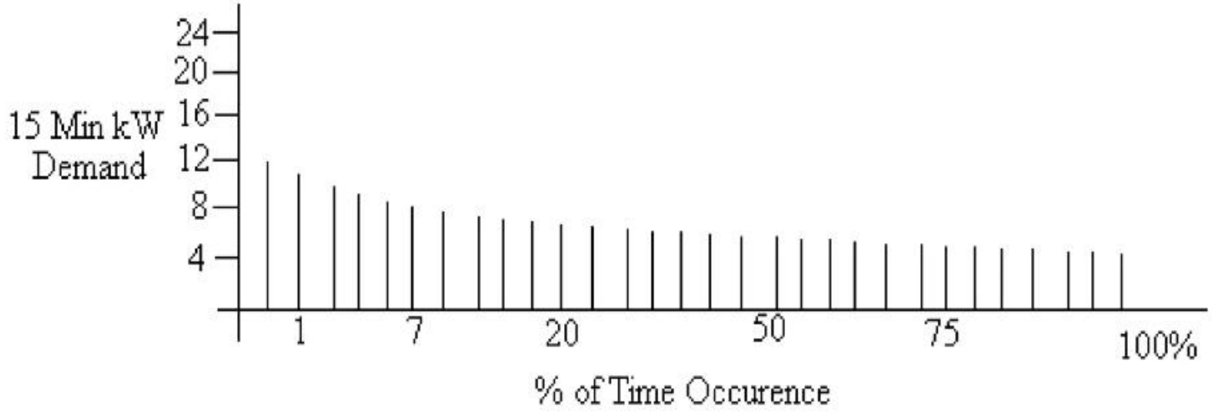
•For the transformer, the 15 min kW demand exceeds 16kW twice.

•The greater of this is the 15 min max. diversified kW demand of the transformer.

•It is 16.16kW and occurs at 17:30.

•Note that this does not occur at any of the individual load's maximum demand and it is <u>not</u> the sum of the max. demands of each load.

Load Duration Curve for a Transformer



- Curve shows that the transformer operates with 15 min kW Demand of 8kW or greater 22% of time.
- Curve gives an indication whether transformer needs to be replaced due to overload conditions.

Max. Noncoincident Demand

For the transformer, the 15min max. non-coincident kW demand for the day is sum of individual customer 15min max. kW Demands.

From table:

$\therefore$ Max noncoincident demand = 6.18 + 6.82 + 4.93+7.05

= 24.98kW

- **Load Factor** – It is the ratio of average load in given interval of time to the peak during the interval.

Load Factor = Average load. /Maximum load during a given period.

It can be calculated for a single day, for a month or for a year.

Its value is always less than one. Because maximum demand is always more than avg. demand.

It is used for determining the overall cost per unit generated. Higher the load factor, lesser will be the cost per unit.

Example: Motor of 20 hp drives a constant 15 hp load whenever it is on.
The motor load factor is then 15/20 = 75%.
Load factor is term that does not appear on your utility bill, but does affect electricity costs. Load factor indicates how efficiently the customer is using peak demand.

- **Annual Load Factor** – Ratio of total energy supplied in a year to annual peak load multiplied by 8760

- **Utilization Factor -** The utilization factor gives an indication of how well the capacity of an electrical device is being utilized. It is the ratio of maximum demand to the rated capacity of the system

Utilization Factor = The time that a equipment is in use./ The total time that it could be in use.

Example: The motor may only be used for eight hours a day, 50 weeks a year. The hours of operation would then be 2000 hours, and the motor Utilization factor for a base of 8760 hours per year would be 2000/8760 = 22.83%. With a base of 2000 hours per year, the motor Utilization factor would be 100%. The bottom line is that the use factor is applied to get the correct number of hours that the motor is in use.

- Demand factor is the ratio of the sum of the maximum demand of a system (or part of a system) to the total connected load on the system (or part of the system) under consideration. Demand factor is always less than one.

- **Demand Factor = Maximum demand of a system / Total connected load on the system**

Demand factor is always less than one.

Example: if a residence having 6000W equipment connected has a maximum demand of 300W,Than demand factor = 6000W / 3300W = 55%.

The lower the demand factor, the less system capacity required to serve the connected load.

- Diversity factor is the ratio of the sum of the individual maximum demands of the various subdivisions of a system (or part of a system) to the maximum demand of the whole system (or part of the system) under consideration. Diversity is usually more than one.

A sub-station has three outgoing feeders:

1. feeder 1 has maximum demand 10 MW at 10:00 am,
2. feeder 2 has maximum demand 12 MW at 7:00 pm and
3. feeder 3 has maximum demand 15 MW at 9:00 pm,
4. While the maximum demand of all three feeders is 33 MW at 8:00 pm.

Here, the sum of the maximum demand of the individual sub-systems (feeders) is 10 + 12 + 15 = 37 MW, while the system maximum demand is 33 MW. The diversity factor is 37/33 = 1.12. The diversity factor is usually greater than 1; its value also can be 1

Diversity Factor(F_D)

- It is the ratio of the maximum noncoincident demand of a group of customers to the maximum diversified demand of the group.
- The idea behind the diversity factor is that when the maximum demands of the customers are known, then the maximum diversified demand of a group of customers can be computed.

$$F_D = \frac{\text{Sum of individual max. demand}}{\text{Coincident max. demand}}$$

$$= \frac{D_1 + D_2 + D_3 + \ldots\ldots\ldots\ldots + D_n}{D_g}$$

D_i = max. demand of load i, disregarding time of occurrence

$D_g = D_{1+2+3+\ldots\ldots+n}$ $\quad\quad F_D >= 1$

$$F_D = \frac{\sum_{i=1}^{n} D_i}{D_g}$$

Coincidence factor (F_C)

- It is the ratio of max coincident total demand of a group of consumers to the sum of the max power demands of individual consumers comprising the group both taken at the same point of supply for the same time

$$F_c \triangleq \frac{\text{coincident maximum demand}}{\text{sum of individual maximum demands}}$$

Thus, the coincidence factor is the reciprocal of diversity factor; that is,

$$F_c = \frac{1}{F_D}$$

the demand factor is

$$\mathrm{DF} = \frac{\text{maximum demand}}{\text{total connected demand}}$$

$$\text{Maximum demand} = \text{total connected demand} \times \mathrm{DF}$$

the diversity factor can also be given as

where TCD_i = total connected demand of group, or class, i load

DF_i = demand factor of group, or class, i load

$$F_D = \frac{\sum_{i=1}^{n} \mathrm{TCD}_i \times \mathrm{DF}_i}{D_g}$$

Load diversity

- It is the difference between the sum of the peaks of two or more individual loads and peak of the coincident load.

$$\mathrm{LD} \triangleq \left(\sum_{i=1}^{n} D_i \right) - D_g$$

Contribution factor: defines c_i as "the contribution factor of the ith load to the group maximum demand." It is given in per unit of the individual maximum demand of the ith load. Therefore,

$$D_g \triangleq c_1 \times D_1 + c_2 \times D_2 + c_3 \times D_3 + \cdots + c_n \times D_n$$

$$F_c = \frac{D_g}{\sum_{i=1}^{n} D_i}$$

$$F_c = \frac{c_1 \times D_1 + c_2 \times D_2 + c_3 \times D_3 + \cdots + c_n \times D_n}{\sum_{i=1}^{n} D_i}$$

$$F_c = \frac{\sum_{i=1}^{n} c_i \times D_i}{\sum_{i=1}^{n} D_i}$$

Special cases

Case 1: $D_1 = D_2 = D_3 = \cdots = D_n = D.$

$$F_c = \frac{D \times \sum_{i=1}^{n} c_i}{n \times D}$$

or

$$F_c = \frac{\sum_{i=1}^{n} c_i}{n}$$

coincidence factor is equal to the average contribution factor.

Case 2: $c_1 = c_2 = c_3 = \cdots = c_n = c.$

$$F_c = \frac{c \times \sum_{i=1}^{n} D_i}{\sum_{i=1}^{n} D_i}$$

or

$$F_c = c$$

That is, the coincidence factor is equal to the contribution factor.

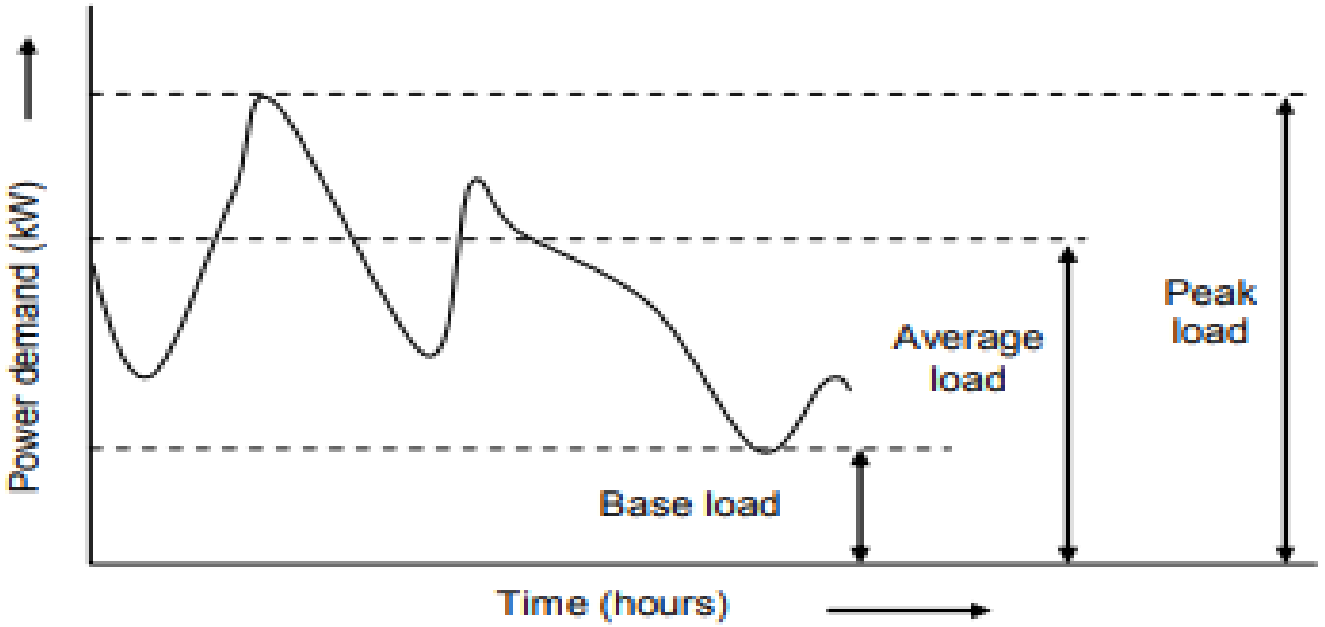
Loss factor: It is “the ratio of the average power loss to the peak-load power loss during a specified period of time” [1]. Therefore, the loss factor (F_{LS}) is

$$F_{LS} \triangleq \frac{\text{Average power loss}}{\text{Power loss at peak load}}$$

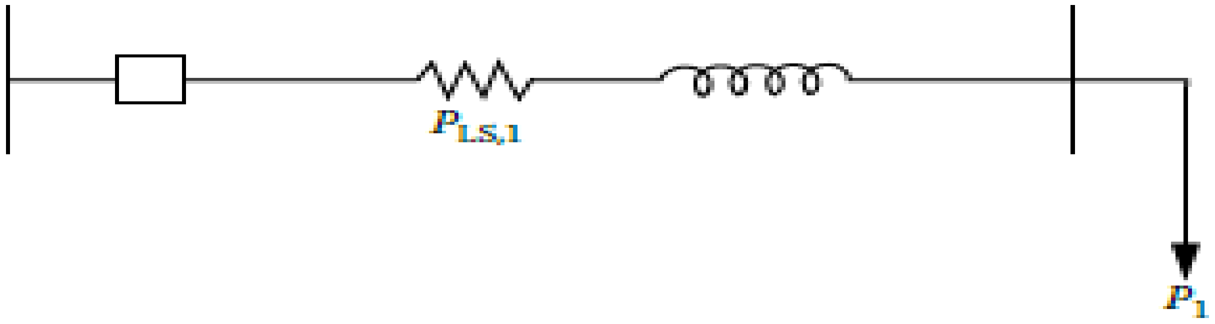
applicable for the copper losses of the system but not for the iron losses.

Load Duration Curve

- It is constructed by selecting the peak points and connecting them by a curve. The curve can be daily, weekly, monthly or annual.



- **RELATIONSHIP BETWEEN THE LOAD AND LOSS FACTORS**
- In general, the loss factor cannot be determined from the load factor. However, the limiting values of the relationship can be found. Assume that the primary feeder shown in Figure is connected to a variable load.



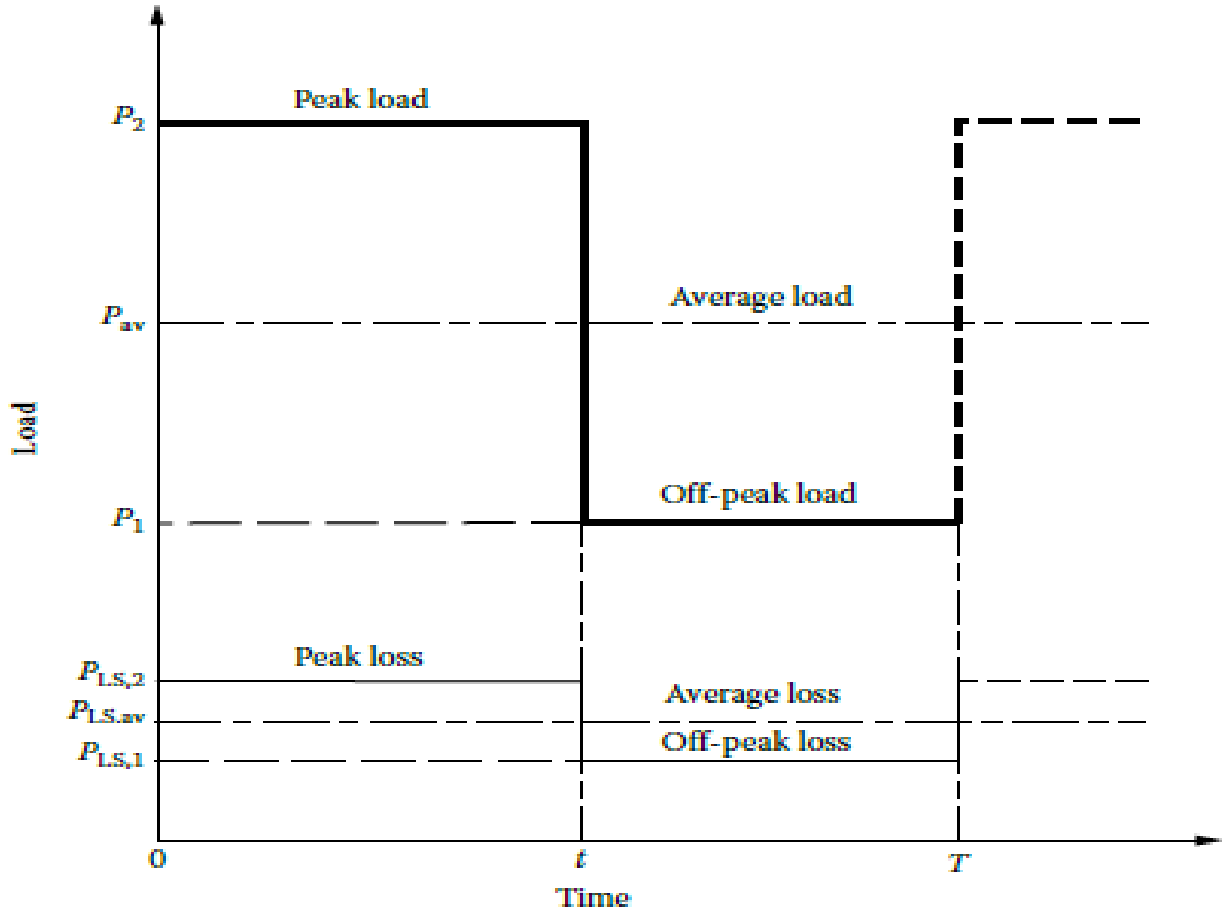


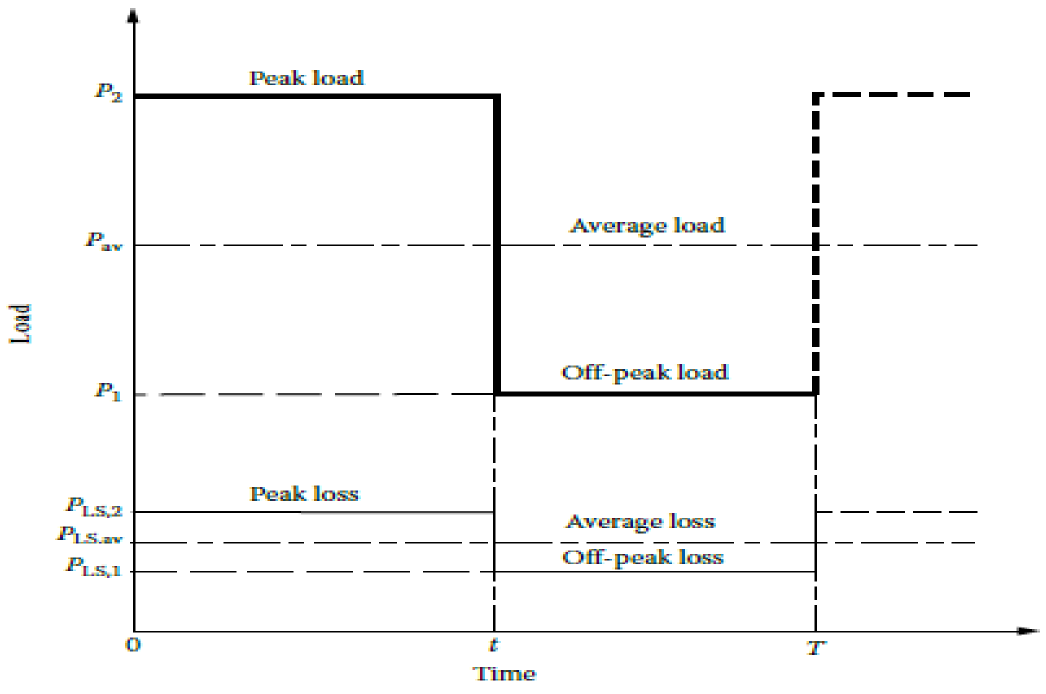
Figure shows an arbitrary and idealized load curve. However, it does not represent a daily load curve.

- Assume that the off-peak loss is at some off-peak load and that the peak loss is at the peak load . The load factor is

$$F_{LD} \triangleq \frac{\text{Average load}}{\text{Peak load}} = \frac{P_{av}}{P_2}$$

$$P_{av} = \frac{P_2 * t + P_1 * (T - t)}{T}$$

$$F_{LD} = \frac{t}{T} + \left(\frac{P_1}{P_2} * \frac{(T-t)}{T}\right)$$



- The loss factor is

$$F_{LS} \triangleq \frac{\text{Average power loss}}{\text{Power lossat peak load}} = \frac{P_{LS,av}}{P_{LS,max}} = \frac{P_{LS,av}}{P_{LS,2}}$$

$$P_{LS,av} = \frac{P_{LS,2} * t + P_{LS,1} * (T - t)}{T}$$

$$F_{LS} = \frac{t}{T} + \left(\frac{P_{LS,1}}{P_{LS,2}} * \frac{(T - t)}{T}\right)$$

- The copper losses are the function of the associated loads. Therefore, the off-peak and peak loads
- can be expressed, respectively, as

$$P_{LS,1} = k * P_1^2$$

$$P_{LS,2} = k * P_2^2$$

$$F_{LS} = \frac{t}{T} + \left(\left(\frac{P_1}{P_2} \right)^2 * \frac{(T-t)}{T} \right)$$

- The load factor can be related to loss factor for three different cases.

Case 1: Off-peak load is zero. Here since = 0.

- Then

$P_{LS,1} = 0$ P_1

- That is, the load factor is equal to the loss factor, and they are equal to the constant.

$$F_{LD} = F_{LS} = \frac{t}{T}$$

- Very short-lasting peak. Here,
- t=0 then

$$\frac{(T-t)}{T} = 1$$

$$F_{LS} = F_{LD}^{\ 2}$$

That is, the value of the loss factor approaches the value of the load factor squared.

Case 3: Load is steady. Here

t=T then

$$F_{LD} = F_{LS}$$

- That is, the value of the loss factor approaches the value of the load factor.
- Therefore, in general, the value of the loss factor is
- Therefore, the loss factor cannot be determined directly from the load factor. The reason is that the loss factor is determined from losses as a function of time, which, in turn, are proportional to the time function of the square load.

$$F_{LD}^{2} < F_{LS} < F_{LD}$$

- However, Buller and Woodrow developed an approximate formula to relate the loss factor to the load factor as $F_{LS} = 0.3F_{LD} + 0.7F_{LD}^{2}$

- Figure gives three different curves of loss factor as a function of load factor. Relatively recently, the formula given earlier has been modified for rural areas.
- Loss factor curves as a function of load factor