Electrical Distribution Systems

Unit I –part 2

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Load Modeling

The load on a substation bus may consist of several types of loads such as motors, arc furnaces, lighting, and heating.

The real and reactive power requirements at a particular station bus as a function of voltage very much depend on the types of electrical loads connected to that bus, as well as the proportion of each type.

These individual loads can be represented by three analytical static load models based on the load-voltage relationship: a) constant-power (constant MVA), b) constant-impedance, c) constant-current.

- Furthermore, a composite load in a plant may consist of any number of induction motors, synchronous motors, rectifiers, and impedance loads.
- The load-voltage characteristics of such a composite load can be determined for stability studies by onsite tests.
- Although the composition of individual loads may be entirely random, a certain average pattern is recognizable at the distribution bus level, and loads can be grouped under the three models listed earlier.

- For such a composite load the load-voltage characteristic can be determined analytically by combining the effects of all types of individual load models.
- The analytical determination would, however, need a detailed survey to determine the composition of individual types of loads and their real and reactive power characteristics as function of voltage.
- A composite load is generally characterized by much lower voltage dependency than a constant-impedance load.
- A composite load might increase with increasing frequency, whereas a constant-impedance load (RL impedance load) actually decreases with increasing frequency.
- This is due to the predominance of motors which will experience increased load as frequency increases (due to increase in speed).

Constant Power

Constant real and reactive power (constant PQ)

- A constant power varies its impedance on change of input voltage to keep the power constant.
  - Induction motors
  - air conditioners
  - controlled power supplies
  - Tap changing transformer

$P = P_i$ $\quad\quad$ $Q = Q_i$

Constant Impedance

Constant Impedance (Z)

- Constant impedance means that if the voltage decreases the current will decrease with the same ratio also and then the power at the square of the voltage.
  - Incandescent lighting
  - resistive water heating
  - cooking loads (stove and oven with resistive heating coils)

$$P = P_l V^2 \qquad Q = Q_l V^2$$

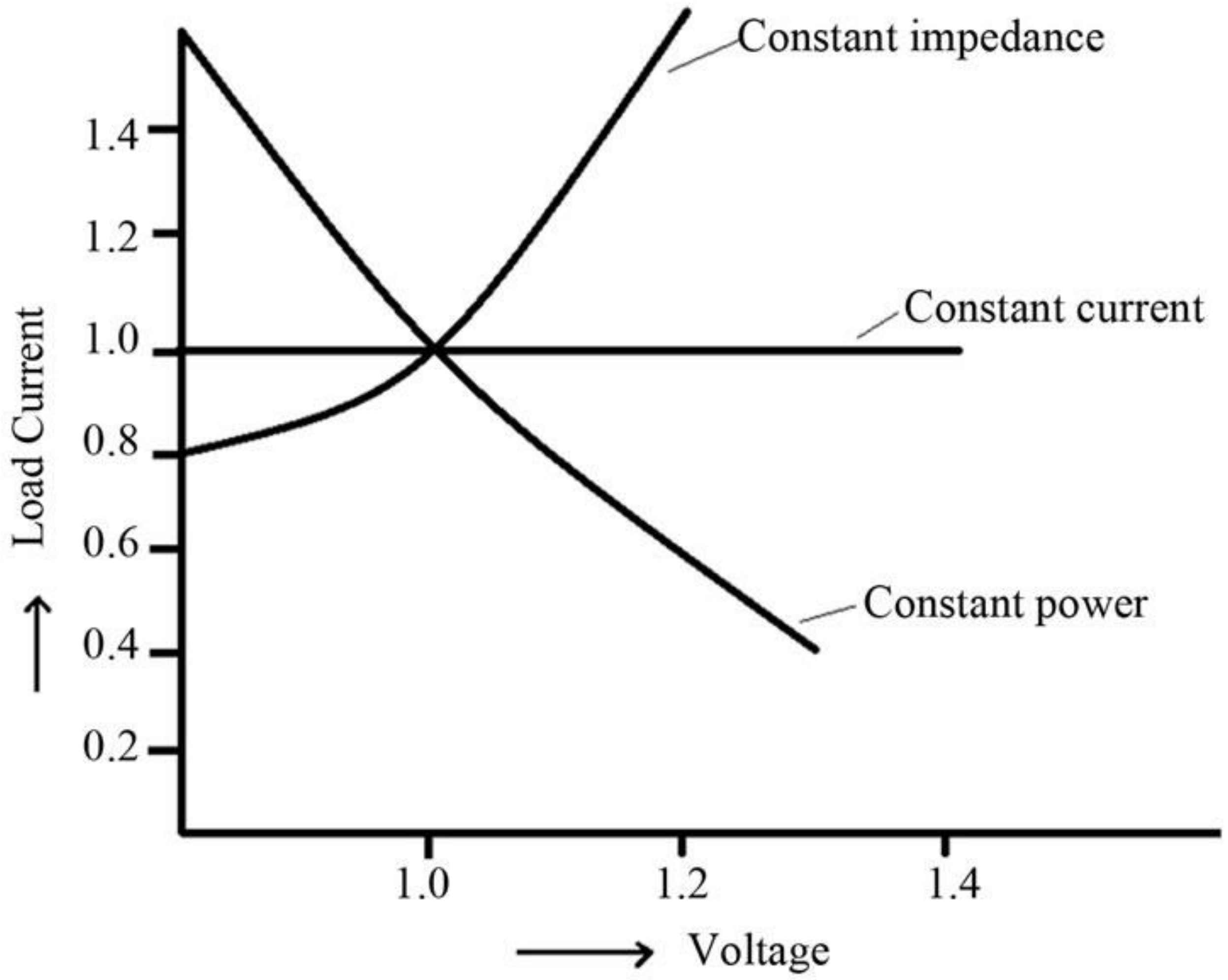
Constant Current

Constant current (I)

- A constant current load is the one which varies its internal resistance to achieve a constant current regardless of the voltage which is being fed to it.
    - welding
    - smelting
    - electroplating operation
    - thyristor application drives

$P = P_i V$ $Q = Q_i V$

Voltage Current Characteristics



- Combination or mix type
  - Polynomial (ZIP)
  - Exponential (EXP)

Polynomial load model

- The polynomial load model is also called as ZIP load model. Z stands for constant impedance, I represent constant current and P refers to constant power

$$P = P_i\left[P_1\overline{V}^2 + P_2\overline{V} + P_3\right] \qquad Q = Q_i\left[Q_1\overline{V}^2 + Q_2\overline{V} + Q_3\right]$$

Here $\overline{V} = \dfrac{V}{V_0}$

Exponential Load model

Exponential Load Model

The exponential load model for real and reactive power at load bus is represented as below.

$$P = P_i\left(\frac{V}{V_0}\right)^a \qquad\qquad Q = Q_i\left(\frac{V}{V_0}\right)^b \qquad (4)$$

P_i, Q_i, V_i are the initial values of real power, reactive power and voltage at a load bus respectively.

a, b are the load parameters of this model, the value of a and b vary between 0 to 2, for different load models as follows.

If a=b=2, it is constant impedance characteristic

If a=b=1, it is constant current characteristic.

If a=b=0, it is constant power characteristic.

Types of loads

- **Domestic** : lights, fan, domestic appliances such as heaters, refrigerators, AC, mixers, ovens, small motors for pumping, ...
  - ✓ Demand factor – 70 – 100 %
  - ✓ Diversity factor – 1.2 – 1.3
  - ✓ Load factor – 10 – 15 %

- **Commercial** : Lighting for shops and advertisement, fans, AC , heating and other electrical appliances
  - ✓ Demand factor – 90 – 100 %
  - ✓ Diversity factor – 1.1 – 1.2
  - ✓ Load factor – 25 – 30 %

- **<u>Industrial</u>** :
  - Cottage industries - < 5 KW
  - Small scale - 5 – 25 KW
  - Medium scale - 25 – 100 KW
  - Large scale - 100 – 500 KW
  - Heavy - above 500 KW

- For large scale industries
  - ✓ Demand factor – 70 – 80 %
  - ✓ Load factor – 60 – 65 %
- For heavy industries
  - ✓ Demand factor – 85 – 90 %
  - ✓ Load factor – 70 – 80 %

- **<u>Municipal</u>** : street lighting and remains practically constant through out night
  - ✓Demand factor – **100 %**
  - ✓Diversity factor – **1**
  - ✓Load factor – **25 – 30 %**

- **Agriculture** : Water pumps uses electric motors
  - ✓Demand factor – 90 – 100 %
  - ✓Diversity factor – 1 – 1.5
  - ✓Load factor – 15 – 20 %

Load Characteristics

LOAD CURVE

- ✓ A graphical plot showing the variation in demand for energy of the consumers on a source of supply with respect to time is known as the **load curve**.

- ✓ If this curve is plotted over a time period of 24 hours, it is known as **daily load curve**. If its plotted for a week, month, or a year, then its named as the **weekly, monthly or yearly load curve** respectively.

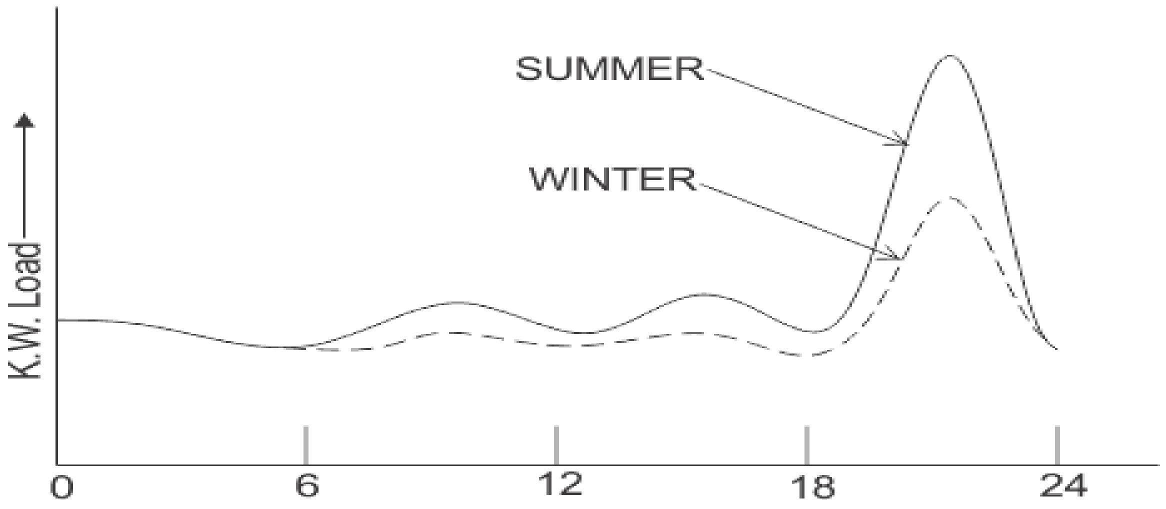
A device which taps electrical energy from the electric power system is called a load on the system. The load may be resistive (e.g., electric lamp), inductive (e.g., induction motor), capacitive or some combination of them. The various types of loads on the power system are

- Residential Loads
- Commercial Loads
- Agricultural Loads
- Industrial Loads

- **Residential Loads/ Domestic Loads**

Residential Loads or Domestic load consists of lights, fans, refrigerators, heaters, television, small motors for pumping water etc.

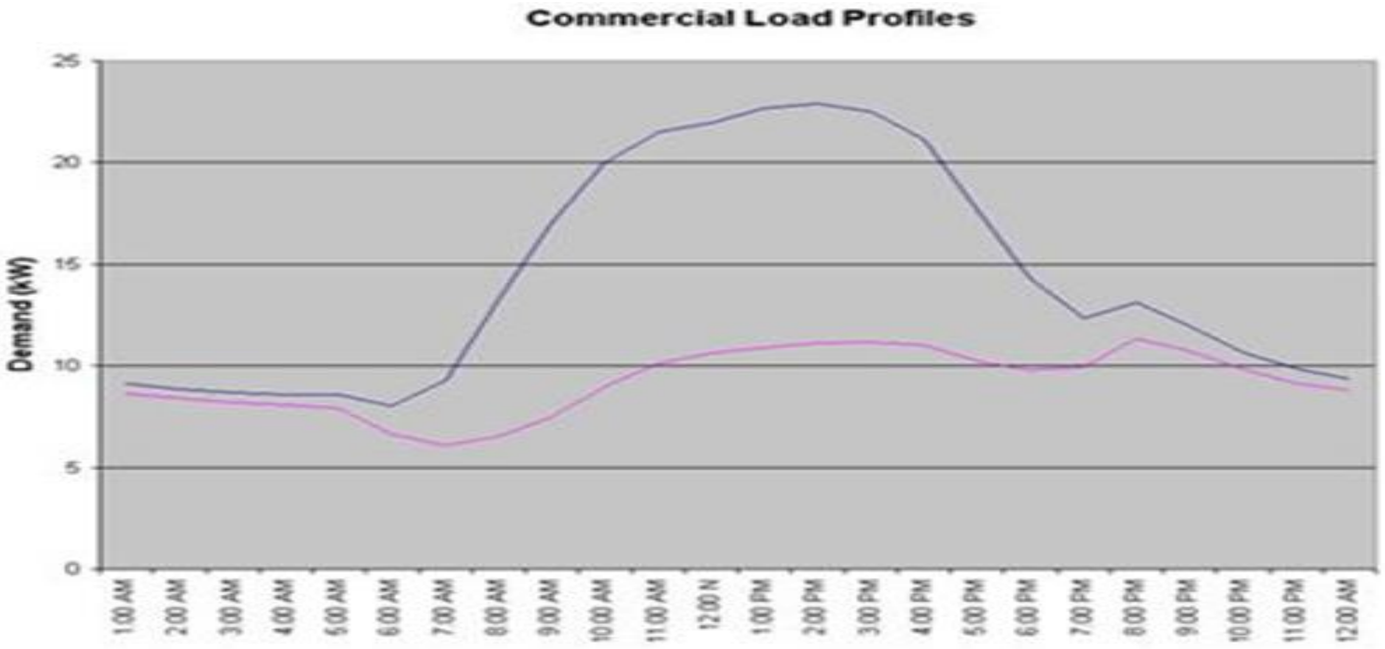
Most of the residential load occurs only for some hours during the day (i.e., 24 hours) e.g., lighting load occurs during night time and domestic appliance load occurs for only a few hours. For this reason, the load factor is low (10% to 12%).



Residential Load

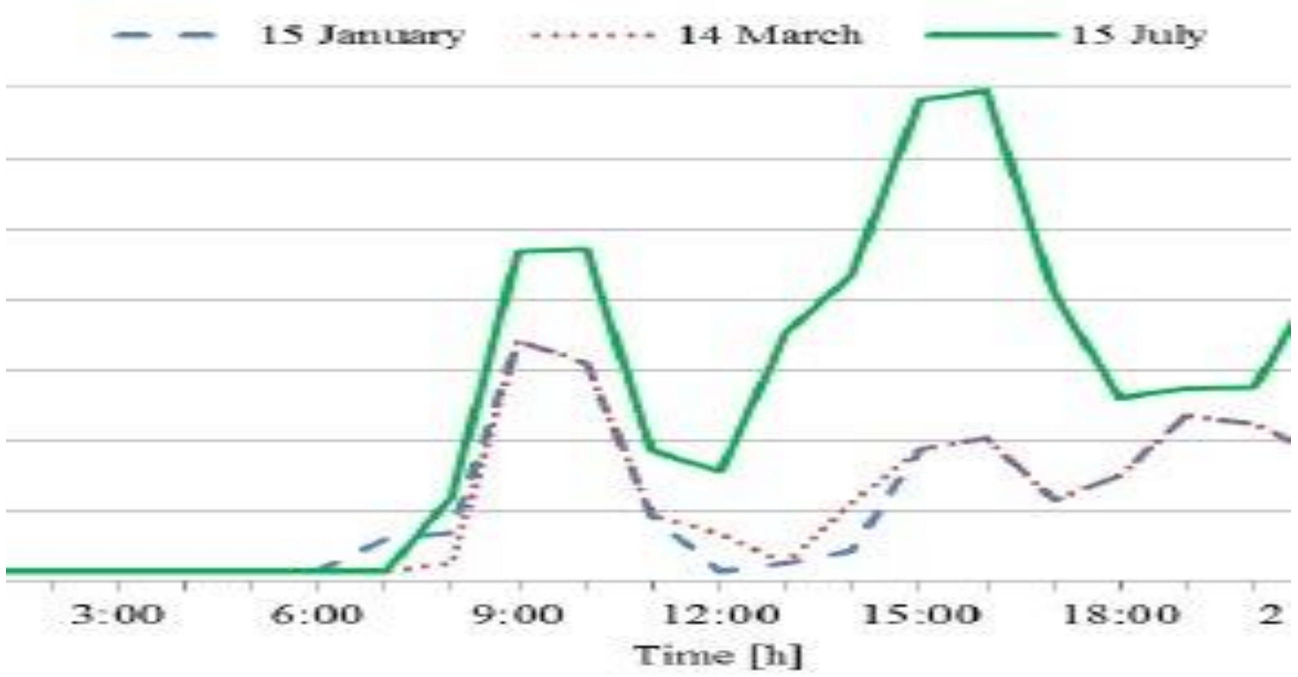
- **Commercial Loads**

  Commercial load consists of lighting for shops, fans and electric appliances used in restaurants etc. This class of load occurs for more hours during the day as compared to the domestic load. The commercial load has seasonal variations due to the extensive use of airconditioners and space heaters.



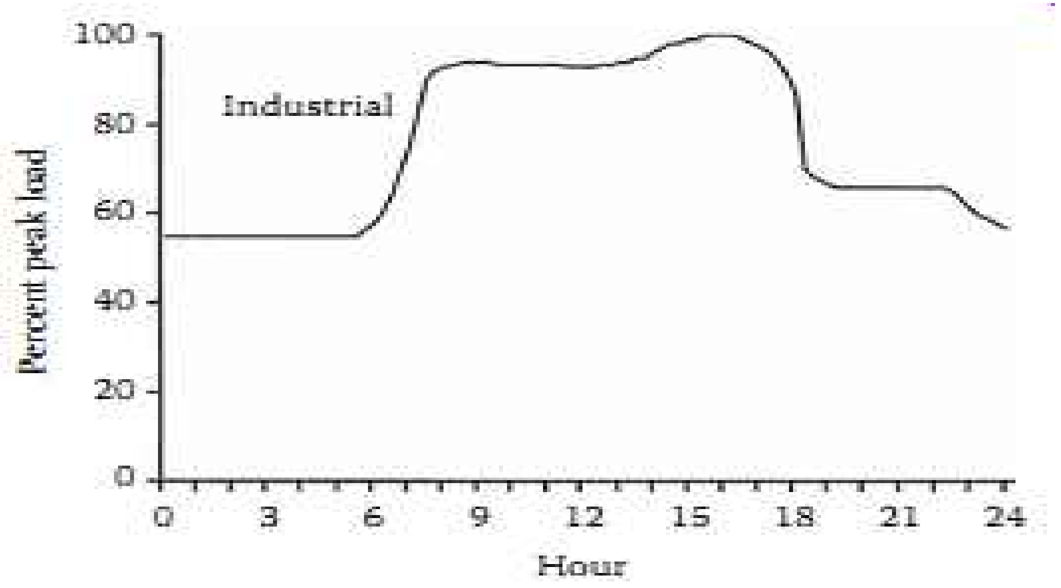
- **Agricultural Loads/ Irrigation Loads**

This type of load is the electric power needed for pumps driven by motors to supply water to fields. Generally this type of load is supplied for 12 hours.



• Industrial Loads

Industrial load consists of load demand by industries. The magnitude of industrial load depends upon the type of industry. Thus small scale industry requires load upto 25 kW, medium scale industry between 25kW and 100 kW and large-scale industry requires load above 500 kW. Industrial loads are generally not weather dependent.



- **Municipal load:** Municipal load consists of street lighting, power required for water supply and drainage purposes. Street lighting load is practically constant throughout the hours of the night. For water supply, water is pumped to overhead tanks by pumps driven by electric motors. Pumping is carried out during the off-peak period, usually occurring during the night. This helps to improve the load factor of the power system.
- **Traction load:** This type of load includes tram cars, railways etc. This class of load has wide variation. During the morning hour, it reaches peak value because people have to go to their work place. After morning hours, the load starts decreasing and again rises during evening since the people start coming to their homes.

Consider a single phase, 230V, 15 kW load connected at a node

If the load is modelled as constant-impedance and operated at voltage **215 V**, the power consumed by the load is

Solution:

Given; single phase, 230 V, 15 kW

What will the **'P'** at 215 V, if the load is constant impedance load.

The general formula for power at mixed load condition is

$$P(V_a) = P_o\left(a_0 + a_1\left(\frac{V_a}{V_o}\right) + a_2\left(\frac{V_a}{V_o}\right)^2\right)$$; For constant impedance load, $a_0=0$, $a_1=0$, $a_2=1$

$$P(215) = 15\left(0 + 0\left(\frac{215}{230}\right) + 1\left(\frac{215}{230}\right)^2\right) = 15 * 0.874 = 13.11 kW$$

$$\boxed{P(215) = 13.11 kW}$$

If the load is modelled as constant-current and operated at voltage **215 V**, the power consumed by the load is

Solution:

Given; single phase, 230 V, 15 kW

What will the **'P'** at 215 V, if the load is constant current load.

$$\boxed{P(215) = 14.02\,kW}$$

The general formula for power at mixed load condition is

$$P(V_a) = P_o\left(a_0 + a_1\left(\frac{V_a}{V_o}\right) + a_2\left(\frac{V_a}{V_o}\right)^2\right)$$; For constant impedance load, $a_0=0$, $a_1=1$, $a_2=0$

$$P(215) = 15\left(0 + 1\left(\frac{215}{230}\right) + 0\left(\frac{215}{230}\right)^2\right) = 15 * 0.935 = 14.02\,kW$$

If the load is modeled as mix-load **(50% PQ, 10% I, and 40% Z)** and operated at voltage **215 V**, the power consumed by the load is

Solution:

Given; single phase, 230 V, 15 kW

What will the **'P'** at 215 V, if the load is **(50% PQ, 10% I, and 40% Z)**.

The general formula for power at mixed load condition is

$$P(V_a) = P_o\left(a_0 + a_1\left(\frac{V_a}{V_o}\right) + a_2\left(\frac{V_a}{V_o}\right)^2\right)$$

; For **(50% PQ, 10% I, and 40% Z)**, $a_0=0.5$, $a_1=0.1$, $a_2=0.4$

$$P(215) = 15\left(0.5 + 0.1\left(\frac{215}{230}\right) + 0.4\left(\frac{215}{230}\right)^2\right) = 15 * 0.943 = 14.15\,kW$$

$$\boxed{P(215) = 14.15\,kW}$$