EEN-206: Power Transmission and Distribution

Lecture -04

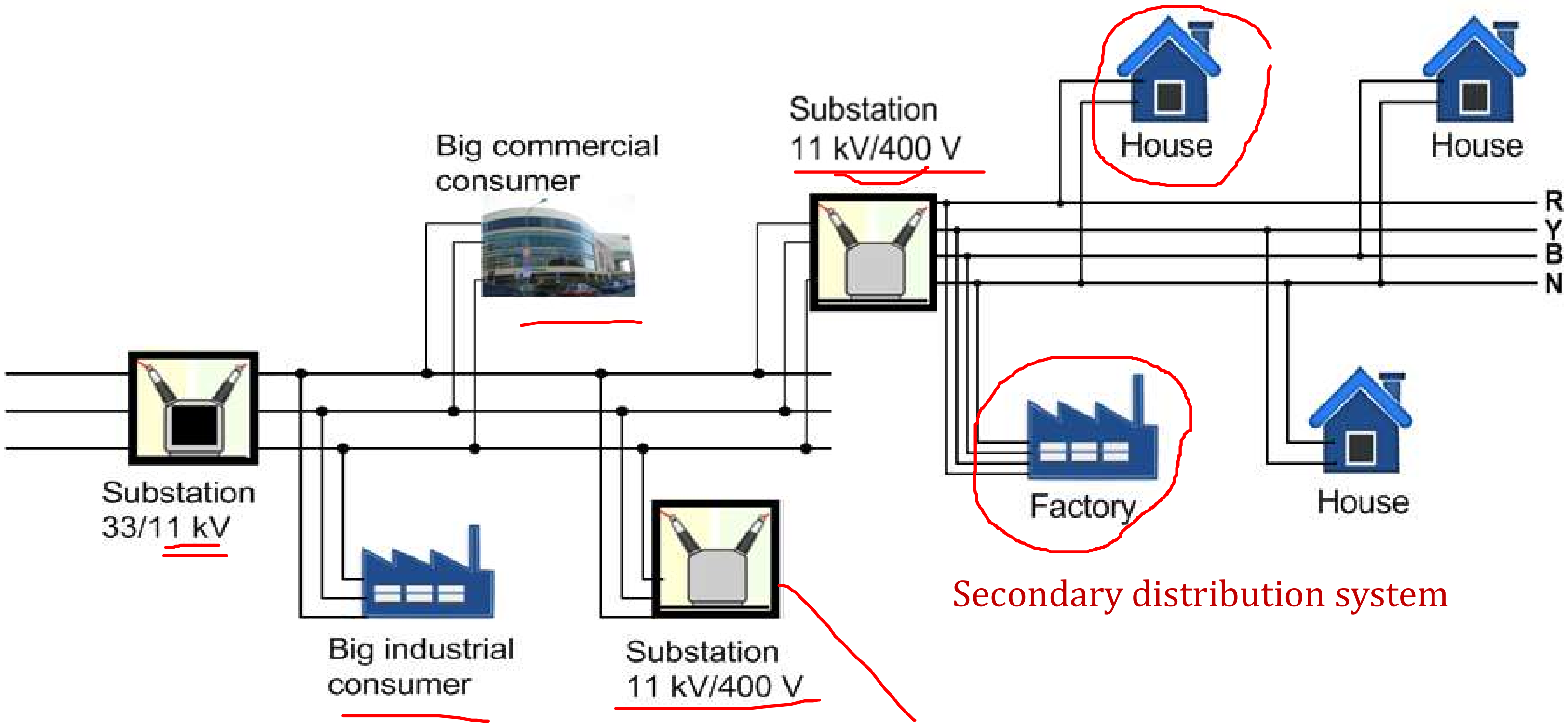
Chapter 1: Introduction

- Choice of working voltage
- Choice of conductor size
- Course Content
- Tutorial 01

Overhead vs. Underground Systems

- **Advantages of cables:** less maintenance, less accidents/interruptions, higher safety, less voltage drop, less electromagnetic interference, higher life, preserve aesthetic beauty, theft free.
- **Disadvantages of cable:** High initial cost, longer time for restoration, capacitance is predominant.
- Therefore long distance transmission overhead lines are preferred for AC transmissions.
- Cables are mainly used at distribution levels.
- Cables are preferred in following conditions:
  - Public safety involved and low interference is required
  - Large populated cities
  - Scenic beauty of city is important
  - DC transmission through cable in sea
  - Substation and transformer connections

Distribution System



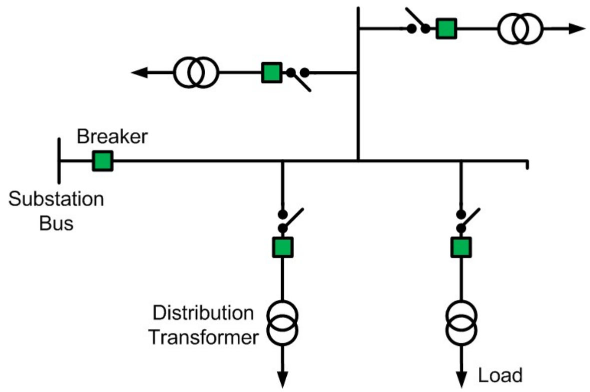
Secondary distribution system

Primary distribution system

Distribution System Topology

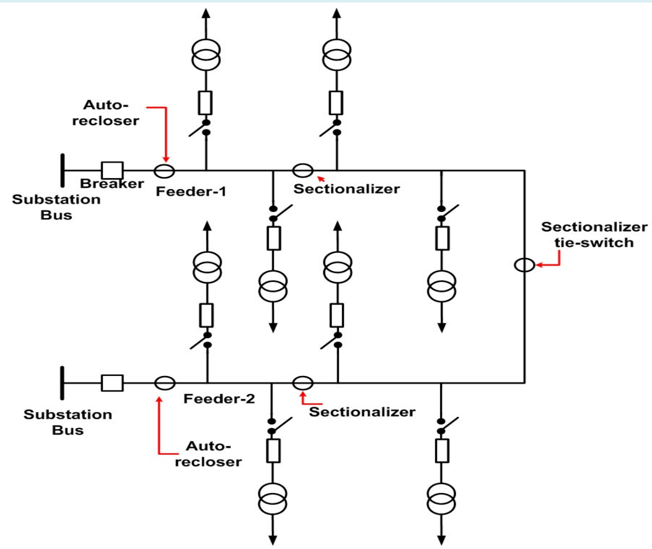
Radial System

- **Advantages**
  - Simple in Planning, Design and Operation, Lower cost, Simple Protection, Easier voltage control
- **Disadvantage**
  - Poor reliability

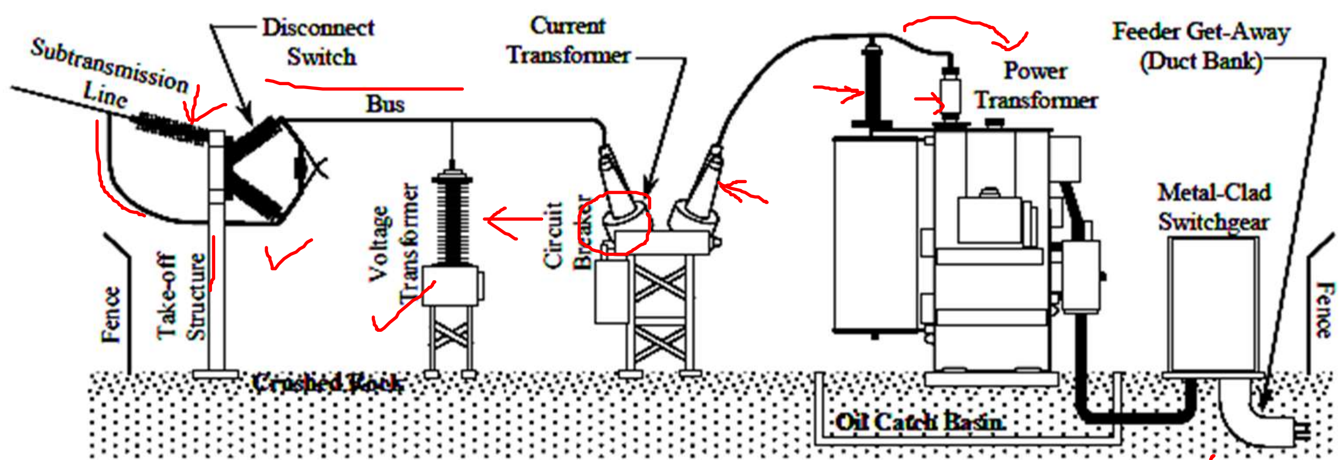


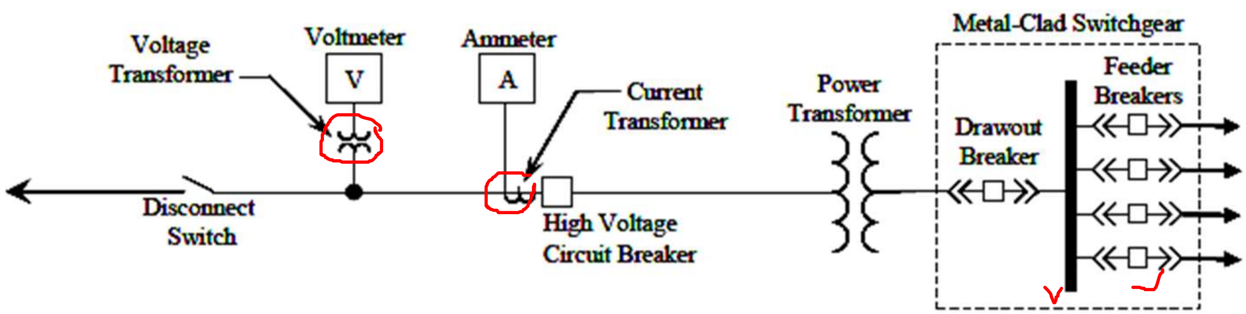
Loop System/Ring Main

- **Advantages**
  - More reliable
- **Disadvantage**
  - Larger conductor and more number of switches
  - Cost is more, protection is more complicated than radial systems.



Distribution Substation

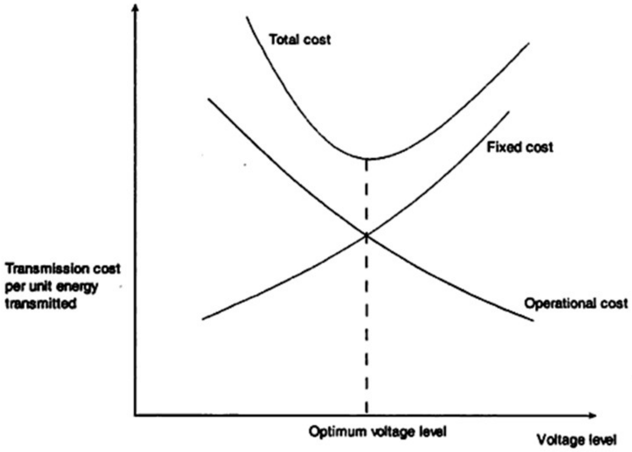




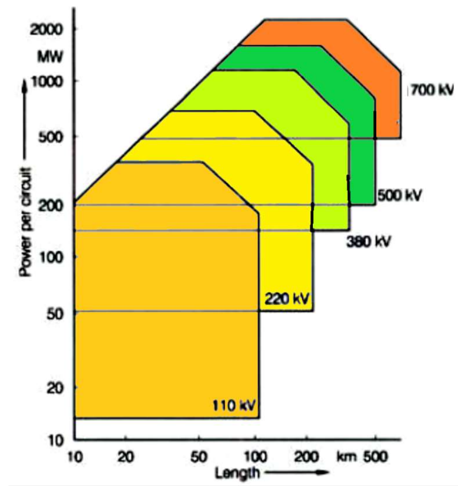
Source: Brown, R., Willis, H. . *Electric Power Distribution Reliability*, Second Edition. Boca Raton: CRC Press, 2008.

Choice of Working Voltage

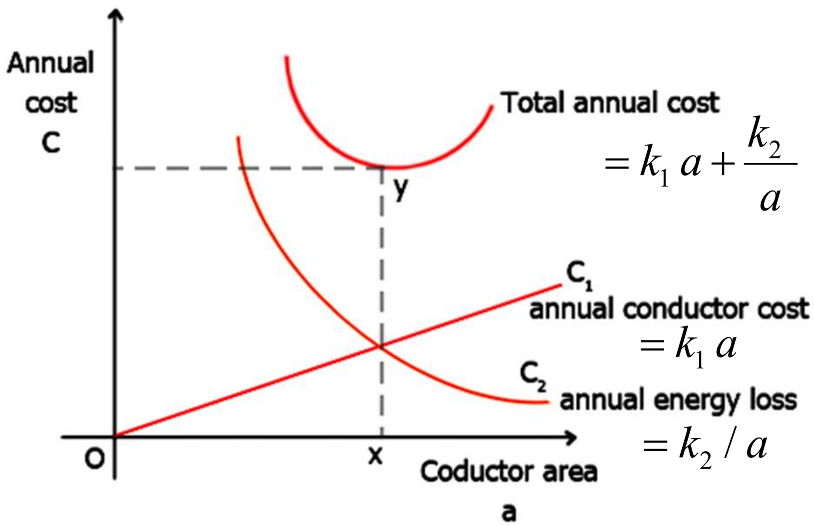
- There will be a saving in operational costs as the losses will decrease if the power is delivered at higher voltages.
- But higher system voltages will entail more cost of insulation in equipments like transformers, circuit-breakers, lightning arresters, switches, etc.
- Cost of insulation increases rapidly with increasing voltages.
- Therefore for certain length of transmission line and certain amount of power transfer the voltage level beyond which it becomes uneconomical.
- Therefore, the question is how to select the transmission and distribution voltages?



$$\text{Losses} = I^2 R$$



Conductor Size (Kelvin's Law)



$$\text{Total Cost} = k_1 a + \frac{k_2}{a}$$

$$\text{Losses} = I^2 R \quad \text{and} \quad R = \frac{\rho l}{a}$$

R is inversely proportional to Condutor cross-section a

$$\text{Total Cost} = k_1 a + \frac{k_2}{a}$$

Minimization

$$\frac{d}{dt}\left(k_1 a + \frac{k_2}{a}\right) = 0$$

$$k_1 - \frac{k_2}{a^2} = 0$$

Therefore

$$a = \sqrt{\frac{k_2}{k_1}}$$

Limitations

- Difficult to get accurate estimate of losses without actual load curves.
- Does not consider other effects temperature rise, voltage drop, mechanical strength, etc.
- Only accounts for the capital cost. Does not count structure, erection, insulator cost, etc.
- For underground cables, the cost of insulation and laying

Syllabus (Autumn 2020-21)

1. Subject Code: **EEN-206**		Course Title: **Power Transmission & Distribution**		
2. Contact Hours:	**L: 3**	**T: 1**	**P: 0**	
3. Examination Duration (Hrs.):	**Theory:3**		**Practical:0**	
4. Relative Weight:	**CWS: 50**	**PRS:00**	**MTE:0**	**ETE:50**	**PRE:00**
5. Credits: **4**		6. Semester: **Spring**	7. Subject Area: **DCC**	

1. Introduction (Power Transmission and Distribution Systems)
2. Overhead Transmission Lines
3. Underground Cables
4. Line Parameters and Performance of Transmission Lines
5. HVDC Transmission Systems
6. Tariff
7. Surge Performance and Travelling Waves

Reference Books

- B. M. Weedy, B. J. Cory, N. Jenkins, Janaka B. Ekanayake, and Goran Strbac, "Electric Power Systems", 4th Ed., John Wiley and Sons, 2012
- Grainger J. J. and Stevenson W.D., Elements of Power System Analysis", Tata McGraw-Hill Publishing Company Limited, 2008.
- Gonen T., Electric Power Transmission System Engineering: Analysis and Design", John Wiley and Sons, 1990.
- Nagrath I. J. and Kothari D. P., "Power System Engineering", 3rd Ed., Tata McGraw-Hill Publishing Company Limited, 2008
- Roy S., "Electrical Power System- Concepts, Theory and Practices". Prentice Hall of India Private Limited, 2007
- C. L. Wadhwa, Electrical Power System, New Age Techno Press, New Delhi, 2010.
- S. N. Singh, Electric Power Generation, Transmission and Distribution, Second Edition, PHI, New Delhi, 2011.

TUTORIAL - 01

Question-01

A capacitor needs to be connected across a 100 kV, 50 Hz, AC source to generate 75 MVAr. What should be the value of the capacitance? (Consider single-phase ac 50Hz source)

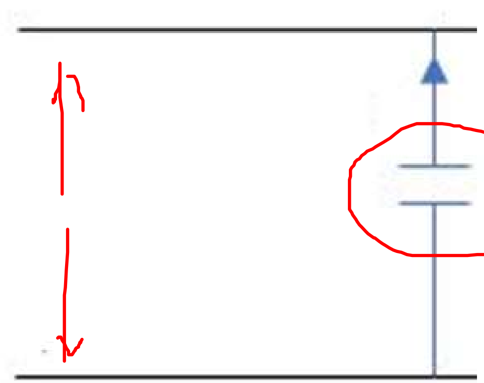
Explanation & Hints:

Reactive Power = Q

Voltage = V

$Q = \frac{V^2}{X_c}$

$X_c = \frac{1}{2\pi f C}$



Question-02

A single phase AC voltage of 240 V is applied to a series circuit whose impedance is $10\angle 60°\Omega$. Find R, X, P, Q and power factor of the circuit.

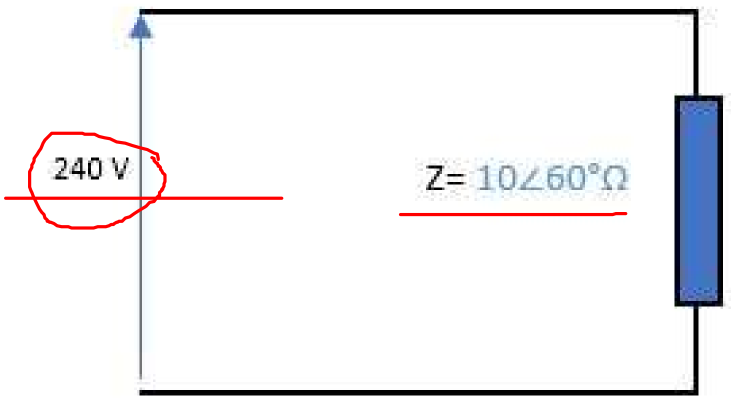
Explanation & Hints:

Impedance = $Z = |Z|\angle\phi = R + jX$

Current = $I = |I|\angle -\phi = \dfrac{V\angle 0}{|Z|\angle\phi}$

Complex power = $S = VI^* = |S|\angle\phi = P + jQ$

Power factor = $\cos(\phi)$



Question-03

If a capacitor is connected in parallel with the circuit of the previous problem and if this capacitor supplies 1250 VARs. Find P and Q supplied by 240V source and resultant power factor.

Explanation:

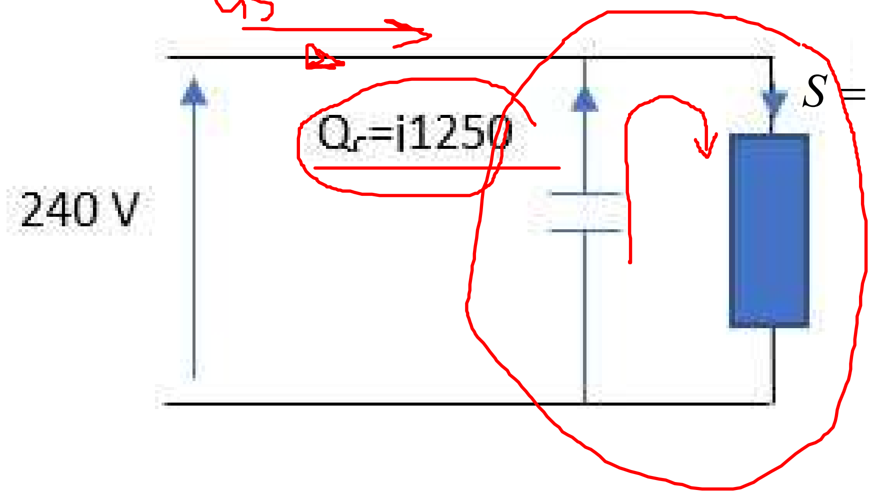
$P_s \cong P$

Q_s

$$Q_S = Q - Q_C$$

$$S_{new} = P + jQ_S = |S_{new}| \angle \phi_{new}$$

$$\text{pf}_{new} = \cos(\phi_{new})$$

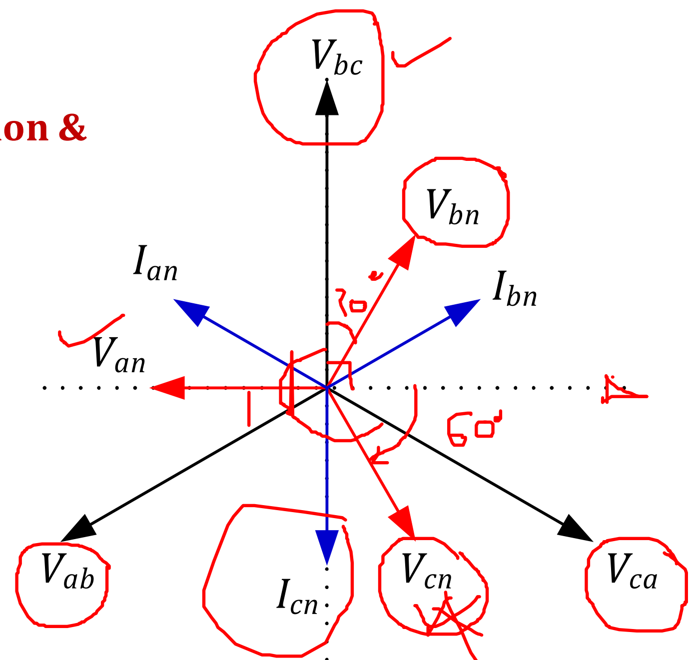


$$S = VI^* = |S| \angle \phi = P + jQ$$

Question-04

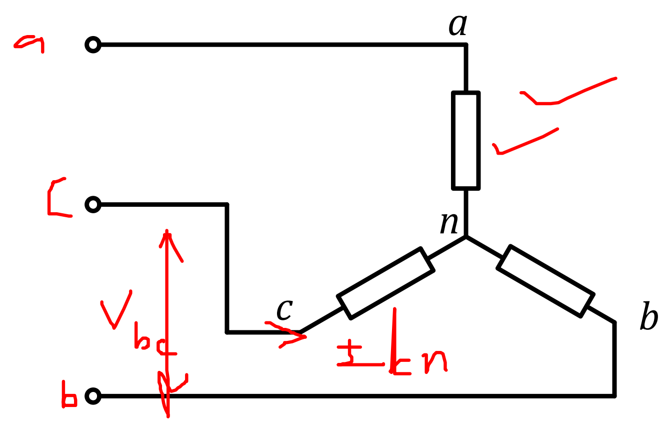
In a balanced three phase system, the Y connected impedance are 10∠30°Ω . If V_{bc}=416∠90° V, specify I_{cn} in polar form.

Explanation & Hints:



$$I_{cn} = \frac{V_{cn}}{Z}$$

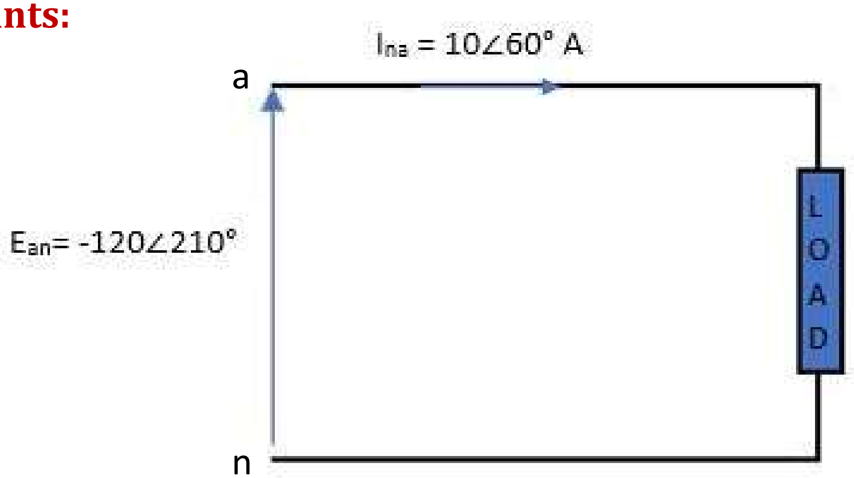
$$|V_{cn}| = \frac{|V_{bc}|}{\sqrt{3}}$$



Question-05

A voltage source E_{an} = -120∠210° V and the current through the source is given by I_{na} = 10∠60° A. Find the values of P and Q, and state whether the source is delivering or receiving each.

Explanation & Hints:



The complex power consumed by load, $S = E_{an} I_{na}^*$

Real Power:

- Positive sign means that source is delivering
- Negative sign means that source is receiving

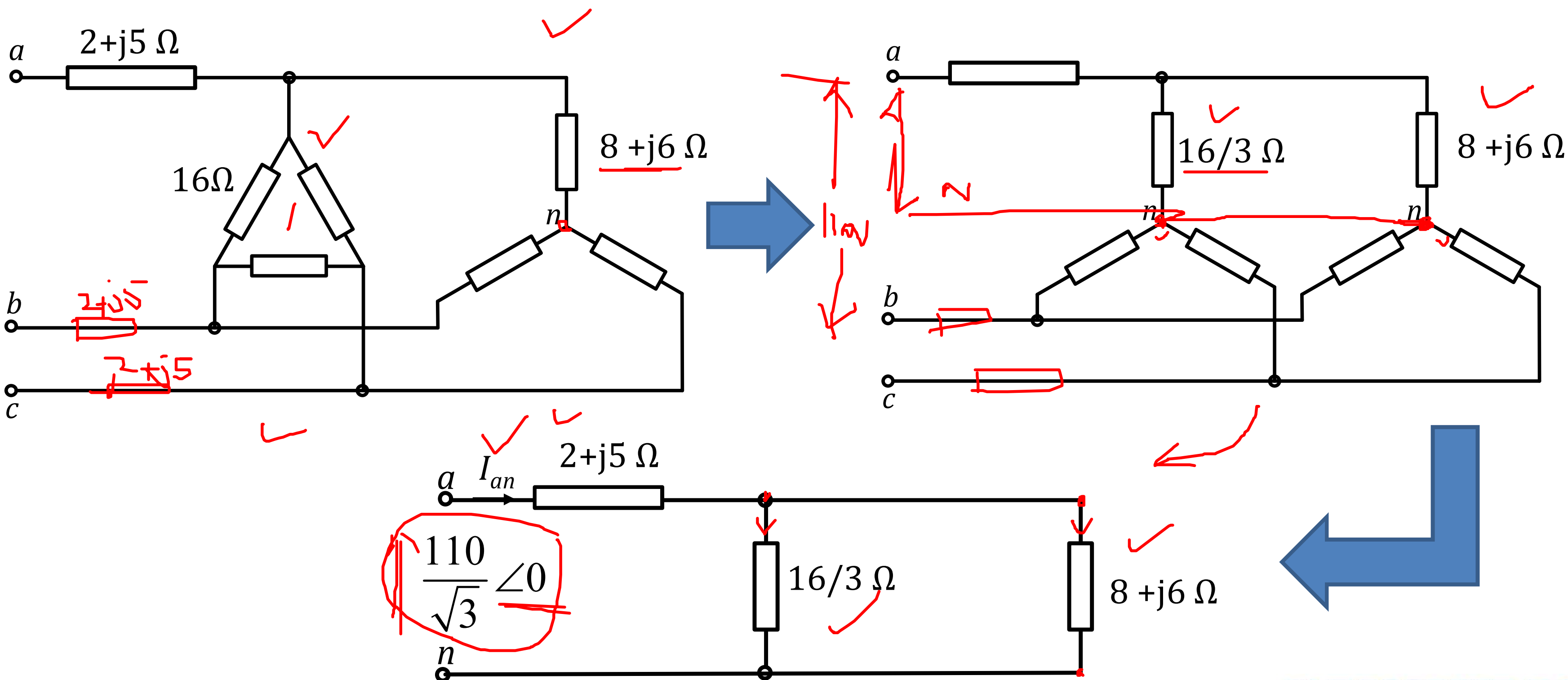
Reactive Power:

- Positive sign means that source is delivering
- Negative sign means that source is receiving

Question-06

A balanced Δ-load consisting of pure resistances 16Ω per phase is in parallel with a balanced Y-load having phase impedances of 8 +j6 Ω. Identical impedances of 2+j5 Ω one in each of the three lines connecting the combined load to 110V three-phase supply. Find: (a) Current drawn from the supply (b) Line voltages at the combined-load.

Explanation & Hints:

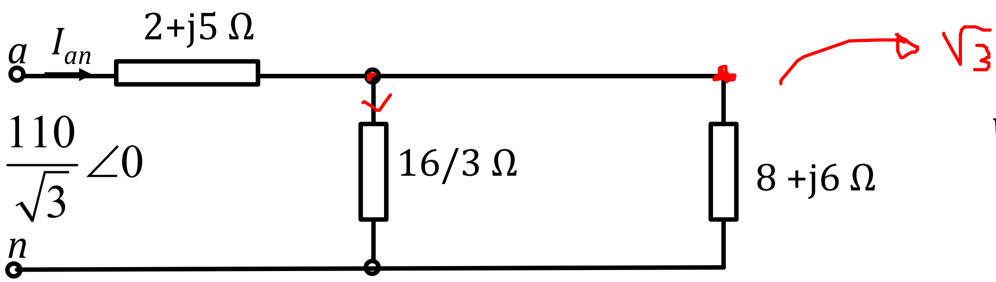


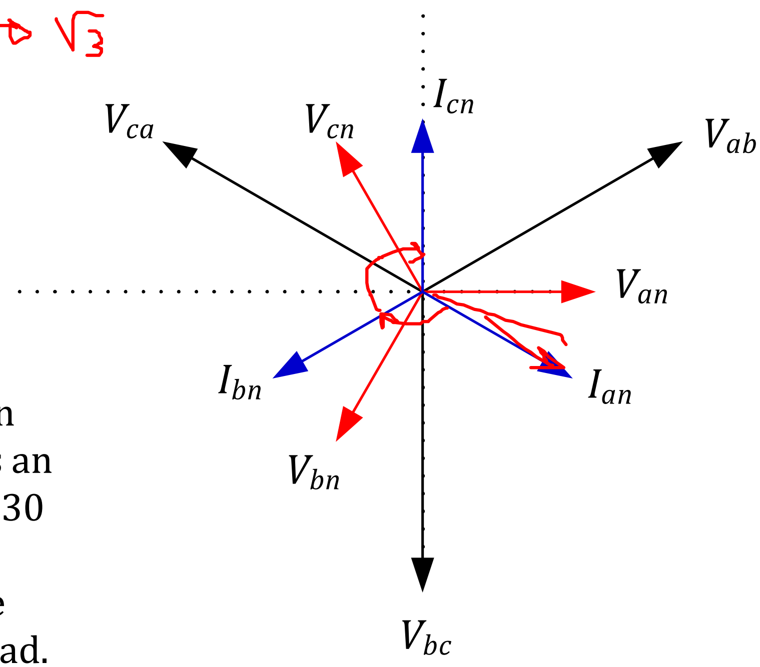
Question-06

A balanced Δ-load consisting of pure resistances 16Ω per phase is in parallel with a balanced Y-load having phase impedances of 8 +j6 Ω. Identical impedances of 2+j5 Ω one in each of the three lines connecting the combined load to 110V three-phase supply. Find: (a) Current drawn from the supply (b) Line voltages at the combined-load.

Explanation & Hints:

$$V_{an} = \frac{110}{\sqrt{3}}\angle 0$$



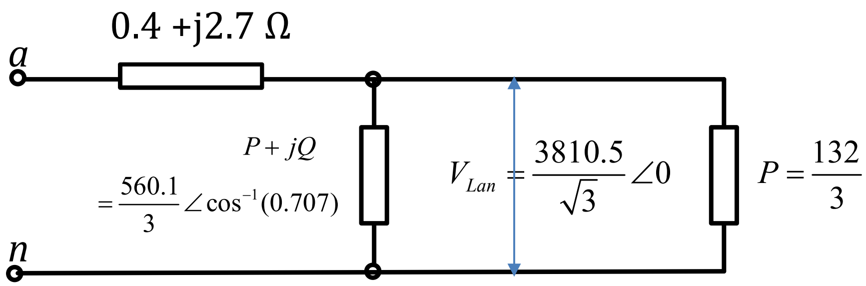


Q.7: A three-phase line has an impedance of 2 +j4 Ω. The line-to-line voltage is 207.85 V. Two three-phase loads are connected to this line in parallel: one is a Δ-load, the other is a Y-load. Each leg of the Δ-load has an impedance of 60 -j45 Ω and each leg of the Y-load has an impedance of 30 +j40 Ω. Taking the phase voltage V as a reference, determine: (a) The current, real power, and reactive power drawn from the supply. (b) The line voltage at the combined loads. (c) The current per phase in each load. (d) The total real and reactive powers in each load and the line.

Question-08

A three-phase line has impedance of 0.4 +j2.7 Ω per phase. The line feeds two balanced three phase loads that are connected in parallel. The first load is absorbing 560.1 kVA at 0.707 power factor lagging. The second load absorbs 132 kW at unity power factor. The line-to-line voltage at the load end of the line is 3810.5 V. Determine: (a) The magnitude of the line voltage at the source end of the line. (b) Total real and reactive power losses in the line. (c) Real and reactive power supplied at the sending end of the line.

Explanation & Hints:



$$\text{Real Power Loss} = I^2 R$$

$$\text{Reactive Power Loss} = I^2 X$$

$$\text{Real at supply end} = P_{L\_Total} + I^2 R$$

$$\text{Reactive Power Loss} = Q_{L\_Total} + I^2 X$$

Thank You