Module
1
Illumination Engineering Basics

Lesson
1
Introduction

Instructional Objectives

- State the need for Illumination.
- Define good Illumination.
- State what comprises an electric utility?
- List standard voltage levels.
- State need for high voltages for transmission.

Course Overview

- Radiation and colour.
- Eye and vision.
- Different entities of illuminating systems.
- Light sources: daylight, incandescent, electric discharge, fluorescent, arc lamps and lasers.
- Luminaries, wiring, switching and control circuits.
- Laws of illumination; illumination from point, line and surface sources.
- Photometry and spectrophotometry, photocells.
- Environment and glare.
- General illumination design.
- Interior lighting – industrial, residential, office departmental stores, indoor stadium, theater and hospitals.
- Exterior lighting – flood, street, aviation and transport lighting, lighting for displays and signaling – neon sign's, LED – LCD displays beacons and lighting for surveillance.
- Utility services for large building/office complex and layout of different meters and protection units.
- Different type of loads and their individual protection.
- Selection of cable/wire sizes; potential sources of fire hazards and precautions.
- Emergency supply-stand by and UPS.
- A specific design problem on this aspect.

Introduction

Light by definition connotes Electromagnetic radiation that has a wavelength in the range from about 4,000 (violet) to about 7,700 (red) angstroms and may be perceived by the normal unaided human eye. In fact in the prehistoric days, all human activities were coordinated with Sunrise and Sunset. Today, in principle activities are carried out round the clock. All this is made possible because of Artificial Lighting systems. The lighting systems comprise of a source employing any physical phenomenon among Incandescence, Electrolumniescence or Flourescence. Some control scheme and a Luminaire. In fact all this has lead to a class of professionals called Lighting Engineers or Illumination Engineers. Unlike other group of professionals they need to be adept at not only at exact sciences of Maths, Physics, Chemistry; but be wary of Physiology and Psychology of users (like a medical professional); have good aesthetic sense and economically utilize resources (like an architect video Fig. 1). Efficacy of these systems is talked in terms of Illuminance per Watt of energy consumed. Efforts are on to reduce energy conmsumption yet have efficient Illumination to enhance productivity. Need less to mention that all these sources employ electrical energy. Trend these days is to employ, modern electronic controls together with energy efficient lamps. These aspects are borne in mind, right from the planning stage of a building. As electrical energy is being used for the purpose, it becomes important for Illuminating Engineer to come up with an integrated system for the complete electrical system of a building.

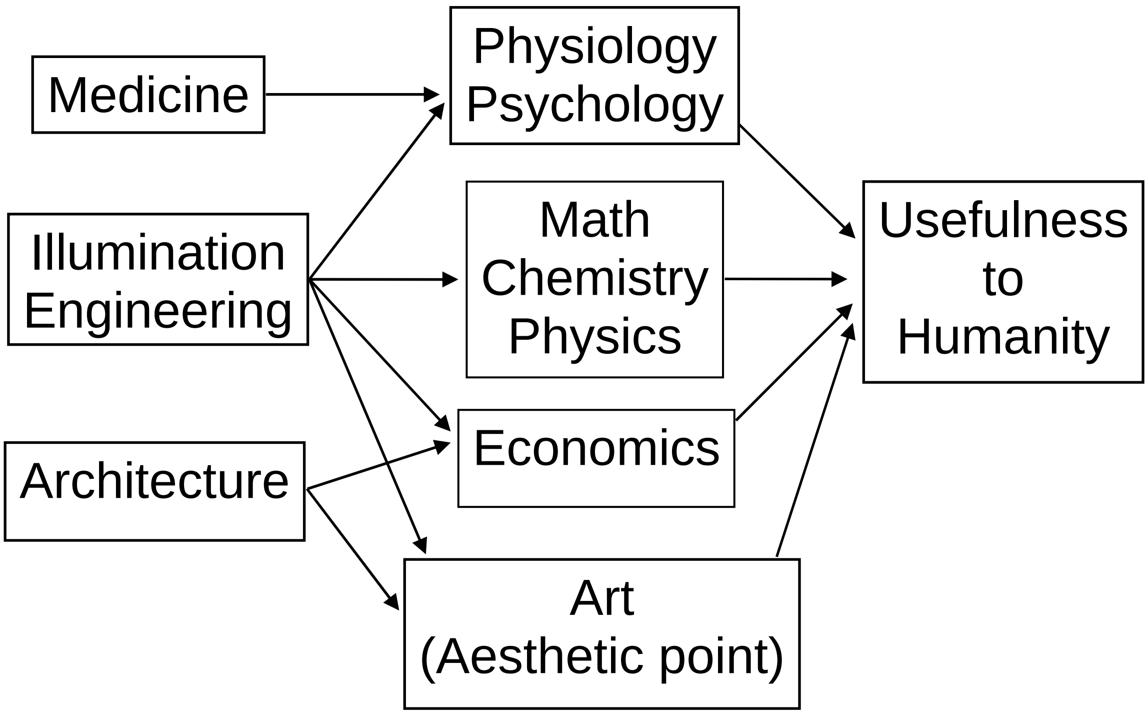


Fig. 1 Professions-sciences-usefulness relationship.

1. Necessity of Illumination

Humans depend on Light for all activities. Light is a natural phenomenon, very vital for existence, which is taken for granted. In fact, Life involves day night cycles beginning with sunrise and ending with sunset. Pre-historic man had activities limited only to day time. Artificial light enables extended activity period employing in an planned optimized manner, minimizing the resources.

Vision is the most important sense accounting for 80% information acquisition for humans. Information may be acquired through sun/moon light (direct/ reflected) or by using artificial light (closest to natural light). Before we go any further, it is worth looking at Teichmuller's definition for lighting. "We say the lighting is good, when our eyes can clearly and pleasantly perceive the things around us". Therefore Artificial light should be Functional and pleasant both Physiologically and Psychologically. This is often achieved employing multiple sources. It must be borne in mind that the sources should be economic and energy efficient. As all of us are aware, all sources today employ electrical energy.

Electrical energy is supplied as a.c. (alternating current) or d.c. (direct current). Usually electric power supply is a.c. in nature, either single phase or three phase. It must be borne that close circuit is a must for current flow. As it is well known losses exist in all electrical circuits or lines.

By definition Losses = i^2 R, where i = line current in A,
R = line resistance in Ω longer the line higher the resistance and higher level.
Thus for a particular power level current decreases with increase in voltage i.e.
p = v x i (instantaneous power). Hence, losses are minimized by supplying at higher voltages.
Normal sources of electrical energy are either hydro or thermal (coal based or nuclear). Usually power stations are located very far from load centers. Therefore, power is transmitted at high voltages.

It may be mentioned that, standard levels of power transmission being 132, 220, 340, 400, 735, 765, 1000 kV ac. HVDC or High Voltage Direct Current transmission is also fast catching up as an alternative.

Fig.2 shows a single line diagram of a typical Power System with all its components.

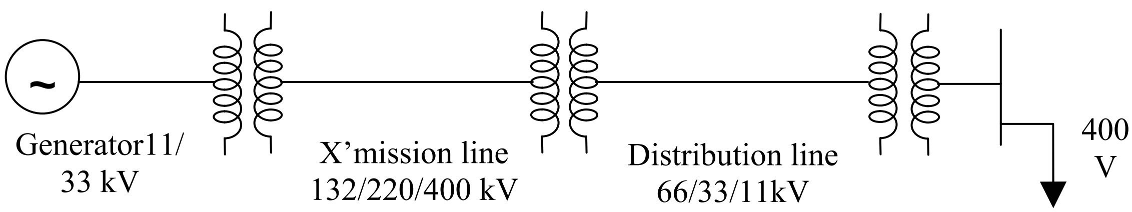


Fig. 2 Typical Power System

We know that load is always unbalanced for a practical 3-phase system. Fig 3 shows the waveform of a 400 V 50 Hz a.c supply. Here, 400 V, 3 phase, 50 Hz connotes that supply is three phase a.c. at a frequency of 50 Hz with a line to line voltage of 400 V rms, which translates to 564 V peak value.

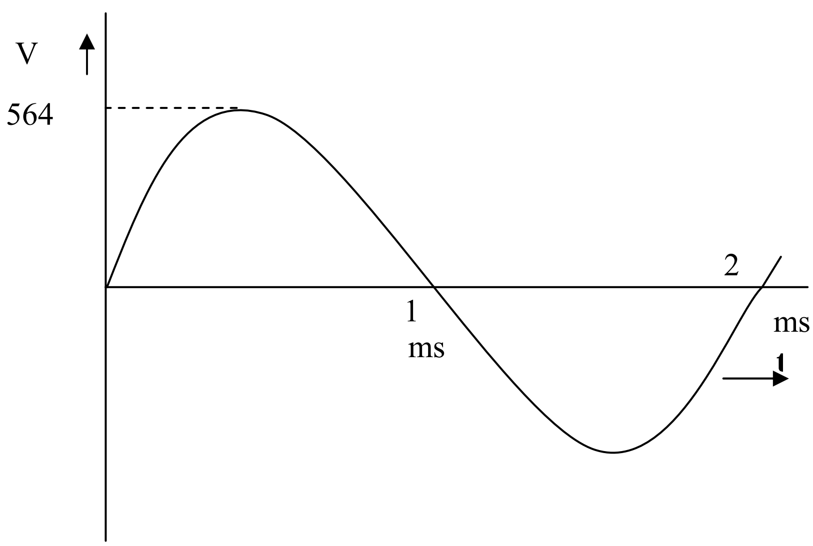


Fig. 3 Waveform of 400V, 50Hz a.c supply

In view of the fact that artificial Illumination employs electrical energy in a.c form, next, we address each fundamentals of a.c generation.

Fundamentals of a.c Generation

Single Phase AC Generation

Fig 4: shows Loop AB carried by a spindle rotated anti clockwise in a uniform magnetic field due to poles NS. This explains the single phase a.c generation

In this Coil ends C_1 and C_2 are brought out through
(but insulated) Slip Rings
and connected to two carbon brushes E1 E2 across which E m f is developed when connected to load 'R'. When plane of coil is horizontal no E.m.f. is developed as sides A and B do not cut any flux. If v be the peripheral velocity of each side in m/s AL – represents v in Fig. 5.
As rotating coil is rotated through an angle 'θ' from horizontal resolving A_L , we have , AM – Horizontal Component, AN – Perpendicular Component.

$$\because \angle MLA = 90^o - \angle MAL = \angle MAO = \theta$$

$$AM = AL \sin\theta = v \sin\theta$$

$$AN = AL \cos\theta = v \cos\theta$$

We know E.m.f generated in 'A' is only due to AM perpendicular to magnetic flux density

- 'B'
- If ℓ be the length of the sides A and B

$\therefore$ e.m.f generated on one side =

$B\ell v \sin\theta$ volts …………………..(1)

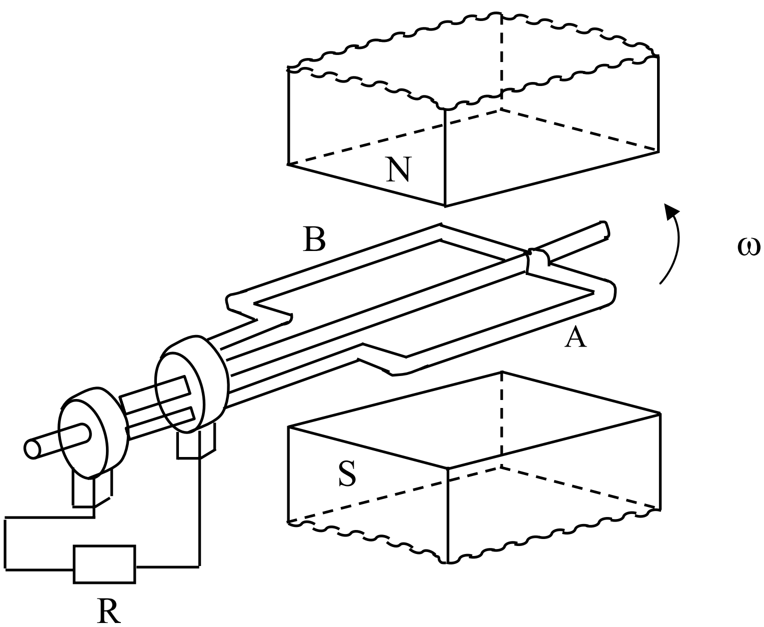


Fig. 4 Single Phase Generation

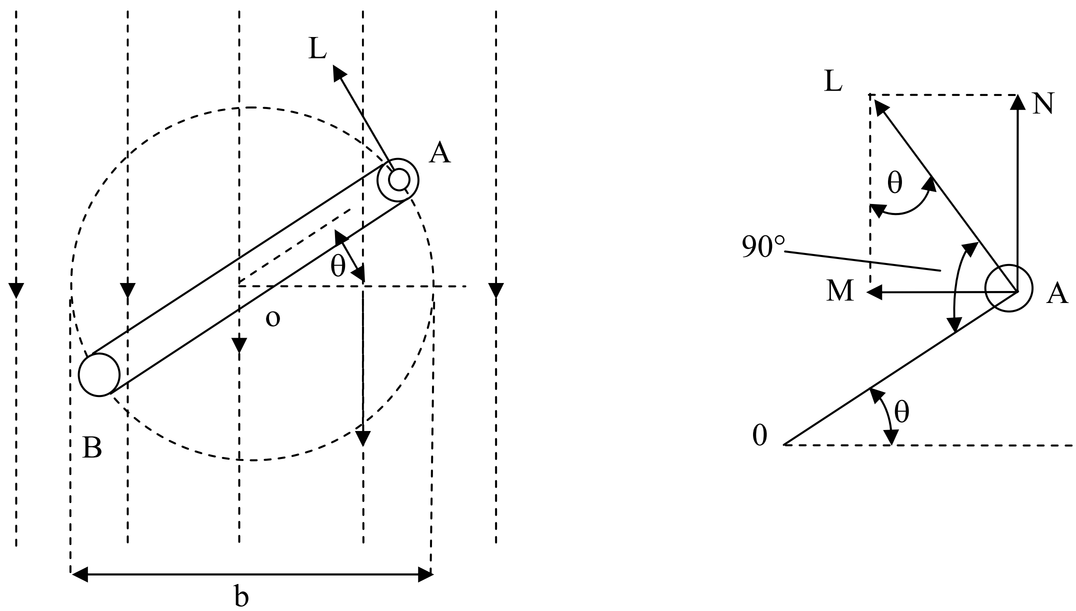


Fig. 5 Single Phase Generation

- Total e.m.f. generated = $2B\ell v \sin\theta$ ….(2)
  if $\theta = 90°$. Coil is vertical. E.m.f. generated is maximum.

  $E_m = 2B\ell v$ ………………………………..(3) or in other words

  $\therefore\ e = E_m \sin\theta$ ……………………………...(4)

Let b = breadth of loop
n = speed of rotation in r.p.s
then $v = \pi bn$ m/s
$\therefore\ E_m = 2\pi Bb\ell nv = 2\pi BAn = A =$ Loop area
If coil of 'N' turns replaces the loop

$E_m = 2\pi BAnN$ …………………………..(5)
$e = E_m \sin\theta = 2\pi BAnN \sin\theta$ ………….. (6)

Generation of 3 phase E.m.f.

- Just as we saw how single phase ac is generated by rotating a coil through a magnetic field. If three similar loops fixed to each other at 120° on a common spindle and rotated as shown in Fig 6.
- Connected to slip rings – on the shaft
- R, Y, B on there coils – termed finish and R_1, Y_1, B_1 are termed start when
- Rotated anti clock wise at uniform speed in magnetic field due to NS.
- For the position in figure (1) E.m.f. in $RR_1 = 0$
- When moved by 90° (2) – E.m.f. is $RR_1 \approx$ max generated e.m.f. in YY_1 and BB_1 have same amplitude as in RR_1 but lag by 120° and 240° respectively. Generated voltages in three coils are

$\therefore\ e_R = E_m \sin\theta$

$e_Y = E_m \sin(\theta - 120°)$ and

$e_B = E_m \sin(\theta - 240°)$

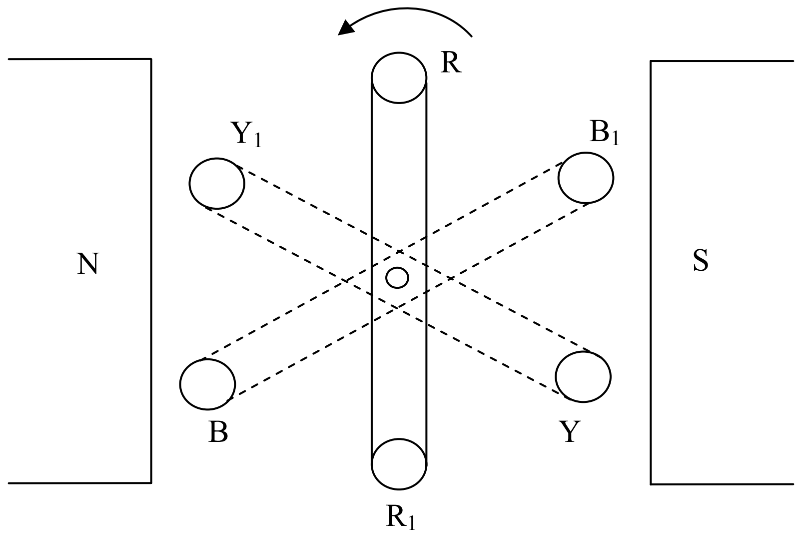


Fig.6 Generation of three-phase e.m.f.s.

The waveform of the Generated emf is shown in Fig.8

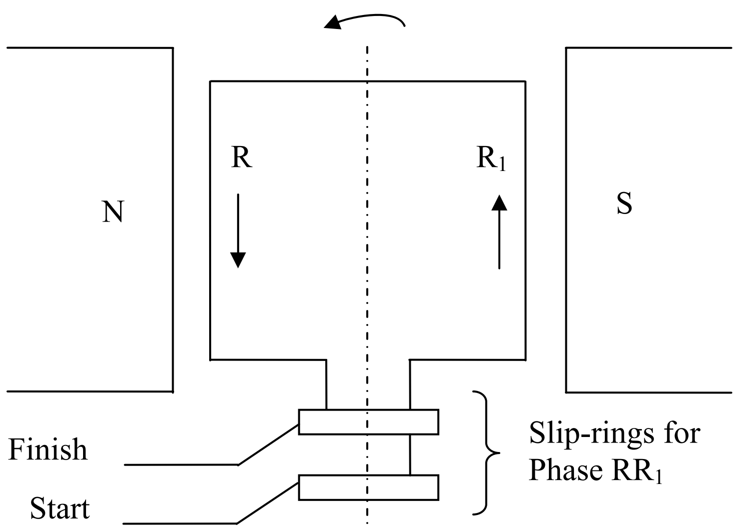


Fig. 7 Loop RR_1 at instant of maximum e.m.f.

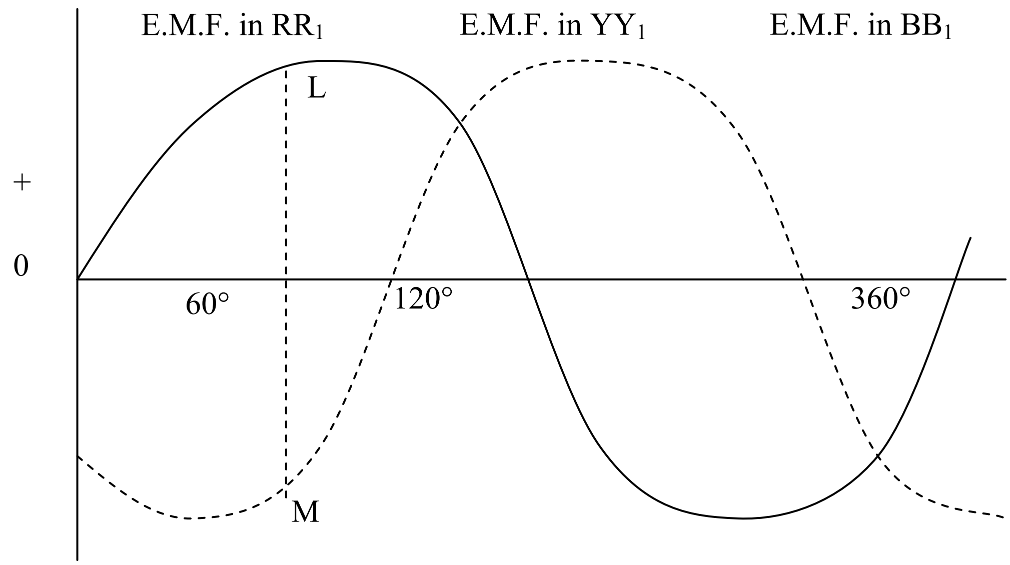


Fig. 8 Three Phase ac waveforms.

Next we need to look at how three phase circuits are connected. As already well know

Three Phase Connections could be – Delta as shown in Fig 9.

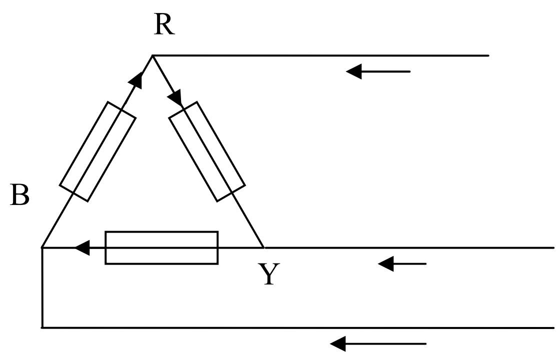


Fig.9 Delta connection.

Where Line Voltages = Phase Voltages. Line Quantities are I_R, I_Y, I_B, V_{RY}, V_{YB} and V_{BR} Phase Quantities are I_{RY}, I_{YB}, I_{BR}, V_{RY}, V_{YB} and V_{BR}. Three phone connection could also be a star as shown in Fig 10.

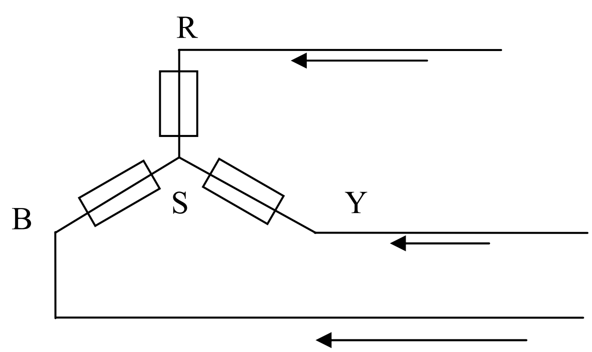


Fig. 10 Star Connection.

Where Line currents = Phase currents. Phase quantities are I_R, I_Y, I_B, V_{RS}, V_{YS} and V_{RS} Line quantities are I_R, I_Y, I_B, V_{RY}, V_{YB} and V_{BR} Further Loads may be balanced as shown in Fig. 11
What is a balanced load?
A Balanced Load is one where Impedance Nature is same in all three phases i.e. equal in both magnitude and Phase and draw equal current in all the three phases.

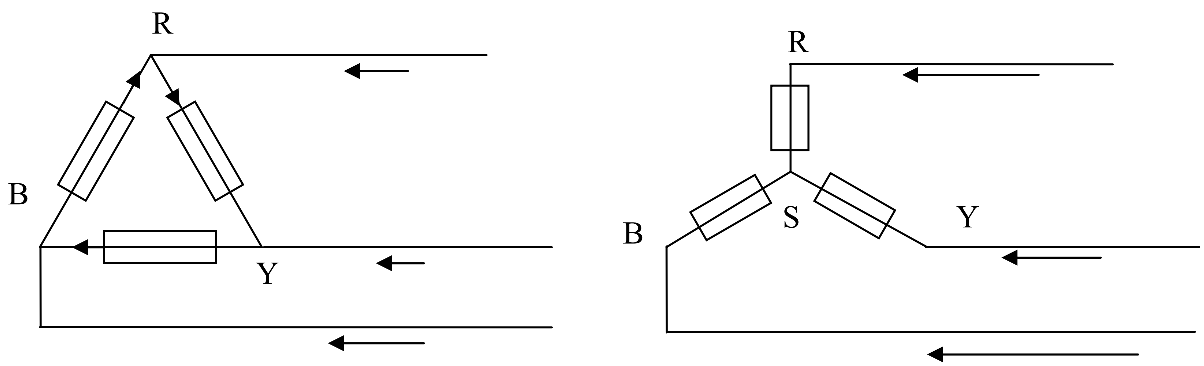


Fig. 11 Balanced Loads

Loads may also be unbalanced as shown in Fig. 12
A load if Unbalanced Load when Impedance Nature is not same in all the three phases and draw unequal currents in the three phases
.

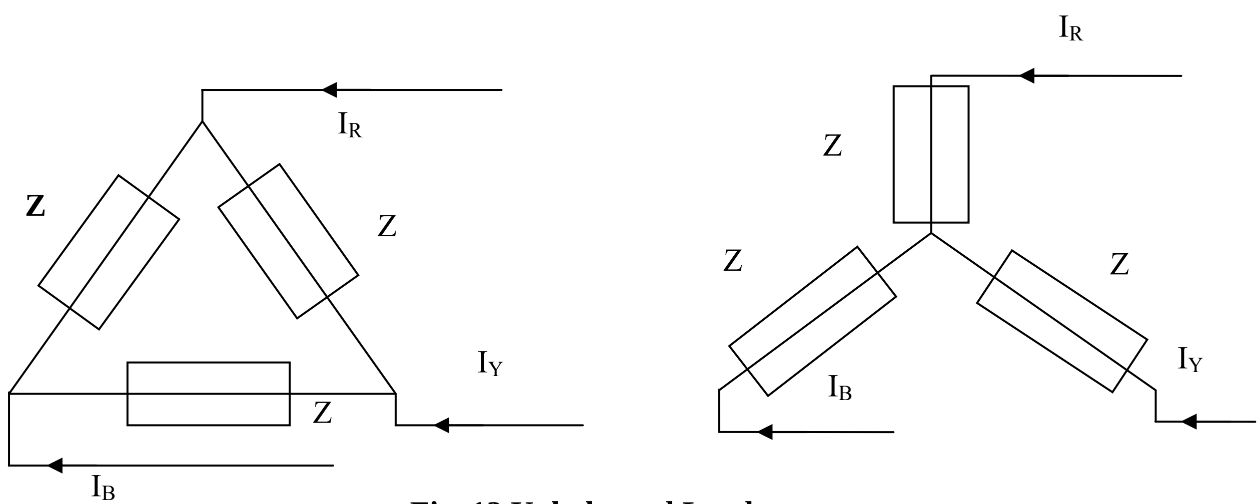


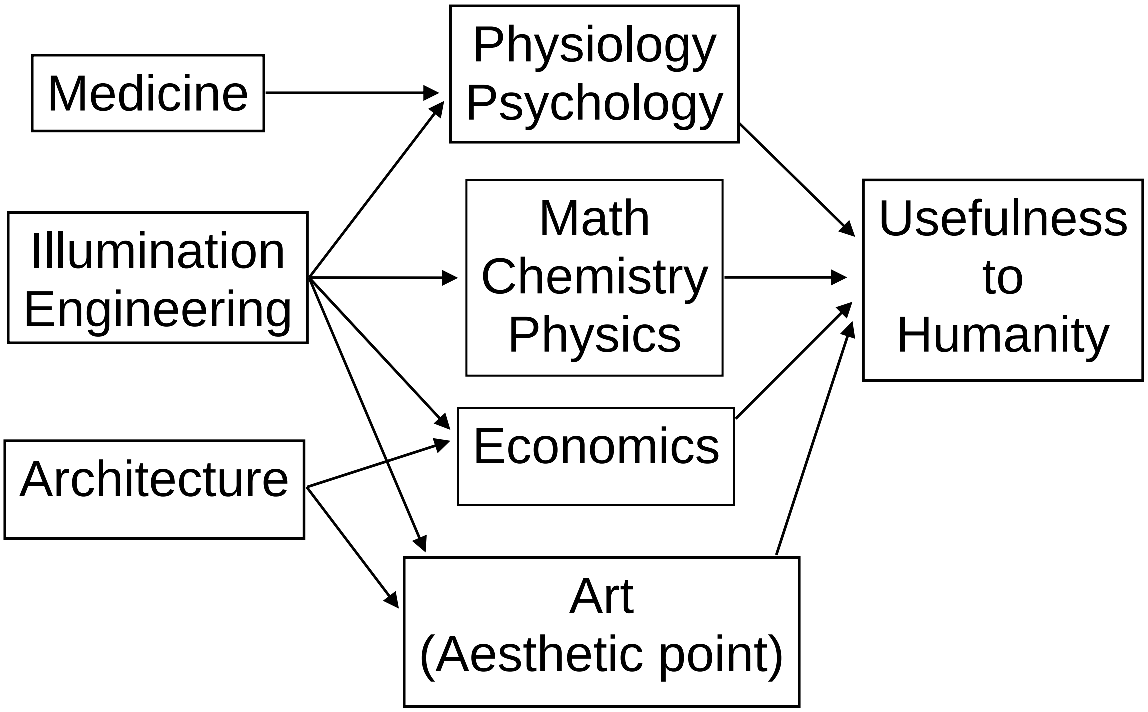
Fig. 12 Unbalanced Loads

How do we connect the sources to loads. Through lines which are either overhead lines or underground cables. Commonly employed cables are XLPE (Cross Linked Polyethylene) or PILC (Paper Insulated Lead covered), they could be single cored at higher voltages or multi cored at lower voltages.
Normally Single storied small buildings are serviced by single phase a.c. i.e. 220V, 50Hz
Where as large buildings are serviced by three phase a.c. i.e. 400V, 50Hz. It may be mentioned that sparsely populated, short distances are serviced by distribution at 400 V. In densely populated, vast areas power distribution is at 11 kV / 33 kV. Distribution of power may be through underground (UG) cables or overhead (OH) lines urban localities are serviced by UG cables. Rural settings are serviced by OH lines, where there is a lot of free space.

Conclusion

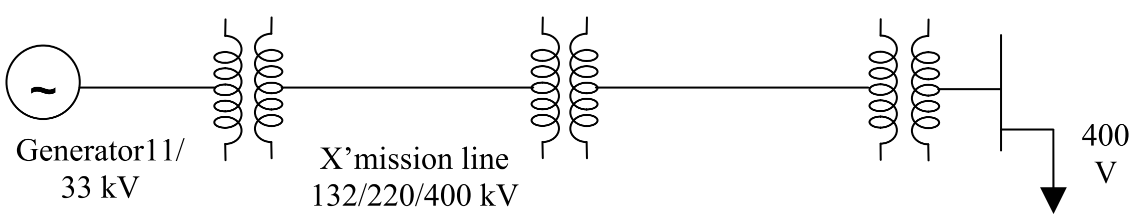
This Lecture essentially covered need for illumination, and fundamentals of electric utility

Lecture Summary



Good lighting → our eyes clearly and pleasantly perceive things. Artificial lighting → use some form of physical phenomena. All lighting sources today employ electrical energy.

- Electric Current sources
  - DC
  - AC – single phase and three phase.
- Sources of electrical energy – Hydro & Thermal.



- Load is always unbalanced for a practical 3-phase system.

Tutorial Questions

- Why do we go for transmission of power at higher voltages?

  Because power losses on transmission lines is inversely proportional to the operating voltage

- What are two ways through which power can be distributed?

  By underground cables & overhead transmission lines

- How do you decide the distribution voltage level for a particular area?

  Sparsely populated short distance distribution – 400V Densely populated vast area distribution – 11/33kV

- What do you mean by 400V, 3-phase in Indian system?

  In Indian system, it means 3-pahse 400Vline to line rms voltage at a frequency of 50 Hz.

- When is a load balanced?

  When both the magnitude and phase of the load impedances for a 3-phase system are equal

- When do you go for 1-phase & 3-phase supply?

  For a single storied small building-1-phase supply For a large building – 3-phase supply

Source:http://www.nptel.ac.in/courses/Webcourse-contents/IIT%20Kharagpur/Illumination%20Engg/Illumination%20%20Engineering/Lesson-01/pdf/L-1(NKK)(IE)%20((EE)NPTEL).pdf