Module 5

Distribution and Reliability and Quality of Distribution System

That part of power system which distributes electric power for local use is known as distribution system. In general, the distribution system is the electrical system between the substation fed by the Transmission system and the consumer's meters. It generally consists of feeders, distributors, and service mains.

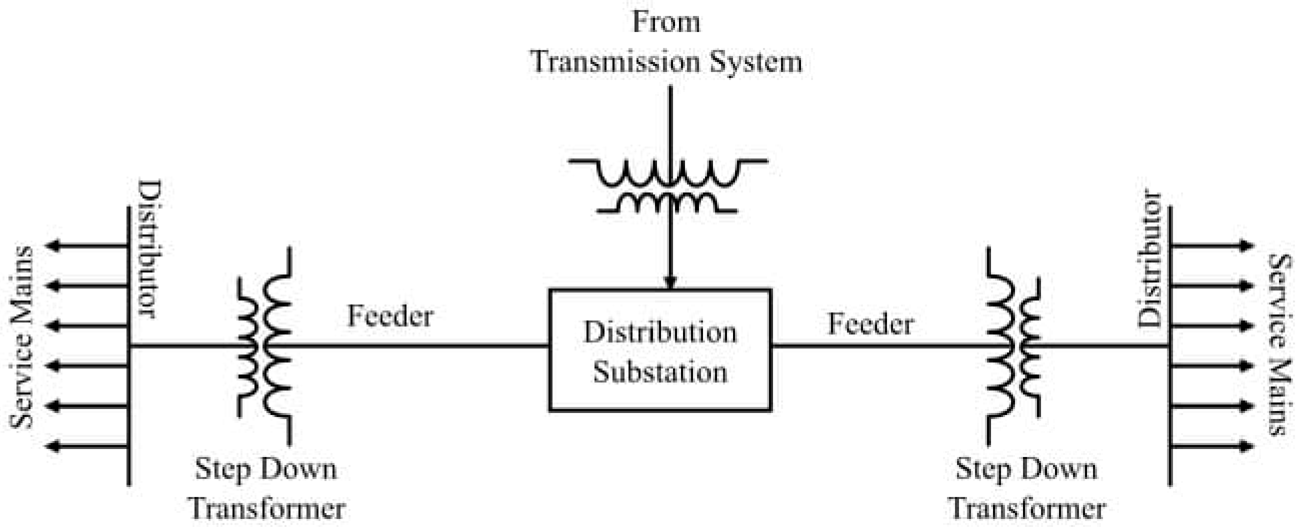
The necessary requirements of a good distribution system are,

1. The continuity in the power supply must be ensured. Thus system should be reliable.
2. The specified consumer voltage must not vary more than the prescribed limits. As per Indian Electricity Rules, the variation must not be beyond ± 5 % of the specified voltage.
3. The efficiency of the lines must be as high as possible.
4. The system should be safe from consumer point of view. There should no be leakage.
5. The lines should not be overloaded.
6. The layout should not affect the appearance of the site or locality.
7. The system should be economical.

Though the a.c. transmission and distribution is used, still for certain applications such as d.c. motors, electrochemical work, batteries, electric traction etc. the d.c. supply is must. Hence along with a.c., d.c. distribution is also equally important. In a d.c. distribution, d.c. generators are used in the generating stations or a.c. is converted to d.c. using the converters like mercury are rectifiers, rotary converters etc. at the substations. Then the d.c. supply is distributed to the consumers as per the requirement.

General Distribution System

The part of the power system that distributes electric power for local use is called as *distribution system*. Generally, a distribution system is the electrical system between the substation fed by transmission system and the consumer's meters. A typical distribution system is shown in the figure.



Components of Distribution System

- **Distribution Sub-Station** – A distribution sub-station is the electrical system which transfers power from transmission system to the distribution system of an area.
- **Feeders** – A feeder is a conductor which connects the distribution sub-station to the area where power is to be distributed. The current in a feeder remains the same throughout its length because no tapings are taken from it. The main consideration in the design of a feeder being its current carrying capacity.
- **Distribution Transformers** – The distribution transformer is a step-down transformer in which primary and secondary are delta and star connected respectively. It is also termed as *service transformer*. The output voltage of distribution transformer is 440 V in 3-phase system whereas 230 V in 1-phase system in India.
- **Distributor** – A distributor is a conductor from which tapings are taken for supply to the consumers. Due to the taping is done at various places in a distributor, the current being not same throughout its length. The main design consideration of a distributor is the voltage drop across its length because the statutory limit of voltage variations is ± 6 % of rated voltage at the consumer's terminals.
- **Service Mains** – Service Mains is a small cable which connects the distributor to the consumer's meter.

CLASSIFICATION OF DISTRIBUTION SYSTEMS

A distribution system may be classified according to; i) **Nature of current**

According to nature of current, distribution system may be classified as

a) d.c. Distribution system
b) a.c. Distribution system

Now-a-days, a.c. system is universally adopted for distribution of electric power as it is simpler and more economical than direct current method

ii) Type of construction

According to type of construction distribution system may be classified as

a) Overhead system
b) Underground system.

The overhead system is generally employed for distribution as it is 5 to 10 times cheaper than the equivalent underground system. In general, the underground system is used at places where overhead con struction is impracticable or prohibited by the local laws

(iii) **Scheme of connection**

According to scheme of connection, the distribution system may be classified as

a) Radial system
b) Ring main system
c) Inter-connected system

AC DISTRIBUTION

Now-a-days electrical energy is generated, transmitted and distributed in the form of alternating cur-rent. One important reason for the widespread use of alternating current in preference to direct current is the fact that alternating voltage can be conveniently changed in magnitude by means of a transformer. Transformer has made it possible to transmit a.c. power at high voltage and utilize it at a safe potential. High transmission and distribution voltages have greatly reduced the current in the conductors and the resulting line losses.

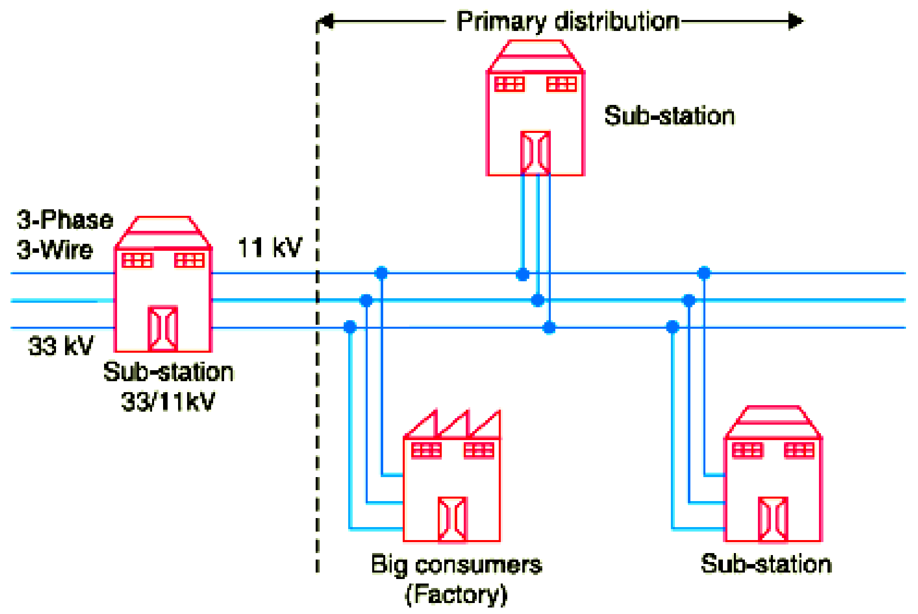
There is no definite line between transmission and distribution according to voltage or bulk capacity. However, in general, the a.c. distribution system is the electrical system between the step- down substation fed by the transmission system and the consumers' meters. The a.c. distribution system is classified into

i. primary distribution system and
ii. Secondary distribution system.

i)Primary distribution system.

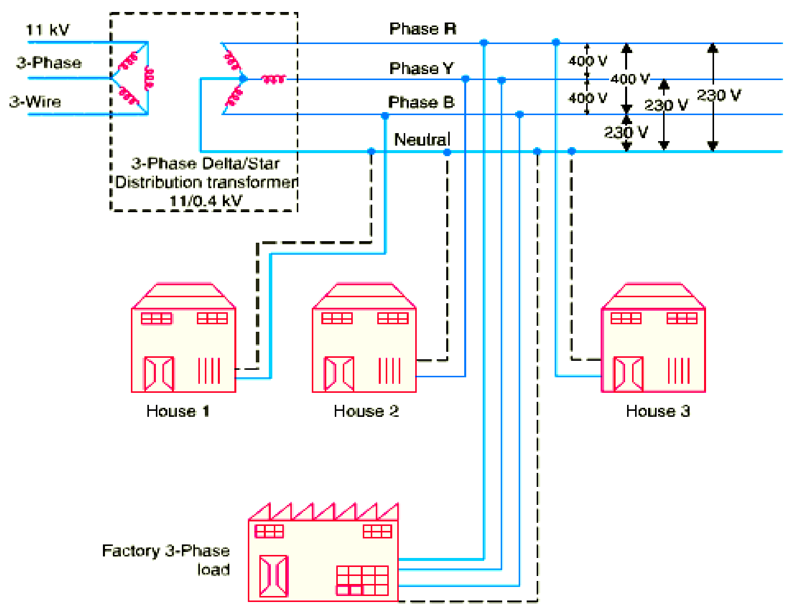
It is that part of a.c. distribution system which operates at voltages somewhat higher than general utilization and handles large blocks of electrical energy than the average low- voltage consumer uses. The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the substation required to be fed. The most commonly used primary distribution voltages are 11 kV, 6·6 kV and 3·3 kV.

Due to economic considerations, primary distribution is carried out by 3- phase, 3-wire system Fig. shows a typical primary distribution system Electric power from the generating station is transmitted at high voltage to the substation located in or near the city.



ii) Secondary distribution system

It is that part of a.c. distribution system. The secondary distribution employs 400/230V,3-phase,4wire system. Fig shows a typical secondary distribution system. The primary distribution circuit delivers power to various substations, called distribution sub-stations. The substations are situated near the consumers' localities and contain step-down transformers. At each distribution substation, the voltage is stepped down to 400Vandpowerisdeliveredby 3-phase,4- wire a.c. system. The voltage between any two phasesis400Vandbetween any phase and neutralize 230V. The single-phase domestic loads are connected between anyone phase and the neutral, whereas3- phase400Vmotor loadsareconnectedacross3- phase lines directly.

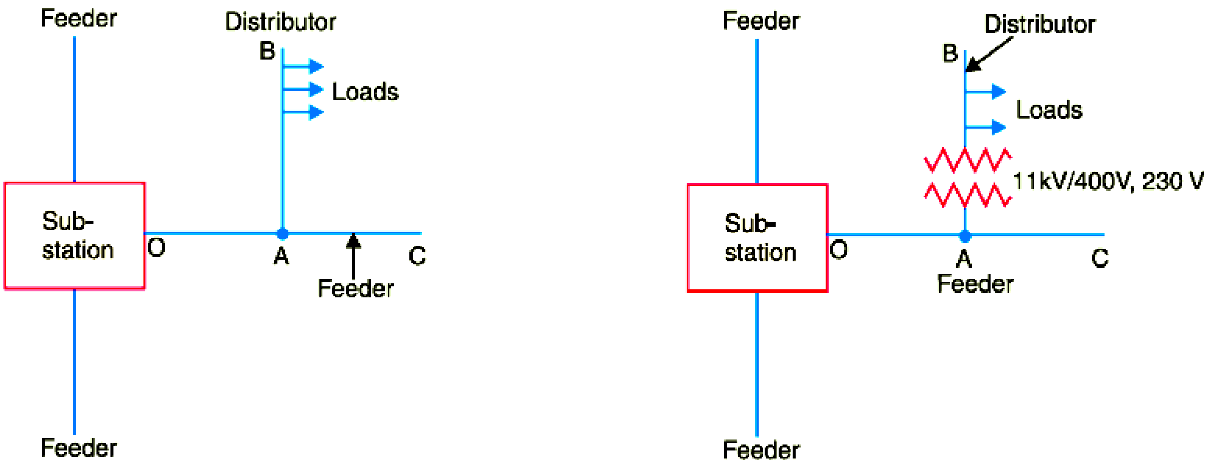


CONNECTION SCHEMES OF DISTRIBUTION SYSTEM

All distribution of electrical energy is done by constant voltage system. In practice, the following distribution circuits are generally used:

(i) Radial System.

In this system, separate feeders radiate from a single substation and feed the distributors at one end only. Fig. shows a single line diagram of a radial system for d.c. distribution where a feeder OC supplies a distributor A B at point A. Obviously, the distributor is fed at one end only i.e., point A is this case. Fig (ii) shows a single line diagram of radial system for a.c. distribution. The radial system is employed only when power is generated at low voltage and the substation is located at the center of the load.



This is the simplest distribution circuit and has the lowest initial cost.

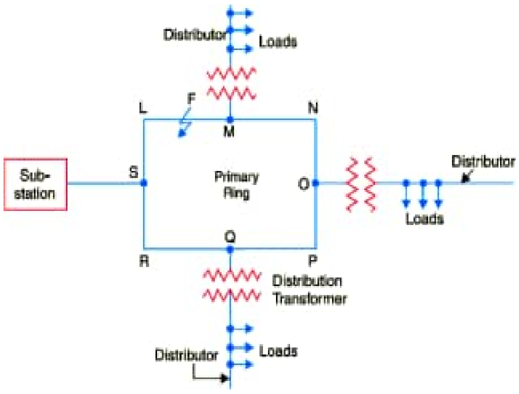
However, it suffers from the following drawbacks:

- The end of the distributor nearest to the feeding point will be heavily loaded.
- The consumers are dependent on a single feeder and single distributor. Therefore, any fault on the feeder or distributor cuts off supply to the consumers who are on the side of the fault away from the substation.
- The consumers at the distant end of the distributor would be subjected to serious voltage fluctuations when the load on the distributor changes.

Due to these limitations, this system is used for short distances only.

(ii) Ring main system.

In this system, the primaries of distribution transformers form a loop. The loop circuit starts from the substation bus-bars, makes a loop through the area to be served, and returns to the substation. Fig. 12.9 shows the single line diagram of ring main system for a.c. distribution where substation supplies to the closed feeder LMNOPQRS.

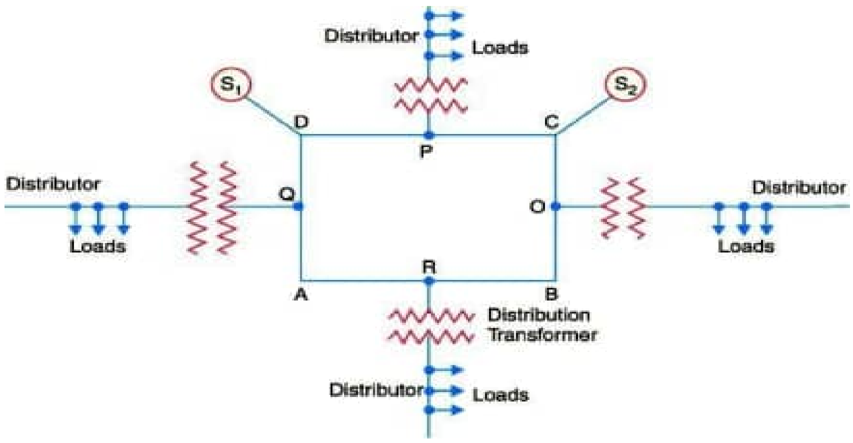


The distributors are tapped from different points M, O and Q of the feeder through distribution transformers. The ring main system has the following advantages:

- There are less voltage fluctuations at consumer's terminals.
- The system is very reliable as each distributor is fed via *two feeders. In the event of fault on any section of the feeder, the continuity of supply is maintained. For example, suppose that fault occurs at any point F of section SLM of the feeder. Then section SLM of the feeder can be isolated for repairs and at the same time continuity of supply is maintained to all the consumers via the feeder SRQPONM.

(iii) Interconnected system.

When the feeder ring is energized by two or more than two generating stations or substations, it is called inter-connected system. Fig. 12.10 shows the single line diagram of interconnected system where the closed feeder ring ABCD is supplied by two substations S and S at points D and C respectively.



Distributors are connected to points O, P, Q and R of the feeder ring through distribution transformers. The interconnected system has the following advantages:

- It increases the service reliability.
- Any area fed from one generating station during peak load hours can be fed from the other generating station. This reduces reserve power capacity and increases efficiency of the system.

REQUIREMENTS OF A DISTRIBUTION SYSTEM

A considerable amount of effort is necessary to maintain an electric power supply within the requirements of various types of consumers. Some of the requirements of a good distribution system are: proper voltage, availability of power on demand and reliability.

(i) Proper voltage.

One important requirement of a distribution system is that voltage variations at consumer's terminals should be as low as possible. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage causes lamps to burn out permanently and may cause failure of other appliances. Therefore, a good distribution system should ensure that the voltage variations at consumer's terminals are within permissible limits. The statutory limit of voltage variations is $\pm$ 6% of the rated value at the consumer's terminals. Thus, if the declared voltage is 230 V, then the highest voltage of the consumer should not exceed 244 V while the lowest voltage of the consumer should not be less than 216 V.

(ii) Availability of power on demand.

Power must be available to the consumers in any amount that they may require from time to time. For example, motors may be started or shut down, lights may be turned on or off, without advance warning to the electric supply company. As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules.

(iii) Reliability.

Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately, electric power, like everything else that is man-made, can never be absolutely reliable. However, the reliability can be improved to a considerable extent by (a) interconnected system (b) reliable automatic control system (c) providing additional reserve facilities.

DESIGN CONSIDERATIONS IN DISTRIBUTION SYSTEM

Good voltage regulation of a distribution network is probably the most important factor responsible for delivering good service to the consumers. For this purpose, design of feeders and distributors requires careful consideration.

(i) Feeders.

A feeder is designed from the point of view of its current carrying capacity while the voltage drop consideration is relatively unimportant. It is because voltage drop in a feeder can be compensated by means of voltage regulating equipment at the substation.

(ii) Distributors.

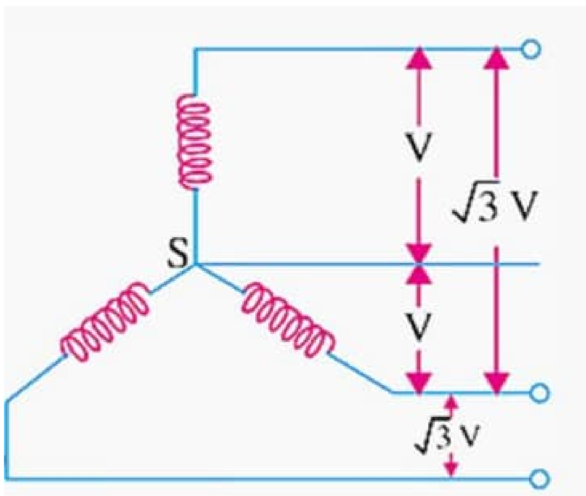
A distributor is designed from the point of view of the voltage drop in it. It is because a distributor supplies power to the consumers and there is a statutory limit of voltage variations at the consumer's terminals (± 6% of rated value). The size and length of the distributor should be such that voltage at the consumer's terminals is within the permissible limits.

Distribution of AC power

AC power transmission is always at high voltage and mostly by **3-phase system**. The use of single-phase system is limited to single-phase electric railways. Single-phase power transmission is used only for short distances and for relatively low voltages.

Three-phase, 4-wire system

The 4th or neutral wire is taken from the star point of the star-connection as shown in Figure 6 and is of half the cross-section of the outers or line conductors. If V is the voltage of each winding, then line voltage is **3 V**. Usually, phase voltage i.e. voltage between any outer and the neutral for a symmetrical system is **230V** so that the voltage between any two lines or outers is **3×230=400V**.

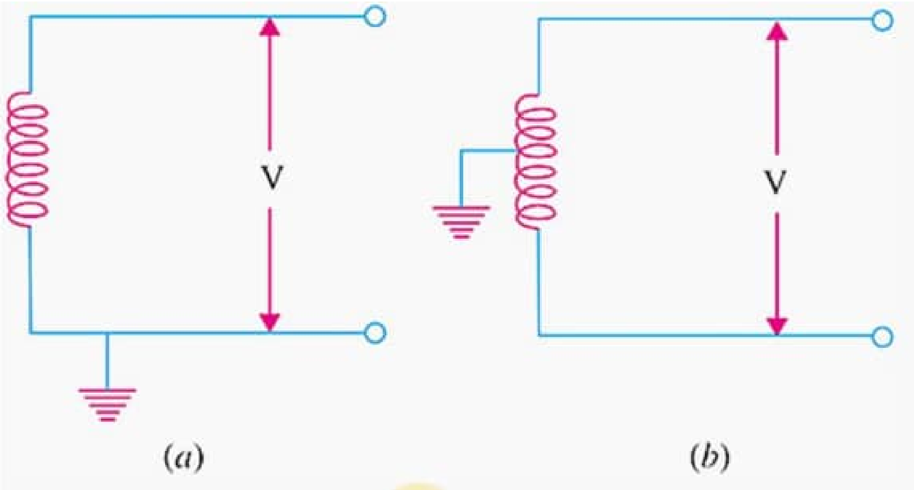


Single-phase residential lighting loads or single-phase motors which run on **230 V** are connected between the neutral and any one of the line wires. These loads are connected symmetrically so that line wires are loaded equally. Hence, the resultant current in the neutral wire is **zero or at least minimum**. The three phase induction motors requiring higher voltages of 400 V or so are put across the lines directly.

Single-phase, 2-wire System

It is shown in Figure 1 (a) and (b). In Figure 1 (a), one of the two wires is earthed whereas in Figure 1 (b) **mid-point of the phase winding is earthed**.

For the residential consumers who utilize electrical power mainly for lighting and running small rating electrical appliances, they are supplied with a single-phase two-wire distribution system. A concentric cable or multi-core (two-core) cable can be used for this purpose.



AC Distribution Calculations:

AC Distribution Calculations differ from those of d.c. distribution in the following respects:

- In case of d.c. system, the voltage drop is due to resistance alone. However, in a.c. system, the voltage drops are due to the combined effects of resistance, inductance and capacitance.
- In a d.c. system, additions and subtractions of currents or voltages are done arithmetically but in case of a.c. system, these operations are done vector ally.
- In an a.c. system, power factor (p.f.) has to be taken into account. Loads tapped off form the distributor are generally at different power factors. There are two ways of referring power factor viz
- It may be referred to supply or receiving end voltage which is regarded as the reference
- It may be referred to the voltage at the load point itself.

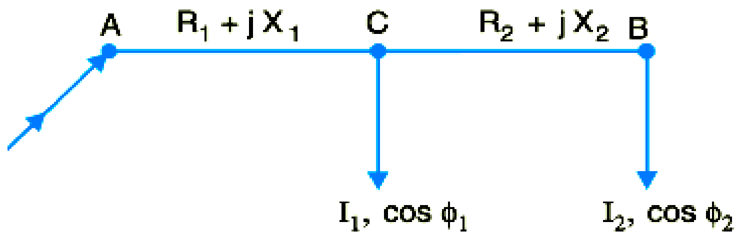
There are several ways of solving AC Distribution Calculations. However, symbolic notation method has been found to be most convenient for this purpose. In this method, voltages, currents and impedances are expressed in complex notation and the calculations are made exactly as in d.c. distribution.

Methods of Solving AC Distribution Problems: (AC Distributors with concentrated load)

In AC Distribution Calculations, power factors of various load currents have to be considered since currents in different sections of the distributor will be the vector sum of load currents and not the arithmetic sum. The power factors of load currents may be given (i) w.r t. receiving or sending end voltage or (ii) w.r.t. to load voltage itself. Each case shall be discussed separately.

(i) Power factors referred to receiving end voltage.

Consider an a.c. distributor A B with concentrated loads of I1 and I2 tapped off at points C and B as shown in Fig. Taking the receiving end voltage VB as the reference vector, let lagging power factors at C and B be cos φ1 and cos φ 2 w.r.t. VB . Let R1 , X1 and R2 , X2 be the resistance and reactance of sections A C and CB of the distributor.



Impedance of section AC, $\overrightarrow{Z_{AC}} = R_1 + j\,X_1$

Impedance of section CB, $\overrightarrow{Z_{CB}} = R_2 + j\,X_2$

Load current at point C, $\overrightarrow{I_1} = I_1\,(\cos\phi_1 - j\sin\phi_1)$

Load current at point B, $\overrightarrow{I_2} = I_2\,(\cos\phi_2 - j\sin\phi_2)$

Current in section CB, $\overrightarrow{I_{CB}} = \overrightarrow{I_2} = I_2\,(\cos\phi_2 - j\sin\phi_2)$

Current in section AC, $\overrightarrow{I_{AC}} = \overrightarrow{I_1} + \overrightarrow{I_2}$

$= I_1\,(\cos\phi_1 - j\sin\phi_1) + I_2\,(\cos\phi_2 - j\sin\phi_2)$

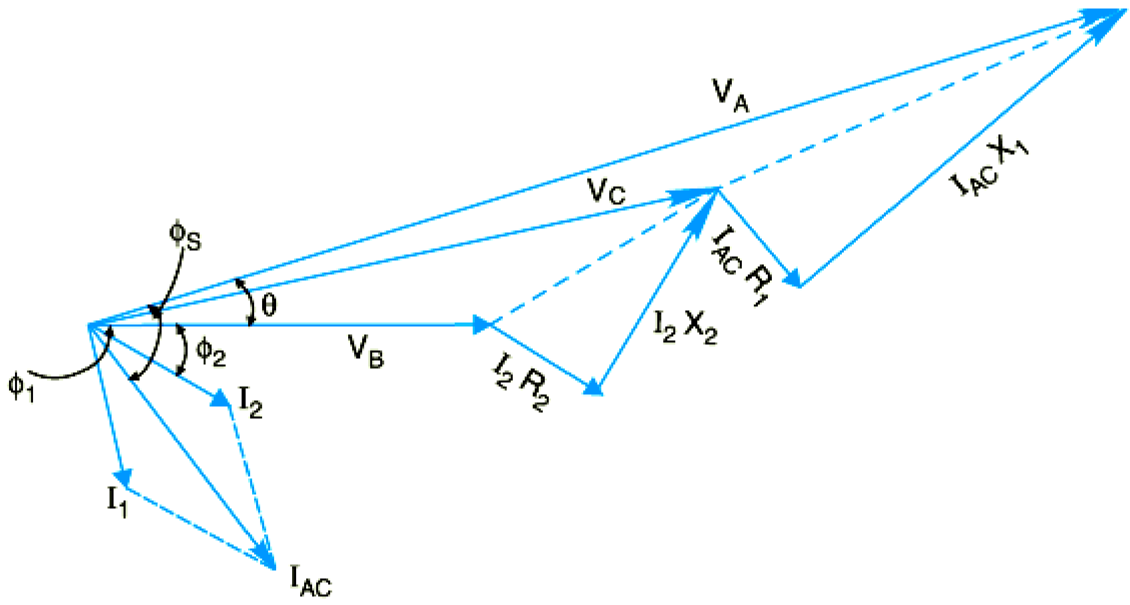
Voltage drop in section CB, $\overrightarrow{V_{CB}} = \overrightarrow{I_{CB}}\,\overrightarrow{Z_{CB}} = I_2\,(\cos\phi_2 - j\sin\phi_2)\,(R_2 + j\,X_2)$

Voltage drop in section AC, $\overrightarrow{V_{AC}} = \overrightarrow{I_{AC}}\,\overrightarrow{Z_{AC}} = \left(\overrightarrow{I_1} + \overrightarrow{I_2}\right) Z_{AC}$

$$= [I_1(\cos\phi_1 - j\sin\phi_1) + I_2(\cos\phi_2 - j\sin\phi_2)][R_1 + jX_1]$$

Sending end voltage, $\overrightarrow{V_A} = \overrightarrow{V_B} + \overrightarrow{V_{CB}} + \overrightarrow{V_{AC}}$

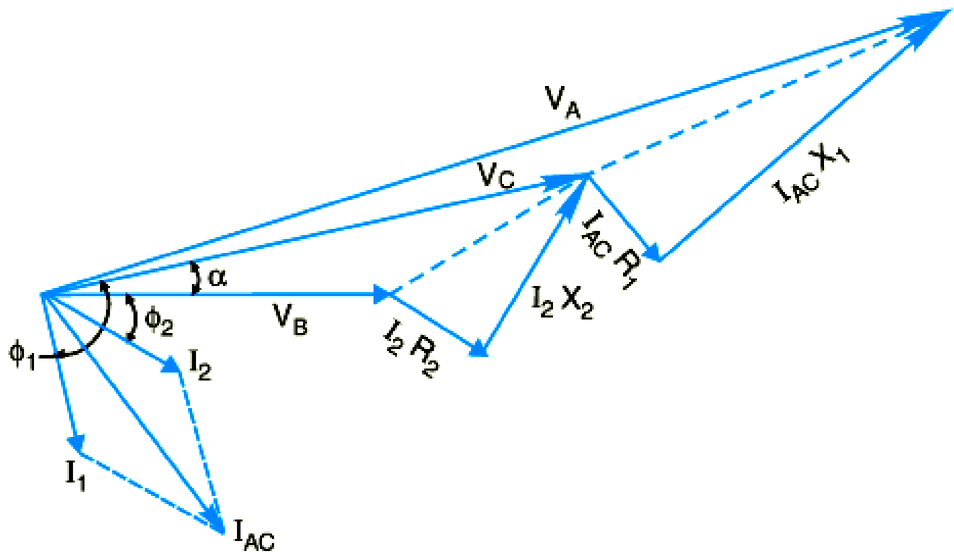
Sending end current, $\overrightarrow{I_A} = \overrightarrow{I_1} + \overrightarrow{I_2}$



The vector diagram of the a.c. distributor under these conditions is shown in Fig. Here, the receiving end voltage VB is taken as the reference vector. As power factors of loads are given w.r.t. VB , therefore, I1 and I2 lag behind VB by φ1 and φ2 respectively.

(i) Power factors referred to respective load voltages.

Suppose the power factors of loads in the previous Fig. are referred to their respective load voltages. Then φ1 is the phase angle between Vc and I1 and φ2 is the phase angle between VB and I2 . The vector diagram under these conditions is shown in Fig



$$\text{Voltage drop in section } CB = \vec{I_2}\,\overrightarrow{Z_{CB}} = I_2(\cos\phi_2 - j\sin\phi_2)(R_2 + jX_2)$$

$$\text{Voltage at point } C = \vec{V_B} + \text{Drop in section } CB = V_C \angle \alpha \text{ (say)}$$

$$\text{Now} \quad \vec{I_1} = I_1 \angle -\phi_1 \quad w.r.t. \text{ voltage } V_C$$

$$\therefore \quad \vec{I_1} = I_1 \angle -(\phi_1 - \alpha) \quad w.r.t. \text{ voltage } V_B$$

$$i.e. \quad \vec{I_1} = I_1[\cos(\phi_1 - \alpha) - j\sin(\phi_1 - \alpha)]$$

$$\text{Now} \quad \overrightarrow{I_{AC}} = \vec{I_1} + \vec{I_2}$$

$$= I_1[\cos(\phi_1 - \alpha) - j\sin(\phi_1 - \alpha)] + I_2(\cos\phi_2 - j\sin\phi_2)$$

$$\text{Voltage drop in section } AC = \overrightarrow{I_{AC}}\,\overrightarrow{Z_{AC}}$$

$$\therefore \quad \text{Voltage at point } A = V_B + \text{Drop in } CB + \text{Drop in } AC$$

What happens when neutral wire is disconnected?

When the neutral wire in a 3 – phase, 4 – wire system is disconnected, the loads which are connected between any two line conductors and the neutral are get connected in series and the potential difference across the combined load becomes equal to the line voltage. The potential difference across each load is changed according to the rating of the load.

Illustration: The effect of disconnecting neutral wire in a 3 – phase 4 -wire system can be explained more clearly by the following illustration:

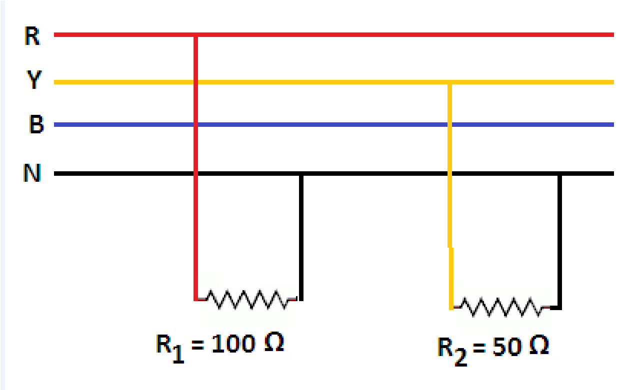


Figure A

Suppose a resistance of 100 Ω is connected between R – phase and neutral and a resistance of 50 Ω is connected between Y – phase and neutral in a 3 – phase, 4 wire supply as shown in Figure (a). The simplified diagram is shown in Figure (b).

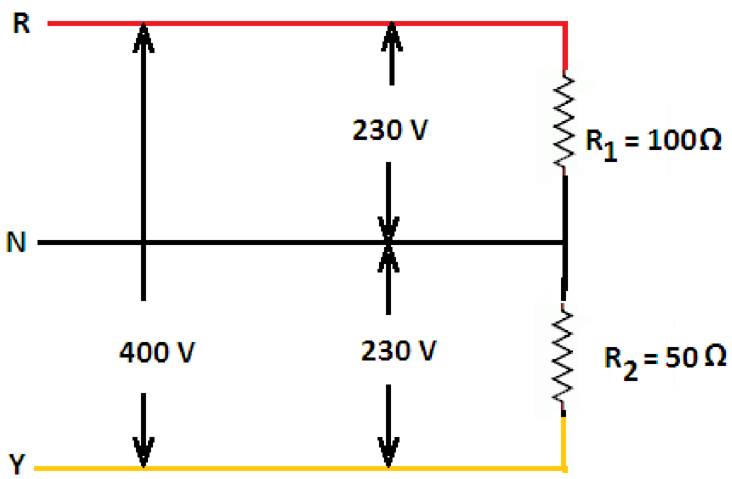


Figure B

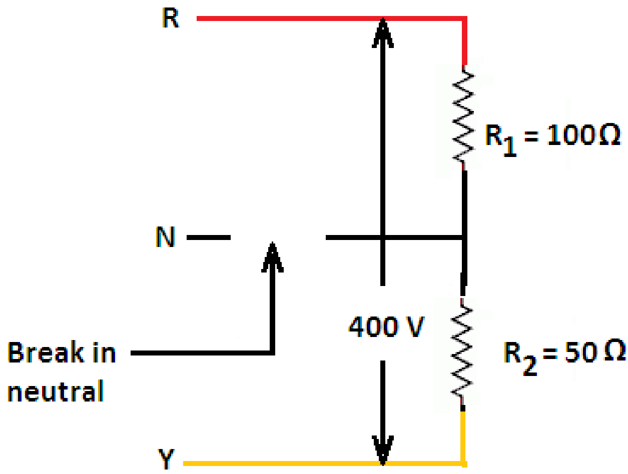


Figure C

If the neutral wire is disconnected, the two loads R_1 and R_2 are get connected in series and the potential difference across them becomes equal to the line voltage i.e. 400 V.

Therefore,

current through loads, $I = V_L/(R_1 + R_2)$

$= 400 /(100 + 50) = 2.67$ A

Therefore,

potential difference across the resistance $R_1 = I*R_1$

$= 2.67*100 = 267$ V

Similarly,

potential difference across the resistance $R_2 = I*R_2$

$= 2.67*50 = 133$ V

It is clear from the above illustration that if the neutral wire is disconnected in a 3 – phase, 4 – wire system **the potential difference across the high resistive load is increased and the potential difference across the low resistive load is decreased.**

In this process, the voltage across the high resistive load may rise more than the designed value and may damage the high resistive load. Thanks for reading about *neutral wire function in 3 phase 4 wire system.*

Reliability and Quality of Distribution System

Introduction and Reliability

The distribution system reliability evaluation considers the ability of the distribution system totransfer energy from bulk supply points such as typical transmission system end-stations, and from local generation points, to customer loads. These advancements are expected to improvethe performance of power system.

Power systems are one of the most complex infrastructures found worldwide and they are expected to operate with high quality and reliability. The fundamental purpose of power systems is to provide an economic and reliable channel for electrical energy to transfer from points of generation to customer locations. The economic and reliability constraints can be mutually competitive, making planning and operation of power systems a complex problem. The distribution system reliability evaluation considers the ability of the distribution system to transfer energy from bulk supply points such as typical transmission system end-stations, and from local generation points, to customer loads. In the early stages of extensive power system construction, relatively less attention was given to distribution networks because of their lower capital intensiveness when compared to generation and long-distance transmission systems. Also, the outages in distribution networks are expected to have a localized effect. However, analysis of practical utility failure registers and fault statistics reveals that distribution networks as a sub-section ofthe power systems contribute the most to customer interruptions and failure events. With advancements in technologies both integrated in power systems and employed in relation to it, a risk of increase in failure frequencies in power distribution components is expected. Introduction and additions in system automation, wide expansion in power demand complications due to distributed generation etc., are contributing factors to this risk.

Definition of Reliability: Reliability of a power distribution system is defined as the ability to deliver uninterrupted service to customer. Distribution system reliability indices can be presented in many ways to reflect the reliability of individual customers, feeders and system oriented indices related to substation.

System adequacy : Related to the sufficient facilities within the system to satisfy customer demand.

System security : Related to the ability of the system to respond to disturbances arising within that system.

9.3 Bath Tub Curve

The typical hazard function of many devices is shown in Fig. 9.3.1. As its shape resembles a bath tub it is known as **bath tub curve**.

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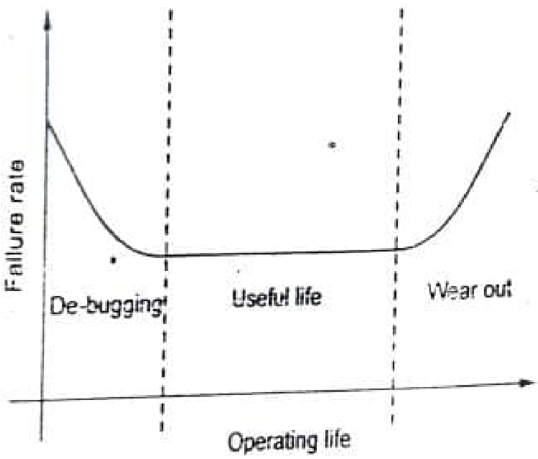


Fig. 9.3.1

The curve shows the three different regions in the total life of a component.

- The initial period is known as **debugging** period or the **period of infant mortality.**

  In this failures may be high due to errors in design or manufacturing.

  These errors are detected or removed in an initial period. This region shows a decreasing failure rate.

- The middle portion is **normal operating life** or **useful life.**

  In useful life period failure rate is only due to chance and failure is comparitively low and failure rate is nearly constant.

- Last region is **wear out period** or old age. In this period failure rate increases and usually repairs in this period are very costly. Therefore it is preferable to replace component by a new one.

  Power systems components can be kept within useful life period for long time by useful and proper periodic maintenance.

9.4 Outage

It is the state of the device when it is unavailable to perform its specified function due to some problem or event which is directly associated with that device.

An outage of the component may or may not cause interruption of service depending on system configuration.

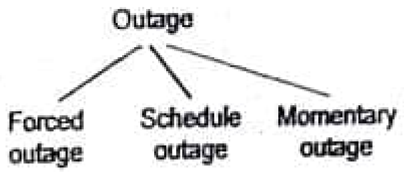


Fig. 9.4.1

Forced outage

- Results from emergency conditions.

Schedule outage

- Also called maintenance outage
- Deliberately taken out for service at a selected time. Usually for preventive maintenance or repair.

Momentory Outage

- Caused by reclosing of CB to clear temporary fault.
- This outage lasts for very short, only a few seconds.

Forced outage and momentary outage in system are due to different reasons. Some of these are lightining, tree contact, wind, vehicle accidents etc.

Failures

There are many causes of power failures in an electricity network. Examples of these causes include faults at power stations, damage to electric transmission lines, substations or other parts of the distribution system, a short circuit, cascading failure, fuse or circuit breaker operation.

11 major causes of power system failures

Underground Cable.

Transformer Failures.

Lightning. Tree Contact.

Birds.

Squirrels.

Snakes.

Insects.

Power grid failure: Illegal utilization of electricity is also a major reason for power grid failure. India's basic energy shortage is compounded by the policy of selling electricity to consumers at politically correct prices i.e. sometimes cheap and even free to voters. Here the government-owned distribution monopolies have failed.

Electrical overstress: An electrical device suffers electrical overstress when a maximum limit for either the voltage across, the current through, or the power dissipated in the device is exceeded and causes immediate damage or malfunction, or latent damage resulting in an unpredictable reduction of its lifetime.

The number of failures per unit time is known as failure rate of the component.

It is denoted by λ

$\lambda = \frac{Total\ Number\ of\ failures}{Total\ operating\ time}$

The life time distribution of a component with constant failure rate is exponential.

The no. of repairs per unit time is known as repair rate.

It is denoted by μ

$\mu = \frac{Total\ number\ of\ rapairs}{Total\ operating\ time}$

The reciprocal of λ is defined as mean time to failure.

$MTTF = \frac{1}{\lambda}$

The reciprocal of μ is mean down time or mean time to repair

$MTTR = \frac{1}{\mu}$

Thus MTBF=Mean time between failure

=MTTF+ mean down time

Limitations of Distribution System

AC and DC modes of transmission and distribution of power has both advantages and disadvantages:

DC requires only two conductors for transmission and it is possible to transmit the power through only one conductor by using earth as return path. Hence much copper is saved

There will be no inductance, capacitance, phase displacement and surge problem in dc transmission

Because of the skin effect in ac system current conducts only through the surface of the conductor. On the other hand, dc system will not have skin effect. Hence all the conductor will be utilized for carrying conductor. Therefore, conductor size reduces in dc for the same current carrying capacity when compared to ac system

The potential stress on the insulator in the case of dc system is 1/ (21/2) times of that in ac system for the same working voltage. Hence for the same working voltage less insulation is required in dc compared to ac system

Charging currents which contributes to the continuous loss even on no load is eliminated in dcsystem compared to ac system

A DC line has less corona loss compared to ac system and reduced interference with the communication circuits.

Since there is no inductance, the voltage drops in the dc transmission system line due to inductive reactance does not exist. Hence the same load and sending end voltage regulation ofthe dc system is better compared to ac system

No stabilizer is required for transmission over long distances

Since the concept of power factor is absent in dc systems, no need of power factor correction equipment in the power system

The only difficulty in the dc system is to obtain the high voltage required for transmission as electrical power neither generated at high voltages nor the dc voltage cannot be stepped up where as ac system can be stepped up and can be stepped down based on the requirement

Other advantage of ac system is that electrical power can be generated at high voltages easily and maintenance of ac substation is cheaper and easier

Distribution of ac system is undoubtedly superior to that of a dc system as in the ac system voltage control is easy by means of transformers

POWER QUALITY

Power is simply the flow of energy and the current demanded by a load is largely uncontrollable. “Power quality” is a convenient term for many; it is the quality of the voltage, rather than power or electric current. The term is used to describe electric power that drives an electrical load and the load's ability to function properly. The performance of electronic devices is directly linked to the power quality level in a facility. The electric power industry comprises electricity generation (AC power), electric power transmission and ultimately electricity distribution to an electricity meter located at the premises of the end user of the electric power. The electricity then moves through the wiring system of the end user until it reaches the load. The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of supply to be compromised.

IMPACT OF POWER QUALITY PROBLEMS

Without the proper power, an electrical device may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor-quality power. Some of the most common power supply problems and their likely effect on sensitive equipment:

1. Voltage surges/spikes

Voltage surges/spikes are the opposite of dips – a rise that may be nearly instantaneous (spike) or takes place over a longer duration (surge). A voltage surge takes place when the voltage is 110% or more above normal. The most common cause is heavy electrical equipment being turned off. Under these conditions, computer systems and other high tech equipment can experience flickering lights, equipment shutoff, errors or memory loss. Possible Solutions are surge suppressors, voltage regulators, uninterruptable power supplies, power conditioners.

2. Voltage Dips

Short duration under-voltages are called “Voltage Sags” or “Voltage Dips [IEC]”. Voltage sag [5, 6] is a reduction in the supply voltage magnitude followed by a voltage recovery after a short period of time. The major cause of voltage dips on a supply system is a fault on the system, i.e. sufficiently remote electrically that a voltage interruption does not occur. Other sources are the starting of large loads and, occasionally, the supply of large inductive loads. The impact on consumers may range from the annoying (non-periodic light flicker) to the serious (tripping of sensitive loads and stalling of motors.

3. Under voltages

Excessive network loading, loss of generation, incorrectly set transformer taps and voltage regulator malfunctions, causes under voltage. Loads with a poor power factor or a general lack of reactive power support on a network also contribute. Under voltage can also indirectly leadto overloading problems as equipment takes an increased current to maintain power output (e.g.motor loads).

4. High-Voltage Spikes

High-voltage spikes occur when there is a sudden voltage peak of up to 6,000 volts. These spikes are usually the result of nearby lightning strikes, but there can be other causes as well. The effects on vulnerable electronic systems can include loss of data and burned circuit boards. Possible Solutions are using Surge Suppressors, Voltage Regulators, Uninterruptable Power Supplies, Power Conditioners.

5. Frequency Variation

A frequency variation involves a change in frequency from the normally stable utility frequency of 50 or 60 Hz, depending on your geographic location. This may be caused by erratic operation of emergency generators or unstable frequency power sources. For sensitive equipment, the results can be data loss, program failure, equipment lock-up or complete shutdown. Possible Solutions are using Voltage Regulators and Power Conditioners.

6. Power Sag

Power sags are a common power quality problem. Despite being a short duration (10ms to 1s) event during which a reduction in the RMS voltage magnitude takes place, a small reduction in the system voltage can cause serious consequences. Sages are usually caused by system faults, and often the result of switching on loads with high demand start-up currents. For more details about power sags visit our newsletter archives. Possible Solutions are using Voltage Regulators, Uninterruptable Power Supplies, and Power Conditioners.

7. Electrical Line Noise

Electrical line noise is defined as Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) and causes unwanted effects in the circuits of computer systems. Sources of the problems include motors, relays, motor control devices, broadcast transmissions, microwave radiation, and distant electrical storms. RFI, EMI and other frequency problems can cause equipment to lock-up, and data error or loss. Possible Solutions are using Voltage Regulators, Uninterruptable Power Supplies, and Power Conditioners.

8. Brownouts

A brownout is a steady lower voltage state. An example of a brownout is what happens during peak electrical demand in the summer, when utilities can’t always meet the requirements and must lower the voltage to limit maximum power. When this happens, systems can experience glitches, data loss and equipment failure. Possible Solutions are using Voltage Regulators, Uninterruptable Power Supplies, and Power Conditioners.

9. Blackouts

A power failure or blackout is a zero-voltage condition that lasts for more than two cycles. It may be caused by tripping a circuit breaker, power distribution failure or utility power failure. A blackout can cause data loss or corruption and equipment damage. Possible Solutions is using Generators.

10. Very short interruptions

Total interruption of electrical supply for duration from few milliseconds to one or two seconds. Mainly due to the opening and automatic reclosure of protection devices to decommission a faulty section of the network. The main fault causes are insulation failure, lightning and insulator flashover. Consequences of these interruptions are tripping of protection devices, loss of information and malfunction of data processing equipment.

11. Long interruptions

Long interruption of electrical supply for duration greater than 1 to 2 seconds. The main fault causes are Equipment failure in the power system network, storms and objects (trees, cars, etc) striking lines or poles, fire, human error, bad coordination or failure of protection devices. A consequence of these interruptions is stoppage of all equipment.

12. Voltage swell

Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds. The main causes are Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours). Consequences is data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

13. Harmonic distortion

Voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to thesum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency. Main Causes are Classic sources: electric machines working above the knee of the magnetization curve (magnetic saturation), arc furnaces, welding machines, rectifiers, and DC brush motors. Modern sources: all non-linear loads, such as power electronics equipment including ASDs, switched mode power supplies, data processing equipment, high efficiency lighting. Consequences are increased probability in occurrence of resonance, neutral overload in 3-phase systems, overheating of all cables and equipment, loss of efficiency in electric machines, electromagnetic interference with communication systems, and errors in measures when using average reading meters, nuisance tripping of thermal protections.

14. Voltage fluctuation

Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz. Causes are arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads. Consequences are most consequences are common to under voltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.

15. Noise

Superimposing of high frequency signals on the waveform of the power-system frequency. Main Causes are Electromagnetic interferences provoked by Hertzian waves such as microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment. Improper grounding may also be a cause. Consequences are disturbances on sensitive electronic equipment, usually not destructive. It may cause data loss and data processing errors.

16. Voltage Unbalance

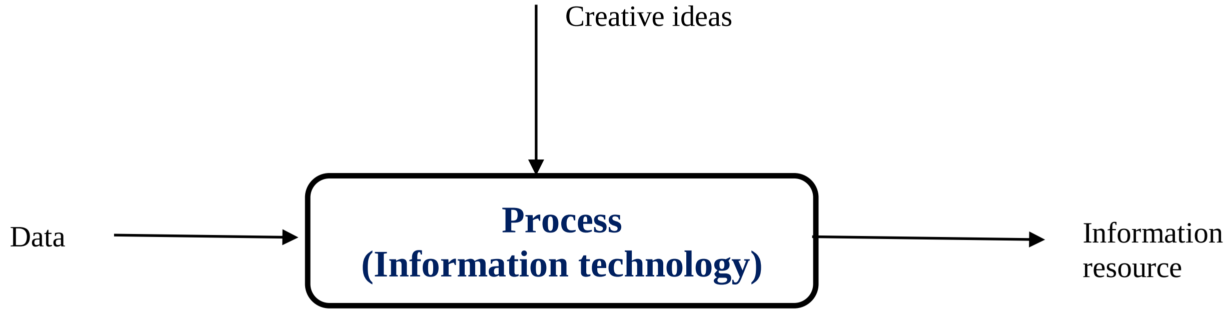
A voltage variation in a three-phase system in which the three voltage magnitudes or the phase angle differences between them are not equal. Causes are large single-phase loads (induction furnaces, traction loads), incorrect distribution of all single-phase loads by the three phases of the system (this may be also due to a fault). Consequences are Unbalanced systems imply the existence of a negative sequence that is harmful to all three phase loads. The most affected loads are three-phase induction machine

Reliability-Aids

i) Mastering information

Everything in universe is energy and information aggregated data is information and information helps to take decisions. Information is such a resource that can be utilized to use al l the other resource in best possible manner. E.g. A decision to replace a substation transformer will be based upon an aggregation of loading data.

As we organize the information, we deepen our scientific understanding of the system and use for transforming the process of production and services with the help of information technology. The enterprise will be more dynamic, integrated effective and responsible.



For useful deployment of IT:

1. Does IT connect various activities of whole organization?
2. Is the information system centrally managed and compatible throughout?
3. Is the information n/w widely accessible?
4. Does it capture relevant and useful information?
5. Does it convert help to make accurate and fact based decisions?
6. Does it information system allows to know consumers well??

Probability concepts

Probability distributions: Consider the device has probability of failure as 'P' after a given no of years of operation & the device is still operating then its probability as 'q' and $q = 1-P$

a) Binomial distribution: The rule to find probabilities of different values of r out of n devices is given by Bernoulli's theorem.

$$P(x=r) = {}^nC_r\, p^r q^{n-r}$$

where $x = r = 0, 1, 2 \ldots n$

The relation is also called Binomial distribution.

In order to find any probability in Binomial we must know n & p. They are called parameters.

The binomial distribution is discrete distribution. It can be used where r is an integer.

The standard deviation & mean μ in binomial distribution are given as $\sigma = \sqrt{npq}$ and $\mu = np$

b) Poisson distribution

It is another discrete distribution. If P is small & np is very large then poisson distribution is used to find the probability of occurrence

$$P(x=r) = \frac{e^{-np}(np)^r}{r!}$$

$$= \frac{e^{-\mu}(\mu)^r}{r!}$$

where μ = mean = np

$r = 0, 1, 2 \ldots$

Standard deviation is given as

$$\sigma = \sqrt{np} = \sqrt{\mu}$$

c) Normal distribution

This is most important continous probability distribution
If p & n both are large, normal distribution is used
Probability by normal distribution can be found as

$$P(x=r) = \frac{1}{\sigma\sqrt{2\pi}} e^{-1/2}\left(\frac{r-m}{\sigma}\right)^2.$$

where $\mu = np$ & $\sigma = \sqrt{npq}$

The equation is also called Gaussian distribution
The failure of devices is extremly useful in reliability since a Knowledge of mean $\mu = np$ is required to apply the distribution.