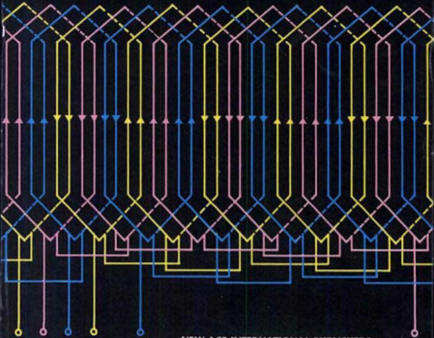
SECOND EDITION

ELECTRICAL ENGINEERING DRAWING

S.K. BHATTACHARYA



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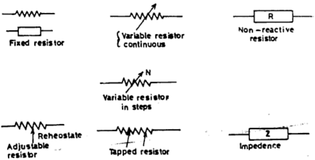
Assembly Drawing and Working Drawing of Simple Electrical and Mechanical Items

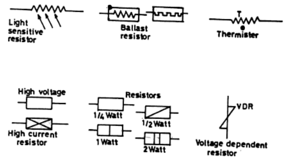
Drawing is the graphical language of engineers which is built upon certain basic principles and standards. A good drawing can be prepared making use of these principles and standards. Some of the principles and standards include use of proper symbols, lettering and dimensioning, selecting standard sizes of drawing sheets, different types of projections, isometric and sectional views etc. In this section these basic standards and principles will be discussed. In addition, assembly drawing and working drawings of simple electrical and mechanical items will be dealt with.

1.1 SYMBOLS FOR ELECTRICAL AND ELECTRONICS ENGINEERING DRAWING

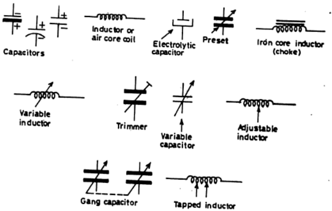
In engineering drawing it is a common practice to employ graphical symbols to denote the various components and accessories used. These symbols must convey the same meaning to everyone who reads the drawing. Symbols are therefore standardized by the Bureau of Indian Standards. An important consideration in selecting symbols is that they should be, as far as possible, self explanatory and easy to draw. Following are some of the symbols in common use. IS: 1032 gives a complete list of symbols.

1.1.1 Resistors

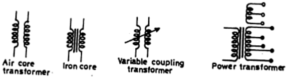


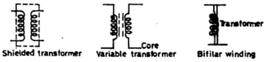


1.1.2 Capacitors and Inductors

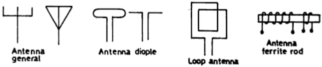


1.1.3 Transformers

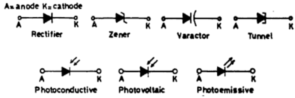




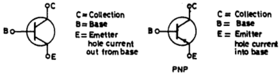
1.1.4 Antennas



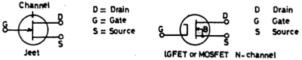
1.1.5 Semiconductor Diodes



1.1.6 Bipolar Junction Transistor

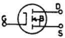


1.1.7 Field-Effect Transistor (FET)



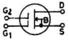
IGFET or Mosfet
P-channel

D = Drain
G = Gate
S = Source



IGFET or MOSFET
N-channel enhancement

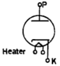
D = Drain
G = Gate
S = Source



Dual gate IGFET or
MOSFET N-channel

D = Drain
G_2 = Gate 2
S = Source
G_1 = Gate 1

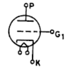
1.1.8 Vacuum Tubes



P = Plate
K = Cathode

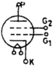
Diode

Heater



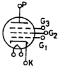
P = Plate
G_1 = Control grid
K = Cathode

Triode



P = Plate
G_2 = Scren grid
G_1 = Control grid
K = Cathode

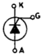
Tetrode



P = Plate
G_1 = Suppressor grid
G_2 = Screen grid
G_1 = Control grid
K = Cathode

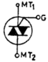
Petode

1.1.9 Thyristors



Silicon controlled
rectifier (SCR)

K = Cathode
G = Gate
A = Anode

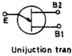


Triac

MT_1 = Main terminal 1
G = Gate
MT_2 = Main terminal 2

MT1 = Main terminal 1
MT_2 = Main terminal 2

Diac



B2 = Base 2
E = Emitter
B1 = Base 1

Unijuction transistor (UJT)

1.1.10 Meters

Voltineter

Ammeter

Wattmeter

Frequencymeter

1.1.11 Motors & Generators

Motor

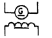
Generator

ac Motor, General symbol

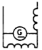
Direct current motor,
General symbol

Direct Current Generator,
General symbol

ac Generator, General symbol



dc two wire generator (G)
or motor (M), seperately excited

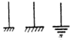


dc two wire generator (G)
or motor (M), compound excited,
short shunt

dc two wire shunt generator (G)
or motor (M)

1.1.12 Miscellaneous

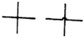
Direct current



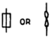
Earth or ground

Chassis earth connection

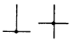
Alternating current



Conductor not joined



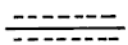
Fuse



Conductors joined

Screen

Zero adjuster



Screened cable

Electrostatic screening

Magnetic screening

1.1.13 The Greek Alphabets

Α	α	alpha	=	a	Ξ	ξ	xī	=	x (*ks*)
Β	β	bēta	=	b	Ο	ο	omīcron	=	o
Γ	γ	gamma	=	g	Π	π	pi	=	p
Δ	δ	delta	=	d	Ρ	ρ	rhō	=	r
Ε	ε	epsīlon	=	e	Σ	σ'ς	sigma	=	s
Ζ	ζ	zēta	=	z	τ	τ	tau	=	t
Η	η	ēta	=	ē	Υ	υ	ūpsīlon	=	u (yōō, oo, ü)
Θ	θ	thēta	=	th (*th*)	(oftedn transcribed *y*)				
Ι	ι	iōta	=	i	Φ	φ	phī	=	ph (*f*)
Κ	κ	kappa	=	k	Χ	χ	chī	=	kh(*hh*)
Λ	λ	lambda	=	l	(often transcribed *ch* as in Latin)				
Μ	μ	mū	=	m	Ψ	ψ	psī	=	ps
Ν	ν	nū	=	n	Ω	ω	ōmega	=	ō

1.1.14 Prefixes for SI units

The following prefixes may be used to indicate decimal fractions or multiples of the basic or derived SI units.

Fraction	*Prefix*	*Symbol*	*Multiple*	*Prefix*	*Symbol*
10^{-1}	deci	d	10	deca	da
10^{-2}	centi	c	10^2	hecto	h
10^{-3}	milli	m	10^3	kilo	k
10^{-6}	micro	μ	10^6	mega	M
10^{-9}	nano	n	10^9	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

Compound prefixes should not be used, *e.g.* 10^{-9} metre is represented by

1 nm, *not* 1 mμm

The attaching of an exponent to a unit in effect constitutes a new unit, *e.g.*

$$1\ \text{km}^2 \text{ signifies } 1\ (\text{km})^2 = 10^6\ \text{m}^2$$

$$\text{and} \quad \textit{not} \quad 1\ \text{k}(\text{m}^2) = 10^3\ \text{m}^2$$

Where possible any numerical exponent should appear in the numerator of an expression. Symbols for units do not take a plural form and should not be followed by a full stop; *e.g.* 5 cm but not 5 cms or 5 cms., and not 5 cm. (except at the end of a sentence).

The decimal point should be a dot on the line. In most Continental publications the comma is used as the decimal sign; it should therefore be avoided as a spacer for grouping figures in thousands, a small space being used instead: 12 345; 12. 345 678. Four-digit whole numbers and four-digit decimal numbers should be unspaced: 1234; 1234. 12 345.6789.

A central point may be used as a multiplication sign: $x \cdot y$, $\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-2}$

1.2 SIZE OF DRAWING SHEETS

The following drawing sheet sizes are as per Indian Standard Code for general engineering drawing: IS: 696-1972.

Designation	*Trimmed size (mm)*	*Untrimmed Size (mm)*
A0 Size	841 × 1189	880 × 1230
A1 Size	594 × 841	625 × 880
A2 Size	420 × 594	450 × 625
A3 Size	297 × 420	330 × 450
A4 Size	210 × 297	240 × 330
A5 Size	148 × 210	165 × 240

The untrimmed size is the size of the paper on which the drawing is to be made. When the drawing is compreted the paper is cut to the trimmed size. On the trimmed size a margin of 10 mm on all sides is to be drawn, except for A4 and A5 where the margin is only 5 mm. Sufficient space should be left for the title block. The standard size for title block is 185 mm × 65 mm.

1.3 LETTERING

(i) The main requirements for 'lettering' in engineering drawing are legibility, uniformity, ease and rapidity in execution.

(ii) Both the vertical and sloping types of letters and numerals are suitable for general use. All letters should be in capitals, except where lower size letters are accepted in international usage for abbreviations. If sloping type is used, an inclination of approximately 75 degrees is recommended.

(iii) Letters and numerals are designated by their heights. Recommended sizes of letters and numerals to suit different purposes are given below:

Purpose	*Size in mm*
Main title and drawing No.	6, 8, 10, 12
Sub-titles and headings	3, 4, 5, 6
Notes such as legends, schedules, materials and dimensions	2, 3, 4, 5

(iv) All letters and numerals should be kept clear off the line. Words may be underlined in a drawing where preferred.

(v) Lettering should be done on the drawing in such a way that it may be read when the drawing is viewed from the bottom edge or from the right hand edge.

(vi) When drawings are to be reproduced to a smaller scale by photographic process the size of letters in the original drawing should be accentuated (i.e. highlighted) to permit legibility after reproduction.

1.4 DIMENSIONING

(i) Dimension lines in a drawing should be placed as far as possible outside the outline of a view.

(ii) All dimensions should be placed above their respective dimension lines, and normal to the lines, such that these can be easily read from the bottom or right hand side of the drawing sheet.

(iii) Dimension lines should not cut each other. Smaller dimensions should be placed first, that is, the dimensions should be marked in the ascending order.

(iv) Dimension lines are never shown dotted.

(v) Dimensions must only be given once and not be repeated on other views.

(vi) Holes are dimensioned by stating their diameters.

There are usually three representations as follows:

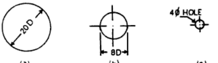


Fig. 1.1 Three types of dimensioning holes

1.5 TYPES OF PROJECTIONS

The most common types of projections are:

(i) isometric projection and (ii) orthographic projections

1.5.1 Isometric Projection

Isometric projection conveys an impression of the overall appearance of the object, as it is a pictorial form of representation. To make an isometric drawing, three axes are assumed to make equal angles to one another, *i.e.*, 120°, one axis (OA) being vertical to the base (horizontal) and the other two axes (OB and OC) are in opposite directions making 30° to the horizontal, as illustrated in Fig. 1.2(a). The object is assumed to be placed on these axes with its edges coinciding them, and the view is obtained by drawing all the sides and edges along and parallel to these three axes. In Fig. 1.2(b) is shown the isometric view of a rectangular box drawn using the above method.

1.5.2 Orthographic Projections

In an orthographic system of projection, a number of views are arranged in a particular way to represent the exact shape of the object. Three planes namely the vertical plane, the horizontal plane and the side vertical plane, as shown in Fig. 1.3 (a), are assumed at right angles, to one another.

The object is placed in front of the two vertical planes and above the horizontal plane. The projections of the object on the three planes are taken. The projection on the Vertical Plane is called Elevation, and the projection on the Horizontal Plane is called Plan, and that on the Side Vertical Plane is called Side View or Side Elevation. If the horizontal plane, vertical plane, and the side vertical plane are so as to form one plane as shown in Fig. 1.3 (b) the projections are obtained as if they are drawn on a plain sheet of paper. This method of projection is known as first angle method projection.

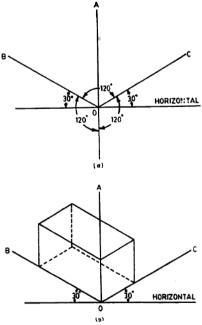
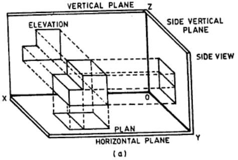


Fig. 1.2 (a) Representation of axes in isometric projections; (b) Isometric projection of a rectangular box

(a) First angle projection: In this method of projection, the object is assumed to be placed in between the observer and the planes of projection. The view seen from the front is shown on the plane at the back of the object and is called as front view or elevation. Similarly, the plan or top view is seen when looking from the top and is shown on the plane at the bottom of the object. In the case of side view, the view obtained by looking from the left is placed on the right side vertical plane or vice-versa.

(b) Third angle projection: In the *third angle method of projection*, the object is assumed to be placed behind the planes of projection, and the planes are assumed to be transparent, as illustrated in Fig. 1.4(a). The front view or elevation is obtained on the vertical plane at the front of the object, the top view or plan, as seen from the top is obtained on the horizontal plane at the top of the object. Side view of the object looking from the left is placed on the left side vertical plane. If these planes are turned out into one plane, the projections



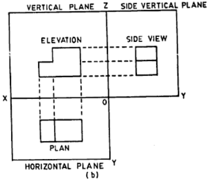


Fig. 1.3 (a) Pictorial view; (b) Orthographic (first angle) projection of an object

can be seen as if drawn in a plain sheet of paper as shown in Fig. 1.4 (b). The side view of the object as seen from the right can be obtained and placed on the right side vertical plane as shown in Fig. 1.5 (a) and (b).

This method of projection appears to be a more logical representation because the plan or top view as seen from the top is obtained on the horizontal plane at the top of the object. Also in the case of side view, looking from the right is placed on the right side vertical plane, or vice versa. This will not create confusion, as in the first angle method of projection, where the view looking from the left is placed on the right side vertical plane. The Burean of Indian Standards has recommended the adoption of this system of projection as a

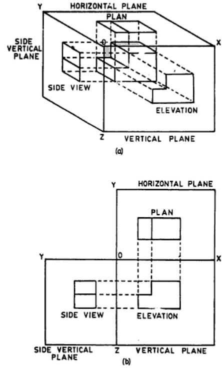


Fig. 1.4 (a) Pictorial view; (b) Orthographic (third angle) projection of the object

standard practice. In this book, the third angle method of projection has been followed widely.

We have considered the two types of projections of an object, *i.e.*, isometric and orthorgraphic. The student should be able to recognise the different surfaces of the isometric view of an object from the given orthographic projections. To obtain the isometric view from the orthographic projections, the student should draw the three axes first. Then by taking and marking out on the axes, the different dimensions of the object from the given orthographic projections the isometric projection can be drawn. A few examples of orthographic and isometric projections are given as under:

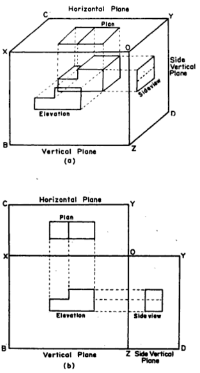


Fig. 1.5 Another representation of the three projections of the object: (a) Pictorial view; (b) Orthographic (third angle) projection of the object

Example 1. Draw according to third angle projection method the orthographic projections (plan, elevation and side view) from the isometric view of the given object as shown in Fig. 1.6.

Solution. The orthographic projection *i.e.*, plan, elevation, and side view have been drawn as in Fig. 1.7 following the third angle projection method.

Example 2. An isometric view of an object is shown in Fig. 1.8. Draw the following views: (1) Plan (2) Elevation and (3) Side view.

Solution. The plan, elevation and side view of the object are shown in Fig. 1.9.

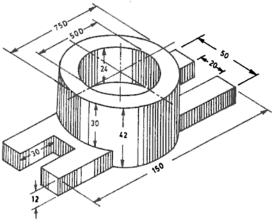


Fig. 1.6 Isometric view of an object

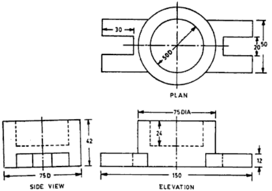


Fig. 1.7 Orthographic projections of the object (of example 1)

Example 3. Fig. 1.10 shows the plan, elevation and side view of an object. Draw the isometric view of the given object.

Solution. The isometric view of the object is shown in Fig. 1.11.

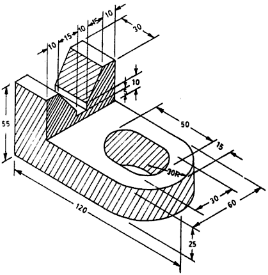


Fig. 1.8 Isometric view of an object (of example 2)

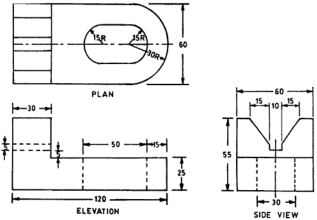


Fig. 1.9 Orthographic projections of the object (of example 2)

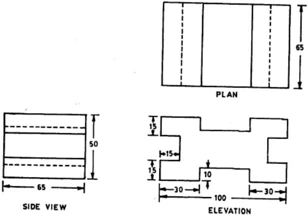


Fig. 1.10 Orthographic projections of an object

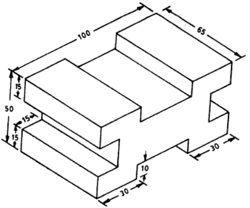


Fig. 1.11 Isometric view of the object

Example 4. Draw the isometric view of the object from the orthographic projections given in Fig. 1.12.

Solution. The isometric view of the object is as shown in Fig. 1.13

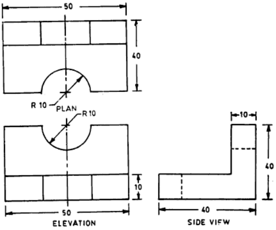


Fig. 1.12 Orthographic projections of an object

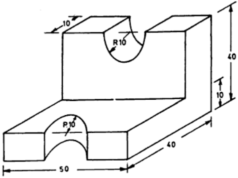


Fig. 1.13 Isometric view of the object

1.6 SECTIONAL VIEWS

In engineering drawing, the interior invisible details of objects to be drawn are shown by dotted lines. In case of complicated objects, views are drawn 'in section'. This makes the drawing more clear with its interior details. In making sectional drawings, object is imagined to be cut by a plane in a particular position and direction and the part of the object is assumed to be removed. The projected view of the remaining portion of the object is called its sectional view.

See Fig. 1.14. The object is assumed to be cut by a cutting plane AB half way through with the front portion of the object removed

Fig. 1.15 shows the plan and the full sectional elevation of an object. Note that the cutting plane AB is shown in the plan as line AB, and the Sectional

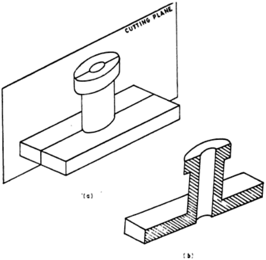


Fig. 1.14 (a) Representation of a cutting plane (AB); (b) Isometric view of the sectioned object

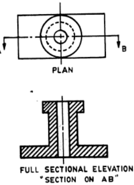


Fig. 1.15 Plan and full-sectional elevation of an object

elevation is labelled 'section on AB'. The exposed out surface is indicated in the drawing by uniformly spaced hatched lines at 45°.

The sectional views can be in full section, half section, or offset section depending on the position and direction of the cutting plane. Fig. 1.16 illustrates a half-sectional view and Fig. 1.17 illustrates an offset-sectional view of an object.

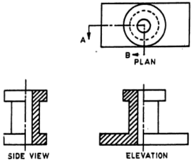


Fig. 1.16 Half-sectional view of an object

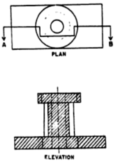


Fig. 1.17 Offset-sectional view of an object

1.7 ASSEMBLY AND DETAILED WORKING DRAWINGS

Detail and assembly drawings are very essential in engineering practice. Detail drawings show the different parts of an item or machine giving the complete information about the structure. Assembly drawing shows the complete view of an object with all its parts assembled together. Detail drawing is necessary for the production of each part of the object in the workshop, and assembly drawing is necessary for fitting or assembling the different parts of the item or machine together. Fig. 1.18 shows assembled view of a pole core and coil. Fig. 1.19 shows the detail drawing of the pole core and coil separately.

Fig. 1.18 Assembled view of a pole core and coil

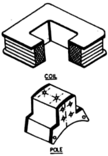


Fig. 1.19 Detail drawing of the pole core and coil

1.8 DRAWING OF SIMPLE ELECTRICAL ITEMS

In Fig. 1.20 is shown the method of writing the value of a resistor with the help of some colour code. Different colour bands are painted around the surface of the resistor, each colour representing some value. The first three bands represent the value of the resistor. (The first two bands indicate the first two digits in the resistance value whereas the third band indicates the number of zeros that must follows the first two digits). The fourth band represents the tolerance in percentage. In Fig. 1.20 an example of a 6.8 kilo ohm resistor has been given. The students are advised to draw a resistor of value 270 kilo ohm ± 5 percentage tolerance.

1.8.1 Types of Cable Joints

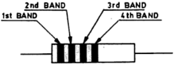
Joints of cables can be made in different ways such as married joints, tee joints etc. Figs. 1.21 (a), (b), (c) and (d) show different types of cable joints.

The procedure for each type of jointing is as follows:

(a) Married joint

1. Use 3/0.914 PVC single core cable
2. Strip off 8 cm insulation from each cable

COLOUR	BAND NOS 1	2	3	4
BLACK	–	0	–	
BROWN	1	1	0	
RED	2	2	00	
ORANGE	3	3	000	
YELLOW	4	4	0000	
GREEN	5	5	00000	
BLUE	6	6	000000	
VIOLET	7	7		
GREY	8	8		
WHITE	9	9		
GOLD				± 5%
SILVER				± 10%
NO 4th BAND				± 20%



EXAMPLE	COLOUR	VALUE
1st BAND	BLUE	6
2nd BAND	GREY	8
3rd BAND	RED	00
4th BAND	GOLD	5%

RESISTANCE = 6800Ω ± 5%
= 6.8 kΩ ± 5%

Fig. 1.20 Resistor colour code

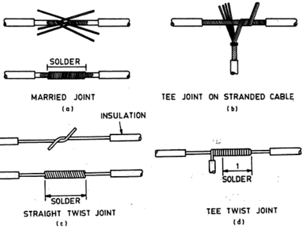


Fig. 1.21 Types of cable joints: (a) Married joint; (b) Tee joint, (c) straight twist joint; (d) Tee twist joint

3. Twist strands of each cable firmly in direction of lay for 3 cm
4. Leave 5 cm splayed out
5. Bring strands together, each strand lying between two strands of opposite cable
6. Hold strands of right hand cable along left hand cable.

7. Wrap three strands of left hand cable round right hand cable half a turn at a time tightly and close together
8. Wrap other side in opposite direction
9. Tighten with pliers and solder the joint.

(b) Tee joint on stranded cable

1. Use 7/0.737 PVC single core cable
2. Strip off 8 cm insulation from through wire. Do not cut cable
3. Strip 8 cm of tee wire
4. Twist tee wire for 3 cm in direction of lay
5. Secure with two or three turns of 1/0.737 binding wire
6. Divide tee wire strands, three on one side of through wire and four on other side
7. Wrap three strands tightly round through wire to the right
8. Wrap four strands in opposite direction to the left
9. Tighten with pliers and solder the joint.

(c) Straight twist joint

1. Remove insulation, clean and tin the ends for 8 cm
2. Lay wires together 5 cm from ends
3. Twist tightly round each other in opposite directions, each turn of wire fitting closely to the next
4. Solder the joint.

(d) Tee twist joint

1. Bare 'through wire' for 5 cm (this wire is not cut)
2. Bare 'tee wire' for 5 cm
3. Tightly bind round through wire from left to right
4. Solder the joint leaving first two or three turns free to allow flexibility.

1.8.2 Bus-bar Post

Bus-bars are thick copper strips from where connections of electrical sub circuits are taken. Bus-bars are fitted in bus-bar chambers. They should be insulated from the body of the bus-bar chamber. Ceramic bus-bar posts are used for this purpose. Each bus-bar is supported by two insulated bus-bar posts at the two ends. Fig. 1.22 shows the three views of a bus-bar post at the two ends. Fig. 1.22 shows the three views of a bus-bar post. The students may draw the bus-bar post in isometric view. Any dimension not given in the figure may be assumed proportionately.

1.8.3 Kit Kat Fuse Assembly

(a) One part of a kit kat fuse assembly in isometric view: Fig. 1.23 shows an isometric view of one part of a kit kat fuse assembly. The students may draw the three views *i.e.*, the plan, elevation and side view from the isometric view.

(b) Three views of the male part of a kit kat fuse assembly. Fig. 1.24 shows the three views of one part of a kit kat fuse assembly. Draw its isometric view.

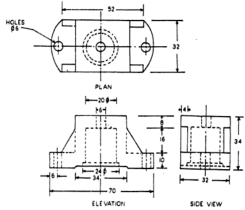


Fig. 1.22 Three views of a ceramic bus-bar post

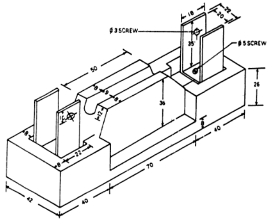


Fig. 1.23 One part of a kit-kat fuse assembly shown in isometric view

1.8.4 Single Pole Single Throw Knife Switch

Knife switches are available in single pole, double pole and triple pole type. These switches can be of single throw type or double throw type.

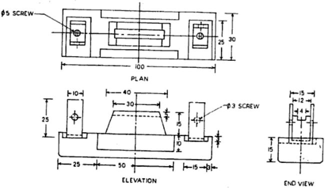


Fig. 1.24 Three views of one part of a kit kat fuse assembly

A single pole single throw knife switch is shown in isometric view in Fig. 1.25. Students may redraw the knife switch on a proportionate scale.

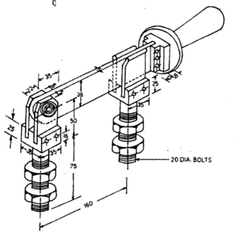


Fig. 1.25 Isometric view of a SPST knife switch

1.8.5 Carbon Brush Holder

A brush is mounted in such a way that it is pressed on to the commutator for delivering or receiving current. Brush holder carries the brush such that it is held firmly without vibration. To provide a continuous electrical circuit, the brush should evenly press over the whole contact area, with correct pressure. A flexible copper connector wire is attached to the brush through which the supply is taken out to the terminals.

Usually brushes are made of hard carbon. Graphite brushes are used in case of collecting high currents. In case of very high current densities, brushes are made from a mixture of copper and graphite.

Innumerable patterns of brush holders are there, out of which two are discussed as follows:

Figs. 1.26 (a) and (b) show two types of box type carbon holders. The brush slides in a box, open at top bottom. The brush is pressed against the commutator surface by means of a pressure arm and an adjustable spring. See Fig. 1.26 (a).

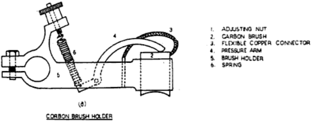


Fig. 1.26 (a) Box type carbon brush holder

In the other type of brush holder, the pressure on the brush is produced by using a clock spring, adjusted by a lever as shown in Fig. 1.26 (b).

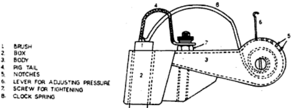


Fig. 1.26 (b) Another type of box type carbon brush holder

1.8.6 Iron Clad Switch

Switch fuse unit, mounted in a cast-iron enclosure, is called an iron-clad switch. Iron-clad double-pole (ICDP) switches are used for controlling single-phase two wire circuits, iron-clad triple-pole (ICTP) switches for three phase three wire circuits and iron-clad triple-pole with neutral link (ICTPN) switches for three phase four wire circuits. All these three types of iron clad switches are shown in Figs. 1.27 (a), (b) and (c).

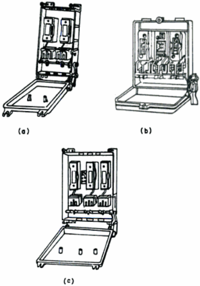
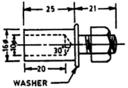


Fig. 1.27 (a) ICDP Switch; (b) ICTP Switch; (c) ICTPN Switch

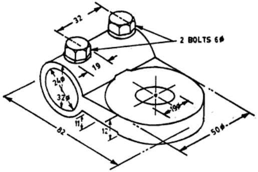
1.8.7 Cable Lugs or Thimbles

To make connections with a cable, a suitable form of cable lug or thimble is to be fitted at the end of the cable. It is also called as cable socket. Fig. 1.28 shows various forms of cable sockets suitable for single core cables.

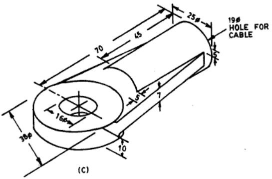
Usually a cable lug consists of two parts *viz.*, the tail part where the cable end is fixed and gripped in tightly and the head part which is bolted on to the terminal face. Fig. 1.28 (a) and (b) show cable lugs in which the cable end is gripped in by bolts and nuts. In some other types, the cable inlet of the lug is crimped with the cable end in, gripped in by bolts and nuts. In some other types, the cable inlet of the lug is crimped with the cable end in, to keep it in position. There are also cable lugs in which the cable end and the socket tail part is soldered together to keep the cable tightly in position.



(a)



(b)



(C)

Fig. 1.28 *(continu*

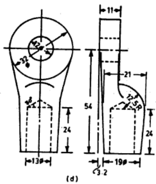


Fig. 1.28 Various types of cable sockets

The head part of the cable socket is flattened with a hole in it for connecting it to the terminal face with bolts and nuts.

1.9 DRAWING OF SIMPLE MECHANICAL ITEMS

Different drawings of simple mechanical items like shafts and keys, couplings, bearings, joints etc. are discussed in this section.

1.9.1 Shafts and Keys

1.9.1.1 Shafts: A shaft is a rotating bar in any rotating machine which transmits power. Shafts are made of either mild steel or high-carbon steel. Shafts are usually round and may be either solid or hollow. The diameter of the shaft varies from point to point along its length. The diameter at the middle is greater than the diameter at the ends. Strength and stiffness of a shaft is a very important criterion for determining the diameter of the shaft. Different machine parts such as armature, commutator spider, pulley etc. are keyed to the shaft. A motor shaft is shown in Fig. 1.29 in which the position of the armature, commutator etc. are indicated. Two key ways are also shown, one for armature and the other for pulley.

1.9.1.2 Keys: Machine parts like pulleys, wheels, gears etc. are mounted on a rotating shaft. In order to prevent relative rotation between the shaft and these parts, keys are inserted in between. Grooves are cut on the surface of the shaft and on the bore of the part to be mounted, and are called key ways. The key ways on the shaft and the mounting should be kept in line and the key inserted so that a firm joint is obtained.

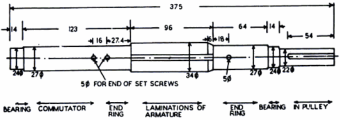


Fig. 1.29 A shaft of a dc motor

Fig. 1.30 shows the isometric view of a key and its key way cut on a shaft. The end view of a pulley mounted on a shaft is also shown in the figure.

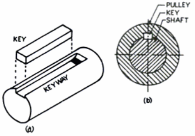


Fig. 1.30 (a) An isometric view of a key and its keyway cut on a shaft; (b) The end view of a pulley mounted on a shaft

The keys can be classified into two types: (1) Saddle keys and (2) Sunk keys.

(1) Saddle keys: Saddle keys are sunk into the key way on the hub of the mounting. There is no key way provided on the shaft. There are two types of saddle keys: (a) hallow and (b) flat.

In the hollow saddle key, the hollow surface, which rests on the shaft, has the same curvature so as to butt against the circular shaft. The flat saddle key is simply a rectangular wedge, to match with the flat surface on the shaft. Fig. 1.31 gives the illustration of the different saddle keys.

These types of keys are used for low power transmission.

(2) Sunk keys: Sunk keys are fitted into the key ways grooved half-way in the shaft and the remaining half in the hub. These are classified into: (a) Rectangular sunk key, (b) Square sunk key, (c) Woodruff key and (d) Feather key.

A rectangular sunk key and a square sunk key are shown in Fig. 1.32. These keys have taper 1 in 100.

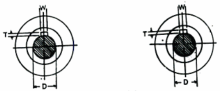


Fig. 1.31 Different saddle keys

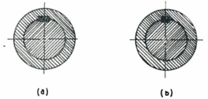


Fig. 1.32 (a) Rectangular sunk key (b) Square sunk key

Woodruff key is a segment of a circular plate. The keyways in the hub and the shaft are cut accordingly as shown in Fig. 1.33. The key is first placed in the keyway in the shaft and the hub is slided over it. This type of key is used to fit pulleys etc. on a tapered shaft.

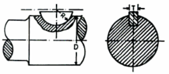


Fig. 1.33 Woodruff key

Feather keys are also known as parallel keys. Such keys are used when the mounting is required to slide along the shaft, i.e., when axial movement, in addition to usual rotary motion is required. Different types of feather keys are illustrated in Fig. 1.34.

1.9.2 Couplings

To increase the length of a shaft, two shafts are connected together by means of couplings. Flanges or muffs, different types of keys, bolts and nuts, pins and cotters etc. are made use of to fabricate the different types of couplings. Shaft

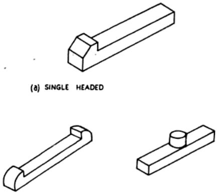


Fig 1.34 Different types of feather keys

couplings are mainly used to couple the shafts of two machines (*e.g.*, and induction motor with a d.c. generator) to run together at the same speed.

Shaft couplings can be classified mainly into two broad categories: (1) Rigid couplings and (2) Non-rigid or flexible couplings.

1.9.2.1 Rigid couplings: If the shafts to be connected are rigid and in axial alignment, rigid couplings are used. The most common forms of rigid couplings are: (1) Muff couplings and (ii) Flange couplings.

(i) *Muff coupling:* It is the simplest form of coupling and is mainly used for connecting small size shafts. A cast iron cylindrical muff or box slides on the two ends of the shafts which butt (kept close together but not overlapping) against each other. A long gib head key is driven through both the shafts and the muff. This is shown in Fig. 1.35.

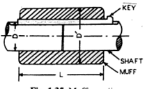


Fig. 1.35 Muff coupling

In half-lap muff coupling the ends of the two shafts overlap each other as shown in Fig. 1.36. The lap being tapered does not separate out if the shaft is in tension.

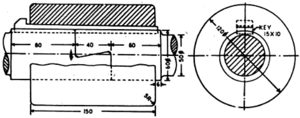


Fig. 1.36 Half-lap muff coupling

Split muff coupling consists of a muff splitted up into two semi cylindrical halves. These two halves are held together by means of bolts and nuts in the recesses provided in the muff. See Fig. 1.37. To keep the two shafts together, a feather key is driven through the shafts and the muff.

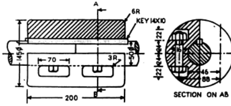


Fig. 1.37 Split muff coupling

(ii) *Flange coupling:* It is a rigid and relatively permanent type of coupling. It consists of two cast iron flanges, exactly similar to each other. The flanges are keyed tightly to the ends of the shafts with the help of rectangular sunk taper keys. The keys are inserted from the inside faces of the flanges and at 90° to each other. This is to prevent the two shafts becoming weak due to the keyways cut at the same longitudinal section. The faces of the flanges are tightly joined and fastened together by means of tight fitting bolts. The diameter and number of the bolts depend upon the size of the shaft for which the flange is designed. The two shafts to be coupled must be in correct alignment. To ensure this, when the flanges are bolted together a circular projection on the face of one flange is made to fit into a corresponding recess on the face of the other flange. Fig. 1.38 shows the half sectional elevation and end view of a simple flange coupling.

A modified type of flange coupling is the projected type flange coupling. See Fig. 1.39. In this type of coupling, a portion of the flange is projected

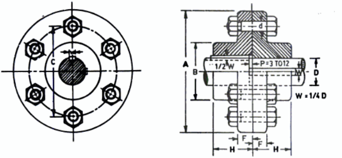


Fig. 1.38 Ordinary flange coupling

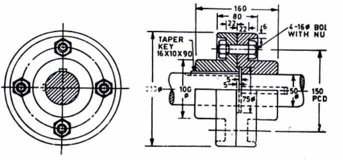


Fig. 1.39 Flange coupling – Projected type

out to cover bolt heads and nuts. This is to avoid workmen's clothes and other materials coming in contact with them and thereby cause accidents. Compression coupling is another type of rigid coupling. It does not employ a key, but a sleeve which is radially flexible and grips firmly both the shafts.

1.9.2.2 Flexible couplings: If the two shafts are slightly out of line or if there is any chance of their getting slightly deflected under load conditions, flexible couplings are employed. This type of coupling is used to couple electric motor with certain types of machines. The most common type of flexible coupling is the pin type flexible coupling which is illustrated in Fig. 1.40. It consists of two flanges bolted together by means of bolts and nuts. Compressible or flexible elements such as rubber, leather etc. are used round the bolts, while joining the flanges. All the other arrangements are the same as in flange coupling.

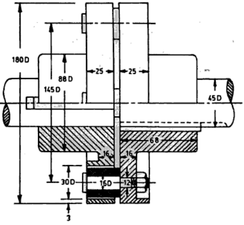


Fig. 1.40 Flexible coupling

This type of coupling is used as direct coupling device, *i.e.*, when an electric motor is directly coupled to a machine. As the motor starts to drive the machine, the starting torque of the motor is often several times the normal full load torque. The sudden shock due to the heavy starting torque may fracture the bolts of a rigid coupling. To prevent this, a flexible coupling is used, in which the leather or rubber washers act as shock absorbers. Thus, it will minimize the shocks and vibrations occurring due to power transmission.

There are some other types of flexible couplings such as (a) Universal coupling, (b) Oldham's coupling etc. Universal coupling is used for connecting two shafts whose axes are not in line but inclined to a certain angle. Oldham's coupling is used to couple two shafts whose axes are parallel but not in one line.

1.9.3 Bearings

Bearings are used to support rotating shafts. They enable free and smooth rotation of shafts. They are required to bear all the loads applied on the shafts. As the shafts are rotating, there is constant frictional resistance and rubbing between the contact surfaces. To reduce wear and tear due to friction, the bearings are lubricated. Bearings are of different types. They are:

- (i) Journal bearings
  - (a) Solid bearing
  - (b) Bush bearing
  - (c) Pedestal bearing or Plummer block
- (ii) Thrust bearings

(iii) Ball and roller bearings

1.9.3.1 Journal bearings: These bearings support the normal loads *i.e.*, bearing load acting perpendicular to the shaft axis. In these the journal rotates inside a stationary member. The common types of journal bearings are: (a) Solid bearing, (b) Bush bearing, (c) Pedestal bearing or Plummer block.

(a) *Solid bearing.* The simplest form of bearing is the solid bearing. It is simply a cast iron block with a central hole to receive the journal. Journal is the part of the shaft which rotates inside the bearing. The inside dimension of the hole is so chosen that the shaft round fits inside. Fig. 1.41 shows the isometric view of a solid bearing. An oil hole is provided at the top to introduce the lubricant into the bearing. The disadvantage of such a bearing is that, due to constant friction and rubbing, the inner surface of the bearing gets worn out, and the whole set is to be discarded.

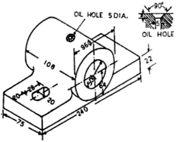


Fig. 1.41 An isometric view of a solid bearing

(b) *Bush bearing:* This bearing is an improved form of a solid bearing. A bush made up of brass, gunmetal, manganese or any soft metal is introduced between the shaft and the hole. When bush gets worn out, it can be replaced. It may be locked with the body of the bearing using a set screw, to prevent relative rotation of the bush in the block. An isometric sectioned view of a bush bearing is shown in Fig. 1.42.

(c) *Pedestal bearing:* It is also known as plummer block. This is used when long shafts rotating at high speeds is to be supported. The upper semi circular position is made separately which is known as cap. The lower position or the body of this bearing is the pedestal. The bush or brasses are also made of two pieces. The snug prevents them from rotating with the shaft. The cap and the pedestal are held together by means of bolts. Fig. 1.43 shows the sectioned isometric view and the half-sectional elevation of a pedestal bearing. The students may redraw half sectional elevation and also draw the half sectional end view and plan.

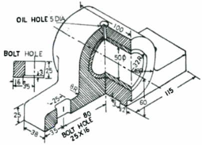


Fig. 1.42 Bush bearing

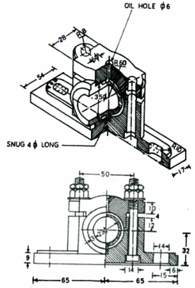
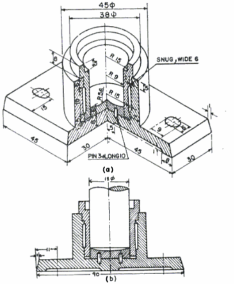


Fig. 1.43 Pedestal bearing or Plummer block

1.9.3.2 Thrust bearings: These bearings support the axial loads, *i.e.*, bearing loads acting along the shaft axis. Pivot or foot-step bearings and the collar thrust bearings are the two types of thrust bearings.

Pivot or foot-step bearing is used only for vertical shafts. In this type of bearing, the bottom end of the shaft rests on a steel disc placed at the base with the bush as shown in Fig. 1.44. This disc is prevented from rotating alongwith the shaft by means of pins. This type of bearing takes care of the axial load on the shaft.



Full Sectional elevation

Fig. 1.44 Pivot or foot-step bearing

Collar thrust bearing is used on horizontal shafts to support axial loads. Collars are made on the shaft and these collars rotate in the grooves of the bearing, thus taking the axial load on the shaft. See Fig. 1.45.

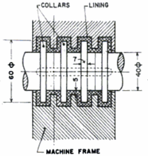


Fig. 1.45 Collar thrust bearing

1.9.3.3 Ball or Roller bearings: These bearings support shafts with high speeds and heavy loads. They occupy very little axial space. In ball bearings, small metal balls are fixed between the shaft and bearing as rolling elements, whereas in roller bearings, they are rollers. A ball or roller bearing consist of four main parts as shown in Fig. 1.46 (a) inner race, (b) outer race, (c) balls or rollers, (d) cage. The balls or rollers run in the grooves of the races. Cage is used to keep the balls separate in position. Pictorial views of a ball bearing and a roller bearing are shown in Fig. 1.47.

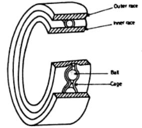


Fig. 1.46 Parts of a ball or roller bearing

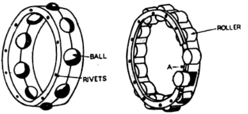


Fig. 1.47 (a) Ball bearing (b) Roller bearing

1.9.4 Wall Brackets

Bearings for shafts which run close and parallel to the wall can be mounted on brackets. The brackets are generally of two types viz. wall brackets and pillar brackets. Fig. 1.48 shows a wall bracket. Pedestal bearings may be cast with the bracket or bolted to it. Pillar brackets are used to support a shaft from a pillar where there is no wall nearby.

1.9.5 Joints

Many a times different structures, vessels, machines etc, are built up of a number of pieces rigidly jointed together by means of joints. Rods, shafts, pipes,

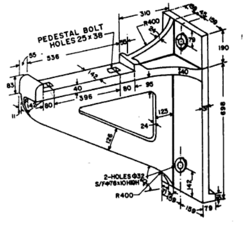


Fig. 1.48 Wall bracket

angles, channels, metal sheets, plates etc. are to be jointed in such cases. In this section, we shall discuss the different types of joints used for such purpose.

1.9.5.1 Cotter and Pin Joints: Such joints are used to fasten together two rods which are subjected to axial forces. A joint employing a 'cotter' is known as a cotter joint and a joint employing 'a pin' is known as a pin joint.

(a) Cotter joint: Two types of cotter joints are discussed below:

(i) *Gib and cotter joint:* This type of joint is used for jointing two square or rectangular rods. The end of one rod is formed into a U-form in which the end of the other rod fits in. Slots are cut in both the pieces. Gib is first kept in position and the cotter is driven in later.

Fig. 1.49 shows the half sectional elevation of a gib and cotter joint. The students may draw the plan and side view.

(ii) *Socket and spigot cotter joint:* This type of joint is used to connect two circular rods. As shown in Fig. 1.50 the end of one rod is enlarged and formed into a socket into which the spigot end of the other rod fits in. Slots are cut in these ends, and cotter is driven tightly through the slots.

(b) Pin joint: Two types of pin joints are Knuckle joint and Hookes' joint (universal joint). Knuckle joint is discussed here in detail.

(i) *Knuckle joint:* In places where relative oscillation of the jointed rods is to be allowed knuckle joints are used. The end of one rod is made into a fork, with circular holes on both limbs of the fork. The end of the other

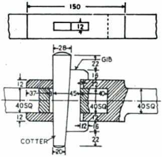


Fig. 1.49 Gib and cotter joint

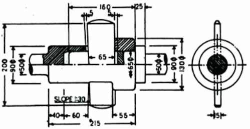


Fig. 1.50 Socket and spigot cotter joint

rod is forged to an eye. The eye and is placed in the fork-end and a pin is passed through the holes and held in position by a collar and taper pin.

Fig. 1.51 (a) shows the isometric view of the parts of a knuckle joint. The students may redraw the orthographic projections shown in 1.51 (b).

1.9.5.2 Pipe joints: Pipes are often used for carrying water, gas, oil, steam etc. Pipes are manufactured in pieces and are connected together to form any length of piping system. The commonly used types of pipe joints are:

(a) *Flanged pipe joint:* Flanges are cast separately and welded or screwed at the ends of pipes. They can also be cast integral with the pipes. At the centre of one flange is made a small spigot, which fits into the corresponding recess in the other flange. The flanges are then bolted together to form a tight junction. A thin packing of suitable soft material is placed between the flanges to prevent leakage.

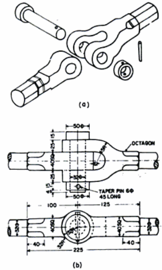


Fig. 1.51 (a) Isometric view of the parts of a knuckle joint; (b) Orthographic projections of a knuckle joint

Fig. 1.52 shows the isometric view (upper half in section) of a flanged pipe joint. The students may draw its half sectional elevation and side view.

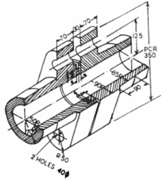


Fig. 1.52 Isometric view (upper half in section) of a flanged pipe joint

(b) *Spigot and socket pipe joint:* Such joints are used for connecting underground pipe lines of large diameters. The spigot end of one pipe fits into the socket end of the other pipe. The space in between is filled in by yarn, jute, or coir, and the rest is closed by molten lead. Fig. 1.53 shows such a joint.

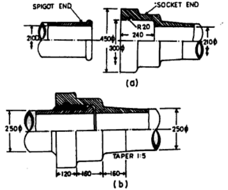


Fig. 1.53 Spigot and socket pipe joint

(c) *Union joint:* Union pipe joints can be used where the making and breaking of the joint is frequently required. This joint is generally used for small size copper tubes. Half sectional elevation of a union pipe joint is shown in Fig. 1.54. The pipes to be jointed are threaded on the outer surface at the ends. Nut A having a step on its end is screwed on one pipe. Nut B having threads on both inner and outer surfaces is threaded

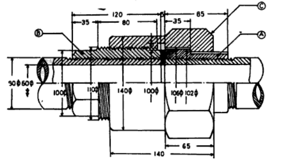


Fig. 1.54 Union pipe joint

on to the second pipe. Nut C screws on to nut B and draws together the two nuts *i.e.*, nut A and B along with the pipes. A thin ring of packing is inserted between the pipes.

(d) *Expansion joint:* Pipes carrying fluid or gases at high temperatures undergo expansion and contraction. Expansion joints are used in such pipelines. Fig. 1.55 shows an expansion joint employing a stuffing box and a gland. Pipe B is free to move inside the stuffing box A. The gland G is fastened to the stuffing box using nuts and bolts. Asbestos packing P prevents any leakage of hot gases. Pipes are not rigidly clamped and therefore allows expansion of the pipes in the joint.

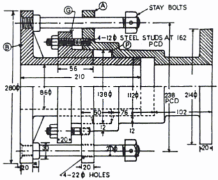


Fig. 1.55 Expansion joint

1.9.5.3 Riveted joints: Rivets are very commonly used in connecting two or more metal plates or sheets. A rivet consists of head, shank and tail as shown in Fig. 1.56. A number of holes are made on the plates to be jointed through rivets.

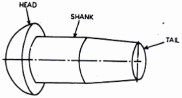


Fig. 1.56 An isometric view of a rivet

The tail end of the rivets are made into heads to hold the plates firmly. This is known as riveting. The two main types of riveted joints are (a) Lap joints and (b) Butt joints.

(a) *Lap joints:* If the ends of the plates are made to overlap each other, and riveted together, then it is called a riveted lap joint. The different types of lap joints are shown in Fig. 1.57. If a single row of rivets hold the plates, the joint is called single-riveted, and if two rows of rivets are used, then the joins called double riveted. In double riveted joints, the rows may be arranged either in a chain fashion as shown in Fig. 1.57 (b) or in a zig-zag fashion as shown in Fig. 1.57 (c). The sectional elevation and plan of these joints show clearly, how the plates overlap and riveting is done.

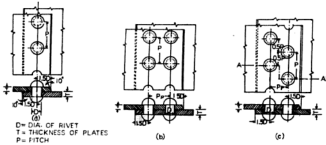


Fig. 1.57 Different of lap joint: (a) Single riveted lap joint; (b) Double riveted chain lap joint; (c) Double riveted zig-zag lap joint

(b) *Butt joints:* If the ends of the plates meet face to face and are riveted with a cover plate either on one side or on both sides, then it is called a butt joint. With a single cover plate the joint is single-strap and with two cover plates one on top and the other on bottom, the joint formed is double-strap type. Fig. 1.58 shows the different types of butt joints.

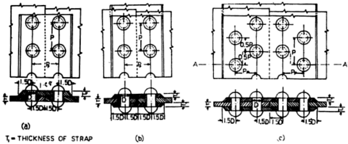


Fig. 1.58 Different types of butt joints: (a) Single riveted, single strap, butt joint; (b) Single riveted, double strap butt joint; (c) Double riveted, double strap zig-zag butt

2

Drawing of Electrical Instruments

2.1 DRAWING OF COMMON ELECTRICAL INSTRUMENTS

Instruments which are commonly used for measuring electrical quantities are (i) Ammeter, (ii) Voltmeter, (iii) Wattmeter, (iv) Energymeter, (v) Frequency meter, (vi) Power factor meter (vii) Phase sequence indicator, (viii) Synchroscope and (ix) Ohm-meters etc.

Ammeters and Voltmeters are the most commonly used instruments. Ammeters are used for the measurement of current and volumeters are used for the measurement of voltage or potential.

Electrical instruments are generally of four types:

(i) Moving iron type
(ii) Moving coil type
(iii) Dynamometer type
(iv) Induction type.

2.1.1 Moving Iron Type Ammeter and Voltmeter

Moving iron type instruments are non-directional and can be used for measuring both A.C. and D.C. values of current and voltage.

Constructional details of a repulsion type moving iron type meter is shown in Fig. 2.1.

A moving iron type instrument of a cylindrical coil or a solenoid made of a number of turns of insulated copper wire. The size of the wire used and the number of turns will depend upon whether the instrument is to be used as a voltmeter or as an ammeter. When it is to be used as a voltmeter, the coil will have large number of turns of thin copper wire. When the instrument is designed to be used as an ammeter, it will have less number of turns of thick copper wire capable of taking the rated current.

There are two concentric iron vanes. One fixed and the other movable placed as shown inside the coil. The fixed vane has a special tapered shape. The

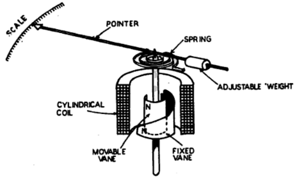


Fig. 2.1 Repulsion type moving iron meter

movable vane has rectangular shape. The design allows the scale to be more uniform *i.e.*, less cramped.

The controlling torque is exerted by a spiral spring of phosphor bronze connected to the shaft of the movable vane. A pointer is also attached to the same shaft. It moves on a calibrated scale.

The scale is non-uniform, cramped towards edges and widened at the middle.

2.1.2 Moving Coil Type Ammeter and Voltmeter

A permanent magnet moving coil type instrument may be used as an ammeter or a voltmeter. These instruments are directional and are used for D.C. measurement only.

A permanent magnet moving coil instrument consists of a powerful permanent magnet fitted with two mild steel pole pieces. A round mild steel core divides the gap into two air gaps of uniform width in order to achieve uniform radial distribution of field.

The moving coil is a light rectangular coil of very thin insulated copper wire wound on an aluminium former. The ends of the coil are connected to two phosphor bronze hair springs. Only one spring has been shown in Fig. 2.2. Current enters and comes out of the moving coil through the springs. They also exert controlling torque on the moving coil.

A pointer is attached to the spindle near the top spring. This pointer moves on a uniform scale.

When the instrument is to be used as a voltmeter, external multiplier resistances are to be connected in series. When it is to be used as an ammeter, shunts are to be connected externally.

Fig. 2.2 shows a permanent magnet moving coil instrument.

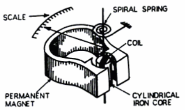


Fig. 2.2 Permanent magnet moving coil meter

2.1.3 Dynamometer Type Instruments

Dynamometer type instruments are also of moving coil type but having no permanent magnet. The magnetic field is produced by two fixed coils (see Fig. 2.3).

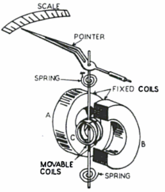
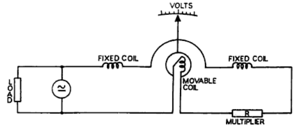


Fig. 2.3 Dynamometer type instrument

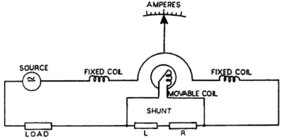
The two fixed coils are positioned co-axially and connected in series. In between the space of these coils, there are two movable coils positioned coaxially on different planes. They are also connected in series.

Two phosphor bronze spiral springs are attached to the shaft, one on top and the other at the bottom. When used as an ammeter, the fixed and moving coils are connected in parallel, whereas in voltmeter, they are in series with each other. Figs. 2.4 (a) and (b) show the circuit arrangement when the instrument is used as a voltmeter and as an ammeter.

2.1.3.1 Dynamometer Type Wattmeter: Wattmeters are used for the measurement of electric power. The most commonly used type of wattmeter is of dynamometer type.



(a)



(b)

Fig. 2.4 Circuit arrangement of dynamometer type voltmeter and ammeter

There are two sets of coils. A pair of fixed coils is made of a few turns of thick insulated copper wire. They are also known as currents coils. The voltage coil (or potential coil) which is free to move consists of large number of turns of thin insulated copper wire. Fig. 2.5 shows the arrangements of coils of a dynamometer type wattmeter.

The current coils are connected in series with the circuit. The voltage coil is connected in parallel to the supply. The controlling torque is provided by spring. The damping is of air friction type. Fig. 2.6 shows the connection diagram of dynamometer type wattmeter.

2.1.4 Induction Type Instruments

These instruments work on the principle of electromagnetic induction. Torque is produced by the reaction between one flux whose magnitude depends upon

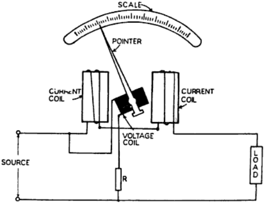


Fig. 2.5 Dynamometer type watt-meter

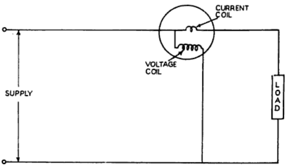


Fig. 2.6 Circuit diagram of a dynamometer type wattmeter

the value of current or voltage to be measured. The torque is proportional to square of current or voltage.

Induction type instruments are necessarily A.C. instruments. They have a full scale deflection of about 300°. Eddy current damping is used in these instruments.

There are two types of induction instruments: (i) the Ferraris type, (ii) the Shaded Pole type.

2.1.4.1 Ferraris Type Induction Instruments: These instruments work on induction motor principle. Fig. 2.7 shows two pairs of laminated poles wound

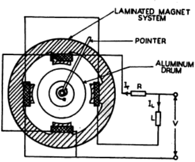


Fig. 2.7 Ferraris-type induction instrument

with insulated copper wire. Both the pairs of poles are supplied from the same source. An inductance is connected in series with the coils of one pair of poles. To the other pair, a high resistance is connected in series. This produces a phase difference of about 90° in the currents flowing through the two pairs of pole windings. This produces a rotating magnetic field which causes the drum to rotate. A controlling torque is provided by a spiral spring. The moving system is carried by a spindle moving freely in jewelled cups. Damping torque is produced in the aluminium disc attached to the spindle and moving in between the air gaps of two permanent magnets.

2.1.4.2 Shaded Pole Type Induction Instruments: As shown in Fig. 2.8, there is a thin aluminium disc mounted on a spindle which is supported by jewelled cups. The spindle also carries a pointer and a control spring attached to it. The edge of the disc moves in the air gap of a laminated electro-magnet which is energised by the current or voltage to be measured. Thin copper bands fixed around one half of each of the two poles provide pole shading. Due to pole shading, a time lag of about 40° to 50° is produced in the two fluxes. This phase displacement produces the deflecting torque.

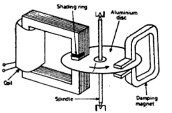


Fig. 2.8 Shaded pole type induction instrument

The instrument is spring controlled. The springs are attached to the same spindle which carries the disc. Damping is achieved by placing a permanent magnet on the opposite side of the disc.

2.1.5 Controlling and Damping Devices

2.1.5.1 Controlling Devices: In measuring instruments, controlling devices are used in order to counteract the deflecting torque. These devices provide the controlling torque. There are two type of controls:

(a) *Spring control:* One or two springs may be used in order to provide the controlling torque. See Fig. 2.9. The spring tightens up as the pointer tends to deflect. The pointer comes to rest when the two torques, the deflecting torque and the controlling torque are equal.

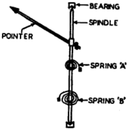


Fig. 2.9 Spring control

(b) *Gravity control.* Gravity controlled instruments have a small weight attached to the moving system in such as way that it produces a restoring or controlling torque when the system is deflected as illustrated in Fig. 2.10. The controlling torque can be varied by adjusting the position of control weight upon the arm which carries it. Instruments which use gravity control must be placed in vertical position in order that the control device operates.

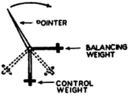


Fig. 2.10 Gravity control

Due to its limitations, gravity control is not suitable for indicating instruments in general and for portable instruments in particular.

2.1.5.2 Damping Devices: In an instrument, damping is necessary in order to bring the moving system quickly to rest in its final deflected position. Without a damping force (to be provided by a damping device) the pointer of the instrument would oscillate about its final deflected position for some time before coming to rest. Thus it causes wastage of time in taking reading.

Three types of damping devices are generally in use. Selection of a particular type of damping device will depend upon the type of instrument.

(a) Air friction damping: As shown in Fig. 2.11, a light aluminium piston is attached to the moving system. As the pointer deflects, the piston moves in an air chamber closed at one end. The pressure of air thus counteracts the movement and the pointer comes to rest without oscillations.

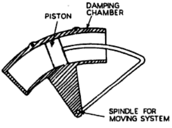


Fig. 2.11 Air friction damping

(b) *Eddy current damping:* The system works on the principle of eddy currents. These currents always oppose the movement which is responsible for producing them.

A thin disc of aluminium or copper is mounted on the spindle which carries the pointer of the instrument as shown in Fig. 2.12 (a). A permanent magnet is placed such that the disc moves in the gap of this

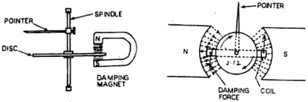


Fig. 2.12 Eddy current damping

magnet. As the spindle rotates, the disc moves and cuts the flux of permanent magnet. Eddy currents are produced which have a damping effect. The pointer attains its final deflected position quickly.

(c) *Fluid friction damping:* In Fig. 2.13 (a) a light disc, attached to the moving system is dipped into a pot containing oil for damping. The damping force is produced when the spindle moves causing the vane to move in oil.

In Fig. 2.13 (b) vanes are used in vertical planes which are attached to the moving spindle. The vanes are immersed in damping oil and they provide the damping force as the spindle moves due to the deflecting force.

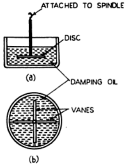


Fig. 2.13 Fluid friction damping

2.1.6 Frequency Meters

Frequency meters indicate the supply frequency and are of different types. They are described as follows:

2.1.6.1 Vibrating Reed Frequency Meter: The working of this instrument depends upon the phenomenon of mechanical resonance. As shown in Fig. 2.14, the instrument consists of a number of thin steel strips or 'reeds' arranged alongside and close to an electromagnet. The electromagnet is laminated and its winding is connected across the supply whose frequency is to be measured. The reeds are about 4 mm wide and 1/2 mm thick, and are not exactly similar to each other. They are either of slightly different lengths and breadths or carry flags of varying weight at their upper ends. As a result the natural frequency of vibration of the needs becomes different. The needs are arranged in ascending order of their natural frequency — say 47 cycles to 53 cycles. When the frequency meter is connected across the supply, the reeds will tend to vibrate. But the reed whose natural frequency of vibration is equal to the supply frequency will vibrate appreciably. The frequency can be read directly from the

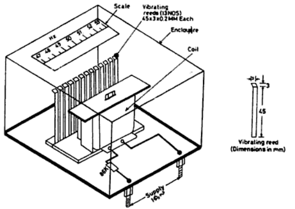


Fig. 2.14 Vibrating reed frequency meter

scale marking. If the supply frequency lies half way between the natural frequencies of two adjacent needs, both of these will vibrate equally.

2.1.6.2 Electrical Resonance Frequency Meter: This type of frequency meter consists of a magnetising coil which is wound on one end of a laminated iron core and is connected across the supply. A moving coil is placed over this, pivoted at one end as shown in Fig. 2.15 and having a pointer attached to it. A capacitor C is connected to it.

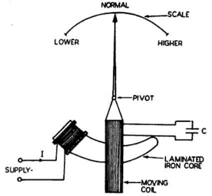


Fig. 2.15 Resonance frequency meter

The capacitive reactance $1/\omega C$ of the circuit depends on the given frequency. As the pivoted coil moves along the iron core its inductive reactance (ωL)

increases. The moving coil is pulled towards the magnetising coil until ωL equal $1/\omega C$. Then the torque is zero, and the circuit is in resonance. The position of the pointer indicates the frequency.

2.1.6.3 Weston Frequency Meter: Here, there are two fixed coils A and B each in two equal parts. These coils are fixed perpendicular to each other. A long, thin soft iron needle is pivoted at their centre which carries a pointer. The inductances L_A and L_B and the resistances R_A and R_B are connected as shown in Fig. 2.16 so that 90° phase difference is obtained between the currents through the coils A and B.

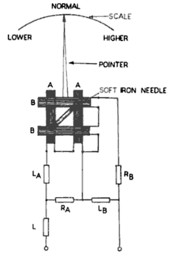


Fig. 2.16 Weston frequency meter

2.1.7 Power Factor Meters

Power factor meters indicate the power factor of a circuit directly. The different types of power factor meters are illustrated as follows:

2.1.7.1 Dynamometer Type Power Factor Meter

(a) *For single phase loads:* As shown in Fig. 2.17 the two fixed coils F and F carry the current in the circuit under test. Between these two fixed coils, there are two coils A and B rigidly fixed at an angle of 90° apart. They can move together and carry a pointer which indicates the power factor of the circuit directly.

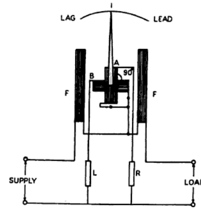


Fig. 2.17 Dynamometer type single phase p.f. meter

(b) *For three-phase balanced loads:* Two moving coils are fixed with their planes 120° apart. They are connected across two different phases of the supply circuit. The fixed coils are connected in the third phase and carry the line current.

A pointer is provided and the instrument is calibrated such that the power factor can be read directly, as shown in Fig. 2.18.

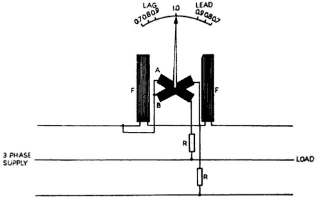


Fig. 2.18 Dynamometer type three phase p.f. meter

2.1.7.2 Nalder-Lipman Power Factor Meter: Three moving irons B_1, B_2, and B_3 are mounted on a single spindle, one above the other and the three pairs of sectors are displaced in space by 120° relative to one another, as shown in Fig. 2.19. Each iron is magnetised by a pressure coil

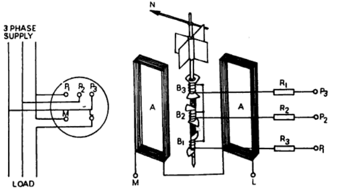


Fig. 2.19 Nalder-Lipman power factor meter

There is one current coil, divided into two equal parts, placed one on each side of the moving system. The pressure coils, are connected across the three phases of the supply while the current coil is connected in any one of the supply lines.

2.1.8 Synchroscope

A synchroscope is used to synchronise two alternators so that they are able to operate in parallel. Synchroscopes have four terminals, two for the already operating machines or bus bars and the other two for the incoming machine or the machine to be synchronised.

There are two types of synchroscopes: (i) Dynamometer type and (ii) Moving iron type.

2.1.8.1 Dynamometer Type Weston Synchroscope: The construction of a dynamometer type synchroscope is similar to the construction of single phase dynamometer type wattmeter. The fixed coil and the moving coil are however designed for small currents.

As shown in Fig. 2.20, the fixed coil is connected in series with a resistor across terminals of incoming machine. The moving coil is connected in series with a capacitor further to the supply terminals or to the terminals of the machine which is already operating. The instrument also incorporates a lamp which is connected to secondary of a special transformer having two primary windings. One winding is connected to the incoming machine and the other to the bus bar.

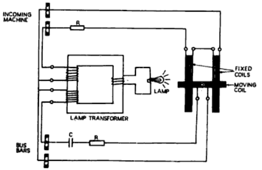


Fig. 2.20 Weston synchroscope

The instrument is marked 'slow' on one side of zero position and 'fast' on the other side. Synchronisation is obtained when the pointer becomes steady at the centre zero position on scale and the lamp is in full brightness.

2.1.8.2 Moving Iron Type Synchroscope: Fig. 2.21 shows a moving iron type synchroscope. These are two iron vanes (P_1 and P_2) mounted one above the other on a single spindle. They are separated by a nonmagnetic distance piece. These iron vanes carry the voltage coils (C_1 and C_2) connected across the machine terminals. A non-inductive resistor (R) is connected in series with one coil and an inductive coil (L) in series with the other. The current coil A_1 A_2 is divided into two equal parts mounted one on each side of the moving system. It is connected across the existing supply with a non-inductive resistor in series.

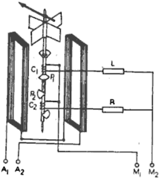


Fig. 2.21 Moving iron type synchroscope

When the frequencies of the two machines are equal, the pointer of the instrument becomes stationary at the central zero position. At this condition the machine is ready for synchronising. In case the two frequencies are not equal, the spindle rotates continuously, the direction and speed of rotation depends upon the difference of frequencies of the two machines.

2.1.9 Maximum Demand Indicator

A maximum demand indicator is used to indicate the maximum power being drawn by a consumer at any interval of time. Some consumers make a sudden heavy demand on the supply than their normal local requirements. Some consumers may have a lower power factor causing larger current being drawn from the mains than the current that would be drawn at a reasonably high power factor. This would necessitate installation of a higher capacity power station to meet the consumer demand and therefore would increase capital cost.

The purpose of installing maximum demand indicator is to ensure that consumers do share a fair amount of burden on capital cost that might occur on account of installation of a higher capacity power station.

One such type of maximum demand indicator is Wright maximum demand indicator which is shown in Fig. 2.22.

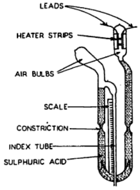


Fig. 2.22 Wright maximum demand indicator

The indicator consists of a glass U-tube whose upper ends are formed into two glass bulbs filled with air. One of the bulbs consists of a heater strip whose leads carry the main circuit current. Near the upper end of the other limb of the U-tube is a narrow side tube having a graduated scale alongside. The U-tube is filled with sulphuric acid, upto the level of the branch tube, and the side tube is also filled upto the zero mark on the scale.

When current flows through the heater, the air in the bulb becomes hot and therefore, expands. The sulphuric acid in the right hand side of the U-tube overflows into the index tube. The instrument thus gives a true record of maximum current flowing during a given period. At the end of each of such accounting period, the instrument has to be re-set.

Since the current has to heat the bulb and the air inside it, and since this heating will depend upon the length of time for which the current will flow in the heater, flow of momentary heavy currents in the circuit will not affect the working of the instrument.

2.2 CONNECTION DIAGRAMS OF ELECTRICAL INSTRUMENTS

Electrical instruments are used to read electrical quantities. It is necessary to connect an instrument correctly in the circuit. For this purpose, it will be necessary to identify the instrument terminals and also to know whether such terminals are to be connected in series or in parallel with the supply.

Connection diagrams of commonly used electrical instruments are given in the following sections.

2.2.1 Ammeter

An ammeter is always connected in series. There are two terminals for an ammeter. One supply terminal may be connected to one terminal of the ammeter. The second terminal of the ammeter is connected to the other supply terminal through the load. When the supply is switched on, the meter will read the amount of current flowing through it. See Fig. 2.23. In multi range ammeters there is one common terminal and others for different range of currents. Connections are always to be made with only two terminals which would depend upon the range selected.

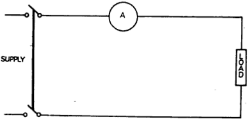


Fig. 2.23 Connecting an ammeter

2.2.2 Voltmeter

A voltmeter is used to read the potential difference of voltage. It is always connected in parallel with the supply. One terminal of the voltmeter is connected to one supply wire and the other terminal to the other supply wire, as shown in Fig. 2.24. A multi range voltmeter will have one common terminal and other terminals for different voltage ranges.

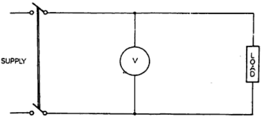


Fig. 2.24 Connecting a voltmeter

2.2.3 Wattmeter Connections

A wattmeter is used for the measurement of electric power. It is generally dynamometer type. It has four terminals. Two terminals are from current coil. These are marked M and L. The other two terminals are from voltage coil. These may be marked as Com. and 220 V/440 V (the voltage to be measured).

The current coil terminals M and L are to be connected in series and the voltage coil terminals Com. and 220 V in parallel (See Fig. 2.25). When the supply is switched on the wattmeter reads the power in the circuit.

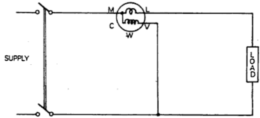


Fig. 2.25 Connecting a wattmeter

Fig. 2.26 shows a circuit diagram in which a voltmeter, an ammeter and a wattmeter are connected to read the values of voltage, current and power respectively.

Fig. 2.27 shows how two wattmeters are connected in a three-phase circuit to read the power in the circuit.

2.2.4 Connecting a Frequency Meter

A frequency meter is used to measure the frequency of AC supply. Frequency meters are usually calibrated in hertz (Hz). For measuring supply of 50 Hz, the markings on scale usually are from 47 Hz to 53 Hz.

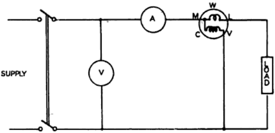


Fig. 2.26 Connecting a voltmeter, ammeter and a wattmeter in a circuit

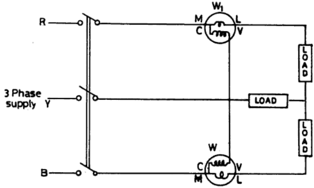


Fig. 2.27 Two wattmeter method of measuring three-phase power

The frequency meter may be moving iron type (Weston frequency meter) or electrical resonance type as explained in Section 2.1.6. A frequency meter will have two terminals which are connected in parallel to supply, like connecting a voltmeter, as shown in Fig. 2.28.

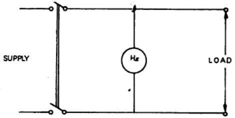
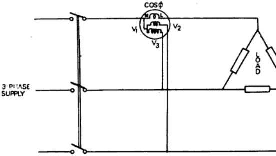


Fig. 2.28 Connecting a frequency meter

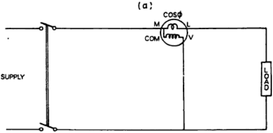
2.2.5 Connecting a Power Factor Meter

A power factor meter is used to measure power factor of a single phase or a three-phase circuit. There are two types of power factor meters, the dynamometer type, and the moving iron type.

For three-phase meters, there are five terminals marked M, L and V_1, V_2 and V_3. Terminals M and L are of the fixed coils which are called current coils. These are connected in series with the load. V_1, V_2 and V_3 are the voltage coil terminals and are connected in parallel to the supply, as shown in Fig. 2.29(a). A single phase power factor meter has four terminals only and is connected as shown in Fig. 2.29 (b).



(a)



(b)

Fig. 2.29 (a) Connecting a three-phase power factor meter, (b) Connecting a single phase power factor meter

2.2.6 Connection Diagram of an Energy Meter

An energy meter is used to register the energy supplied to an electricity consumer over a given period. Energy is the product of power and time. An energy meter has a train of gears and indicating scales to show the energy consumed in a given period of time. The number of rotations made by the aluminium disc for 1 kWH of energy consumed is called the meter constant.

(a) *Single phase energy meter:* The connection diagram of a single phase energymeter is shown in Fig. 2.30 (a).

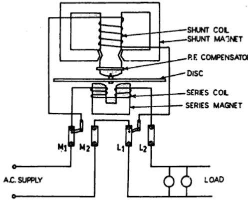


Fig. 2.30 (a) Electrical circuit of a single phase energy meter

When current flows, both the shunt coil and the series coil get energised. Their fluxes produce a resultant torque on the aluminium disc which starts rotating. The speed of disc is proportional to the current. The amount of energy consumed in terms of kWH can be directly read from the meter.

(b) *Polyphase energy meter:* In case of a three phase circuit, the power consumed by the circuit can be measured by using two wattmeters. The total power consumed is obtained by summing the readings of the two wattmeters. Similarly, the energy measurement in the polyphase circuits can be done by using a group of single phase energy meters. But, since this method is not feasible in case of commercial measurements, polyphase energy meters are employed for this purpose. As in case of power measurement in the polyphase circuits, the energy measurement in a 'n' conductor system requires (n-1) measuring elements. Therefore, a 3-phase, 3 wire system will require a 2-element energy meter. This 2-element energy meter consists of two discs mounted on the same spindle. The torque developed by the two elements should be exactly equal for equal amount of power input. In order to achieve this, an adjustable magnet is provided on one or both elements so as to balance the torques produced by them. For adjustment, the coils are energised from a single phase supply. The pressure coils are connected in parallel and the current coils in series (but in phase opposition) so that the torque produced by the two elements oppose each other. The magnet kept near the edge is adjusted so that the two torques are equal and opposite and the disc does not rotate. The magnet placed near the edge of the disc produces a field in which the disc rotates causing an emf to be induced in it. This emf causes eddy currents which interact with the field of the magnet to produce a torque in opposition to the driving torque. The position of this magnet can be adjusted and so the net torque can be increased or decreased as required. Fig. 2.30 (b) shows electrical circuit and other details of a three phase three wire energy meter.

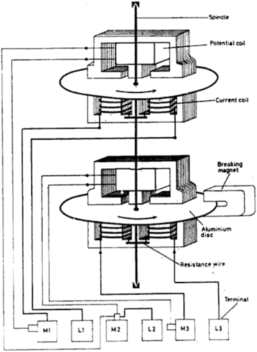


Fig. 2.30(b) Polyphase energy meter.

2.2.7 Current Transformre and Potential Transformer (C.T and P.T)

CT's and PT's are used for the purpose of extension of range of ammeters, voltmeters and wattmeters.

A current transformer is used to extend the range of an ammeter. See Fig. 2.31(a). Irrespective of the rating of the primary of a CT, the secondary is usually rated at 5A. The ammeter to be used is usually calibrated together with the current transformer.

A potential transformer of a voltage transformer is used to extend the range of a voltmeter. See Fig. 2.31(b). Whatever may be the primary rating of a PT, the secondary is usually rated at 110 V. The voltmeter to be used is usually calibrated along with the potential transformer.

Figs. 2.31, 2.33 and 2.34 show how an ammeter, voltmeter, wattmeter and watt-hour meter can be connected through a CT and PT in a circuit.

2.2.8 Extension of Range of D.C. Instruments

Range of d.c. instruments can be extended by using shunts and multipliers. Shunts are very low resistors used to extend the range of a D.C. (moving coil)

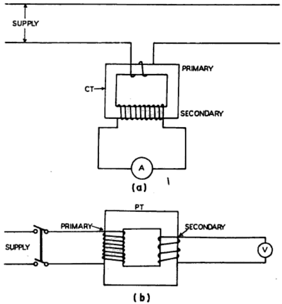


Fig. 2.31 (a) CT used to extend the range of an ammeter, (b) PT used to extend the range of a voltmeter

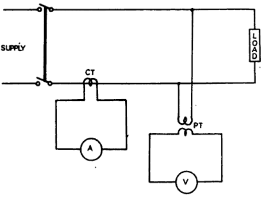


Fig. 2.32 Connection diagram of an ammeter and voltmeter through a CT and PT

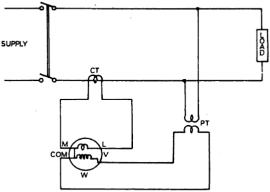


Fig. 2.33 Connection diagram of a wattmeter through a CT and PT

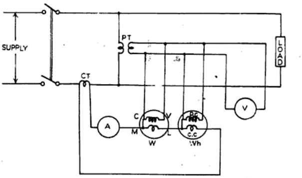


Fig. 2.34 Typical connection diagram of CT and PT and ammeter, voltmeter, wattmeter and watt-hour meter

ammeter. They are used in parallel with the ammeter and carry most of the main current.

Multipliers are non-inductive resistance used in series with the D.C. voltmeter to extend its range. A voltmeter of a lower range can be used for measuring higher voltage by the use of a proper multiplier resistance. The excessive voltage is dropped across the non-inductive resistance.

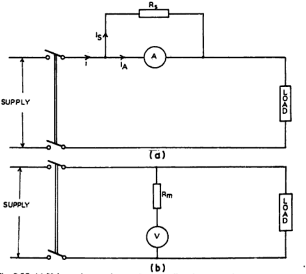


Fig. 2.35 **(a) Using a shunt resistance for extending the range of an ammeter, (b) Using a multiplier resistance for extending the range of a voltmeter**

3

Electrical Machine Drawing

This section deals with mechanical drawings of electrical machines and machine parts. This will include drawings of d.c. machines, induction machines, synchronous machines, fractional kW motors and transformers.

3.1 D.C. MACHINES

Fig. 3.1 shows the isometric cut view of a d.c. machine illustrating its different parts. The main parts are discussed in detail.

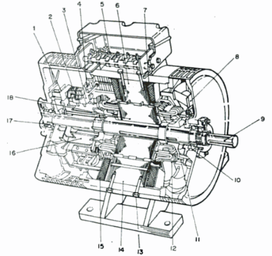
3.1.1 Stator

The stator is the stationary member and consists of the field system. The field system, comprising the field poles and the field windings, when excited by direct current, produces the magnetic field.

A pole is made up of laminated steel sheets. The pole core supports the field coil and the pole shoe spreads out the flux over a large portion of armature periphery. The stampings are made in such a shape as to include both pole core and pole shoe, and they are riveted together under hydraulic pressure. The laminations are 1 mm to 1.5 mm thick. The pole cores are then bolted to hollow cylindrical stator frame called yoke. Figs. 3.2 and 3.3 illustrate the arrangement clearly.

The yoke is built either of cast-iron or cast-steel. In small machines, the yoke is made in one piece, but in large machines, the yoke is made in two pieces. In large machines for convenience, the yoke is divided horizontally, and the two parts are bolted together. Such a frame is shown in Fig. 3.4.

The field winding or field coils are placed on the poles. For making field coils, copper wires or strips are wound on an adjustable former for the correct dimensions. Then the former is removed and the coil is made rigid by impregnating and taping. The coils are placed on the poles after providing proper insulation.



1. BRUSH BAR
2. BRUSHES
3. BRUSH HOLDER
4. BRUSH PRESSURE SPRING
5. TERMINALS (MAIN)
6. INTERPOLE
7. INTERPOLE COIL WINDING
8. FAN
9. DRIVING SHAFT
10. DRIVING END BEARING
11. FAN HUB
12. ARMATURE COILS (COMMUTATOR WINDING)
13. MAIN POLE BOLT
14. MAIN POLE
15. MAIN POLE COIL WINDING
16. COMMUTATOR SEGMENTS
17. COMMUATOR END BEARING
18. ARMATURE CORE

Fig. 3.1 Parts of a d.c. machine

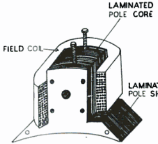


Fig. 3.2 Field pole and field coil

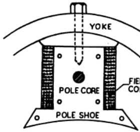


Fig. 3.3 Fixing arrangement of a pole to the yoke

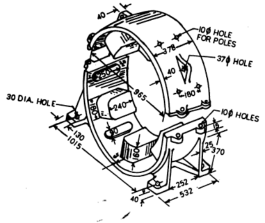


Fig. 3.4 Field magnet frame

3.1.2 Rotor

The rotor is the rotating member which houses the armature windings inside a large number of slots. The rotor of a d.c. machine is called the armature. The armature is a laminated cylinder and is mounted on a shaft. The armature laminations are about 0.4 mm to 0.6 mm thick and are insulated from one another. Slots are stamped on the periphery of the armature laminations. Holes are cut in laminations for air ducts which permit axial flow of air through the armature for cooling purpose. See Fig. 3.5. In small machines, the circular stampings are cut out in one piece and are keyed directly to the shaft. Fig. 3.6 (a) shows such a circular stamping. In large machines, however, the circular

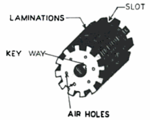


Fig. 3.5 Armature of a d.c. motor showing the laminations

laminations instead of being cut out in one piece, are cut in a number of suitable sections or segments, which form part of a complete ring.

Such a segmental lamination is shown in Fig. 3.6 (b).

The armature winding is placed inside the armature slots. Generally slots are of two types: (1) open type slots and (2) semi-closed type slots, as shown in Fig. 3.7. The slots are lined with tough insulating material such as paper or cotton tape. After this, coils are placed inside the slots and the slot insulation are folded over the armature conductors. The conductors in the slots are secured in their places by hard-wooden wedges or fibre-glass wedges. This is illustrated in Fig. 3.8.

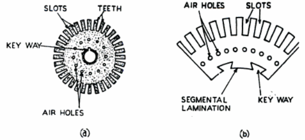


Fig. 3.6 (a) Circular stamping; (b) Segmental laminations

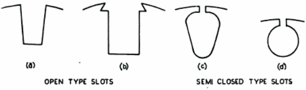


Fig. 3.7 Different types of slots

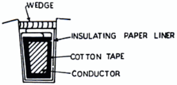


Fig. 3.8 Placing of conductor in a slot (open type)

3.1.3 Commutator

The commutator is an extension of the armature conductor themselves. Each armature coil is connected with each segment of the commutator. A commutator is a cylindrical body mounted on the shaft alongwith the armature. In fact, the armature core and the commutator form one single unit mounted on the shaft. The commutator is made up of wedge-shaped segments of hard drawn copper, arranged to form a cylinder. Mica insulation is provided between commutator segments. Fig. 3.9 shows a simple commutator construction.

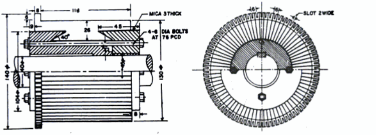


Fig. 3.9 Construction of a (simple) commutator

Brushes are placed on the commutator surface to supply or collect current to the armature coils through the commutator segments. Brushes are made of carbon and are housed in brush holders. A spring in the brush holder maintains the desirable pressure on carbon brushes so that proper contact is maintained between the brushes and the commutator surface. A box type brush and brush-holder unit has been shown in Fig. 1.28 (a).

3.1.4 Interpoles

These are small poles fixed to the yoke and spaced in between the main poles. The interpole winding consists of comparatively few turns of heavy gauge copper wire and is connected in series with the armature. The purpose of the interpole is to neutralize the armature reaction field. The interpoles, also known as auxiliary poles or commutating poles, are usually rectangular in shape. For fixing the coils, a shoe is screwed to it. An interpole and its coil are shown separately in Fig. 3.10.

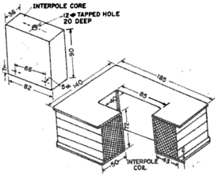


Fig. 3.10 Interpole core and coil of a dc machine

3.1.5 D.C. Motor Starters

Various types of manual face plate d.c. motor starters — commonly known as two-point, three-point, and four-point starters — are available. A degree of similarity exists among these starters. All have a face-plate rotary switch with a connected group of current limiting resistors. The difference lies in the form of protection they contain.

3.1.5.1 Two-point Starter: A two-point starter is used for starting a d.c. series motor, which has the problem of overspeeding due to the loss of load from its shaft. Such a starter is shown in Fig. 3.11. For starting the motor the control arm is moved clockwise from its OFF position to the ON position. The control

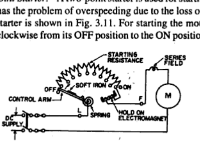


Fig. 3.11 Two point starter

arm is held in the ON position by an electromagnet. The hold-on electromagnet is connected in series with the armature circuit. If the motor loses its load, or if the supply voltage cuts off, the control arm returns to the OFF position. L and F are the two points of the starter which are connected with supply and motor terminals.

3.1.5.2 Three-point Starter: A three-point starter is used for starting a d.c. shunt or compound motor. The coil of the hold-on electromagnet is connected in series with the shunt field coil. Such a starter is shown in Fig. 3.12. In case the motor loses its field excitation, or if the supply voltage is low or is cut off, the control arm will return to its OFF position, due to the protection arrangement called no-volt release (NVR). Also if the motor is overloaded, the overload release (OLR) releases the starter arm to the OFF position. The complete circuit connection for a three-point starter with NVR and OLR is shown in Fig. 3.13. Points L, A and F are the terminals of a three-point starter. Use of a brass arc enables the connection of the field circuit directly with the supply.

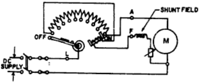


Fig. 3.12 Three-point starter

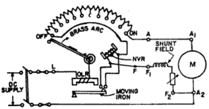


Fig. 3.13 A three-point starter with NVR and OLR

3.1.5.3 Four-point Starter: In a four-point starter the hold-on coil is connected across the line instead of in series with the shunt field circuit. This makes a wide range of field adjustment possible. The connection diagram of a four-point starter is shown in Fig. 3.14. No-volt release (NVR) and overload release (OLR) are also included in the circuit. The four terminals of the four-point starter are L_1, L_2, F and A.

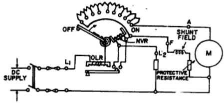


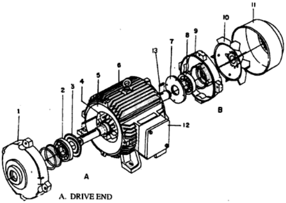
Fig. 3.14 A four-point starter with NVR and OLR arrangement

3.2 A.C. MACHINES

This section deals with the drawings of induction machines, alternators, single phase induction motors and transformers.

3.2.1 Induction Machines

The various parts of an induction machine is illustrated with the help of an exploded view of it as shown in Fig. 3.15.



A. DRIVE END
B. NON-DRIVE END
1. ENDSHIELD, DRIVE END
2. ROLLING-CONTACT BEARING, DRIVE END
3. SEALING RING
4. ROTOR
5. STATOR
6. CAST-METAL HOUSING
7. BEARING COVER, NON-DRIVE END
8. ROLLING-CONTACT BEARING, NON-DRIVE END
9. ENOSHIELD, NON-DRIVE END
10. INTEGRAL FAN
11. END COVER

Fig. 3.15 Exploded view showing the various parts of an induction machine

3.2.1.1 Different Types of Motor Enclosures

There are certain standardised type of motor enclosure. They are:

(a) *Open-protected type:* This type of enclosure is suitable where there is no unusual exposure of dust or damp. The enclosure provides free access of air and also provides sufficient mechanical protection. See Fig. 3.16.

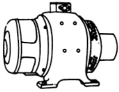


Fig. 3.16 Open-protected type enclosure

(b) *Semi-enclosed type or screen protected type:* In order to give additional protection to the motor, metal grids or perforated covers are provided as shown in Fig. 3.17. This will prevent particles being drawn inside which may cause short circuit or other type of damage to the motor.

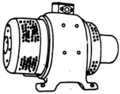


Fig. 3.17 Semi-enclosed type enclosure

(c) *Totally closed type:* In totally closed type motor enclosure design there will be no free circulation of air between inside and outside of the motor; however, the enclosure is not necessarily 'air tight'. A totally closed type motor enclosure is shown in Fig. 3.18. This type of enclosure is used in motors installed in mills and factories where there are dust and moisture in the environment.

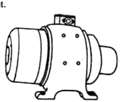


Fig. 3.18 Totally closed type enclosure

(d) *Totally-enclosed fan-cooled type:* In a totally-enclosed machine, an efficient method of cooling can be provided by a fan, driven by the motor itself, blowing external air over the cooling surfaces and through the cooling passages.

(e) *Drip-proof type:* In this type of enclosure the openings for ventilation are so provided as to prevent vertically falling water or dirt entering inside, as shown in Fig. 3.19.

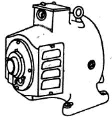


Fig. 3.19 Drip-proof type enclosure

(f) *Splash-proof type:* With such an enclosure, liquid or solid particles falling on or reaching any part of the machine at any angle between the vertically downward direction and 100° from that direction can not enter the machine.

(g) *Pipe-ventilated or duct-ventilated type:* In this type of enclosures, there is a continuous supply of fresh ventilating air. The frame is so arranged that ventilating are is conveyed to and from the machine through pipes or ducts attached to the enclosing case as shown in Fig. 3.20.

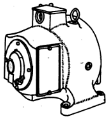


Fig. 3.20 Pipe or duct ventilated type enclosure

3.2.1.2 End-plates: The end-plates support the armature by means of bearings, cover the commutator, and carry the brush gear. The shape and dimension depend upon the type of machine. In open type enclosures the end plates are made open as shown in Fig. 3.21.

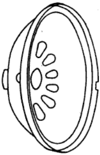


Fig. 3.21 View of an end-plate

In totally enclosed type, the end-plates are solid. Two end-plates are required, one at each end. They may be of the same shape or may differ in their shape.

Different types of motor enclosures and end plates as described, may be used for both ac and dc machines. Design of the suitable type of enclosure and end plates depends upon the atmospheric conditions where the motor is to be used.

3.2.1.3 Stator: The stator consists of the stator frame and the laminated stator core. Laminations of stator are made from high silicon steel and are separated from each other with varnish insulation.

Three-phase windings are housed in the slots punched round the inner periphery of the stator core. The slots are either of open-type or semi-closed type. The windings are made up of formed coils and are placed in insulated stator slots. Three single phase windings displaced in space by 120 deg. electrical, are connected either in star or in delta to form a three-phase winding. A partly wound induction motor stator is shown in Fig. 3.22.

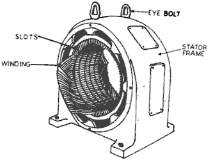


Fig. 3.22 Stator of an induction motor

3.2.1.4 Rotor: There are two types of rotors: (a) squirrel cage type and (b) wound rotor type or slip-ring type. Motors employing each type of rotor are named accordingly.

(a) *Squirrel cage rotor:* A squirrel cage rotor core is a laminated steel cylinder having closed or semi-closed slots in which heavy bars of copper or aluminium are inserted from one end. The rotor bars are shorted at both the ends by end-rings. The rotor slots are not made parallel to the rotor shaft but are skewed at a certain angle with the shaft to reduce the noise during motor operation, and to prevent magnetic locking or rotor with the stator. A cage type rotor showing the slots housing the rotor bars, and end-rings are shown in Fig. 3.23.

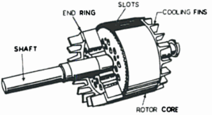


Fig. 3.23 Squirrel cage rotor of an induction motor

(b) *Wound-rotor:* A wound rotor, similar to the stator has slots which carry three-phase windings. The windings are connected in star. The three free ends of the windings are brought to three slip-rings mounted on the shaft. Under operating conditions, the rotor winding is short-circuited at the slip-rings. During starting period, additional resistance can be introduced in the rotor circuit, through brushes and slip-rings. A wound rotor of an inductor motor is shown in Fig. 3.24

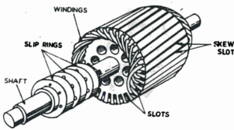


Fig. 3.24 Wound rotor of an induction motor

The rotor is placed inside the stator and is supported on both sides by two end-plates which house the bearings. For easy understanding, a simplified diagram of a slip-ring type induction motor has been shown in Fig. 3.25.

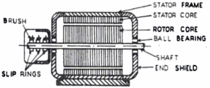


Fig. 3.25 Simplified diagram of a slip-ring induction motor

3.2.1.5 Slip-rings: Through slip-rings current is given to or taken out from the rotor. These are mostly made of brass or gun metal. Usually a slip-ring assembly will have three circular shape slip-rings. A slip-ring assembly with upper half in section is shown in Fig. 3.26.

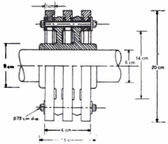


Fig. 3.26 Half-sectional elevation of a slip-ring assembly

3.2.1.6 Outside Dimensional Drawings of Induction Motor: As per IS: 1231-1974, the outside dimensions of an induction motor have been standardised. The end view and elevation (outside) of a foot mounted, 3-phase induction motor is shown in Fig. 3.27.

The different dimensions are indicated using letter symbols. The list of letter symbols is given as follows:

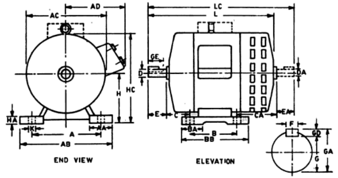


Fig. 3.27 End view and elevation of a three-phase induction motor

List of letter symbols

A	Distance between centre-lines of counting holes (end view)
AA	Width of end foot (end view)
AB	Over-all dimensions across feet (end view)
AC	Diameter of machine
AD	Distance from centre-line of machine to extreme outside of terminal box
B	Distance between centre-lines of fixing holes (elevation)
BA	Length of foot (elevation)
BB	Overall dimension across feet (elevation)
C	Distance from shoulder of shaft to centre-line of mounting holes in the nearest feet
CA	Distance from shoulder of second shaft to centre-line of mounting holes in the nearest feet
D	Diameter of shaft extension
DA	Diameter of second shaft extension
E	Length of shaft extension from shoulder
EA	Length of the second shaft extension from shoulder
F	Width of keyway
G	Distance of bottom from keyway to the opposite surface of the shaft extension
GA	Distance from the top of the key to the opposite surface of the shaft extension
GD	Thickness of key
GE	Length of keyway at the crown of shaft
H	Distance from centre-line of shaft to bottom of feet
HA	Thickness of feet
HC	Top of horizontal machine to bottom of feet

K Diameter of holes for width of slots in the feet of machine
L Overall length of the machine with single shaft extension
LC Overall length of the machine when there is a double shaft extension

Table 3.1 Gives the preferred values for the different dimensions represented by different letters.

Table 3.1 Preferred Values for Dimensions

Sl. No.	Frame	H (mm)	A (mm)	B (mm)	C (mm)	K (mm)	D (mm)	F (mm)	E (mm)
1	56	56	90	71	36	5.8	9	3	20
2	63	63	100	80	40	7	11	4	23
3	71	71	112	90	45	7	4	5	30
4	80	80	125	100	50	10	19	6	40
5	90 S	90	140	100	56	10	24	8	50
6	90 L	90	140	125	56	10	24	8	50
7	100 L	100	160	140	63	12	28	8	60
8	112 M	112	190	140	70	12	28	8	60
9	132 S	132	216	140	89	12	38	10	80
10	132 M	132	216	178	89	12	38	10	80
11	160 M	160	254	210	108	15	42	12	110
12	160 L	160	254	254	108	15	42	12	110
13	180 L	180	279	279	121	15	28	14	110
14	200 S	200	318	305	133	19	55	16	110
15	225 S	225	356	286	149	19	60	18	140
16	225 M	225	356	311	149	19	60	18	140
17	250 M	250	406	349	168	24	65	18	140
18	280 S	280	457	368	190	24	75	20	140
19	315 S	315	508	406	216	28	80	22	170
20	315 M	315	508	457	216	28	80	22	170

3.2.1.7 A.C. Motor Starters: Various methods of starting three-phase squirrel cage induction motors are discussed as follows:

(a) *Direct-on-line starting.* Direct-on-line (DOL) method of starting of induction motors, applicable upto a rating of 5 hp, is shown in Fig. 3.28. When the ON push button is pressed, the contactor coil A becomes energised. The motor gets connected across the supply mains through the main contacts of the contactor. The motor continues to get supply, even when the pressure on the push button is released, through the hold-on contact 'a' of the contactor. When the OFF push button is pressed, the coil gets de-energised, and the motor stops. A thermal overload relay has been used to protect the motor winding against overload. Fuses are provided for short circuit protection.

(b) *Auto-transformer starting:* An auto-transformer starter consists of an auto-transformer and a switch as shown in Fig. 3.29.

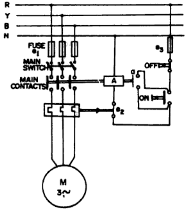


Fig. 3.28 Push button operated direct-on-line starter

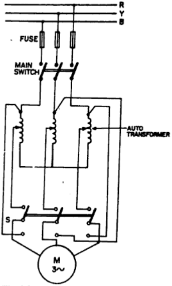


Fig. 3.29 A manual auto-transformer starter

When the switch S is put on START position, a reduced voltage is applied across the motor terminals. When the motor picks up speed, say to 80% of its normal speed, the switch is put to RUN position. Then the auto-transformer is cut out of the circuit and full rated voltage gets applied across the motor terminals. The auto-transformer may have more than one tapping to enable the user to select any suitable starting voltage depending upon the conditions.

3. *Star-delta method of starting:* The stator phase windings are first connected in star and full voltage is connected across the free terminals. As the motor picks up speed the windings are disconnected through a switch and they are reconnected in delta across the supply terminals. A simple manual star-delta starter is shown in Fig. 3.30 (a).

   Manual star-delta starters may also be designed using contactors and over-load relays as shown in Fig. 3.30 (b). In this type of star-delta starters when push button "P" is pressed and the handle of the starter switch S is brought to Y position, the contactor coil "A" gets energised. The stator winding terminals get star connected and receive three-phase supply. The motor starts rotating with the stator windings star connected.

   The starting current drawn from the lines will be only one-third of the current which the motor would have drawn if the windings were delta connected during starting. After the rotor has picked up speed the current drawn by the motor automatically gets reduced and, therefore, the windings are connected in delta turning the switch S to D position with the help of the handle. The pressure on the push button P can now be released. The contactor coil "A" remains energised by getting supply through the hold-on contact of the contactor A.

   The thermal over load relay contact "*e*" remains connected in series with the contactor coil for all the time of motor operation. In the event of any persistent over-load on the motor the thermal over-load relay will

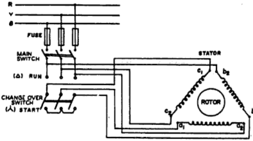


Fig. 3.30 (a) A manual star-delta starter

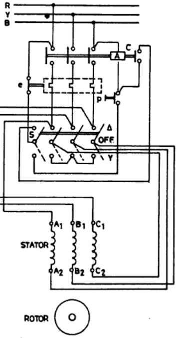


Fig. 3.30 (b)

operate, its contacts "*e*" will open and the contactor will get de-energised thereby switching off the motor.

Star-delta starter may be designed to be of semi-automatic type or of automatic type using contactors, push-buttons, etc. In the semi-automatic star-delta starter connection of stator windings in star is achieved by keeping the ON push-button pressed. At the instant when the ON push-button is released, the changeover from star to delta takes place. The power circuit diagram and the schematic diagram of the control circuit are shown in Fig. 3.31 (a) and (b).

The automatic star-delta starter uses time-delay relay (TDR) through which star to delta connections take place automatically with some pre-fixed time delay. The schematic diagram of the control circuit is shown in Fig. 3.32.

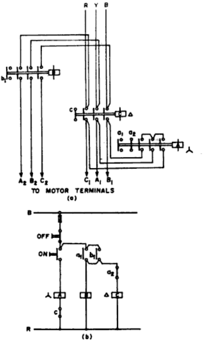


Fig. 3.31 (a) Power circuit diagram; (b) Schematic diagram of control circuit of a semi automatic star-delta starter

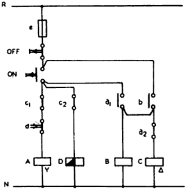


Fig. 3.32 Schematic diagram of the control circuit of an automatic star-delta starter

3.2.1.8 Starting of Wound Rotor (Slip-ring) Induction Motors: An extra starting resistance is connected across the slip-ring terminals of the rotor while starting. The connection diagram is shown in Fig. 3.33.

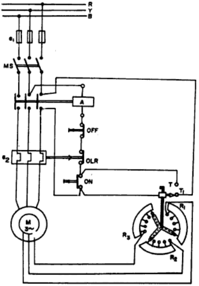


Fig. 3.33 Slip-ring induction motor starter

When the ON push button is pressed, the contactor A gets energised. As the motor starts rotating, the full extra resistance gets connected to the rotor circuit. As the resistance is gradually cut out, the position of the switch changes from T_1 to T, and acts as 'hold-on' to the push button. At RUN position, the full resistance is cut out, and the motor attains rated speed.

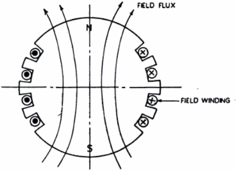
3.2.2 Alternators

A synchronous generator is also referred to as an alternator since it generates alternating voltage. An alternator like any other electrical rotating machine has two main parts *viz.*, the stator and the rotor. In a synchronous generator, the armature winding is placed on the stator slots. The rotor carries the field poles.

3.2.2.1 Stator: The stator consists of stator core and stator frame. Stator core is built up of laminations of special magnetic iron or steel alloy. Laminations are cut out in complete rings or in segments. The slots for housing the armature conductors lie along the linear periphery of the core. The stator core is held by the outer frame, called the yoke. Three-phase windings are placed on the stator slots wound for a particular number of poles.

3.2.2.2 Rotor: The rotor carries the field poles, which produce the required magnetic lines of force. The construction of the rotor may be made (a) non-salient type (cylindrical type) or (b) salient type (projected type). Type of rotor construction depends upon the type of prime mover used to drive the alternator.

(a) *Non-salient pole type rotor:* For alternators using high speed turbines (3000 rpm) like steam turbines as prime movers the number of rotor poles required to generate electricity at 50 Hz is only two. Non-salient (cylindrical) type rotor construction is made for such alternators. In this case, the poles do not project out from the surface of the rotor. The length of such a rotor is more than its diameter. Simplified representation and isometric view of such a rotor are shown in Fig. 3.34 (a) and (b).



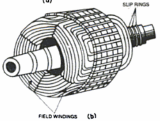
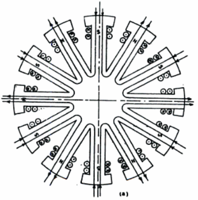
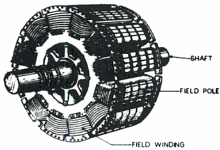


Fig. 3.34 (a) Simplified representation of non-salient pole type rotor; (b) Isometric view

(b) *Salient pole type rotor:* Alternators driven by low-speed prime movers like water turbines and medium-speed prime-movers like diesel engines will have salient-pole rotors. This is because, to generate electricity at 50 Hz the number of rotor poles required becomes more. Salient pole (projected pole) rotor construction is convenient in such a case. For such a rotor the diameter is bigger than its length. Figs. 3.35 (a) and (b) illustrate such a rotor.


(a)



(b)

Fig. 3.35 (a) Simplified representation of a salient pole type rotor; (b) Isometric view

3.2.3 Single Phase Induction Motors

Single phase motors are manufactured in fractional kilowatt (fractional horsepower) range to be operated on single phase supply. Hence they are also called fractional kilowatt (FKW) motors. These motors are classified on the basis of their construction and starting methods employed.

A single phase induction motor physically looks similar to that of a three-phase induction motor except that its stator is provided with a single phase winding. The rotor is identical to the short-circuited squirrel cage rotor. There is uniform air-gap between the rotor and the stator. The stator slots are distributed uniformly and usually a single phase double layer winding is employed.

A simple single phase winding would produce no rotating magnetic field, and no starting torque. Therefore, it is necessary to modify or split the stator winding into two parts, each displaced in space on the stator to make the motor self-starting.

Single phase rotors are classified into:

(a) Split-phase type;

(b) Capacitor type; and

(c) Shaded pole type.

The above classification is based on the starting methods employed.

3.2.3.1 Split-phase Induction Motors: In a split-phase induction motor, in addition to the main single phase winding, an auxiliary winding is provided on the stator slots. Both of them are connected in parallel to the single phase a.c. supply. The main (running) winding and the auxiliary (starting) winding are distributed uniformly around the stator in slots and are displaced in space by 90° electrical from each other. See Fig. 3.36.

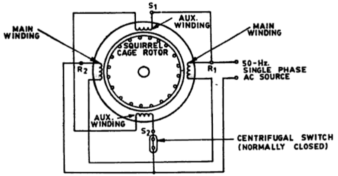


Fig. 3.36 Split-phase induction motor

3.2.3.2 Capacitor Motor: In capacitor motors, a capacitor is connected in the auxiliary (starting) winding circuit to produce a time phase difference between the currents of the main winding and the auxiliary winding. There are different types of capacitor motors.

3.2.3.3 Shaded Pole single Phase Motor: Shaded pole single phase motors have salient poles on the stator and a squirrel cage type rotor. Short-circuited coils known as shading coils are fixed on one portion of each pole. A pole on which a shading ring is fixed is called shaded pole. Shading coils may be of thick single turn in the form of a ring or may have a number of short circuited turns. The poles are excited by applying single-phase supply to the field coils connected in series. Fig. 3.37 shows a shaded pole motor.

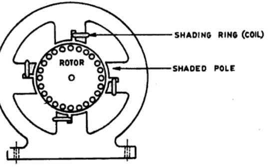


Fig. 3.37 Shaded pole single phase motor

3.2.4 Transformers

A transformer is an electrical device having no moving parts. It transfers electrical energy from one circuit to another at the same frequency, by electromagnetic induction. In its simplest form it consists of two windings insulated from each other and wound on a common core made up of magnetic material such as silicon steel.

3.2.4.1 Components of a Transformer: The main components of a transformer are: (i) Magnetic core, (ii) Windings.

(i) *Magnetic core:* The magnetic circuit of the transformer may be core-type or shell-type. A core-type transformer is one in which there is only one iron path and the windings are wound on two opposite limbs. In shell-type construction, there are two parallel magnetic paths and the primary and secondary windings are wound on the central limb one above the other.

In short, a core-type transformer is one in which the iron core is surrounded by windings, whereas a shell-type transformer is one in which the windings are surrounded by iron core. Fig. 3.38 (a) and 3.38 (b) illustrate both these types of transformers.

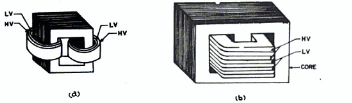


Fig. 3.38 (a) Single phase core-type transformer; (b) Single phase shell-type transformer

The core is built from thin silicon sheet steel laminations, cut into particular sizes and shapes and stacked together. Laminated sheets are insulated from each other by applying a thick layer of varnish insulation on them. The thickness of lamination used is 0.4 mm or less.

A small size core type transformer will have rectangular limbs, whereas a large size transformer will have circular limbs. Circular shape of the limbs is obtained by using laminations of different widths. Fig. 3.39 shows the various shapes *i.e.*, Square, Cruciform, Three-stepped, Four-stepped, etc. of the core limb which are used in practice.

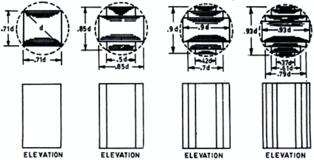


Fig. 3.39 Various shapes of the core sections

The core-construction of a three-phase transformer is similar to a single phase one. A three limbed core is used on which the three-phase windings are placed.

Three-phase transformers are usually built core-type. Fig. 3.40 shows a three-phase core-type transformer.

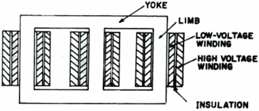


Fig. 3.40 Three-phase core-type transformer

(ii) *Windings:* There are two windings in a transformer. The winding to which voltage is applied is known as primary winding, and the other winding is known as secondary winding.
These windings are also referred to as high voltage and low voltage windings depending upon the voltage applied to the winding.
The primary and secondary windings are made of a series of multiturn coils, would round the core. The coils of transformer windings are generally of two main types *viz.*, (i) Cylindrical concentric coils and (ii) Sandwitch coils.

3.2.4.2 Core and Coil Assembly: In core-type transformers, the primary and secondary windings are mounted concentrically on the limbs using cylindrical coils taking up the whole length of the transformer core limb as shown in Fig. 3.41. To make the core limb circular in shape, insulating material like empire cloth is wrapped round the core, or any other insulating material is used to fill in the space. The low voltage winding is placed nearer to the core, as it requires less insulation between the core and the windings. The high voltage winding is placed concentric to the low voltage winding, and sufficient insulation is provided in between them. In oil-immersed type transformers, a bakelite cylinder is provided between high voltage and low voltage windings having oil ducts which facilitates oil circulation and provides better insulation. This

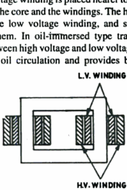


Fig. 3.41 Winding configuration in a core type transformer

bakelite cylinder is kept in position by placing bakelite rectangular pieces along the height of the winding between the bakelite cylinder and high voltage winding. Bakelite or metal rings, wooden packings, may always be used on the core limb above and below the winding.

After assembling the core and coil, the core yoke at the top and bottom are held tight by means of channels. The core and coil assembly of a three-phase transformer, as shown in Fig. 3.42, illustrates this clearly.

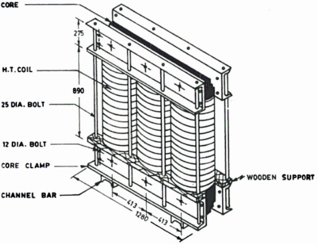


Fig. 3.42 Core and coil assembly of a three-phase transformer

In shell-type transformers a series of flat coils of primary and secondary winding sections are placed one above the other on the core limb as shown in Fig. 3.43.

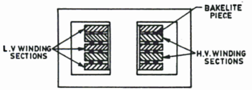


Fig. 3.43 Winding configuration of a shell type transformer

Proper insulation is provided between each winding section. The low voltage winding sections placed at the two ends have half the number of turns of the normal low voltage sections. This is to reduce the insulating material required between the core yoke and the winding sections.

3.2.4.3 Cooling Arrangement in Transformers: Air cooling method is used for cooling small low-voltage transformers, whereas transformers with high ratings are oil-cooled. Oil, in addition to cooling, provides insulation to the windings. The transformer is placed inside a tank filled with transformer oil and the tank is sealed. Heat is radiated to the atmosphere through the outside surface of the transformer tank.

To increase the radiating area, hollow tubes or fins are provided with the transformer tank. Oil circulates through these radiating tubes or fins and accelerates heat dissipation. Fig. 3.44 shows a transformer oil tank with radiating tubes.

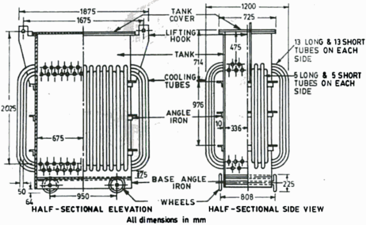


Fig. 3.44 Transformer oil tank. (a) Half-sectional elevation; (b) Half-sectional side view

3.2.4.4 Terminal Bushings: Ordinary porcelain insulators are used at the high voltage terminals of the transformers upto about 33 kV rating. For higher than 33 kV, to prevent faults due to flashover between the conductor and the metal tank, two types of bushings are mainly used. They are (i) Oil-filled bushing and (ii) Condenser type bushing.

(i) *Oil-filled bushing:* This type of terminal bushings consists of a hallow cylinder made up of annular rings of porcelain, with a conductor through its centre. The porcelain hollow cylinder is filled with oil. To prevent suspended particles in the oil to line up and cause breakdown, bakelite tubes surround the conductor concentrically. Such a bushing is shown in Fig. 3.45.

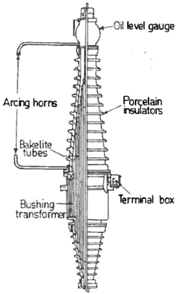


Fig. 3.45 Oil-filled bushings

(ii) *Condenser type bushing:* In this type of high voltage bushings the conductor at the centre is wound with alternate layers of bakelised paper and tin foil. A series of capacitors are formed by these tin foil layers. The axial length of the layers is reduced as the radius increases, for the capacitances to be made equal. See Fig. 3.46. Such an arrangement will provide uniform field strength between conductor and earth.

3.3 SOLVED EXAMPLES

Example 1. Fig. 3.47 shows isometric view of a pole with shoe and the isometric view in section of the field coil of a d.c. machine. Draw the full plan, and half sectional elevation of the assembly view of the field pole and field coil.

Solution. The full plan and half sectional elevation of the assembly view of the field pole and field coil are shown in Fig. 3.48. All dimensions mentioned in the figure are in mm.

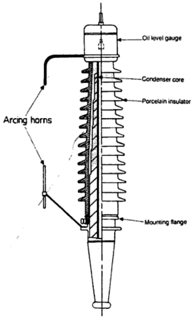


Fig. 3.46 Condenser type bushing

Example 2. Draw the side view and upper half sectional elevation of the armature of a d.c. machine with the main dimensions given below:

Outside diameter	= 100 cm
Inside diameter	= 58 cm
Length of armature core	= 28 cm
Length of armature with spider.	= 54 cm
Number of slot	= 56
Size of slot	= 3.5 × 1.5 cm
Diameter of the shaft	= 14 cm

The armature stampings are mounted on a cast iron spider keyed to the shaft and clamped between end plates. All dimensions are in cm.

Solution. The side view and half sectional elevation are shown in Fig. 3.49.

Example 3. Make a suitable sketch of a 10 hp squirrel cage induction motor and show the various parts of the motor.

Solution. See Fig. 3.50.

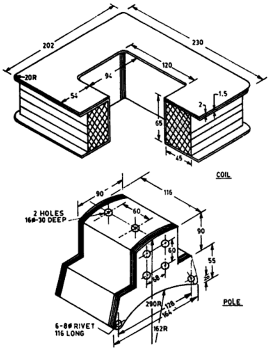


Fig. 3.47 Isometric views of a pole with shoe and a field coil of a d.c. machine

Example 4. The half sectional elevation and half-sectional end view of an alternator with salient pole rotor having four poles are shown in Fig. 3.51. Redraw the figure and mark the various parts of the machine.

Solution. See Fig. 3.51

Example 5. Part sectional elevation of an end-cover is shown in Fig. 3.52. Draw the end view looking from the open side of the end cover.

Solution. See Fig. 3.53.

Example 6. The half-section elevation and half-sectional end view of a shaded pole type single phase induction motor is shown in Fig. 3.54 (a). Redraw the figure and mark the various parts of the machine.

Solution. See Fig. 3.54 (a)

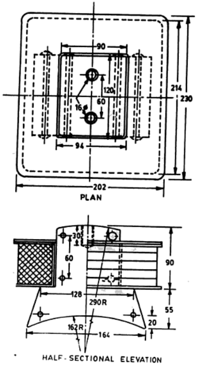


Fig. 3.48 Plan and half sectional elevation of the assembly view of the field pole and field coil of a d.c. machine of figure 3.47 (Solution of example 1)

Example 7. Draw two views (in half section) of a single phase capacitor type induction motor used in certain specific application.

Solution. Fig. 3.54 (b) shows two half sectional views of a Bracket fan type single phase induction motor. The main dimensions of the motor have been shown in the figure. The motor is rated at 60 watts. All dimensions shown are in MM.

Example 8. Draw the full-sectional elevation, sectional plan and sectional end view of the core and yoke assembly of a three-phase transformer as per dimensions given below. Show clearly the method of fixing the core and yoke. All dimensions are in mm.

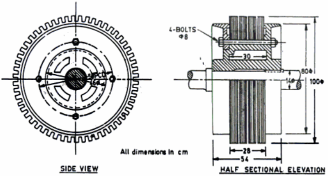


Fig. 3.49 Side view and half sectional elevation of the armature of a d.c. machine (Solution of example 2)

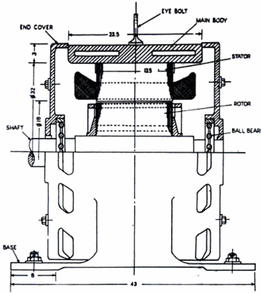


Fig. 3.50 Induction motor assembly (Solution of example 3)

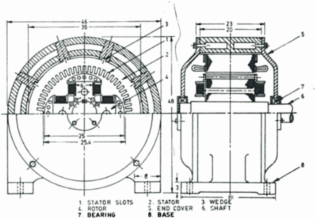


Fig. 3.51 Elevation and end view in half sections of an alternator (Example 4)

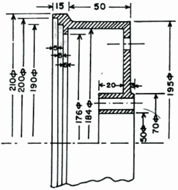


Fig. 3.52 Sectional elevation (part) of an end cover (Example 5)

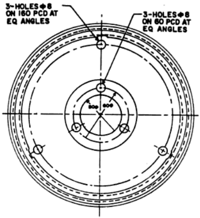


Fig. 3.53 End-view (looking from the open side) of the end-cover (Solution of example 5)

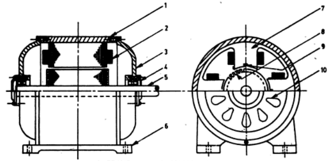


Fig. 3.54 (a) Shaded pole single phase motor (Example 6)

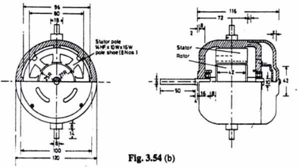


Fig. 3.54 (b)

Core : 3 step construction
Core diameter D = 26 mm
Height of the core = 55 mm
Height of the yoke = 28 mm
Length of the yoke = 110 mm

Solution: See Fig. 3.55

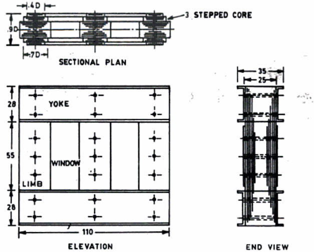


Fig. 3.55 Three views in section of a three-phase transformer (Example 8)

3.4 EXERCISES

1. The isometric view of a field magnet frame had been shown in Fig. 3.54. Draw the elevation and side view and mark the different parts.
2. The detailed isometric views of the interpole, pin and the interpole coil in section are shown in Fig. 3.56. Draw the following views of the interpole and coil assembly.
   (a) Plan
   (b) Elevation left half in section
   (c) End view right half in section

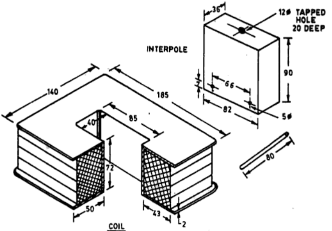
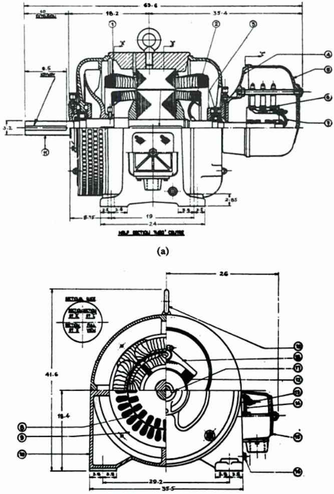


Fig. 3.56 Isometric views of interpole, pin, and interpole coil in section of a d.c. machine

3. The half-sectional elevation and the sectional end view of a slip-ring induction motor are shown in Fig. 3.57. Redraw the figure choosing a convenient scale and show the different parts of the motor.
4. Fig. 3.58 shows the half-sectional elevation of the slip ring assembly of an induction motor. With the help of the dimensions indicated, redraw the figure and also the end view.
5. Draw a neat sketch of a foot-mounted, three-phase induction motor showing both elevation and side view. Show the following dimensions on it as per Indian Standard Specifications.



(a)

(b)

Fig. 3.57 Half-sectional elevation and sectional end view of slip-ring induction motor

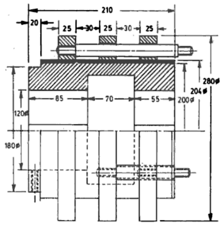


Fig. 3.58 Half-sectional elevation of slip-ring assembly of an induction motor

(i) Distance from centre-line of shaft to bottom of feet (H)

(ii) Distance between centre-line of mounting holes (A)

(iii) Overall dimension across feet (BB)

(iv) Diameter of shaft extension (D)

(v) Overall length of machine with single shaft extension (L)

(vi) Distance from shoulder of shaft to centre-line of mounting holes in the nearest feet (C)

(vii) Length of the second shaft extension from shoulder (EA)

(viii) Overall length of the machine when there is a double shaft extension (LC)

6. Fig. 3.59 shows a single phase core type transformer in plan and elevation indicating clearly the dimensions on it as per ISS.

   (a) Redraw the Fig. 3.59 on a different scale.

   (b) Draw a diagramatic representation of three-phase core type transformer in plan and elevation and mark the dimensions on it.

7. Redraw the transformer tank as in Fig. 3.44 choosing a convenient scale.

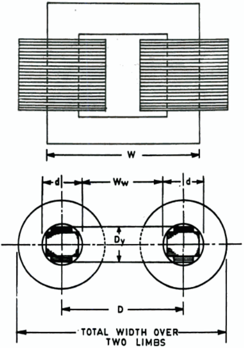


Fig. 3.59 Single phase core type transformer

8. The half-sectional elevation of the armature of a large d.c. machine is shown in Fig. 3.60. Draw the end view of the armature. There are 60 slots each having a depth of 60 mm.
9. The isometric view of a half cut squirrel cage rotor and the details of the rotor stampings, fan blade etc. are shown in Fig. 3.61. Draw the full-sectional elevation and half-sectional end view.

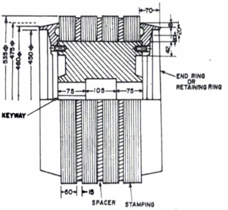


Fig. 3.60 Half sectional elevation of the armature of a large d.c. machine

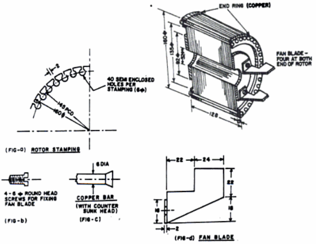


Fig. 3.61 Half cut squirrel cage rotor of an induction motor with other details

4

Panel Wiring Diagrams

The instruments and accessories required to control and measure electrical quantities are properly arranged on a panel board. The accessories like switches, fuses, regulators, supply indicators, relays for protection of equipments and various meters for measuring the different parameters are all mounted on a steel sheet cubicle, and the necessary connections and wiring are also done. Switch board panels are named after the purpose for which these are used. In this chapter, the switch board panels for controlling d.c. generators, alternators, transmission lines etc., will be discussed.

4.1 D.C. GENERATOR PANELS

A d.c. generator is connected to the busbars through a control panel as shown in Fig. 4.1. As the main switch is switched ON, the busbars become live and they feed the outgoing feeders. A voltmeter is connected across the main leads at the generator side of the double pole knife switch, so that it shows the voltage of the machine, even when the switch is open. In Fig. 4.1(a) the front view of a panel board is shown. The wiring diagram is shown in Fig. 4.1(b).

4.1.1 Switch Board Panel for Parallel Operation of Compound Generators

Wiring diagram of a switch board panel for parallel operation of two d.c. compound generators is shown in Fig. 4.2. For paralleling two d.c. generators the generated voltage of both the machines should be the same. Usually two voltmeters are used for the two generators. In Fig. 4.2, however, only one voltmeter has been employed. When the voltmeter plug is inserted in the voltmeter socket (VS), the voltage of each machine can be read separately. At the instant when voltages of the two machines are same, the switch is put on, and the machines run in parallel.

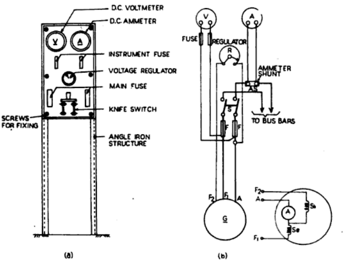


Fig. 4.1 DC generator switch board panel: (a) Front view of a panel; (b) Connection diagram

4.2 ALTERNATOR PANELS

In power stations a number of alternators run in parallel. All the alternators are synchronised with a common busbar. If another alternator is to be added, it should be synchronised either (a) by using three-lamp method, or (b) by using a synchroscope.

Before connecting an alternator in parallel with the busbars, the following conditions are to be fulfilled:

(i) The generated voltage of the incoming alternator should be same as the busbar voltage.

(ii) The frequency and phase-sequence of the voltage of the alternator should be same as that of the busbar voltage.

4.2.1 Three-lamp Method of Synchronising

Three-pairs of lamps are connected between the alternator and busbar, as shown in Fig. 4.3. One pair of lamps are connected between the R phases of the alternator and the busbar. Other two pairs of lamps are connected between the Y-phase of the alternator and the B-phase of the busbar and vice-versa. At the moment of synchronisation, the lamps connected in phases RR will be dark whereas the other two pairs of lamps will be bright.

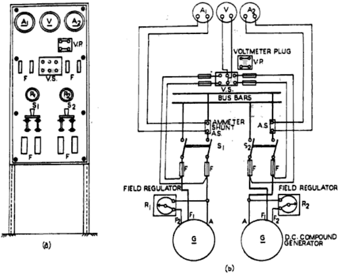


Fig. 4.2 Panel diagram for parallel operation of two d.c. compound generators: (a) Front view of panel, (b) Connection diagram

4.2.2 Synchronising Using a Synchroscope

A synchroscope determines the instant of synchronism more accurately than the three-lamp method. A synchroscope consists of a moving coil and a fixed coil, one of which is connected to the incoming alternator and the other to the busbar through switches S_1 and S_2 as shown in Fig. 4.4. If there is difference in frequencies of the incoming alternator and the busbar, the synchroscope pointer will rotate. Anti-clockwise rotation of the synchroscope pointer indicates that the frequency of the alternator is lower, whereas clockwise rotation of the pointer indicates that the frequency is higher than the busbar frequency. Voltmeter 'V' can be used to read either the busbar voltage or the generator voltage by means of a two-way switch.

For high-voltage machines, potential transformers are used to measure the voltage. The incoming machine is first synchronized on auxiliary synchronising busbars. This is done to avoid disturbance when the machine is switched on to main busbars. Such an arrangement with other protection and metering arrangements of an alternator panel is shown in Fig. 4.5.

Note: Following are the symbols and their names used in Fig. 4.5 and 4.6

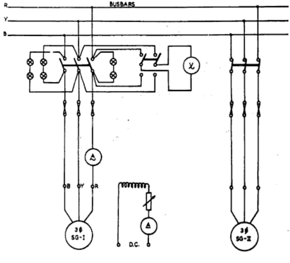


Fig. 4.3 Synchronising of 3-phase alternator by three-lamp method

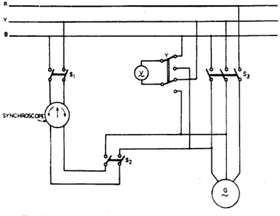


Fig. 4.4 Synchronising of an alternator using a synchroscope

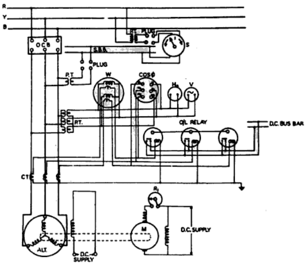


Fig. 4.5 Alternator panel wiring diagram

Hz	Frequency meter
V	Voltmeter
A	Ammeter
W	Wattmeter
P.F.	Powerfactor meter
S	Synchroscope
SBB	Synchronising busbar
R_1	Voltage regulator
OCB	Oil circuit breaker
CT	Current transformer
PT	Potential transformer
Alt	Alternator
M	DC Motor
O/L	Overload relay.

4.3 CONTROL PANEL IN A SUB-STATION

In a sub-station, a feeder is coming from a distant generating station and the voltage is stepped down through a step-down transformer. The incoming feeder is received through an OCB to the transformer. The protection and measuring accessories included in such an OCB panel are shown in Fig. 4.6.

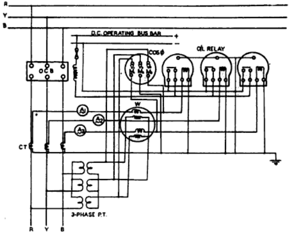


Fig. 4.6 OCB panel for a sub-station

4.4 EXERCISES

1. Draw the front view and the connection diagram of a d.c. generator switchboard panel with voltmeter, ammeter, etc.
2. Draw the wiring diagram of an alternator panel with protection and metering arrangements including arrangement for synchronisation with the busbar.
3. Draw the panel diagram for parallel operation of two d.c. compound generators.
4. Draw the panel wiring diagram for an alternator to be synchronised with the bus-bars either through a synchroscope or through three lamp method.
5. Design and draw panel wiring diagram for installation of an emergency supply diesel-generator set for an existing electrical installation.
6. Design and draw a panel board wiring diagram for an electrical laboratory having provision to giving dc and both 3-phase and 1-phase supply to the machines and switching arrangement for connecting electrical loads. Provision should also be made for connecting measuring instruments.

5

Winding Diagrams

Electrical machines usually employ windings distributed in slots over the circumference of the armature core. It is this armature winding in which emfs are induced. The armature winding is made up of a group of conductors connected together in different types of series — parallel combinations. In a d.c. winding, conductors are connected together to form a closed loop or series of loops. But an a.c. winding may be closed in case of delta connected windings or open in the case of star connected windings. All these different types of windings are discussed as follows.

5.1 LAP AND WAVE WINDINGS FOR DC MACHINES

Definitions of certain important terms used in windings are given below:

(a) *Pole-pitch (Y_p):* Med ís the distance between the centre of two adjacent poles. It is the number of slots per pole or the number of coil-sides per pole. See Fig. 5.1.

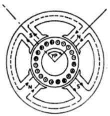


Fig. 5.1 Pole Pitch

$$\text{Pole-pitch} = \frac{\text{Number of slots in a machine}}{\text{Number of poles}}$$

$$= \frac{\text{Number of coil–sides in a machine}}{\text{Number of poles}}$$

(b) *Back-pitch (Y_b):* Is the distance measured in terms of number of armature conductors (coil-sides) between the two coil-sides of a coil measured around the back of the armature; *i.e.*, away from the commutator end of the armature. See Fig. 5.2.

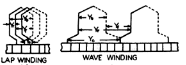


Fig. 5.2 Figure showing Y_b, Y_f, Y_r, Y_c in (a) Lap-winding (b) Wave winding

(c) *Front pitch (Y_f):* is the distance between two coil-sides connected to the same commutator segment.

(d) *Resultant pitch (Y_r):* Med is defined as the distance in terms of the number of coil-sides between the start of one coil and the start of the next coil to which it is connected. This is also known as winding pitch.

(e) *Commutator pitch (Y_c):* Med is the distance measured in terms of commutator segments between the segments to which the two ends of a coil are connected. For a simplex winding $Y_c = 1$, and for a duplex winding $Y_c = 2$.

Depending upon the method of connecting coils together, the windings are classified into (i) Lap winding and (ii) Wave winding.

5.1.1 Lap Winding

In a lap winding the finishing end of one coil is connected via the commutator segment to the starting end of the adjacent coil situated under the same pole. As the sides of the successive coils overlap each other, this type of winding is called as lap winding. Following are the characteristics of a lap winding:

(a) The back pitch (Y_b) and front pitch (Y_f) must be odd.

(b) The average pitch should be equal to the pole-pitch

i.e. $$Y_a = \frac{Y_b + Y_f}{2} = \frac{Z}{P}$$

where Z is the number of conductors, and P is the number of poles.

(c) $Y_b = Y_f \pm 2\,Y_c$

When Y_b is greater than Y_f, the winding is progressive, and when Y_b is less than Y_f, the winding is retrogressive.

For a simplex lap winding, $Y_c = 1$

i.e. $$Y_b = Y_f \pm 2 \text{ or } Y_b - Y_f = \pm 2$$

(d) The resultant pitch is always even, being the difference of two odd numbers.

(e) The number of parallel paths in the armature winding for a simplex lap winding is equal to the number of poles P.

5.1.2 Equalisers for Lap Windings

In a lap winding, the number of parallel paths is equal to the number of poles. The emf's induced in each parallel path may not be exactly equal. This will cause internal circulating currents in the armature circuit and in the brushes. This could cause excessive heating, sparking at the brushes and mechanical vibration. To overcome this problem equaliser connections are provided to bypass the circulating current in the parallel paths. Such points on the windings are connected together which should under ideal conditions be exactly at the same potential. Equalisers are low resistance copper conductor rings provided at the back of the armature.

$$\text{No. of equaliser rings} = \frac{\text{No. of coil-sides per pole}}{2}$$

No. of connections to one equaliser ring = no. of pair of poles.

As an example, a winding diagram for a d.c. machine has been shown as under:

Example 1. Design and draw a developed winding diagram for a 16 slots, double layer, 4 pole, d.c. lap winding. Make provision for equaliser rings.

Solution. No. of conductors or coil-sides $Z = 16 \times 2 = 32$

No. of poles $P = 4$

We know that $Y_a = \dfrac{Y_b + Y_f}{2} = \dfrac{Z}{P} = \dfrac{32}{4} = 8$

$$Y_b + Y_f = 16$$

For a simplex progressive lap winding $Y_b - Y_f = 2$

$$Y_b + Y_f = 16$$

$$Y_b - Y_f = 2$$

Adding the two equations,

$$2\,Y_b = 18, \text{ i.e., } Y_b = 9 \text{ and } Y_f = 7$$

$$\text{No. of equaliser rings} = \frac{\text{No. of coil-sides per pole}}{2}$$

$$\frac{Z}{2P} = \frac{32}{2 \times 4} = 4$$

No. of connections each equaliser ring = No. of pair of poles

$$= 2$$

Fig. 5.3 shows the developed winding diagram and Fig. 5.4 shows the schematic diagram of the winding.

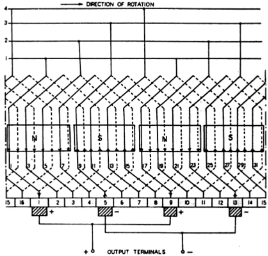


Fig. 5.3 Developed lap winding diagram

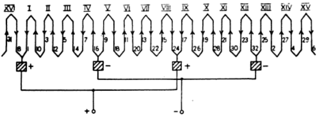


Fig. 5.4 Schematic diagram of the above winding

The sixteen coils are divided into four parallel paths as shown in Fig. 5.5.

5.1.3 Wave Windings

In a wave winding, a coil-side under one pole is connected to a second coil-side which approximately occupies the same position under the next pole through

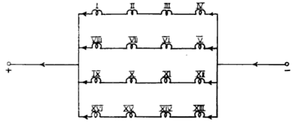


Fig. 5.5 Schematic diagram showing the four parallel paths

back connection. The second coil-side is then connected forward to another coil-side under the next pole.

The characteristics of a wave winding are:

(a) Both back pitch (Y_b) and front pitch (Y_f) should be odd numbers.

(b) Average pitch $Y_a = \dfrac{Y_b + Y_f}{2} = \dfrac{Z \pm 2}{P}$

If Y_a is taken equal to Z/P, the winding will close itself without including all the coils, which is not desirable.

(c) Average pitch should be a whole number. To make it a whole number, wave winding is not possible with any number of coil-sides. Further, if standard stampings with a definite number of slots are to be used, the coil-sides need to be placed in all the slots. In such cases, the extra coils are left unconnected and are called dummy coils.

In the example to follows, we shall see how a wave winding diagram is made.

Example 2. Design and draw the winding diagram for a 4 pole, 13 slots, double layer, wave winding with 13 commutator segments.

Solution. No. of conductors $Z = 13 \times 2 = 26$

No. of poles $P = 4$

$$\text{We know that } Y_a = \frac{Y_b + Y_f}{2} = \frac{Z \pm 2}{P}$$

$$= \frac{26 \pm 2}{4}$$

$$= 7 \text{ or } 6$$

Since Y_b and Y_f have to be odd integers, $Y_b = Y_f = 7$

Figs. 5.6 and 5.7 show the developed wave winding diagram and schematic diagram respectively.

We know that, in a wave winding, the coils are divided into only two parallel paths. In Fig. 5.8 the two parallel paths are shown.

5.2 A.C. MACHINE WINDINGS

Basically the a.c. machine winding and the d.c. machine winding are identical, but in an a.c. winding the commutator and its connections are not required. The standard d.c. winding is a closed loop, *i.e.*, it closes in itself. A.C. windings may be open, in the case of star connected windings, and closed in the case of delta connected windings.

A.C. winding is designed so as to give a sinusoidal emf as near as possible. A.C. windings can be single phase or polyphase. In a three-phase winding, there are three identical separate windings displaced 120° from each other. The

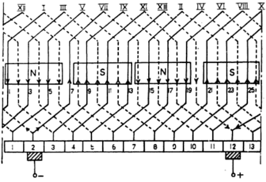


Fig 5.6 Developed wave winding diagram

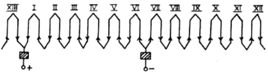


Fig. 5.7 Schematic diagram of the wave winding of Fig 5.6

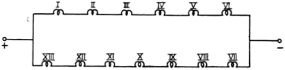


Fig. 5.8 Schematic diagram showing the two parallel paths

three-phase windings are wound for a particular number of poles, depending upon the speed requirement. The classification of different types of windings are as follows.

- AC windings
  - Three phase windings
    - Single layer
      - Mush type
      - Concentric type
        - Unbifurcated
        - Bifurcated
    - Double layer
      - Lap winding
      - Wave winding
        - (Lap winding and Wave winding)
          - Integral slot
            - Full chorded
            - Short chorded
          - Fractional slot
  - Single phase windings

Before giving the details of different types of winding, definition of some of the important terms used in ac windings are provided as follows:

(a) *Slots per pole per phase (spp):* To divide the slots around the armature periphery into different phase-groups, slots per pole per phase is used. If spp = 3, then one phase group consists of three slots. If spp is an integer, then the winding is referred to as integral slot winding and if spp is a fractional number, then it is a fractional slot winding.

(b) *Coil-pitch or coil-span:* Coil pitch or coil-span is the distance between two active sides of a coil in terms of slots. See Fig. 5.9.

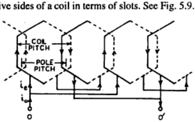


Fig. 5.9 Figure showing coil-pitch and pole-pitch

If the coil-pitch is equal to the pole-pitch, the winding is said to be full-pitched, and if the coil-pitch is less than the pole-pitch, then it is called short-pitched winding.

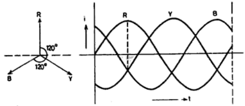


Fig. 5.10 Representation of phase differences of the three-phase currents

In this developed winding diagram, at the instant of start, current direction in phase R is in the upward direction, and in phase Y and B are in the downward direction. If the current direction in coil sides 1, 2, 3 are in the upward direction then 10, 11, 12 will carry current in the downward direction. The current direction in the other pole phase groups are also decided in the same manner. The developed mush winding diagram is shown in Fig. 5.11.

5.2.1.2 Concentric Type Winding: A concentric type winding is made up of concentric coils of different pitch, for each pair of poles.

The concentric windings are divided into two main groups *viz.*, (a) unbifurcated winding and (b) bifurcated winding. In an unbifurcated winding, a pair of adjacent pole phase groups form a concentric coil, whereas in bifurcated winding, each pole-phase group is split-up into two sets of concentric coils sharing its return coil sides with another such group. The above will be clear by refering to Figs. 5.12 and 5.13. In such windings, overhang or end connections should be accommodated in separate planes. If the number of pole pairs is even, the overhang can be accommodated in two planes. If the number of pole pair is multiple of three, then a three-plane overhang can be used. In case, if the overhang has to be accommodated in two planes, a cranked coil group results which is shown clearly in Fig. 5.14. In the following examples, all the above types of winding arrangements are shown:

Example 4. Draw a single layer concentric winding unbifurcated diagram with two plane overhang, for a three-phase, 48 slots, 8 poles a.c. armature.

Solution.

$$\text{Slots per pole per phase } = \frac{48}{8 \times 3} = 2$$

Thus one pole phase group consists of two slots.

$$\text{Coil span} = \text{pole-pitch} = \text{slots per pole} = \frac{48}{8} = 6$$

$$\text{Angle between consecutive slots} = \frac{180^\circ}{6} = 30^\circ \text{ electrical}$$

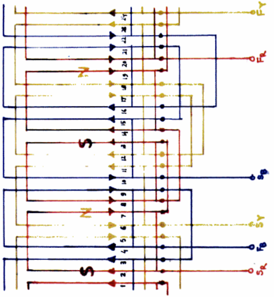


Fig. 5.13 Developed diagram of bifurcated concentric winding with three plane overhang

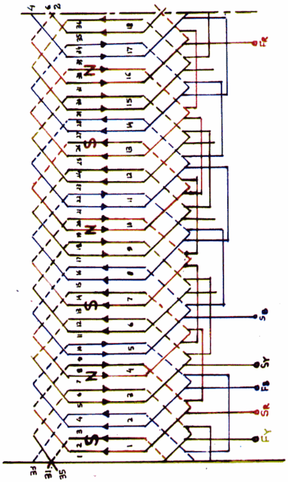


Fig. 5.15 Developed winding diagram of double layer full pitched lap windings

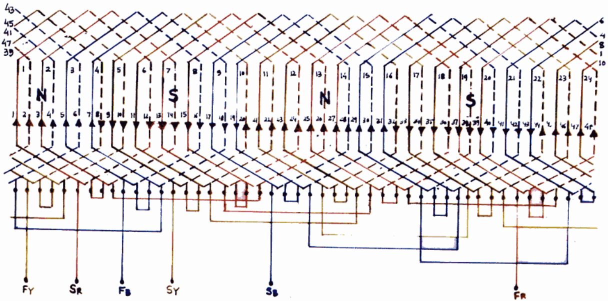


Fig. 5.16 Developed winding diagram of double layer, short chorded lap winding

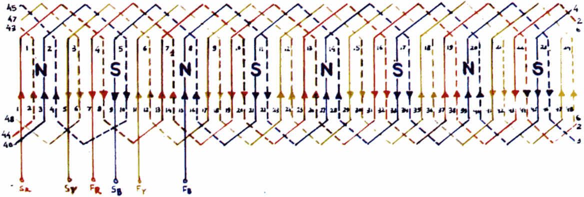


Fig. 5.17 Developed winding diagram of double layer full pitched wave winding

The displacement in slots between the start of phase R and start of phase $Y = \frac{120^\circ}{30^\circ} = 4$ slots.

One coil group is placed in four slots, one pole-pitch apart. Therefore, the number of coil groups $= \frac{48}{4} = 12$.

The number of pole-pairs is even. Hence the overhang is arranged in two planes (tiers).

In a coil group, the end wire of one coil is connected to the beginning wire of the next coil in the same group, and then goes to the next group. The developed unbifurcated winding diagram as explained is shown in Fig. 5.12.

Example 5. For a three phase a.c. machine, the armature is having 24 slots. A single layer concentric bifurcated winding for four poles is to be made. Draw the developed winding diagram with the overhang in three planes.

Solution.

$$\text{Slots per pole per phase (spp)} = \frac{24}{4 \times 3} = 2$$

That is, one pole phase group consists of two slots. In bifurcated winding, these two coil sides are split into two sets of concentric coils sharing its return coil side with another group.

In single layer windings, chording is not done.

$$\therefore \text{ Coil span} = \text{pole–pitch} = \frac{24}{4} = 6$$

$$\text{Angle between consecutive slots} = \frac{180^\circ}{6} = 30^\circ \text{ electrical}$$

The angular displacement between two phases = 120° electrical

$\therefore$ The displacement in slots between the start of phase R and the start of phase $Y = \frac{120}{30} = 4$ slots.

In a bifurcated winding, one coil group is placed in two slots.

$$\text{Therefore, number of coil groups} = \frac{24}{2} = 12$$

As the first pole phase group is split into two, the start of phase R is placed in slot 2, the start of phase *Y* lies in slot 6, and the start of phase B lies in slot 10.

The overhang is accommodated in three planes.

The coils in the coil groups are arranged in such a way that the emfs of the coil groups becomes additive. That is, the finish of the first coil group of phase R is connected to the finish of the second coil group of same phase. Similarly the start of the second coil group is connected to the start of the third coil group. The developed winding diagram with all these details are shown in Fig. 5.13.

Example 6. Develop a single layer concentric unbifurcated type winding diagram with two plane overhang for a three-phase, 36 slots, 6 pole armature.

Solution.

Slots per pole per phase (spp) $= \dfrac{36}{6 \times 3} = 2$

i.e., one pole phase group consists of two slots.

Coil span = pole-pitch $= \dfrac{36}{6} = 6$

Angle between consecutive slots $= \dfrac{180}{6} = 30^\circ$

The displacement in slots between the start coil sides of phase R and Y = $\dfrac{120}{30} = 4$ slots

Number of coil groups $= \dfrac{36}{4} = 9$

The number of pole-pairs = 3

Hence the overhang can be arranged in three planes.

But if the overhang has to be accommodated in two planes, we get cranked coil groups. The cranked coil group is shown in Fig. 5.14.

5.2.2 Double Layer Windings

Double layer windings have two coil sides per slot. The winding is made up of identical coils, one coil side of each coil lying in the top half of one slot and the other coil side in the bottom half of another slot spread approximately one pole-pitch apart. If the coil-span is exactly equal to the pole-pitch, then the winding is full pitched (full chorded) winding, and if coil-span is less than the pole-pitch the winding is fractional pitched (short-pitched or chorded). Chording is advantageous because undesirable harmonics are eliminated and the waveform of the induced emf is made more towards a sine wave. Another advantage of fractional pitched winding is that there is saving in copper and reduction in inductance of the coil.

Double layer windings are of two types: (i) lap type and (ii) wave type. Lap windings are used in the stators of high speed machines. Wave windings are used for wound rotors of medium and large size induction motors.

5.2.2.1 Lap Winding

Example 7. Design and draw a developed winding diagram of a double layer lap winding for a three-phase, 6 poles, 18 slots machine. Assume that the winding is full pitched.

Solution.

Slots per pole per phase (spp) = $\frac{18}{6 \times 3}$ = 1 slot

For full pitched coils, coil span = pole pitch

$$= \frac{18}{6} = 3 \text{ slots}$$

Top coil side 1 in slot 1 is connected to bottom coil side 8 in slot 4. Top coil side 3 in slot 2 is connected to bottom coil side 10 in slot 5 and so on.

We know that one pole-pitch corresponds to 180° electrical.

Here, the number of slots in one pole-pitch = 3 slots.

∴ Angle between two consecutive slots = $\frac{180°}{3}$

$$= 60° \text{ electrical}$$

Also we know that the phase are displaced by 120° electrical.

No. of slots by which the phases are displaced = $\frac{120°}{60°}$ = 2 slots

i.e. the start coil side of phase Y is two slots away from the start coil side of phase R *i.e.* it lies in slot 3. Start coil side of phase B is again two slots away from the start coil of phase Y *i.e.* it lies in slot 5.

The developed winding diagram is as shown in Fig. 5.15.

Example 8. A double layer lap winding is to be made for a three phase 4 pole machine having 24 slots in its armature. The coil span is reduced by one slot. Draw the developed winding diagram.

Solution.

Slots per pole per phase (spp) = $\frac{24}{4 \times 3}$ = 2 slots

Pole pitch = $\frac{24}{4}$ = 6 slots

Coil span = 5 slots

Top coil side 1 in slot 1 is connected to bottom coil side 12 in slot No. 6 and so on. It is clear that the top and bottom coil sides in one slot may not belong to the same phase in all cases.

Angle between two consecutive slots = $\frac{180°}{6}$ = 30° electrical

No. of slots by which phases are displaced = $\frac{120}{30}$ = 4 slots

The developed winding diagram is as shown in Fig. 5.16.

5.2.2.2 Wave Winding: Wave windings are mainly used in large and medium size machines with more number of poles. This is because, in the case of lap winding, interconnections are used for connecting individual coils and pole

6

Transmission and Distribution Lines

Overhead transmission and distribution lines are often carried on line supports. Line supports are broadly classified into (a) Poles and (b) Towers.

6.1 POLES

Overhead line conductors are supported on poles by means of cross arms and insulators. There are different types of poles which can be used as line supports. They are: (a) wooden poles, (b) steel poles and (c) concrete poles.

6.1.1 Wooden Poles

The use of wooden poles is mainly limited to support low voltage distribution lines for short spans. If properly impregnated with suitable preservative, wooden poles may give a long useful life. Double-pole structures of the 'A' or 'H' type can be employed for 33 kV and 66 kV lines. See Fig. 6.1.

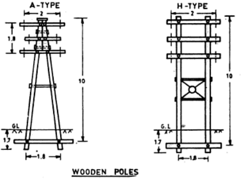


Fig. 6.1 Wooden poles (a) A-type (b) H-type

Such wooden poles are also sometimes used as transmission line support in areas where supply of timber is in plenty and transportation cost of steel poles and towers is high.

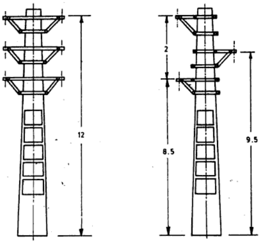
Single pole structures, being cheaper, are often used in LT lines for rural electrification.

6.1.2 Steel Tubular Poles

Steel poles are stronger than wooden poles. Longer spans are possible with the help of steel poles. They occupy less space and their use is generally favoured in cities. To increase the life of such poles, they are galvanised or painted regularly.

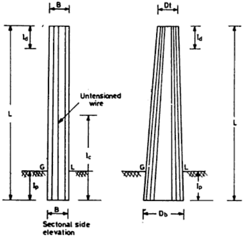
6.1.3 Concrete Poles

Reinforced Cement Concrete (RCC) poles as shown in Fig. 6.2(a) are very strong, have longer life and need little maintenance. They are quite heavy and bulky, and hence cost of transportation and handling is high. To overcome these difficulties Prestressed Cement Concrete (PCC) poles have been developed. Since PCC poles are lighter, their transportation, handling and erection are easier. These poles are in extensive use of 11 kV and LT lines particularly for rural electrification. In figures 6.2 (b) and 6.2 (c) are given design data of a prestrssed concrete pole.



ALL DIMENSIONS IN M.

Fig. 6.2 (a) 11 kV concrete poles

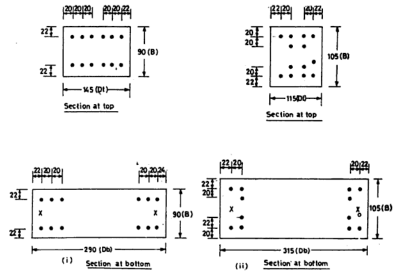


Length of Pole (L)	*Load on the Pole*	*Depth of Planting l_P*	*Distance of Concentrated Load from Top-section (ld)*	*Bottom Depth 'D_b'*	*Top Depth (D_t)*	*Breadth (B)*	*No of Tensioned Wire*	*No. of Untensioned Wire*	*Length of Untensioned Wire (l_C)*
8 M	200 kg	1.5 M	0.6 M	29.0 cm	14.5 cm	9 cm	12	2	4.00 M
9 M	200 kg	1.5 M	0.6 M	31.5 cm	11.5 cm	10.5 cm	12	2	5.00 M

Fig. 6.2 (b) Typical Design of a Prestressed Concrete Pole 8 M & 9 M Long. Showing Dimensions of Vertical Section

6.2 STEEL TOWERS

Steel towers are mainly used for supporting transmission lines at high voltage and extra-high voltage. They are space-frame structures fabricated from different sizes of steel-angle sections, painted or galvanised to prevent corrosion. Steel towers have the advantage of a long life and are capable of withstanding the most severe climatic conditions. These can be classified into (a) narrow-base type and (b) broad-base type. The narrow-base lattice steel towers are not used for long spans. When the span is too long, a broad base tower is appropriate. Fig. 6.3 shows a narrow-base lattice steel tower for supporting 33



NOTE

- • Denotes the Tensioned Wire.
- X Denotes the Untensioned Wire.
- O Denotes the Earth Wire.
- All Dimensions are in MM.

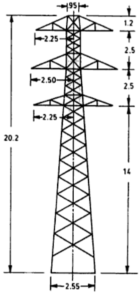
Fig 6.2(c) Typical design of a prestressed concrete pole showing dimensions for section at top and bottom. For (i) 8 M pole (ii) 9 M pole

kV three-phase single circuit transmission lines. Fig. 6.4 shows a broad-base lattice steel tower for supporting 66 kV three-phase double-circuit transmission lines.

6.3 ARRANGEMENT OF CONDUCTORS

In this section are discussed the different methods of arrangement of conductors in poles and towers, used in transmission and distribution lines.

Transmission lines are mainly three-phase type. But distribution lines are of single phase and three-phase types. Depending on the load and safety requirement, the lines may be of (a) single circuit or (b) double circuit. The different methods of arrangement of conductors on poles are as under:



ALL DIMENSIONS IN M.

Fig. 6.4 66 kV broad-base steel tower (double circuit line)

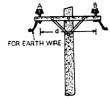


Fig. 6.5 Single phase, single circuit distribution lines running on a pole

6.4.1 Wooden Poles

Wooden poles should not be concreted or provided with a concrete collar (muff) at the ground level. The portion of a wooden pole below ground should be painted with bitumen to avoid deterioration. After a wooden pole is ereated, the pit should be partially filled with brick-bats and rammed well with a crowbar. Thereafter earth filling should be done with simultaneous ramming.

work, backfilling should be started. Backfilling should be done with the excavated soil.

6.5 HT & LT INSULATORS

For distribution and transmission lines, conductors are supported on poles and towers. These conductors have a potential difference with respect to each other which may be as low as 415 V for LT lines and as high as 400 kV for extra high tension lines. In order to prevent short circuit between the different phase conductors of the line and also to prevent leakage of current to earth through cross-arms on poles and towers, insulators are provided between conductors and supporting structures. An insulator is an important item of transmission and distribution lines.

6.5.1 LT Insulators

For low and medium voltage lines pin type and shackle type insulators are used.

6.5.1.1 Pin Insulators: Pin insulators are manufactured for low voltages in one piece and for higher voltages in two or three pieces of porcelain, cemented together. Fig. 6.10 shows a one piece insulator used for LT lines. One piece insulators are more prone to cracking because of rain. For rural lines, carrying less load and using light conductors, however, such single piece insulators are used for reasons of economy. These insulators are mounted rigidly on a supporting structure by a pin passing upwards inside the insulator.

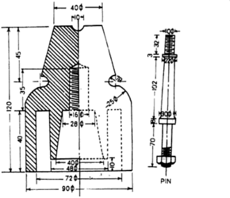


Fig. 6.10 Low voltage pin insulator

6.5.1.2 Shackle Insulators: A shackle insulator is one consisting of a single porcelain part. It should be mounted vertically or horizontally between and in contact with the two ends of a U-strap. Shackle fitting is of two types. In one type, the shackle insulator is fitted directly on the pole. In the other type it is fitted on the cross-arm of the pole by means of U clam. See Figs. 6.11 (a) and (b).

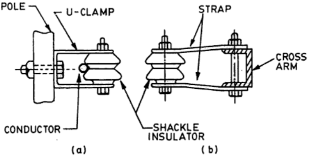


Fig. 6.11 (a) Shackle insulator fitted on pole; (b) Shackle insulator fitted on cross-arm

Shackle insulators take tension of conductors at dead ends, junctions of overhead lines with cables, road crossing and at angle poles. Thus these insulators are used at all positions, intermediate, terminal or at angles. Fig. 6.12 shows a shackle insulator (half in section), fitted on a pole using a GI strap.

6.5.1.3 Guy Insulators: These insulators are also called strain insulators or egg-type insulators. They are generally used with pole-guys on low-voltage lines, where it is necessary to insulate the lower part of the guy wire from the pole for the safety of people or animals on the ground. See Fig. 6.13. This type of insulators consist of a porcelain piece pierced with two holes at right angles to each other through which the two ends of the guy wire are looped. This keeps the porcelain between the two loops in compression and the guywire remains in position even if the insulator breaks due to any reason.

6.5.2 HT Insulators

6.5.2.1 11 kV Pin Type Insulators: Pin type insulators for high voltage consists of two or more pieces of procelain permanently fixed together. These insulators are intended to be mounted rigidly on a supporting structure by an insulator pin fixed inside the insulator. Fig. 6.14 shows a two-piece pin insulator. The pin insulator is installed on the cross-arm of the pole. The conductor is mounted on the insulator in the grooves provided for it. Such an arrangement of a pin insulator is shown in Fig. 6.15.

6.5.2.2 Disc Insulators: Pin insulators cannot take conductor load in tension which often occurs at angles and dead ends. To meet this requirement, disc insulators, also known as tension insulators are used. Besides being used at

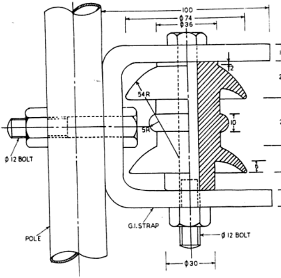
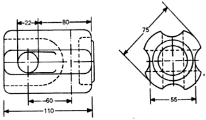


Fig. 6.12 A shackle insulator (half in section) fitted on a pole



All dimensions in mm

Fig. 6.13 Guy insulator

angles and at dead ends, disc insulators are also used as suspension insulators in straight runs for line voltages of 66 kV and above. Suspension insulators are also used in straight runs on 11 kV and 33 kV lines if the conductor size is large i.e. 48 mm^2 and above.

A disc insulator consists of a porcelain disc of sufficient thickness which grooved at the bottom in order to increase the creepage distance, ther

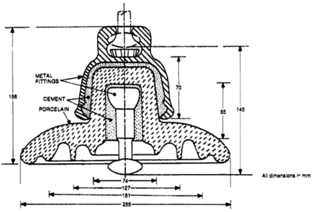


Fig. 6.16 Ball-and-socket type disc insulator

reducing chances of flashover. There are two types of disc insulators viz (a) ball-and-socket type and (b) tongue-and-clevis type. The main features of these two types of insulators are the same except for the end fittings. Fig. 6.16 shows a ball-and-socket type disc insulator and Fig. 6.17 shows a tongue-and-clevis type disc insulator. One of the discs has been shown in full section.

6.5.2.3 String Insulators with Arcing Horn and Guard Rings: For high voltage lines operating at 33 kV and above, suspension insulator strings are used. These consists of a number of porcelain discs in series, connected to one another by metal links. The line conductor is secured to the bottom disc of the string and the top disc is connected to the cross-arm of the pole or tower. The number of discs in series in the insulator string depends on the voltage of the line — the higher the voltage of the line, the larger is the number of discs required for the insulator string.

The larger the number of insulator units, the longer will be the string, the voltage distribution across the various insulator units will be non-uniform, resulting in poor efficiency of the string. A uniform distribution of voltage across the insulator units of a string can be obtained by providing a large metal ring called the guard ring connected to the metal work at the bottom of the unit. The guard ring, when used alongwith the arcing horn fixed at the top end of the string, also serves the purpose of an arcing shield and protects the insulator string from damage on account of overvoltage on the system. If overvoltage occurs in the system, sparking occurs between the guard ring and the arcing horns thus safeguarding the insulator string. Such an arrangement of a string insulator with arcing horns and guard ring is shown in Fig. 6.18.

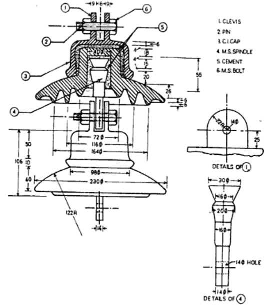


Fig. 6.17 Tongue-and-clevis type disc insulator

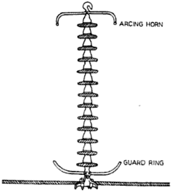


Fig. 6.18 String insulator with arcing horn and guard ring

6.6 STAYS OR GUYS

The terminal poles of overhead lines experience pull on one side only and tends to tilt the pole in the direction of the line. Similar situations causing tendency for the pole to tilt occurs at poles (a) where the line takes a turn at an angle, (b) where a branch line is tapped from main line and (c) where the line is crossing a road, a railway-line, a canal or another power line. To keep such poles perpendicular, guys or stays may be used. Also intermediate poles on straight run may be subjected to high-velocity winds under abnormal weather conditions, which may tilt and uproot the poles. For these reasons every fifth pole in a straight run may be provided with two wind guys.

6.6.1 Different Types of Guys

Guys are classified as follows:

1. Aerial guy
   (a) Span guy (b) Head guy
2. Ground guy
   (a) Stranded steel wire guy (b) Strut guy

Aerial guys do not need an anchor in the ground. They can be erected from the top of one pole to the top of another pole as in a span guy, or from the top of one pole to the bottom of the next guy as in a head guy.

In ground guys, the anchor is put in the ground. A stranded steel wire guy is shown in Fig. 6.19. Such wire guys are fixed on the opposite side of the conductor to prevent the pole from tilting towards the conductor side.

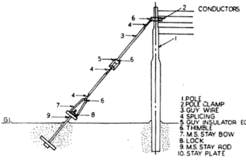


Fig. 6.19 Stranded steel wire guy

When it is not possible to instal wire guys because of conditions of site, strut guys are used. A strut guy is shown in Fig. 6.20.

These are made of line poles and are installed on the same side as the conductors, and they take compression.

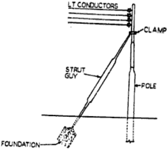


Fig. 6.20 Strut guy

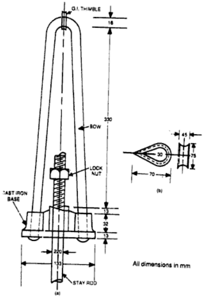


Fig. 6.21 (a) Guy bow assembly; (b) GI thimble

6.6.2 Guy Bow Assembly

In Fig. 6.19, the different parts of a stranded steel wire guy are shown. The guy plate holds the guy assembly firmly in the ground. The guy plate is fitted on to

3. Fig. 6.23 shows the views of broad base lattice steel towers for supporting 132 kV three-phase transmission lines for (a) double circuit disposition and (b) single circuit disposition. Redraw the figures choosing another convenient scale.
4. Draw the full sectional view of an 11 kV pin insulator made of three pieces.
5. Draw the half sectional view of a ball and socket type disc insulator with two discs.
6. Draw the view of a stranded steel wire guy and mark all the accessories.

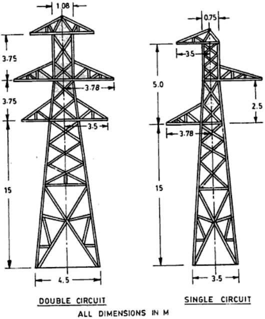


Fig. 6.23 132 kV broad-base steel towers

7

Plant and Substation Layout Diagrams

7.1 LAYOUT DIAGRAMS OF DISTRIBUTION SUBSTATIONS

Distribution substation may be subdivided into the following types:

(i) H-pole mounted: Transformers of low rating say 25, 40, 63, 100 and 200 kVA are mounted on rolled steel fixtures which are rigidly fastened to the two poles.

(ii) Platform mounted: A platform is constructed on a four-pole structure for placing the transformer on it. Platform mounting is done for transformers of capacity 250, 300 and 400 kVA.

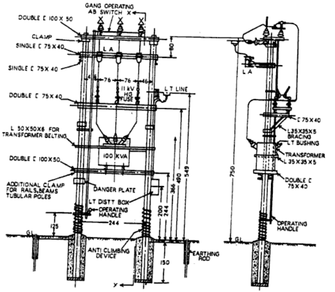
(iii) Plinth or foundation mounted: Transformers above 500 kVA are placed on a plinth or foundation with a wall or fence surrounding it.

7.1.1 H-pole Mounted Distribution Substation

The arrangement of equipments in a pole mounted substation is shown in Fig. 7.1. A single line diagram of the equipments connected is also shown in Fig. 7.2.

The 11 kV/415 V transformer is mounted on a MS channel at a height 2.44 m from ground level. For the protection of the transformer against lightning 11 kV lightning arrestors are erected at the top of the H-pole structure. Supply is given to the H-pole substation through a 11 kV gang operating air break switch. The operating handle of the G.O. (Gang Operating) switch is located on one of the poles of the structure at a height of 1.25 m from ground. 11 kV horn gap fuse, installed on the HT side below the gang operating switch, protects the transformer on the 11 kV side.

On the LT side of the transformer a three and a half core LT cable is taken from the LT bushing terminals to the LT main switch. This main switch with fuse unit provides isolation and protection against feeder faults. LT cable is selected according to the capacity of the transformer.



ALL DIMENSIONS ARE IN cm.
AB AIR BREAK
HG HORN GAP
C CHANNEL
L ANGLE IRON
LA LIGHTING ARRESTOR

Fig. 7.1 A pole mounted substation layout

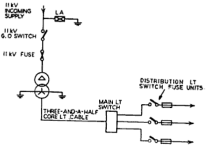


Fig. 7.2 Single line diagram of a pole mounted substation

7.1.2 Platform Mounted Distribution Substation

When the transformer capacity is more than 200 kVA and is to be mounted outdoor, platform mounted type of substation is to be installed. A four-pole structure is erected and platform is constructed on it. The transformer is mounted on this platform. Air break switches, lightning arrestors, insulators etc. are installed on the four-pole structure. A platform mounted distribution substation is shown in Fig. 7.3.

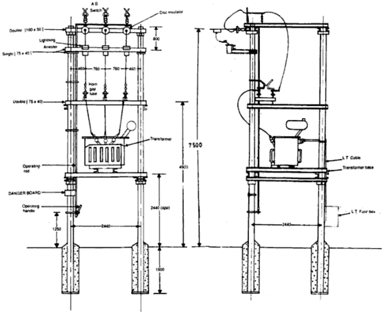


Fig. 7.3 Platform mounted distribution substation

7.1.3 Plinth or Foundation Mounted Distribution Substation

Transformers of capacity above 500 kVA are too heavy for pole mounting and therefore are to be installed on ground. Plinth or foundation mounted substations can be installed outdoor or indoor. The equipments installed should be enclosed by a fence or a wall. The switch gear consists of circuit beakers, isolators etc. A foundation mounted outdoor substation is shown in Fig. 7.4.

In Indoor substations, the transformer, switchgear and the allied equipment are installed inside a building. The building should be spacious and sufficiently high, with adequate provision for ventilation. Adequate clearance between the

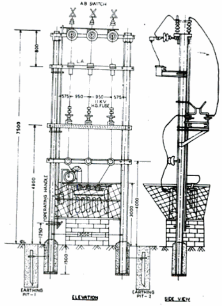


Fig. 7.4 Foundation mounted outdoor substation

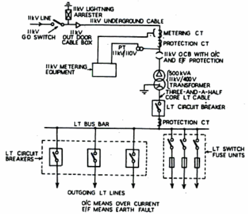


Fig. 7.5 Single line diagram of an indoor substation

walls and equipment and between different equipment should be provided to ensure safety of personnel. The single line diagram and layout of an indoor substation are shown in Figs. 7.5 and 7.6.

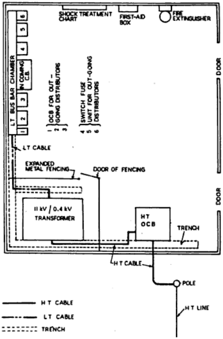


Fig. 7.6 Layout of an indoor substation

7.2 LAYOUT OF 33 kV AND 11 kV SUBSTATION

Single line representation of 11 kV and 33 kV substations are given as under:

(i) 11kV/415 V substation with two 400 kVA transformers and one generator set is shown in Fig. 7.7.

The 11 kV supply is received in an HT panel consisting of three 11 kV OCBs, one incoming and two outgoing. The LT sides of the transformers are connected to M.V Panel board through LT ACBs. Sectionalising to the bus is done through the bus couplers. During power cut period, essential loads can be supplied through a DG (Diesel Generator) set and a changeover switch. The bus coupler is mechanically interlocked with

The 33 kV incoming line is connected to the 33 kV busbars through a G.O. switch. Two nos. 33 kV/11 kV transformers of 2 MVA and 1 MVA ratings step down the voltage to 11 kV. The LT sides are connected to two separate 11 kV busbars through 11 kV OCBs. Feeders are run from these busbars.

7.3 LAYOUT OF POWER PLANTS

Layout diagrams of hydro-electric and thermal power plants are given below:

7.3.1 Hydroelectric Power Plants

Hydroelectric power plants convert the energy stored in water into electrical energy by the use of water turbines coupled with generators. The water from a height (called, water head) is allowed to fall on the blades of turbine through long pipes or tunnels, called penstocks. This causes the turbine blades to rotate which in turn rotates the rotor of an alternator.

Depending upon the head or the height from which the water falls, the hydroelectric plants are classified into the following categories:

(i) High head hydroelectric plants: 200 m and above
(ii) Medium head hydroelectric plants: 50 m to 200 m
(iii) Low head hydroelectric plants: Upto about 50 m

7.3.1.1 High Head Hydroelectric Plants: A dam is constructed to make a storage reservoir, from where a high pressure tunnel is taken off to the valve house. A high head hydroelectric plants is shown in Fig. 7.9.

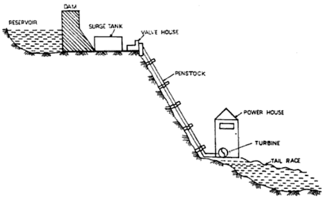


Fig. 7.9 High head hydroelectric plant

The penstocks are large pipes which carry huge quantity of water from valve house to the power house. A surge tank is situated just beside the valve house.

In case due to reduction of load on the turbines, the inlet valves to the turbines are suddenly closed, water hammer due to a very high pressure is created which may damage the penstocks. Surge tank absorbs water hammer by increasing the water level in it. In case of heavy load, it will lower its water level and will increase the water supply to the turbine. Thus is acts like a flywheel. The common type of turbine used is pelton wheel.

7.3.1.2 Medium Head Hydroelectric Plants: In these types of hydroelectric plants we have forebay instead of surge tank. See Fig. 7.10. Water is generally carried in open channels from the main reservoir to the forebay and then to the power house through the pen stock. The common type of prime movers used in this case are Francis, Propeller and Kaplan turbines.

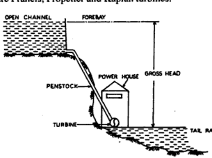


Fig. 7.10 Medium head hydro electric plant

7.3.1.3 Low Head Hydroelectric Plants: A low head hydroelectric plant stores water by constructing a dam across a river and the power house is installed near the base of the dam on the down-stream side. The tail-race of turbine is joined to the river on the downstream side. A low head hydroelectric plant is shown in Fig. 7.11.

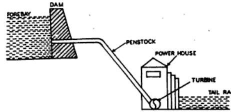


Fig. 7.11 Low head hydro-electric plant

7.3.2 Thermal Power Plant

These plants employ steam turbines to run the alternators. Steam is obtained from high pressure boiler. The fuel used for the boiler is coal; generally bituminous coal is used. To increase the efficiency of boiler, the coal is burnt in powdered form. Fig. 7.12 shows a line diagram of a thermal power plant. The process of generation of electric power is carried out as explained below.

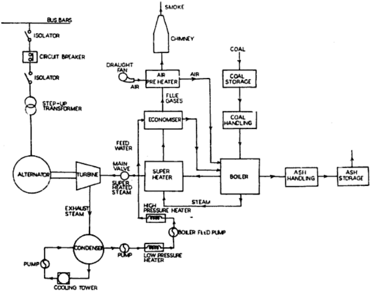


Fig. 7.12 Line diagram of a thermal power plant

Coal in powdered form is fed to the boiler furnace where is burnt and the water in the boiler is converted into steam. For efficient combustion of the fuel enough air must be supplied. The steam at high pressure is further heated in a superheated to increase its temperature. The superheated steam is supplied to the turbine through the throttle valve. The steam at high pressure is expanded through the turbine and as a result the turbine rotates. The shaft of the turbine is coupled with the rotor of an alternator. Thus heat energy of superheated steam is converted into electrical energy.

Steam which comes out of turbine, which is at a low pressure, is passed into a condenser. In the condenser, cold water is circulated with the help of a pump and hence the steam is condensed. The condensate *i.e.*, water is pumped back

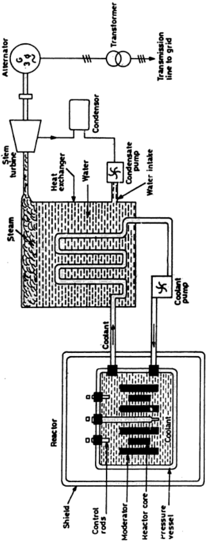


Fig. 7.13 Shows a nuclear power plant in block diagrammatic form

8

Miscellaneous Drawings

In this chapter drawings of different types of earth electrodes, circuit breakers, lightning arrestors etc have been dealt with.

8.1 EARTHING SYSTEM

The purpose of earthing is to ensure that an easier path (of low resistance) is provided for the earth fault current to flow. This prevents the risk of shock. All metallic enclosures of electrical equipments, all metal conduits, cable sheaths, motor starters, etc. should be bonded together and connected to an efficient earthing system. Earthing system consists of main earth electrodes, ring main earth continuity conductors and different connections of earth wire from various equipment. First, we shall discuss the different types of earth electrodes, and then the earthing layout of different substations will be described.

8.1.1 Earth Electrodes

There are two types of earth electrodes in use *viz.*, (i) rod or pipe electrodes and (ii) plate electrodes.

8.1.1.1 Rod or Pipe Earth Electrodes: A typical illustration of rod or pipe earth electrode is given in Fig. 8.1. These electrodes are made of metal rod or pipe having clean surface not coated by at least 16 mm in diameter and those of copper should be at least 12.5 mm in diameter. Pipe electrodes should not be smaller than 38 mm internal diameter if made of galvanised iron or steel and 100 mm internal diameter if made of cast iron.

Pipes or rods as far as possible should be of one piece and not less than 2.5 m in length. These should be driven to a depth of at least 2.5 m.

To increase soil conductivity, artificial soil treatment is done. The pipe at the bottom is surrounded by broken pieces of coke or charcoal for a distance of about 15 cm around the pipe. A cement concrete work is also done so that 3 to 4 buckets of water can be poured through the funnel to moist the earth. The

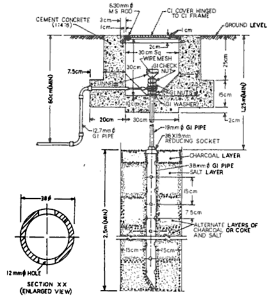


Fig. 8.1 A typical illustration of rod or pipe earth electrode

earth wire is carried in a GI pipe of 12.7 mm diameter at a depth of 60 cm below ground and connected to the pipe electrode using G.I. nuts and washers.

8.1.1.2 Plate Earth Electrodes: Plate earth electrodes when made of galvanized iron or steel should not be less than 6.3 mm in thickness and of copper should not be less than 3.15 mm in thickness. They should be of at least 60 cm × 60 cm in size. They should be buried such that the top edge is at a depth not less than 1.5 m from the surface of the ground. A typical illustration of a plate electrode is shown in Fig. 8.2.

Three or four buckets of water are to be poured into the sump to keep the soil surrounding the earth plate permanently moist.

8.1.2 Earthing Layout of Distribution Transformer Substations

For a pole mounted distribution substation, three pits are provided with earth electrodes as shown in Fig. 8.3. The plan view of earthing layout of a double-pole structure was shown in Fig. 7.1. In that figure two earth electrodes are on either side of (2 m away from) the two poles and the third one is equidistant to the other two. All three electrode pits are equidistantly located 6.5 m away from

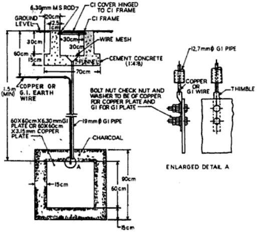


Fig. 8.2 A typical illustration of plate earth electrode

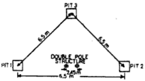


Fig. 8.3 Location of earth pits for a pole mounted distribution substation

each other. One of the three earth electrodes on either side of double pole structure is connected to the lightning arrestor. Of the remaining two earth electrodes, one electrode is connected to the neutral of the transformer on the LT side, and another earth electrode is connected to the transformer body, the handle of the 11 kV Gang Operated (GO) switch, and the body of the LT switches.

8.1.3 Substation Earthing Layout

As per IS 3043-1966 earth electrodes for generating stations and indoor substations are to be installed adjacent to the building and for outdoor substations within and adjacent to the perimeter fence.

A main earthing ring is to be provided around the station, through all the main earth electrodes. Connections are made to all major apparatus such as transformers, circuit breakers etc. and to the framework of each item such as instrument transformers, meters, relays etc. For larger substations the ring should be reinforced by one or more cross connections. From the main earth bus, branch connection should be taken to each apparatus. A typical earthing arrangement for an outdoor substation is shown in Fig. 8.4 (a).

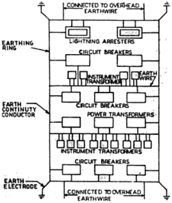


Fig. 8.4 (a) A typical earthing arrangement for an outdoor substation

At a substation the neutral points of transformers should be directly earthed, or should be earthed through a resistance, if the fault current expected is too high.

Metal pipes or conduits in which the cables have been placed, joints of cables, metal sheath and armour of cables should be bonded to the earthing system and connected to the earth electrodes.

Individual earth electrodes should be provided for each station type lightning arrestors while for distribution type lightning arrestors, one earth electrode may be provided for a set of lightning arrestors. (Station type and distribution type lightning arrestors are described in section 8.3). Separate earth electrodes for lightning arrestors are provided for the reason that large earthing systems in themselves may be relatively of little use for lightning protection. These earth electrodes should also be connected to the main earth system.

The secondary windings of current transformers and voltage transformers should also be earthed by connecting to the main earth bus.

8.2 CIRCUIT BREAKERS

Various types of circuit breakers used in a power system are described as follows:

8.2.1 Miniature Circuit Breaker

The Miniature circuit Breaker (MCB) is a high fault capacity, thermal/magnetic, current limiting trip free automatic switching device with early magnetic tripping. Photographic view of an MCB is shown in Fig. 8.4 (b).

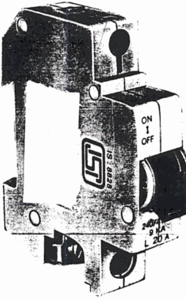


Fig. 8.4 (b) Photographic view of a MCB

Thermal operation is achieved with a bimetal strip which deflects when heated by the overload current flowing through it. In doing so it moves the trip lever, releasing the latch mechanism and causing the contacts to open under spring action.

When short-circuit fault occurs, the rising fault current energises the solenoid, attracting the plunger which strikes the trip lever causing immediate release of the latch mechanism. Rapidity of the magnetic solenoid operation causes quick opening of contacts. The cross sectional view of an MCB is shown in Fig. 8.4 (c).

During short circuit current breaking, the MCB does not allow such high current to pass through it and limits the current to values between 2.5 and 3 KA breaking current. This reduces the let-through energy and opening time and

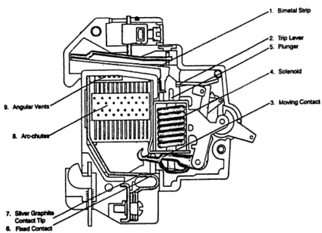


Fig. 8.4 (c) Cross sectional view of a MCB

results in low arcing and effective arc-quenching. Forced magnetic opening due to the reversal of current between the fixed and the moving contact further assists in quicker opening time.

It is considered that just the use of current limiting design may not suffice the requirement of quick breaking mainly due to the intertia of the latch mechanism and inter-connected sequence of operations. A hammer directly connected to the plunger strikes the moving contact with a force proportional to the current peak, thereby separating the contacts much before the latch mechanism operates. The opening time of the MCB is reduced to less than 1 ms. Employing one of the latest techniques used in MCBs, such a design helps to reduce the let-through energy even further, reduces heating during short-circuit, and ensures positive opening of the contacts. Possibility of a contact weld is completely eliminated.

The arc produced on separation of contacts is rapidly moved, under the influence of a magnetic field, into the arc-chute stack, where it is broken down into partial arcs. These partial arcs require a considerably higher voltage than that required to maintain a single arc.

Contact bounce, when making high short circuit current, results in contact welding in pure silver or ordinary silver alloy contacts. The contacts in MCBs are tipped with silver graphite, a non melting sintered material.

The possibility of arc-erosion is also eliminated since the fibre-like graphite grain alignment is perpendicular to the movement of arc. Hence the contact life increases manifold. No thermally stable oxides are formed during arcing and hence contact resistance also remains low.

The body of MCB is made of flame-retardant high strength plastic which has high melting point, low water absorption at saturation, high dielectric strength, high deflection temperature under load and, low coefficient of linear thermal expansion.

The tripping of the MCB is independent of the position of the knob, that is to say that whilst the operating knob may be held in the ON position, the MCB will still open in the event of a fault.

The vents in MCBs are so designed that they prevent any ingress of dust. The chances of dust settlement on the contacts is reduced and dust free perfect electrical contact is made. Hot gases produced are diverted away from the operating personnel during short circuit arc breaking.

8.2.2 Oil Circuit Breaker

In this type of circuit breakers the contacts are surrounded by a pressure chamber. The high pressure generated by the arc causes an immediate displacement of the oil into the space between the contacts after the arc current goes to zero. The pressure developed by the oil is dependent upon the value of current interrupted. There are different types of pressure chambers.

Plain explosion pot. It consists of a strong shell of insulating material. The moving contact is drawn vertically downwards. When the moving contact is withdrawn an arc is struck and high pressure is developed. The oil at high pressure moves violently into the arc and tries to quench the arc. See Fig. 8.5.

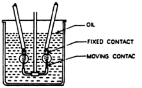


Fig. 8.5 Plain break explosion pot

Cross jet explosion pot. This is similar to the plain explosion pot. The fixed and moving contacts are plug and socket type, and they fit into each other. See Fig. 8.6. These are enclosed in an explosion chamber which is provided with arc splitters. The arc splitters help in increasing the arc length and thus help in reducing the arc which can be easily extinguished by the oil.

Self compensated explosion pot. It is a combination of cross-jet explosion pot and plain explosion pot. Cross-jet explosion pot is efficient for breaking heavy short-circuit currents, while plain explosion pot is used for low currents. There

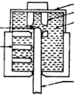


Fig. 8.6 Cross-jet explosion pot

are two chambers, upper one is cross-jet explosion pot and the lower one is a plain explosion pot. Arc is quenched by the plain pot action. See Fig. 8.7.

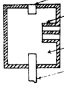


Fig. 8.7 Self-compensated explosion pot

8.2.3 Minimum Oil Circuit Breaker

In bulk-oil circuit breakers the quantity of oil required increases with the increase of system voltage. However in minimum (low) oil circuit breaker, a small volume of oil is used for arc extinction. It consists of a small container having oil which is just enough for arc extinction. This container is supported on porcelain insulators to give the required insulation of the live parts from the earth.

Fig. 8.8 shows the sectional view of a typical high voltage minimum oil content circuit breaker. Current flows between the top and the bottom current terminals in the ON position. When breaking, the contacts begin to separate and arc is established. The moving contact rod forces the arc downwards to enter the explosion pot. The arc energy produces a violent upward blast of oil vapour. The resulting downward jet of cool oil extinguishes the arc.

The details of the explosion pot (chamber) is shown in Fig. 8.9. It is made up of dielectric material and is fitted to the fixed contact of the MOCB. When the moving contact is separated under oil, the arc produced decomposes the oil into hydrogen and other gases. As the arc is forced downward to the explosion chamber, the gases escape through the side vents and thereby cools down and extinguishes the arc. To prevent the contact space getting filled with hot gases,

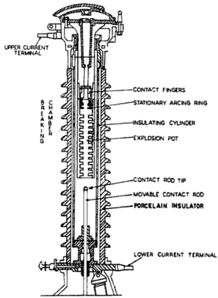


Fig. 8.8 Sectional view of a typical high voltage minimum oil circuit breaker

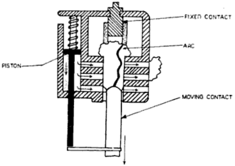


Fig. 8.9 Explosion chamber with auxiliary piston

a piston attached to the moving contact, compresses fresh cool oil into the cylinder to the contact space area.

8.2.4 Air Break Circuit Breakers

Air break circuit breakers are used in d.c. circuits and in a.c. circuits upto 11 kV, in indoor medium voltage and low voltage applications. There are two sets of contacts *viz.*, main contacts and arcing contacts. During normal run, the main contacts conduct current. If the main contacts open, the arcing contacts conduct current for sometime. When the arcing contacts dislodge, the arc is formed between them. The arc is pushed upwards along the arc runners, to the splitters. Due to lengthening and splitting of the arc, it is extinguished. Fig. 8.10 shows the different parts of an air break circuit breaker.

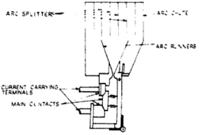


Fig. 8.10 Air break Circuit Breaker

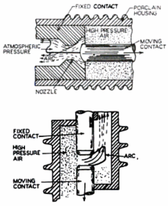
8.2.5 Air Blast Circuit Breakers

In such a breaker when the contacts are separated, high-pressure air is forced on to the arc. The ionized gases between the contacts are blown away by the blast of air. The breaker consists of an air reservoir which contains the high pressure air. During contact separation air flows from this reservoir to the contact space where the arc is formed. Depending on the direction of air flow, air blast circuit breakers are named (1) axial blast type and (2) cross blast type.

In axial blast type circuit breakers air flows axially along the arc, and in the cross blast type, air flows perpendicular to the arc. Fig. 8.11 (a) and (b) clearly shows the difference between the axial flow and cross flow around the contacts in an air blast circuit breaker.

8.2.6 Vacuum Circuit Breaker

Vacuum circuit breaker has three breaker poles each with its vacuum interrupter unit, mounted on a common housing mechanism. One view of a vacuum circuit breaker is shown in Fig. 8.12.



(b)

Fig. 8.11 Air blast circuit breakers (a) Axial blast type; (b) Cross blast type

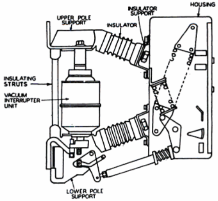


Fig. 8.12 Vacuum circuit breaker

The breaker poles are fixed to the rear of the housing mechanism by two insulators. The insulator supports are made either of aluminium or of sheet steel. The energy storing mechanism and all the control and actuating devices are installed in the housing mechanism.

The vacuum interrupter is rigidly fixed between the two upper and lower pole supports. The external forces due to switching operations and the contact pressure are absorbed by the insulating struts. The basic construction of a vacuum interrupter is shown in Fig. 8.13.

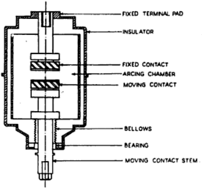


Fig. 8.13 Basic construction of a vacuum interrupter unit

The moving contact moves in the guide. The metal bellows follows the travel of the moving contact and seals the interrupter against the surrounding atmosphere.

When the contacts separate, the current to be interrupted initiates a metal vapour arc discharge and flows through this plasma until the next zero current of the current cycle. The arc is then extinguished and the conductive metal vapour condenses on the metal surface within microseconds. As a result the dielectric strength in the break builds up very rapidly.

8.2.7 Sulpher Hexa Fluoride (SF_6) Circuit Breakers

An SF_6 circuit breaker shown in Fig. 8.14 consists of the following main components:

(i) three breaker poles
(ii) a switch cubicle
(iii) an SF_6 gas supply unit and
(iv) connecting lines of SF_6, air and electrical connecting lines.

(i) The three breaker poles are absolutely identical as regards their function. Each breaker pole consists of (i) a pole column filled with SF_6 gas and (ii) a pole driving mechanism operated with compressed air. Pole column is divided into interrupter unit located in the upper part of the column and the insulator which is the lower part. The interrupter unit consists of the extinction chamber, fixed contacts and moving contacts.

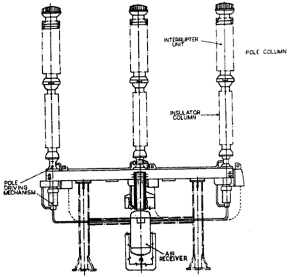


Fig. 8.14 SF_6 circuit breaker

The insulator column consists of the supporting insulator and the operating rod which connects the moving rod and the pole driving mechanism. Pole driving mechanism actuates the interrupter unit assembly. Compressed air is used as the actuating medium.

(ii) The switch cubicle contains all the pneumatic and electrical components necessary for the breaker to operate independently. These components, include OPEN-CLOSE control switch, auxiliary relays, pressure switch, pressure gauge, pulse counter etc.

(iii) The SF_6 gas supply system is responsible for the monitoring and filling of the breaker. Gas is supplied centrally. The system consists of an SF_6 pressure switch and a distributor with filler linear on the central pole and SF_6 couplings on the outer poles and SF_6 connecting lines between the poles.

(iv) *Connecting lines:* The SF_6 connecting lines between the breaker poles are part of the gas supply system. The electrical connecting lines provide the link between the auxiliary switches of the breaker poles and the control cabinet.

8.3 LIGHTNING ARRESTORS

In an electrical system, high voltage surges are produced due to lightning strokes or switching operations. These surges may cause serious faults resulting in line outage and damage to equipment. To divert such overvoltage surges on the line to the earth, lightning arrestors are connected between line and ground. There are different types of lightning arrestors such as (1) horn gap type, (2) electrolytic type, (3) pellet type, (4) thyrite type, (5) expulsion type and (6) valve type.

8.3.1 Horn-gap Lightning Arrestors

A horn gap arrestor consists of two horn-shaped copper rods separated by a small air gap. It is connected between each line and earth. The horns are mounted on porcelain insulators. See Fig. 8.15. Under normal voltage, there is no spark across the gap. During a lightning stroke, very high voltage surges travelling along the line, breakdown the gap and pass on to the earth. Horn gap arrestors are inferior type lightning arrestors because of their limitations. Horns are prone to corrosion as they are affected by climatic conditions. Birds or insects bridging the gap may cause accidental spark over. A horn gap arrestor is not capable of stopping power frequency flow of current. For these reasons horn gap arrestors are practically not used in high voltage power systems.

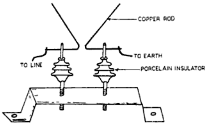


Fig. 8.15 Horn gap arrestor

8.3.2 Electrolytic Arrestor

A thin film of aluminium hydroxide formed on the aluminium plates immersed in electrolyte offers a high resistance to low voltage, and low resistance to high voltages above a critical value. During the formation of the film, current flows but stops flowing when the film is fully formed.

Such a stack of plates connected in series with an impulse gap to form an arrestor is shown in Fig. 8.16. The gap is made of two electrodes A, B and an auxiliary electrode P. At normal voltage and frequencies, impedances of C_1 and C_2 are very high as compared to resistance R. During high frequency lightning

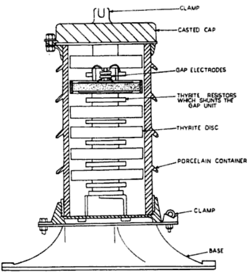


Fig. 8.17 Thyrite arrestor

8.3.5 Expulsion Type Lightning Arrester

This type of an arrestor consists of a fibre tube in which a spark gap is provided. An external gap is also provided in series with the internal spark gap. The arrangement has been shown in Fig. 8.18. During over voltage, the internal and the external gaps spark over and provide a current carrying path for the lightning surges. The arc in the impulse spark gap evaporates the fibrous material of the tube, emitting gas. This gas is expelled through the hollow bottom electrode, and thus the arc is extinguished.

Expulsion type arrestors are mainly installed for the protection of distribution type transformers.

8.3.6 Valve Type Lightning Arresters

A valve type arrester consists of a series of spark gaps connected together, and a stack of porous blocks made from thyrite, metrosil etc. These resistor discs have the property that when applied voltage/current increases, the resistance decreases rapidly. These discs are separated by thin mica rings which provide insulation for normal voltage. These gap elements and the resistor elements are connected in series. Fig. 8.19 shows a valve type lightning arrestor.

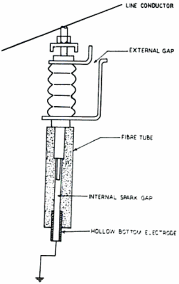


Fig. 8.18 Expulsion type lightning arrestor

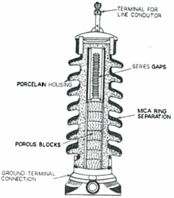


Fig. 8.19 Valve type lightning arrestor

Valve type lightning arrestors are used mainly for the protection of large substation equipments and transformers. They are expensive, efficient and consist of many units and are called station type lightning arresters. Lightning arrestors which are used in small substations, of less weight and cost, are called line type lightning arrestors.

8.4 AIR BREAK SWITCHES

To isolate the substation equipment from the supply, gang operated outdoor air break switches are mounted on the pole structure in case of pole mounted transformer substations. This can be operated from ground, by a handle, mounted on one pole. One set of such a switch is shown in Fig. 8.20.

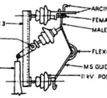


Fig. 8.20 Gang operated air-break switch

8.5 HRC FUSES

High rupturing capacity (HRC) Fuse links provides complete protection to cables, switchgear, controlgear and other equipment by limiting the current, both in magnitude and in the time duration, that can pass through these devices in circuit. The rapid operation in the event of a fault limits the let through current and energy, thus minimizing the electromagnetic and thermal stresses on the electrical apparatus.

Fig. 8.21 shows a particular type of HRC fuse link. These type of fuses comprises a high grade ceramic body within which fuse elements are placed and welded to the end plates. The assembly is filled with dry granular quartz sand. In the event of flow of high short circuit current, this quartz sand solidifies forming high resistance glass in the arc path to ensure effective arc quenching in optimum time. The fuse elements are non deteriorating type which means that they maintain their characteristics over long service period.

Silver plated tag contacts provide good contact with fuse base and keep the fuse temperature low. In type CD-2 HRC fuses the POP-OUT type indicator provides positive indication in the event of fuse blowing. These type of fuses can be plugged in and out even when hot or in service with an insulated fuse puller.

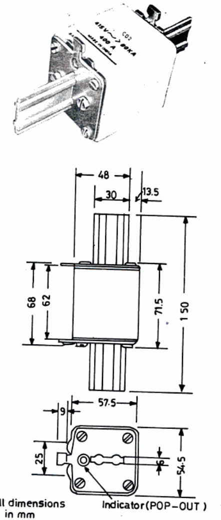


Fig. 8.21 (a) View of a HRC Fuse link (b) Dimension of a HRC Fuse link

9

Graded Exercises on Reading and Interpreting Engineering Drawings

9.1 INTRODUCTION

A technician engineer, whether employed in the shop floor or on an installation: site, is to read and interpret drawings so as to carry out his functions as most of technical communications are accompanied by drawings. This chapter includes exercises, graded from simple to complex, covering various aspects of engineering drawings.

9.2 GUIDELINES FOR READING AND INTERPRETING DRAWINGS

The following are some of the guidelines for reading and interpreting drawings.

(i) *Reading the Title Block:* This includes understanding the title of the drawing, scale, projection, reference drawings, if any, etc.

(ii) *Checking the Projections:* Checking the method of projections, *i.e.*, to ensure that the first angle and the third-angle method of projections are not be intermixed. Line alignment of the two views with the other view is also to be checked.

Checking the relative position of points in views, *i.e.*, to check that any point or line has its respective projection in the other two views also.

These points are to be kept in mind throughout, while checking a given drawings.

(iii) *Checking the Line Work:* This includes the followino:

Checking the thickness of the line.

Checking the border lines of the object with other line work in the drawing such as dimension lines, section lines, centre lines, leader lines etc.

Extension lines should appear to come from the object.

Arrow heads of the dimension lines should touch the dimension leader lines.

Checking the arrow-heads, i.e. to see that they are proportionate. The arrow heads throughout a drawing should be of the same type.

(iv) *Checking the Dimensioning:* Checking the system of dimensioning whether they are all aligned or unidirectional.

Dimensioning throughout a drawing should be in any one system of dimensioning.

Checking whether repetition of dimensions is there in other views. This may be avoided.

Checking whether there are any missing dimensions. Diameters for full circles and radii for part of a circle should be dimensioned.

Location and size dimensions should be given. Checking the labelling *i.e.*, all notes should be indicated with the help of leader lines outside the view.

Checking whether the views are labelled.

Checking whether the dimensioning of threads, chambers, countersanks, areas, angles etc. are done as per ISS in the three views.

(v) *Checking the Lettering:* Checking the size and type of lettering for all notes, labels, sub-heading, main heading, etc.

All the notes and labels should be in simple, block letters.

(vi) *Checking the Sectioning:* Checking the correctness of sectioning in all the three views.

Checking the hatching lines, (thickness, slanting, uniformity in spacing, etc.)

Checking whether hatching lines cross any firm lines or terminate at any dotted line.

(vii) *Checking the Assembly and Details:* Checking the dimensions of each detail drawing.

Checking whether the different parts fit each other as per dimensions. All the parts must tally in dimensions.

If assembly drawing is given, sectional views should be given to understand the interior parts. Major dimensions are only necessary in assembly drawing, and all the dimensions should be given in detail drawings.

Checking whether parts are numbered in detail and assembly drawings, by the same number, and whether the index table is provided.

9.3 GRADED EXERCISES WITH FEEDBACK

9.3.1 Pole of a d.c. machine

Fig. 9.1 shows the isometric view of a pole of a d.c. machine. Complete the orthographic projections. Indicate the appropriate dimensions also.

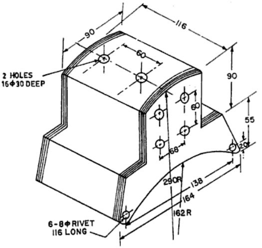


Fig. 9.1 Isometric view of a pole of a d.c. machine

Answer

Complete Orthographic Projections are drawn and dimensioned properly as in Fig. 9.2.

9.3.2 A cable socket

Fig. 9.3 shows sectional elevation and plan (in part) of a cable socket. Draw an ordinary elevation showing all hidden positions in dotted lines and indicate the dimensions also. Mention the drill angle 'a'. Indicate the mistake at 'b'.

Answer

(i) An ordinary elevation showing all hidden details in dotted lines is given as in Fig. 9.4.
(ii) All the dimensions have been indicated.
(iii) Drill angle is 118°
(iv) The mistake at *b* is that no arrow head should be at the centre.

9.3.3 An overhead line insulator

Fig. 9.5 shows an overhead line insulator in half section. Draw the full section of the insulator.

Answer

The full sectional view of the insulator has been drawn as in Fig. 9.6.

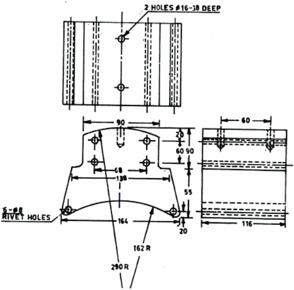


Fig. 9.2 Orthographic projections of a pole of a d.c. machine

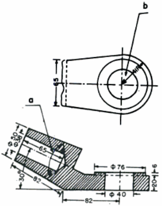


Fig. 9.3 Sectional elevation and plan of a cable socket

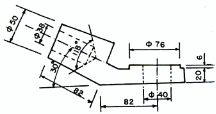


Fig. 9.4 A cable socket in ordinary elevation

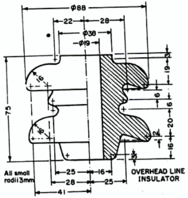


Fig. 9.5 An overhead line insulator in half section

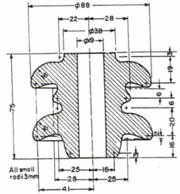


Fig. 9.6 An overhead line insulator in full section

9.3.4 A bus-bar post

Fig. 9.7 shows the two views of a bus-bar post.

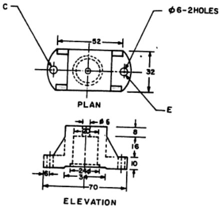


Fig. 9.7 Two views of a bus-bar post

(i) Draw the side view.
(ii) Mention the angle of projection used.
(iii) What is the idea of hole C?
(iv) What is the centre to centre distance of the hole C and E?

Answer

(i) Side view is drawn as shown in Fig. 9.8.
(ii) Third angle method of projection is used.
(iii) 6 mm
(iv) 58 mm.

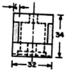


Fig. 9.8 Side view of a bus-bar post

9.3.5 Female part of a kit-kat fuse

Fig. 9.9 shows the plan and front elevation in half section of the female part of a kit-kat type fuse. Draw the side view. Show the dimensions also.

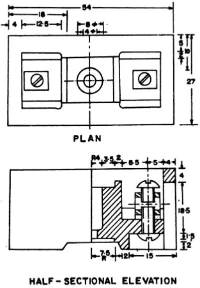


Fig. 9.9 Two views of the female part of a kit-kat type fuse

Answer

The side view has been drawn and the dimensions are indicated as shown in Fig. 9.10.

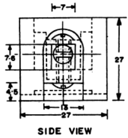


Fig. 9.10 Side view of the female part of a kit-kat type fuse

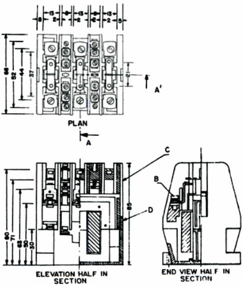


Fig. 9.12 Orthographic projections of an electromagnetic type contractor

(iv) Half section.

9.3.10 Cartridge Type Fuse Assembly

Fig. 9.19 shows the three views of the D-type cartridge fuse assembly. Point out the mistakes in the drawing, if any. Show the section plane in the plan.

Answer

(i) Screw B is to be shown in the top view.
(ii) The portion C is to be shown with the threads.
(iii) Section lines should be drawn at D in the elevation.
(iv) Seat for the screw for fixing the cap with the body is shown at E.
(v) Base and cap should be of the same width as shown at F.
(vi) Section plane is shown as A–A′ as in Fig. 9.20.

9.3.11 Three-phase Core Type Power Transformer

Draw neatly to a convenient scale the front elevation and plan in full section as per main dimensions of a 3 phase core type power transformer.

Diameter of the core circum circle, d = 23 cm

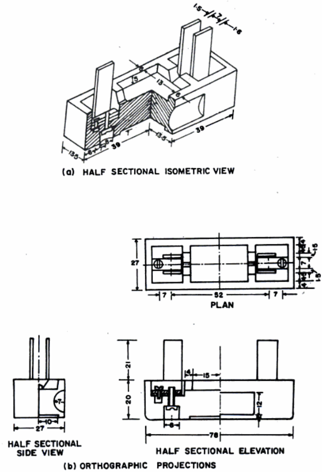


Fig. 9.13 (a) Half sectional isomeric view of a kit-kat fuse, (b) orthographic projections

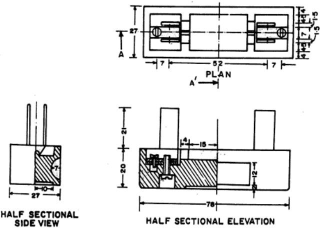


Fig. 9.14 Orthographic projections of one part of a kit-kat fuse

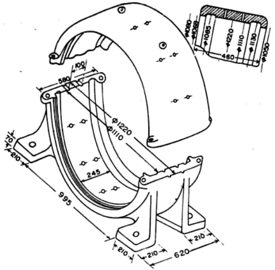


Fig. 9.15 Isometric view of a field magnet frame

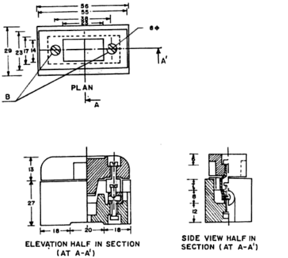


Fig. 9.18 Three views of a kit-kat fuse assembly showing the section plane

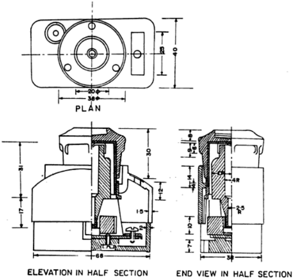


Fig. 9.19 Three views of a cartridge fuse assembly

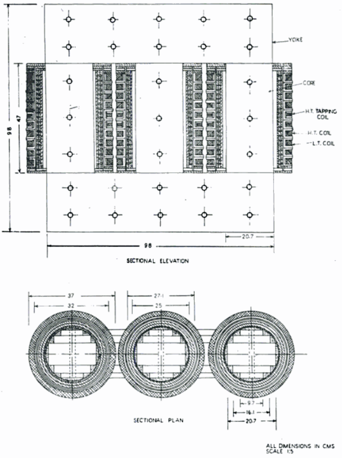


Fig. 9.21 Three phase core type transformer

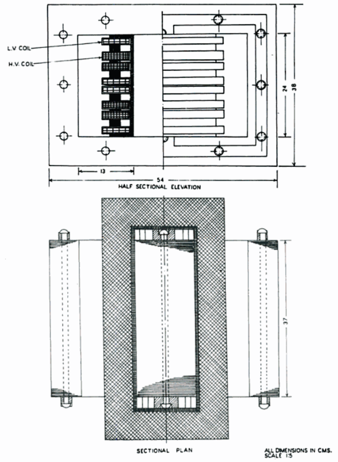
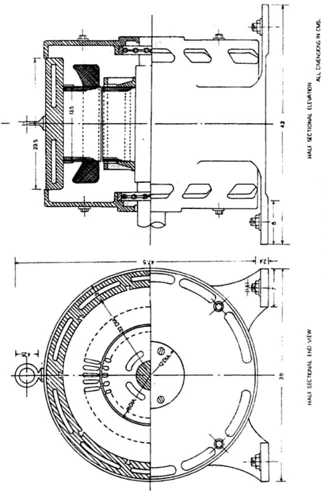


Fig. 9.22 Single phase shell type transformer



SQUIRREL CAGE INDUCTION MOTOR

Fig. 9.23 Half sectional longitudinal view and end view of a squirrel cage induction motor

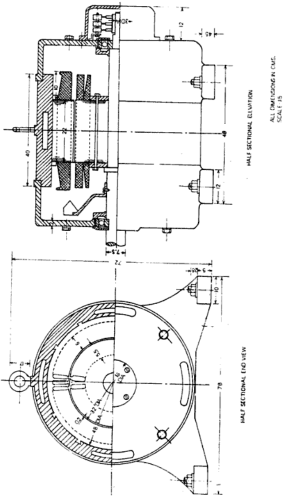


Fig. 9.24 Three phase slipring induction motor

No. of poles = 10
Length of stator = 16 cm
Stator coil overhang on each side = 10 cm
Length of yoke = 22 cm
Overall distance of the base plate from the centre line of the alternator to the ground level = 50 cm.

Draw to the scale (a) half sectional end view of the alternator showing all essential parts (b) half sectional longitudinal view showing the stator core, air ducts, rotor etc.

Answer

See Fig. 9.25.

9.3.16 A D.C. Machine in Sectional Views

The armature core of a D.C. machine is built up of laminations. Slots, to carry armature coils, are made throughout the outer periphery of the laminations. Poles are attached to the yoke by means of bolts. The commutator is built of bars of copper which are insulated from one another by mica segments. The dimensions are as follows:

Diameter of shaft = 5 cm
Outside dia of armature = 36 cm
Axial length of armature = 25 cm
Armature winding overhang on each side = 7.5 cm
No. of radial cooling ducts = 2
Diameter of commutator = 23 cm
Axial length of commutator = 11.5 cm
No. of poles = 4
Pole height = 16 cm
Pole width = 12 cm
Pole arc = 0.65
Pole pitch = 90°
No. of interpoles = 4
Inter pole dimensions = 4 cm × 15 cm
Thickness of yoke = 3.5 cm
Depth of slot = 2.5 cm
Draw (a) half sectional end view (b) half sectional elevation

Answer

See Fig. 9.26.

9.3.17 Power Control Panel

Fig. 9.27 shows the single line wiring diagram of a power control panel of a factory. The supply to the panel is fed from a 500 KVA 11 KV/415 V transformer which is fed from Electricity Boards' supply system. The incoming

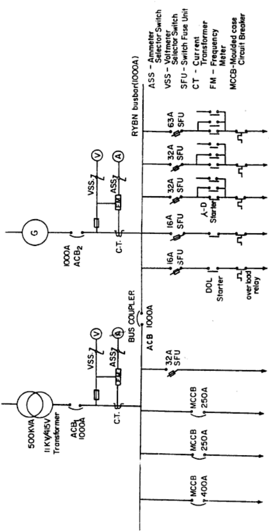


Fig. 9.27 Single Line wiring diagram of a power control panel

supply is fed to the bus-bars through a 1000 A air circuit breaker (ACB) and other metering instruments.

There is an alternative supply arrangement from a diesel generator through another ACB and metering instruments. The RYBN bus bars are divided into two by a bus coupler ACB of 1000 A. The outgoing feeders are as shown in Fig. 9.27.

Interlocking arrangements are provided between the two ACBs and bus coupler ACB. Draw the outside view of the front elevation and side view of a power control panel to be fabricated

Solution. The front elevation and side view of the panel are shown in Fig. 9.28.

The outside dimensions of the following switchgears are given to help decide the dimensions of the panel

	Length	*Breadth*	*Height*
L & T ACB (1000 A)	400	600	459
MCCB: 400 A	210	142	290
250 A	210	142	290
SFU: 63A	70	81	86
32A	70	81	86
16A	70	81	86
S-D Starter	175	164	435
DOL starter	156	144	256

The height of panel should not be more than 2.5 m. The outgoing cable connections are taken from the rear of the panel. As a result the width of the panel is taken as 900 mm. There is a base frame of 100 mm at the bottom and busbar chamber of 300 mm at the top.

9.3.18 Panel Board for Control of Motors and Heaters

Fig. 9.29 shows the schematic diagram of the control circuit and the complete wiring diagram of the control arrangement as described. There are three boilers to which water is pumped into by three 5 hp pump motors. The boilers are fitted with 80 KW heaters. Motors and Heaters are to be controlled by separate ON-OFF pushbuttons, main switch and contactors. Temperature of boilers are controlled with the help of separate thermostats whose contacts are shown in the circuit as TH_1, TH_2, and TH_3, respectively. Float switches (F_1, F_2 and F_3) are fitted in the boilers to prevent overflowing of water. Draw the isometric view of a control panel for the motors and heaters.

Hint. Since the heaters are of 80 kW capacity, the rating of the switch fuse units and the contactors should be 200 A.

Solution. See Fig. 9.30 for the isometric view of tne panel.

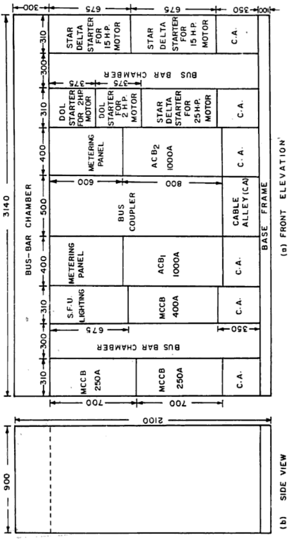


Fig. 9.28 Front elevation and side view of a power control panel board

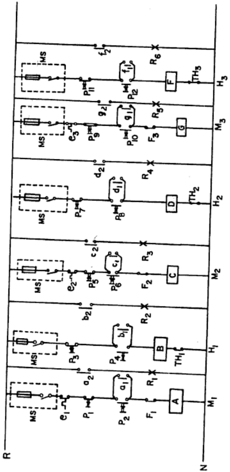


Fig. 9.29 (a)

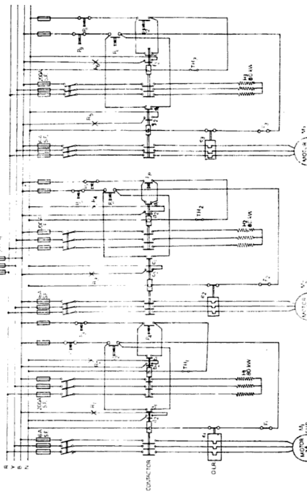


Fig. 9.29 (a) Schematic diagram of the control circuit; (b) complete wiring diagram

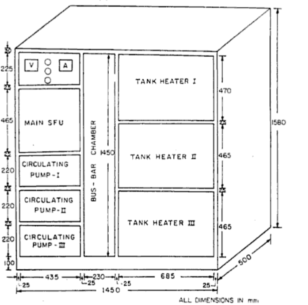


Fig. 9.30 Isometric view of a control panel

9.3.19 Power Control Centre

Fig. 9.31 shows the single line diagram of the supply arrangement in a factory. The electricity boards' industrial supply is taken through a 500 KVA transformer and an 800 A ACB to control the industrial load. Instruments required for measuring and protection are also shown. Another supply is taken from the electricity boards' commercial supply through a 500 KVA transformer and an 800 A ACB, to control the commercial load requirement. Draw the front view and side view of the power control centre.

Solution. General arrangements have been shown in front view and side view as in Fig. 9.32.

9.3.20 Fig. 9.33 shows the developed winding diagram of a 24 slot, 3 phase squirrel cage induction motor. Three phase motors have three independent windings, one for each phase placed at a space phase difference of 120 degrees. Study the diagram and answer the following:

(a) Mark the start and finish terminals of the three phase windings A, B & C i.e. A_S, A_F, B_S, B_F, C_S and C_F.

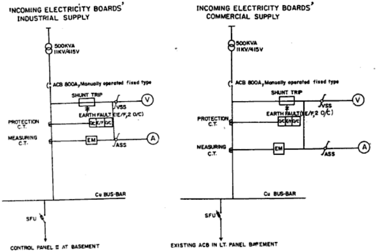


Fig. 9.31 Single line diagram of the supply arrangement of a factory

(b) Identify the type of winding.
(c) What is the coil pitch?
(d) What is the number of slots per pole per phase (Spp)?
(e) For how many poles has the winding been made?
(f) What is the angle (in electrical degrees) between consecutive slots?
(g) Mark the direction of current in the conductors at an instant of time at which the direction of current in C phase is negative and in the other two phases are positive.
(h) Show the location of poles.
(i) What is the pole-pitch?
(j) Is the coil pitch equal to pole-pitch? What is the type of winding in this case?
(k) How will you connect the winding terminals to make it star connected?
(l) How will you connect the winding terminals to make it delta connected?

Answers

(a) A_S, A_F, B_S, B_F, C_S and C_F are 1, 5, 3, 6, 4 and 2 respectively.
(b) Lap winding
(c) Coil pitch is 6 slots
(d) Spp is 2 slots.

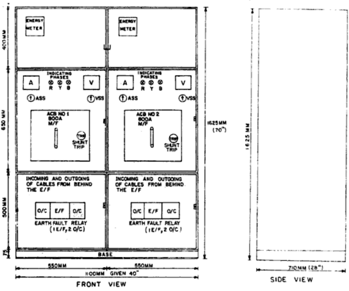


Fig. 9.32 General arrangement of a power control centre in two views

(e) 4 poles
(f) 30 degrees
(g) Current direction is upward in the conductors in slots 1 to 6, and 13 to 18, whereas it is downward in slots 7 to 12 and 19 to 24.
(h) Slots 1 to 6, and 13 to 18-North poles.
Slots 7 to 12 and 19 to 24-South poles.
(i) Pole pitch is 6 slots.
(j) Coil pitch is equal to pole pitch. Such type of windings are called full pitch winding.
(k) To make star connected winding, terminals 2, 5 and 6 are to be shorted or terminals 1, 3 and 4 are to be shorted.
(l) To make delta connected winding, terminals 5 and 3, 6 and 4, 2 and 1 are to be shorted.

9.3.21 Study the developed winding diagram of a 3 phase, 24 slot squirrel cage induction motor shown in Fig. 9.34 and answer the following:

(a) Mark the start and finish terminals of the three phase windings A, B & C.

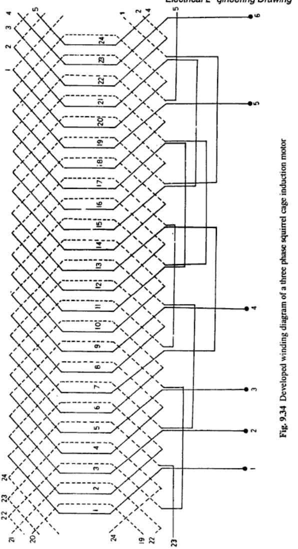


Fig. 9.34 Developed winding diagram of a three phase squirrel cage induction motor

(b) What is the Spp?
(c) How many poles are there?
(d) What is the coil-pitch?
(e) What is the pole-pitch?
(f) Is the coil-pitch equal to pole-pitch? What is the type of winding in this case?
(g) What is the angle between consecutive slots?
(h) Mark the direction of current in the conductors at an instant of time at which the direction of current in phase B is positive and in the other two phases are negative.
(i) Show the location of poles.
(j) How many conductors are there in the winding? What is the number of coils?
(k) How many coil sides are placed in one slot?

Answers

(a) A_S, A_F, B_S, B_F, CS and C_F and 1, 5, 3, 6, 5 and 2 respectively.
(b) Spp is 2 slots.
(c) 4 poles.
(d) Coil pitch is 5 slots.
(e) Pole pitch is 6 slots.
(f) Coil pitch is note equal to pole pitch. Such type of windings are called fractional pitch winding.
(g) 30 degrees.
(h) Current direction is upward in the conductors from lower layer of slot 2 to upper layer of slot 8 and from lower layer of slot 14 to upper layer of slot 20. Current direction is downward in the conductors from lower layer of slot 8 to upper layer of slot 14 and from lower layer of slot 20 to upper layer of slot 2.
(i) Slots 3 to 7 and 15 to 19-North poles.
Slots 9 to 13 and 21 to 1-South poles.
(j) 48 conductors, 24 coils.
(k) 2 coil sides are placed in one slot. Such windings are called double layer windings.

9.3.22 Study the developed winding diagram of a single phase high speed compressor motor shown in Fig. 9.35 and answer the following:

(a) What is the type of winding used?
(b) Mark the direction of currents on both the windings.
(c) Show the location of poles.
(d) How many poles are there?
(e) Name the two separate windings shown in the figure.
(f) In a single induction phase motor why do we provide two windings?
(g) What is the space phase difference between the two windings?

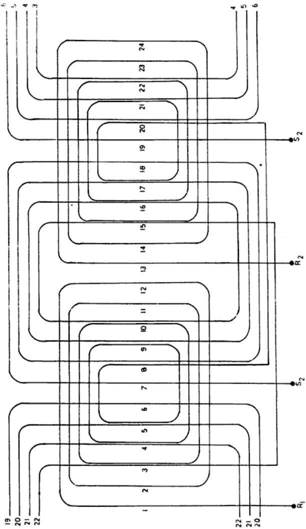


Fig. 9.35 Developed winding diagram of a single phase induction motor

10

Drawings of Electronic Circuits and Components

In this chapter has been included drawings of some of the commonly used electronic circuits and components. They include drawings of rectifiers circuits, CRO, power supply, TV transmitter and receiver, tape recorder, stereo-amplifier, etc.

10.1 RECTIFIER CIRCUITS

(a) *Half Wave Rectifier:* Fig. 10.1 shows the circuit of a half-wave rectifier. During the positive half-cycle of the Input voltage the diode conducts and current i_L flows through the load resistor R_L. During the negative half-cycle of the input voltage, the diode is reverse biased. Therefore the diode will be non-conducting; and hence almost no current will flow and no voltage will be developed across the load resistance.

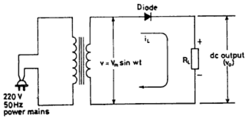


Fig. 10.1 Half wave rectifier

(b) *Centre Tap Rectifier:* The circuit of a centre-tap rectifier is shown in Fig. 10.2. It uses two diodes D_1 and D_2. During the positive half-cycles of the secondary voltage, the diode D_1 is forward biased and D_2 is reverse biased. Current flows through the diode D_1, load R_L and upper half of the transformer winding. During the negative half-cycles diode D_2 becomes forward biased and D_1 reverse biased. Now D_2 conducts and D_1 becomes non-conducting. Current flows through diode D_2, load resistor R_2 and the lower half of the transformer winding.

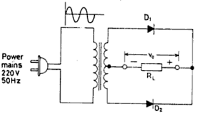


Fig. 10.2 Centre-tap rectifier

(c) *Bridge Rectifier:* A more widely used full-wave rectifier circuit is the bridge rectifier. It requires four diodes instead of two, but avoids the need for a centre-tapped transformer. During the positive half cycle of the secondary voltage, diodes D_2 and D_4 do not conduct. Current therefore flows through the secondary winding, diode D_1, load resistor R_L and Diode D_3. During the negative half cycle current flows through load resistance R_L due to conduction of diodes D_2 and D_4. In both the cases, current passes through the load resistor in the same direction. Therefore, fluctuating, unidirectional voltage is developed across the load.

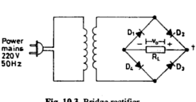


Fig. 10.3 Bridge rectifier

10.2 REGULATED BATTERY ELIMINATOR

Fig. 10.4 shows the circuit diagram for a regulated battery eliminator. The main transformer, diodes, and filter capacitor makes the eliminator, zener diode,

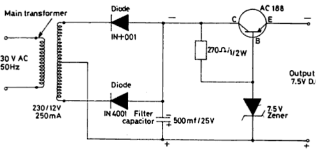


Fig. 10.4 Regulated battery eliminator

transistor and resistor forms the regulation circuit. This circuit provides high input impedance and low output impedance. The effect of variation in the main voltage is eliminated by the zener diode. This diode maintains constant voltage at the transistor base. The output voltage will remain constant even when there is variation in the main voltage or load.

10.3 CATHODE RAY OSCILLOSCOPE (CRO)

(a) Block Diagram of a CRO: Of all the laboratory instruments available today, perhaps the most important and versatile one is the cathode-ray oscilloscope (CRO). It is primarily used for the display of waveforms. Block diagram of a Cathode-Ray Oscilloscope is shown in Fig. 10.5. This diagram shows minimum stages required in a CRO. The subsystems are:

(i) Vertical deflection system
(ii) The horizontal-deflection system, including the time-base generator and synchronisation circuitry
(iii) The CRT (Cathode Ray Tube)
(iv) The high voltage and low voltage power supplies.

The vertical deflection system consists of an input attenuator and a number of amplifier stages. The gain of the vertical amplifier can be controlled by the attenuator. The wave form to be displayed is fed to this Y-input. The horizontal deflection system provides the voltage for moving the beam horizontally. It includes a number of amplifier stages, the gain of which can be controlled. It has a sawtooth oscillator, or a time-base generator. Also included in this subsystem is a synchronization circuit. The purpose of this circuit is to start the horizontal sweep at a specific instant with respect to the waveform under observation. In addition to the internal sweep, there is a provision for the

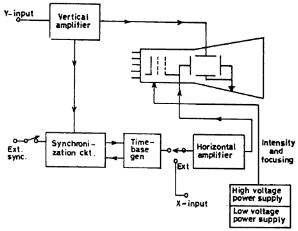


Fig. 10.5 Block diagram of CRO

external horizontal Input (or X-Input). One may either select the internal sweep voltage or any other voltage fed externally for deflecting the beam in horizontal direction. When operated together, they will display the incoming signal on the screen of CRO.

(b) Various Controls of an Oscilloscope. Fig. 10.6 shows the front outside view of a CRO. The various controls have been numbered. Their description have been given as under.

1. CAL	Socket provided for square wave output 2 Vp-p at 1 KHz frequency. Used for probe compensation and checking vertical sensitivity.
2. POWER ON/OFF	Push button switch for supplying power to the instrument.
3. INTENS	Controls the brightness of the trace.
4. FOCUS	Controls sharpness of the trace.
5. TR	Controls alignment of the trace with screw driver adjustment.
6. ILLUM	Controls illumination.
7. IM/30pf	Input signal socket for channel 1 or X-input in case of x-y mode.
8. AC/GND/DC	Selects methods of coupling input signal to the grid of input amplifier (vertical).

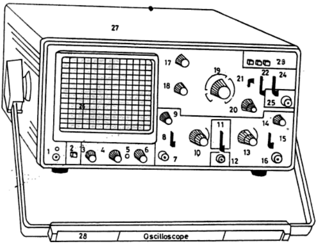


Fig. 10.6 Front panel diagram of a CRO

	AC – DC component of input signal is blocked (by coupling capacitor inserted between input connector and amplifier). GND – Input circuit is grounded (does not ground applied signal). DC – All components of the input signal are passed to the input amplifier.
9. POSITION (vertical)	Controls vertical position of the trace. This control moves the trace up and down to any desired vertical position on the screen. This switch is for channel 1.
10. VOLTS/DIV	Selects vertical deflection factor. The amount of vertical deflection produced is determined by the signal amplitude and the setting of the variable volts/div. control. This switch is for channel 1.
11. VERTICAL MODE (CH1/CH2/DUAL/ADD)	Selects vertical mode of operation. This control is found only on oscilloscopes having more than one mode of operation. CH1-Channel 1 signal is displayed CH2-Channel 2 signal is displayed

	DUAL-Channel 1 & 2 both signals are displayed. ADD-Channel 1 & 2 signals are algebraically added and algebraic sum displayed on the screen.
12. GROUND	Ground of the chassis.
13. VOLTS/DIV	Same as described at number 10 earlier. This switch is for channel 2.
14. POSITION (VERTICAL)	Same as described at number 9 earlier. This switch is for channel 2.
15. AC/GND/DC	Same as described at number 8 earlier. This switch is for channel 2.
16. IM/30 pf	Input signal socket for channel 2 or Y signal input in case of X-Y mode.
17. POSITION (HORIZONTAL)	Controls horizontal position of the trace. This control moves the trace right or left on the screen to any desired position. (common for both the channels).
18. VAR	Controls the time speed in between two steps of TIME/DIV switch.
19. TIME/DIV	Selects the calibrated horizontal sweep rates for the internal sweep generators. The variable control provides continuously variable sweep rates between the settings of the time/div switch.
20. LEVEL	The triggering level control determines the voltage level on the triggering waveform at which the sweep is triggered. When the control is set at (+) the trigger circuit responds at a more positive point on the trigger signal. When the control is set at (–) the trigger circuit responds at a more negative point on the trigger signal.
21. SLOPE	Selects the trigger circuit response on the positive or negative going portion of the trigger signal. When switch is in positive (+) position display will start with the positive going portion of the waveform; in the negative (–) position, the display will start with the negative going portion of the waveform.
22. COUPLING	Determines the method of coupling the triggering signal to the trigger circuit. AC – the ac position blocks the d-c components of the trigger signal. The signals below the frequency of about 30 Hz will be attenuated. HF REJ – This position passes all low frequency signals between frequency of about 30 Hz and 50

KHz. When triggering from complex waveform this position is useful for providing stable display of low frequency waveforms.

TV – This position allows video signal at frame frequency (up to 20 kHz) to be blocked.

DC – D.C coupling provides stable triggering with low frequency signals which would be attenuated in the A.C. position or with low repetition rate signals.

23. SWEEP MODE — Determines the sweep operating mode of a section of the dual trace. This control is also known as sweep selector, and provides three basic modes: linear sawtooth sweep (internal), external and line frequency sine wave (internal).

AUTO TRIG – Used where reference trace is needed and trigger signal is not available

NORM TRIG – This mode is used to display the signals with repetition rate below about 20 Hz, or when a trace is not desired in the absence of the trigger signal.

SINGLE TRIG – When the signal to be displayed is not repetitive or varies in amplitude, shape, time a repetitive display may produce an unstable waveform. This mode is used to avoid this situation.

24. SOURCE — Selects source of triggering signal. This control (also called sync selecto.) selects the type of signal used to synchronize the horizontal sweep oscillator.

INT – In this position the sweep is triggered internally and the trigger signal is obtained from the vertical system.

LINE – In this position a sample of power line frequency is connected to the trigger generator and to the horizontal sweep generator.

EXT – External signal through an ext. trig. input connector is used to trigger the sweep in the ext position of the switch

25. IM/100 Vp max — Input socket for external triggering signal.

26. SCREEN — Known as CRT (Cathode ray tube) is coated with phosphor from inside so that, when electrons strikes this coating, it will fluorence and emit light which in turn displays the waveform on the screen. The screen is equally divided into different portions known as divisions. The X-axis

	and Y-axis reference lines are further subdivided into equal parts for different measurements during the use.
27. PROTECTIVE COVER	This cover protects the internal circuit and the CRT frrm any mechanical damage. It also protects the user from any accidental contact with the live circuit of the oscilloscope. The instrument should never be used with this cover removed.
28. TILTING HANDLE	This serves the purpose of lifting the Oscilloscope as well as a tilting stand which can be adjusted at some suitable angle for viewing the displayed waveforms.

(c) *Front panel diagram of a CRO:* Fig. 10.7 shows the front panel of another type of a solid state oscilloscope. The brief explanation of the various controls have been given as follows:

ON POWER (1)	It is a toggel switch meant for switching on power. In ON position, power is supplied to the instrument and the neon lamp (3) glows.
INTEN (2)	It controls the trace intensity from zero to maximum.
FOCUS (4)	It controls the sharpness of the trace. A slight readjustment of this control may be necessary after changing the intensity of the trace.
X-MAG (5)	It expands length of time-base from 1 to 5 times continuously, and makes maximum time-base to 40 ns/cm.
SQ WAVE (6)	This provides a square wave of a 2v (p – p) amplitude to enable one to check the Y-calibration of the scope.
SAWTOOTH WAVE (7)	This provides a sawtooth waveform output coincident to sweep-speed switch with an output of 5 V (p – p). The load resistance should not be less than 10 k.
VERTICAL SECTION	
CAL-Switch (8)	When pressed, a d.c. signal of 15 mV or 150 mV is applied to vertical amplifier depending upon the position of XI-XO.1 Switch (9).
XI-XO.1 Switch (9)	When switched in 0.1 position, it magnifies basic sensitivity to 5 mV/cm from 50 mV/cm.
Y-POS (10)	This control enables the movement of the display along the Y-axis.
DC BAL (11)	It is a preset control on panel. It is adjusted for no movement of the trace when either XI-XO.1

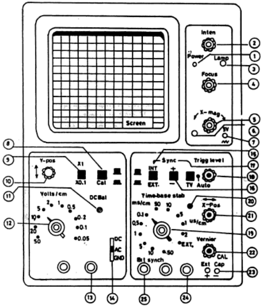


Fig. 10.7 Front Panel of Solid-state Oscilloscope

Switch (9) is pressed or the position of AC-DC-GND coupling Switch (14) is changed.

VOLTS/CM (Alternator) (12) It is a 10 position alternator switch which adjusts sensitivity of the vertical amplifier from 50 mV/cm to 50 V/cm in 1, 2, 5, 10 sequence. Alternator accuracy is ± 3%.

Y-INPUT (13) It connects input signal to vertical amplifier though AC-DC-GND coupling switch (14).

AC-DC-GND Coupling SWITCH (14) It selects coupling to the vertical. In DC mode, it directly couples the signal to the Input; in AC mode, it couples the signal to the Input through a 0.1 µf, 400-V capacitor. In GND position, the Input to the attenuator (12) is grounded whereas Y-input is isolated.

HORIZONTAL SECTION

SYNC Selector (15, 16, 17)	The INT/EXT Switch (15) selects internal or external trigger signal. The + ve or – ve switch (16) selects whether the waveform is to be triggered on + ve or – ve step. NORM/TV Switch (17) permits normal or TV (line frequency) frame.
TRIGG LEVEL (18)	It selects the mode of triggering. In Auto position, the time base line is displayed in the absence of input signal, when the Input signal is present, the display is automatically triggered. The span of the control enables the trigger point to be manually selected.
TIME BASE (19)	This selector switch 3 selects sweep speed from 50 ms/cm to 0.2 μs/cm in 11 steps. The position marked EXT is used when an external signal is to be applied to the Horizontal Input (24).
STAB (20)	It is a preset control on the panel. It should be adjusted so that one just gets the base line in AUTO position of Trigger Level control (18). In any other position of the trigger level control, one would not get the base line.
X-POS (21)	This control enables the movement of display along the X-axis.
VERNIER (22)	This control is fine adjustment associated with the Time-base sweep selector switch (19). It extends the range of sweep by a factor of 5. It should be turned fully clockwise to the CAL position for calibrated sweep speeds.
EXT CAP (23)	This pair of connectors enables the time base range to be extended beyond 50 ms/cm. by connecting a capacitor at these connectors.
HOR INPUT (24)	It connects the external signal to Horizontal amplifier.
EXT SYNC (25)	It connects external signal to trigger circuit for synchronization.

10.4 BLOCK DIAGRAM OF A RECEIVER USING SILICON TRANSISTOR

Most of the receivers use silicon transistors. Block diagram of a receiver is shown in Fig. 10.8. The different blocks as follows :

Antenna: The electromagnetic waves transmitted from transmitters are intercepted by the antenna. The antenna can be in the form of a ferrite rod as in case of MW (Medium Wave) or may have shapes of indoor or outdoor type.

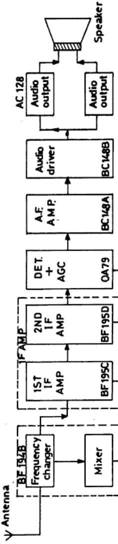


Fig. 10.8 Block diagram of receiver using silicon transistor

Mixer and Oscillator: To select the desired station the first requirement is of a tuner circuit. Antenna coil with gang capacitor forms this tuner circuit. By varying the capacity of the gang capacitor the resonance frequency of the tuner circuit is changed and likewise the desired frequency is selected. There are two important parts of the mixer and oscillator block. First part is the oscillator, which is also known as the local oscillator (L.O.) and second part is the mixer. The high frequency signal produced by the L.O. and the selected signal by tuner circuit are simultaneously fed into the mixer stage. Hereafter hetrodying process (mixing and superimposing the signals) the outgoing signal is connected to the intermediate frequency stage. In case a single transistor is performing both the functions that of L.O. and mixer, it is called the converter stage. In a converter stage usually 194 B transistor is used.

Intermediate Frequency Amplifier (IFA): The IF frequency produced by the mixer stage, after the hetrodying process is amplified by IF amplifier stage. Normally two IF amplifier (IFA) stages are used. These are called the Ist and the 2nd IFA respectively. Transistor BF 195 C is used as Ist IFA and transistor BF 195 D is used as 2nd IFA.

Detector and Automatic Gain Control (AGC): Every signal has two side bands. They are (i) upper side band (USB) and (ii) lower side band (LSB). The detector suppresses either lower side band (LSB) or the upper side band (USB). After this detection (rectification) process, three components are left. First, the RF which act as carrier and by-pass filter, the second, the audio which are coupled to the audio amplifier stage through a capacitor for further amplification, and the third the d.c. voltage. All these three combined are employed as AGC which controls the gain. Diode OA 79 or IN 34 are generally used for this stage. The AGC voltages are applied to the transistor BF 194 B converter stage.

Audio Frequency Amplifier (AFA): The signal received at the output of the detector and AGC is further amplified through the AFA. Normally two stages are used in this section. First is called the pre-amplifier using BC 148 A transistor. Second is the driver stage which may use any driver transistor such as SL 100, BC 148 B etc.

Audio Output Stage: This is the power amplifier stage which boosts power so that loudspeaker can operate effectively. Class B Push-pull amplifier configuration is most commonly used for this purpose. Matched pair of AC 128 is used for forming the class B push-pull amplifier. The AC 128 transistors are fixed on heat sinks for propr heat dissipation.

10.5 BLOCK DIAGRAM OF MONOCHROME T.V. TRANSMITTER

Fig. 10.9 shows block diagramatic representation of a monocrome T.V. Transmitter. A brief description of sound transmission and picture transmission is given as follows.

Sound Transmission. The microphone converts the sound associated with the picture being televised into proportionate electrical signal, which is normally a

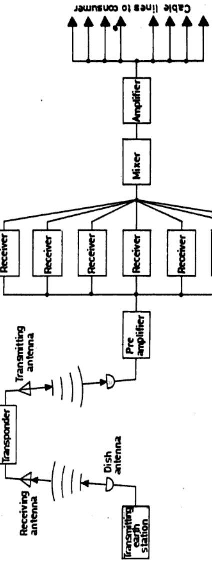


Fig. 10.11 Block diagram of cable TV network

increased TV programmes to subscribers who pay a fee for this service. Signals are transmitted from transmitting earth stations, and these signals are received by the satellite receiving antenna and amplified by amplifier which is inbuilt into the satellite and then finally transmitted by transmitting antenna. These signals are received by dish antenna and then amplified by pre amplifier before being fed into different receivers. Amplification is necessary because during propagation signals become weak. The output of 7 receivers as shown in Fig. 10.11 are fed into the mixer for mixing process and then fed into amplifier to increase the signal level and finally the signal goes into co-axial cable for use by the subscribers.

10.8 SIMPLIFIED SATELLITE COMMUNICATION LINK

Block diagram of a Satellite communication link is shown in Fig. 10.12. It consists of a transmitting earth station, the satellite, receiving earth station and propagation paths travelled by signals. The up-link frequency is 6 GHz and the down-link frequency is 4 GHz. The satellite is assumed to have only one transponder. The up-link consists of an earth station transmitter and its antenna, the up-link propogation path, the satellite receiving antenna and the transponder receiver. The downlink consists of transponder transmitter, satellite transmit-

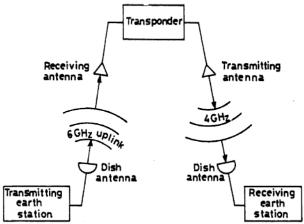


Fig. 10.12 Simplified Block Diagram of a 6/4 GHz Satellite Communication Link

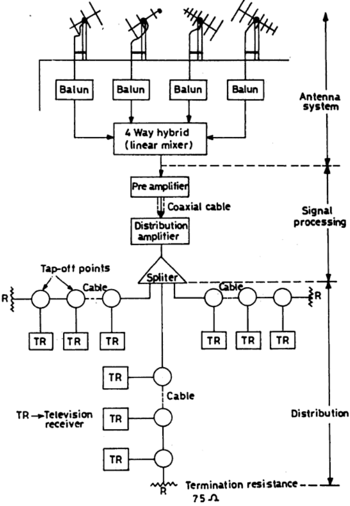


Fig. 10.13 Block diagram of MATV system

ting antenna, down-link propagation path and the earth station receiver antenna. Transmitting earth station transmits the signal through propagation path. The satellite transponder receives the incident signal, converts it from 6 GHz to 4 GHz band and transmits it back to the earth.

10.9 MASTER ANTENNA TELEVISION (MATV)

The block diagram of a basic MATV is shown in Fig. 10.13. The purpose of a MATV system is to deliver a strong signal (over 1 mV) from one or more antennas to every television receiver connected to the system. Typical applications of a MATV system are in hotels, motels, schools, apartment buildings, etc. One or more antennas are usually located on roof top, the number depending on available telecasts and their direction. MATV systems are designed to have a 75 ohm impedance. Since most antennas have a 300 ohm impedance; a balum is used to convert the impedance to 75 ohms. Antenna outputs feed into a 4-way hybrid. A hybrid is basically a signal combining linear mixer which provides suitable impedance matches to prevent development of standing waves. The output from the hybrid feeds into a distribution amplifier via a pre-amplifier. The function of these amplifiers is to raise the signal amplitude to a level which is sufficient to overcome the losses of the distribution system while providing connections to every receiver in the system. The output from distribution amplifier is fed to a splitter through co-axial trunk lines. A splitter is a resistive inductive device which provides trunk line isolation and impedance match. Co-axial distribution lines carry television signals from the output of splitters to points of delivery, called subscriber tap-offs.

INDEX

ELECTRICAL ENGINEERING DRAWING
SECOND EDITION

Electrical drawing is an important engineering subject taught to electrical/electronics engineering students both at degree and diploma level institutions. The course content generally covers assembly and working drawings of electrical machines and machine parts, drawing of electrical circuits, instruments and components. The contents of this book have been prepared by consulting the syllabus of various State Boards of Technical Education as also of different engineering colleges. This book has nine chapters. Chapter I provides latest informations about drawing sheets, lettering, dimensioning, method of projections, sectional views including assembly and working drawings of simple Electrical and Mechanical items with plenty of solved examples. The second chapter deals with drawing of commonly used electrical instruments, their method of connection and of instrument parts. Chapter III deals with mechanical drawings of electrical machines and machine parts. The details include drawings of D.C. machines, induction machines, Synchronous machines, Fractional KW motors and Transformers. Chapter IV includes Panel Board wiring diagrams. The fifth chapter is devoted to winding diagrams of D.C. and A.C. machines. Chapter VI and VII include drawings of Transmission and Distribution line accessories, supports, etc. as also Plant and Substation Layout diagrams.

Miscellaneous drawing like drawings of Earth Electrodes, Circuit Breakers, Lighting arrestors, etc. have been dealt with in Chapter VIII. Graded exercises with feedback on Reading and Interpreting engineering drawings covering the entire course content have been included in IX providing ample opportunities to the learner to practice on such graded exercises and receive feedback. Chapter X includes drawings of Electronic circuits and components. This book, unlike some of the available books in the market, contains a large number of solved examples which would help students understand the subject better. Explanations are very simple and easy to understand. Reference to norms and standards have been made at appropriate places. Students will find this book useful not only for passing examinations but even more in Reading and Interpreting engineering drawings during their professional career.

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