EDO UNIVERSITY IYAMHO
FACULTY OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EEE 313 ELECTRICAL MACHINES I

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Lectures: Tuesday, 10.00am – 12noon, DST, Phone; (+234)7062701842
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Teaching Assistance: *Engr Ogbikaya Stephen*

General Overview of Lecture: The course introduces the classifications of electrical machines, review the concept of electromehanical energy conversion, the theory of electromagnetic induction as it applies to static electrical machine, transformer, rotating magnetic field in the case of electric motors and generators. The principle of operation, analysis, test and areas of applications transformers, DC motors and DC generators will be studied. Parallel operation of power transformers and generators will be discussed. The Performance and methods of speed control of DC machines, induction motors, and linear motor will be highlighted. The essences circle diagrams as it relates to AC machine will be introduced.

Pre-requisite: the students are expected to have strong background knowledge in electrical engineering sciences and engineering mathematic with special emphasis on calculus

Learning outcome: At the completion of this course, the students are expected:
i. to have a better understanding of the classification of electrical machines.
ii. to have a better understanding electromechanical energy conversion process.
iii. to understand and appreciation the principles of electromagnetic induction, static and rotating magnetic field theory.
iv. to know electro technical materials used in the construction of electrical machines.
v. to understand the analysis, test, operations and areas of applications of transformers, electric motors and generators.
vi. to appreciates the various methods of speed control of DC motor.
vii. to gain experience on the types of winding used in the construction of electrical machines.
viii. to understand the essences and construction circle diagram.

Assignments: There will be 5 homework assignments in throughout the course in addition to a Mid – Term Test and a Final Examination. Term papers are given at the beginning of the class and submission will be on the due date before the final examination. Home works in the form of individual assignments and group assignments are organized and structured as preparation for the midterm and final examination, and are meant to be a studying material for both examinations. There will be 10 laboratories and workshop practices related to the topics covered in this course. The laboratory experiments and workshop practices will help the students to have a better understanding and appreciates the theoretical knowledge they gained in the course.

Grading: We will assign 10% of this class grade to home works, 10% for mid- term test, 10% to mid-term paper and 70% for final examination. The final examination is comprehensive.

Textbook: The recommended textbooks for this class are as stated:
Title: Transformers
Authors: Bharat Heavy Electricals Limited
Publisher: Tata McGraw Hill, New Delhi, Second Edition
Year: 2003.

Title: Electrical Machines
Authors: Ghosh S.
Publisher: Dorling Kindersley Pvt Ltd, India
Year: 2007

Title: Installation, Maintenance and Repairs of Electrical Machines and Equipment
Authors: Gupta M.
Publisher: S. K. Katara & Son, New Delhi
Year: 2014

Title: Electrical Machines S. I. Units
Authors: Rajput R. K.,
Publisher: Laxmi Publication (P) Limited, New Delhi
Year: 2008

Title: A Text of Electrical Technology
Author: Theraja B. L. & Theraja A. K.
Publisher; S. Chand & Company Ltd, New Delhi
Year: 2008

Main Lecture: Below is a description of the contents.

Introduction to Electrical Machine

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The electrical energy used in our homes today is obtained from some natural resources. This resources can be classified as renewable (Hydro-power, Biomass, Biofuels Ethanol and Biodiesel, Wind, Geothermal, Solar, Ocean Tides and Waves, Magneto hydrodynamic) and nonrenewable (Oil and Petroleum products, Hydrocarbon gas liquids, Natural gas, coal and Nuclear). The utilization of these natural resources inferably involves the conversion of energy from one form to another. Often, device doing this job that performing some mechanical motion may be called energy conversion machines. For examples; heat exchanger converts the heat supplied by the combustion of fuels into mechanical energy. A sizable proportion of the energy stored by nature in chemical compound, the atom and nuclei of substances, the flow of rivers, the tides of sea, the wind and solar radiation is now being converted to electrical energy. This form of conversion is attracting because electricity can in many cases be transmitted over long distances and distributed among consumers and converted back into mechanical, thermal and chemical energy with minimal loses. From other electro-mechanical energy converting devices, electrical machines differ, in that with a few exceptions, they convert the energy in one direction only continuously. Electrical machines converting mechanical energy into electrical energy is called a generator, while that converting electrical energy into mechanical energy is called a motor.

An electro-magnetic system consist of magnetic circuits and electrical circuits, coupled with each other. Electro-magnetic circuits is made up of a stationary and a rotating magnetic member and a non-magnetic air-gap that separate the two member.

The electric circuit can be in a form of one or separate windings which are arranged to move relative to each other together with the magnetic member carrying them. For their operation, electric machines depends on electro-motive forces that are induced by periodic motion in the magnetic field as the windings and magnetic members are rotated. For these reason electrical machines may be called electromagnetic. This electromagnetic process also applies to devices that contain electrical energy at one value of current, voltage and frequency to electrical energy at some other voltage values of current, voltage and frequency.

The most common devices for this purpose is the transformer. As energy converters, electrical machine are important element in any generating, power consuming, industrial installation; they are widely used as generators, motors or rotary converters at electric power stations, factories, farms, railways, automobiles and aircrafts.

Electrical machines are classified into Alternating current (A.C) and Direct current (D.C)

Classification of Electrical Machines

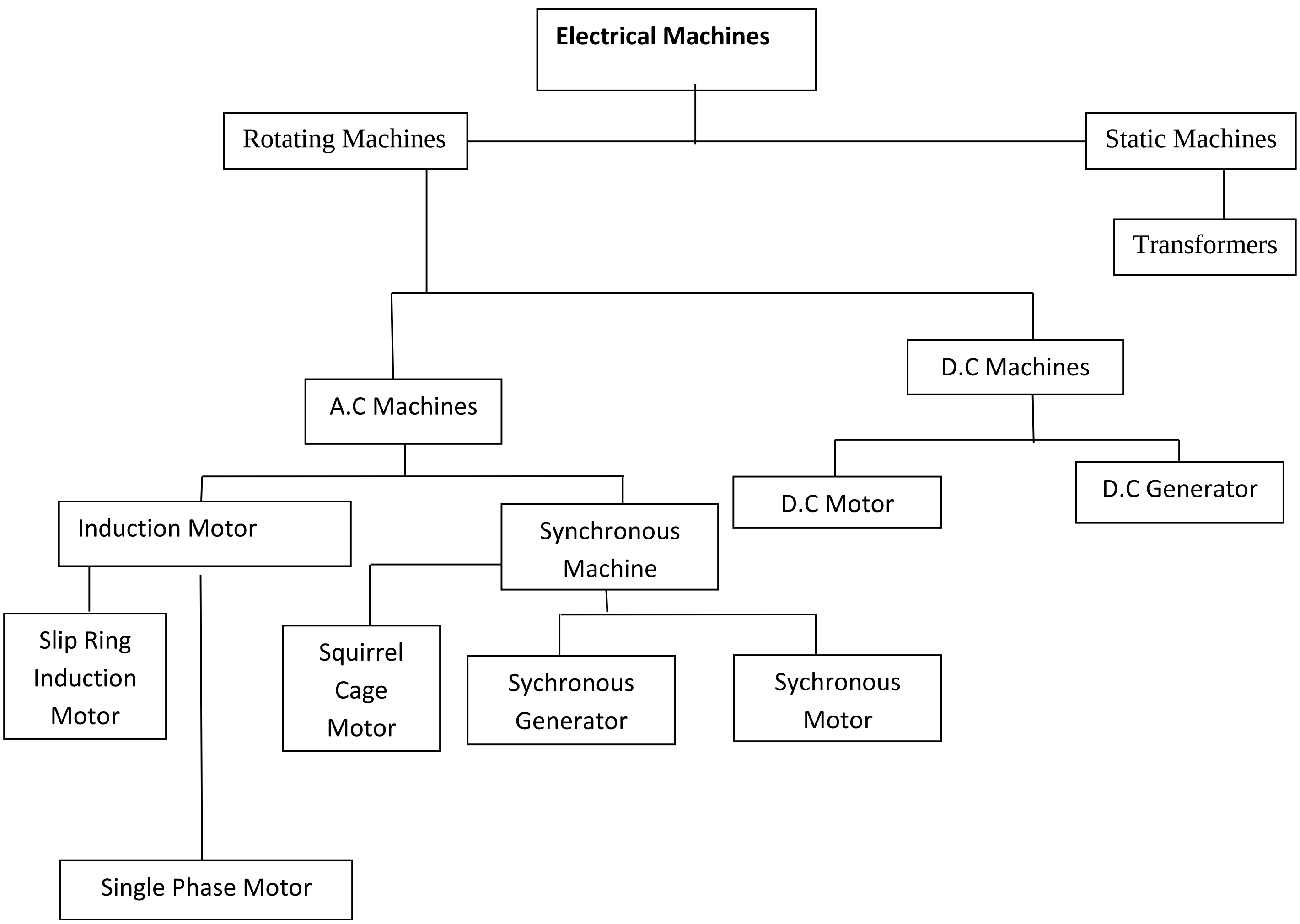


Fig. 1: Classification of Electrical Machines.

Electro Technical Materials use for Machine and Transformer Construction.
In the construction of electrical machines and transformer groups of material, active material, and insulating material are materials for construction.

Active Materials:
Includes electric conductors (copper and aluminum) and the magnetizing material (magnetizing steel sheets).

i. Copper.
The winding of electrical machines and transformer are bound with conductors manufactured from special grades of copper. These grades of copper are obtained by electrolytic refining. The copper obtained by this method should be 99.55% pure.

ii. Aluminum.
As a conductor it's used for the windings of transformers and to some extent in the windings of electric motors and generators.

Magnetic Material
Magnetic sheet material are alloying steel sheets, the chief alloying constituent is silicon which increases permeability at low flux density reduces augmenting the resistivity and eddy current. For transformers, two kinds of steel are;

i. High resistance steel (h. r. s.) of 4-5% silicon content and nominal thickness of 0.35mm.

ii. Cold – rolled grain oriented sheet strip (c. r. o. s.) of 0.33mm nominal value. The magnetic properties in the rolling are far superior to those on another.

Insulating Materials.
This material may be organic or in-organic or heterogonous in composition, an ideal insulator should possess the following quality;
High di-electric strength maintained at extreme temperature.
Good thermal conductivities to transfer heated I^2R losses to the surrounding structures

Coolant.
Mechanical properties: easy of working and application, resistance to failure by moisture, abrasion and bending. The insulant are classified as follows, each class being assigned to maximum operating temperature.
Class Y Insulation: Cotton, Silk, Paper, Wood, Fiber etc. not impregnated normal immerse, (90ºc) max operating temperature for class Y insulation.
Class A: Class Y materials impregnated with natural resins, cellulous ester etc. also laminated wood, vanished paper with cellulous acetate, film 105ºc maximum temperature.
Class E: Synthetic resin, enamel, cotton and paper laminated with formaldehyde etc. temperature is 150ºc.
Class B: Mica, glass fiber, asbestos etc. with suitable bonding substances built up of mica, glass fiber and asbestos etc. temp. 130ºc.
Class F: Class B materials with thermal substance bonding materials. Max temp 155ºc.
Class H: Glass fiber, asbestos and built with silicon resin bond. Temp. 180ºc.
Class C: Mica, Ceramic, Glass, Quartz are bonded with silicon resin with thermal stabilities Temp. >180ºc.

Transformer.
Transformers are electromagnetic devices which transform voltage at one value to another value without a change in frequency.

Transformer Classification.

Due to the great density in size, shape and application of transformer, it becomes necessary to designate types or class of transformer. Transformers are therefore classified in four groups namely;

General Application Transformer;

i. Power system transformer: - they are transformers based in power distribution and transmission systems. This class has the highest power and it ampere rating and highest continuous voltage rating.

ii. Electronics: - These are transformers based in electronic circuits. They are transformer with rating of 300VA and below. Electronics transformers are also called power transformer.

iii. Instrument Transformer: - These are transformer used in sensing voltage and current in electronics circuit or power system. They are often called potential and current transformer.

Classification by Frequency Range

i. Power: - These are generally constant frequency transformer that operates at the frequencies ranging (50, 60, 400Hz etc.).

ii. Audio: - used in the communication circuit to operate at audio frequencies.

iii. Wide band: - Electronics transformer operating at a wide range of frequency.

iv Narrow band: - Electronics transformer design for a specific frequency range.

v. Pulse: - Transformer design for use with pulse as chopped excitation both in electronics and power system application.

Classification by Number of Windings

These include one winding (auto-transformer), convectional and multi-winding transformer where a winding is defined as a 2 terminal electrical circuit with no electrical connections to the other electrical circuits.

Classification by Poly Phase Connection

This classification applies merely to transformers on power systems and it refers to the method of connecting individual windings in poly phase application. In some transformers, the entire poly phase set of transformer is contained within a single housing or case with some resulting reduction of the weight of the magnetic core. The most common connection are the wye (or star) and Delta connection of 3-phase system.

Why Transformer are Essential in Electrical Power System

Transformers make large power system possible by providing a simple means of changing an alternating voltage from one value to another. In other to transmit hundreds of Megawatt of power efficiently over long distance, very high line voltages are necessary on the range of 132-1000kV. Transformers step voltages up or down with very little loss in power. Connecting a step-up transformer between the generator and a transmission line permits a practical design voltage for the generator and at the same time, the efficient transmission line voltage. Step down transformer connected to it permits the transformer power to be used at a safe voltage. The power system existing today could not have been developed without transformers.

Transformers Rating

Transformers are manufactured to relevant specification or standard and are designed to perform specific functions. Accordingly, they are rated in terms of frequency, voltage, power as some values called ratings are rated value. They are given on a name plate attached to each transformer. In this case we shall denote with the subscript "R".

Transformer Constructions

Constructional Features;

The main constructional elements are core, yokes, and clamping devices, primary, secondary and sometimes also tertiary phase. Winding, coil and conductor, insulation, tanks, cooler, conservators and other auxiliary terminals and bushings, connections, cool tapping switches.

Cores of Transformer

In all types of transformer, the core is constructed of transformer sheet steel lamination assembled to provide a continuous magnetic part. The steel used is of high silicon content and sometimes heat treated to provide high permeability and a low hysteresis loss at the usual operating flux density. The eddy current loss is minimized by laminating the core being insulated for each by a light coat of core-plate varnish.

Constructionally, the transformers are of two types, distinguished from each other merely by the manner in which the primary and secondary coils are placed around the laminated sheet. The types are known as;

Core Type &

Shell Type.

In the core type transformer, the winding surround a considerable part of the core, whereas on the shell type transformer, the core surrounds a considerable portion of the winding.

Windings

There are two main type of winding

i. Concentric and

ii. The Sandwich type of windings.

The coils are made of vanish, cotton and paper covered wire on strip and are circular in shape to prevent high mechanical stress at each corners.

Cooling

Heat is produced in a transformer by eddy current and hysteresis losses in the core and by I^2R losses in the winding. To prevent undue temperature rise, this heat is removed by cooling. In small transformer natural air cooling is usually employed, for larger transformer, oil cooling is needed especially where high voltages are used.

Oil cooled transformers must be enclosed in steel tank. Oil has the following advantages over air as a cooling medium;

It has a larger specific heat than air, so that it will absorb larger quantities of heat for the same temperature rise.

It has a greater conductivity than air, to enables the heat to be transferred to the oil more quickly.

It has about six (6) time the breakdown strength of air, ensuring increase reliability at high voltage.

Principle of Operation of Transformers

The principle of operation of transformer is based on Faradays law of electromagnetic induction.

The Ideal Transformer

An ideal transformer is one in which, has no losses i.e. it's winding have no ohmic resistance, there is no magnetic leakage and hence has no I^2R and core losses.

An ideal transformer consist of 2 purely inductive coil wound on a loss free core, it may however be impossible to have such transformer in practice, yet for convenience we will start with such a transformer step by step approach on actual transformer.

E.M.F Equation of A Transformer

The e.m.fs induced in the primary and secondary windings due to the mutual flux in a transformer are given by the equations below;

$E_1 = 4.44 f B_m A N_1$

$E_2 = 4.44 f B_m A N_2$

Where E_1 = Voltage at the primary side of the transformer,

f = Frequency of the supply voltage

B_m = Maximum flux density

A = Cross sectional area of the core

N_1 = Number of turns at the primary

E_2 = Voltage at the secondary side of the transformer

N_2 = Number of turns at the secondary

Φ = Flux= (B_m x A)

Voltage Transformer Ratio

$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$

The constant K is known as the voltage transformation ratio.

If $N_2 > N_1$, ie. K>1 then transformer is a step up transformer.

If N2 < N1 i.e, K < 1, Te transformer is called a step down transformer.

Autotransformer

The Autotransformer has only one winding on both primary and secondary. Its theory and operation is similar to that of a two winding transformer because of one winding, it uses less copper and it is cheaper. It is used where transformation ratio differs little from unity.

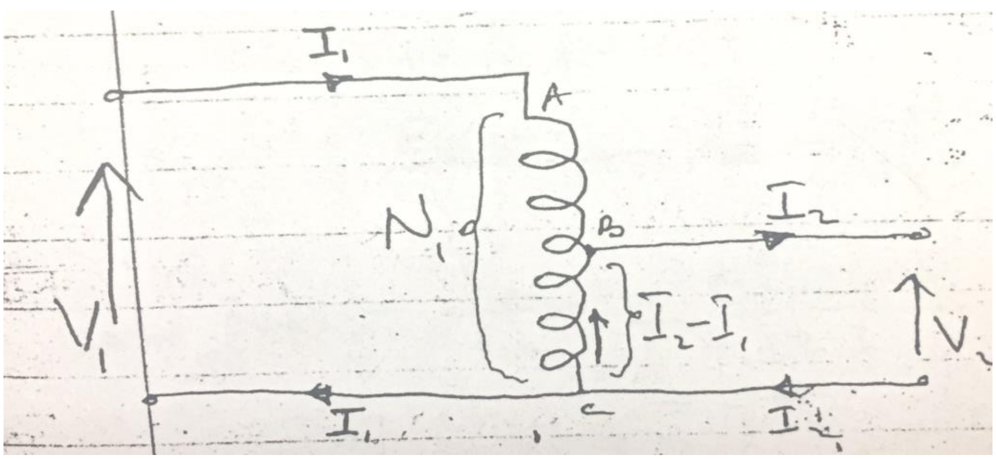


Fig.2.1 (b): Step Down Connection

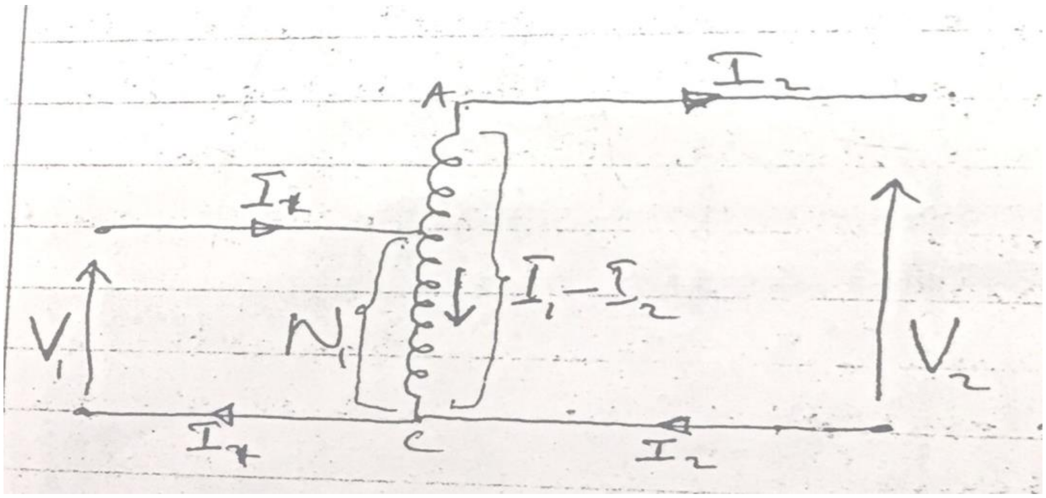


Fig.2.1(b): Step Up Connection Of Autotransformer

As shown in Fig. 2.1(a), AC is primary winding having N_1 turns and CB is secondary winding having N_2 turns neglecting iron losses and non-linear current.

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = K \qquad 2.1$$

The current in section BC, its vector difference of I_2 *and* I_1.

USES

As said earlier Autotransformer are used when K is not equal to unity and where there is no objection to electrical connection between primary and secondary winding. Hence such transformers are used.

To give a small boost to a distribution cable to correct for the voltage drop.

As Auto starter transformer to give up to 50-60% of full voltage to an induction motor during starting.

As furnace transformer for getting a convenient supply to suit the furnace winding from a 240V supply.

Disadvantages of Autotransformer;

There's no electrical insolation between the primary and secondary circuit.

Should an open circuit develop between point B & C the full main voltage would be applied to the secondary.

The short circuit current is much greater than for the normal two-winding transformer.

Transformer in Parallel

Uses of Transformers In Parallel

Parallel connection of several transformers is widely used in electrical system. In many cases it is the only way to convey large bulks of power to larger distances. The use of several transformers operating in parallel offers a more convenient way to tackle the problems of reliability and plant extension.

Should any unit failed, the remaining once will still be operate able and picks up the load previously carried by the faulty transformer. Also if a substation has a sufficiently large number of transformers, it is always possible to combine in parallel as many of them as may be necessary for optimal load sharing and energy conversion at a minimal loss.

Parallel Operation
Transformers are said to be connected in parallel when their primary windings are connected to a common voltage supply and their secondary windings are connected to a common load. If the two transformers are to operate satisfactorily in parallel. The following conditions must be satisfied;
Conditions
The turn ratio of the two transformers should be the same.
The phase displacement between the primary and secondary voltage must be the same for all transformer which are to be connected for parallel operations.
The phase sequence must be the same.

Losses in a Transformer
In a station transformer there are no friction or windage losses, hence the only losses are
Core or iron losses, since the magnetic flux Φ is constant at all load, the loss is constant. It includes both hysteresis loss and eddy current loss.
Hysteresis loss
$P_h = \vartheta^{B_{max}^{1.6}} f v (w)$
Where 1.6 is called steinmetz index.
Eddy current loss
$P_E = P B_{max}^2 f^2 t^2 (w)$
The losses are minimized by using steel of high quality Silicon content for the core and also by using thin lamination.
(ii). Copper loss $P_i = I_1^2 R_1 + I_2^2 R_2 = I_2^2 R_{02}^1$
Where R_{02}^1 is the whole of the primary and secondary resistance referred to secondary.

Transformer Efficiency
Transformer efficiency at a particular load and power factor (cosΦ), is defined as the output power divided by the input power, the two being measured in the same unit (either watt or kilowatt).

Efficiency $\eta = \frac{power\ output}{power\ input} = \frac{output}{input}$
$= \frac{output}{output + copper\ losses + iron\ losses}$
$\eta = \frac{input - losses}{input}$
$\eta = 1 - \frac{losses}{input}$
Power output η= $p = V_2 I_2 Cos\emptyset_2 (w)$
Total copper loss $\eta = P_c = I_2^2 R_{02}^1$(w)
Iron loss = $P_i(w)$
Total loss = $P_c + P_i = I_2^2 R_{02}(w) + P$
Power input = output + loss
For 3Φ transformer, 3-Φ – output is;
$P = \sqrt{3} V_2 I_2 Cos\emptyset_2 = 1.732 V_2 I_2 Cos\emptyset_2$
Total loss $= 3 I_{phase}^2 R_{O2} + P_I$
Efficiency $\eta = \frac{output}{input} = \frac{output}{output + total\ losses}$
Efficiency $\eta = \frac{1.73 V_2 Cos\emptyset_2}{1.73 V_2 Cos\emptyset_2 + 3 I_{phase}^2 R_{O2} + P_I}$

Instrument Transformer

In A.C circuit, measuring instruments are not always connected directly into the circuit, but are supplied by means of instrument transformers. For example, when high voltage or heavy current have to be measured.

The transformer primary winding carries the current or the voltage to be measured and the instrument is connected to the secondary so that it measures a small current or voltage which is proportional to the main circuit value.

Advantages of using Instrument Transformer

The secondary is wound for low voltage which simplifies the insulation of the measuring instrument and makes it safe to handle.

One point in the secondary winding is earthed so that the secondary circuit instrument are always kept at low even when measuring high voltage.

The transformer isolates the measuring instrument from the main circuit.

The measuring instrument can be connected by long leads to the transformer and placed in the most convenient position when reading.

The secondary voltage or current carries standardized usually 110v for voltages and 5A for current transformer.

Potential (Voltage) Transformer

The primary winding of a voltage transformer is connected in parallel with the load for which the voltage is to be measured or controlled. Its construction is similar to that of power transformer and has a special low-loss iron core. Voltage transformer operates with their full supply voltage and their secondary connected to the winding. The current taken will be quite small and the voltage is usually standardized at 110V. The reading of 110V meter must be multiplied by the transformer ratio to give the voltage of the main circuit or instrument, or the instrument may be calibrated to give a direct reading.

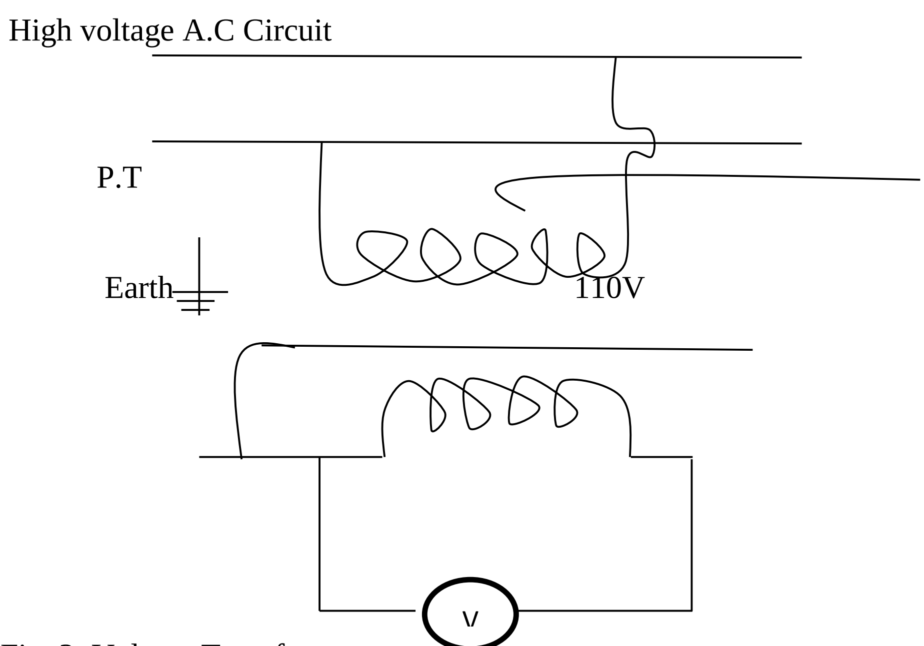


Fig. 3: Voltage Transformer

Current Transformer (Ct)

The primary winding of a current transformer is connected in series with the load for which the current is to be measured or controlled. The transformer has the secondary effectively connected short circuiting the low impedance of an ammeter. The load on the secondary winding is known as the transformer “burden”.

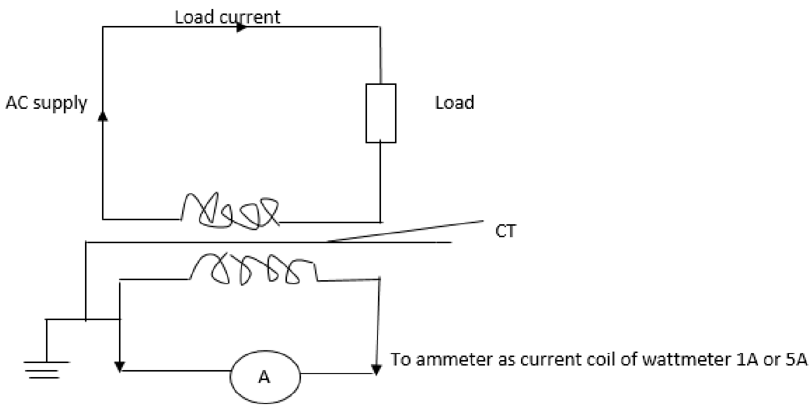


Fig. 4: Current Transformer.

Three Phase Transformer Connection

Single-phase transformer can be connected to form 3-Φ transformer banks for raising or lowering the voltage of 3-Φ system. Four common methods of connecting three single phase transformer for three phase transformation are the Delta-Delta, Star-Star, Star-Delta, and Delta-Star connections.

Terminal Marking

In all cases, the primary terminals will be marked by capital letter A, B, C for the phases as for the neutral and the secondary terminals by small letter a, b, c for the phases and n for the neutral.

Transformer Grouping

The British standard specification(171) for poly phase transformer connection is list transformer into four main group according to the phase shift between corresponding primary and secondary line voltages and each connection within a main group will be specified by the form of the primary and secondary connections. This phase shift is the angle by which the primary line voltage leads the corresponding secondary line voltage and is measured in clockwise increments of 30° in a clockwise direction. Example, if the high voltage (h.v) and low voltage (l.v) terminal voltage will still have the phase, that is, there will be no phase or phase displacement, if the transformers are connected Star-Star or Delta-Delta.

If the connections are Δ-γ (star-delta) there will be a phase shift between h.v and l.v terminal voltage of $\pm 30°$, if the high voltage are reversed, there will be a phase shift replacement of 180°.

The four group are given clock representation eg, no shift displacement (0: O Clock), 180° (6, o clock), -30°(1, o clock) and +30°(11, o clock).

Transformer in each groups are;

Group 1: 90° displacement Y_{yo}, D_{do}, D_{Zo}

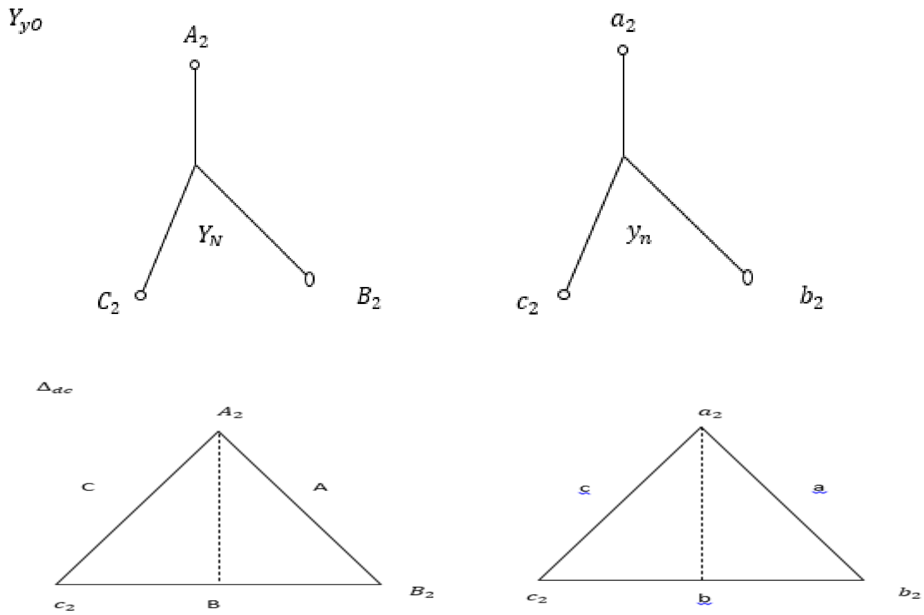
Group 2: 180° displacement Y_{y6}, D_{d6}, D_{Z6}

Group 3: -30° displacement $\Delta_{y1}, Y_{d1}, Y_{z1}$

Group 4: +30° displacement $\Delta_{y11}, Y_{d11}, Y_{z11}$

Phasor Diagram

GROUP 1(0°)



GROUP 2(180°)

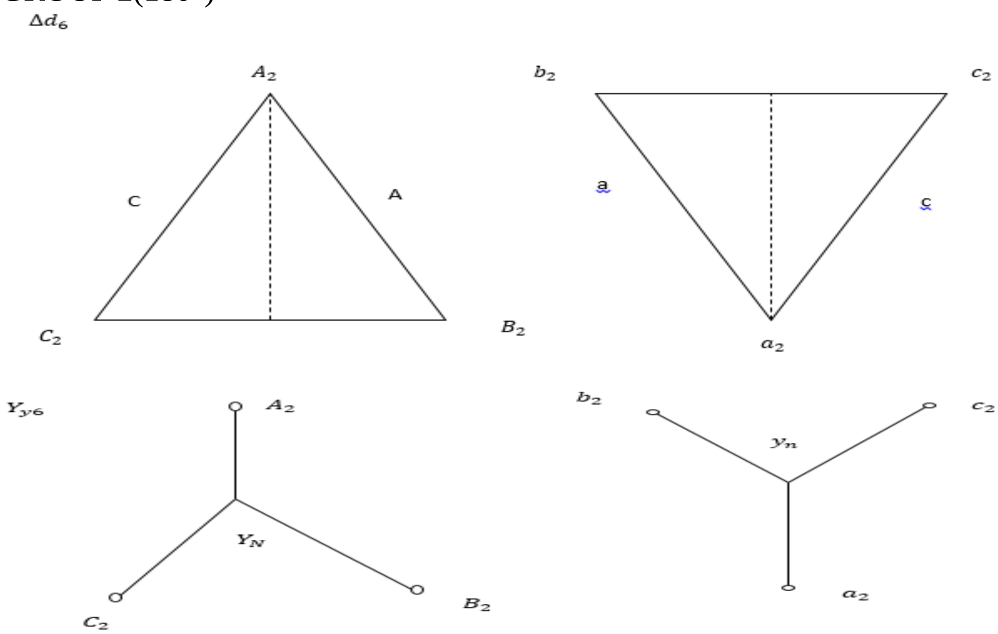


Fig. 5: Standard Connection for a Three Phase Transformer

Delta-Delta connection ($\boldsymbol{\Delta_{d0}\ or\ \Delta_{d6}}$)
Star-Star Connection ($\boldsymbol{Y_{y5}\ or\ Y_{y6}}$)
Delta-Star ($\boldsymbol{\Delta_{Y11}}$&$\boldsymbol{\Delta_{Y11}}$) And Star-Delta

Open Circuit Or No Load Test On Transformer

The purpose of this test is to determine no load test.

Core loss or no load current I, which is useful in findingX_o and R_o.

Short Circuit Test

This is an economical method for determining the following;

Equivalent impedance ($Z_{o1} or Z_{o2}$), leakage reactance ($X_{o1} or X_{o2}$) and total resistance $R_{o1} or R_{o2}$ of the transformer as referred to the winding in which the measuring instrument are placed.

Copper loss at full load (and at any desired load). This loss is used in calculating the efficiency of the transformer.

In this test one winding usually the low voltage winding is solidly short circuited by a thick conductor as shown above, and the voltage applied i_m ıe other winding is gradually raise from zero to until full-load current flow. The readings of the wattm... (P_{sc}) and the voltmeter (V_1) and ammeter (I_1) are noted. Since the exciting voltage is small, the core flux will be small and the core losses will negligible. If the impedance is referred to the primary, then;

Voltage Regulation of a Transformer

The voltage regulation of a transformer is define as the variation of the secondary voltage between no-load and full load expressed as either per unit or percentage of the no load voltage, primary voltage voltage being constant.

Voltage regulation = $\frac{n0-load\ voltage\ \ -\ full-load\ voltage}{no-load\ voltage}$

$V_1 = Primary\ applied\ voltage$

$V_2^1 = Secondary\ voltage\ on\ no - load$

If $V_2 = secondary\ terminal\ voltage\ on\ full\ load$

DC Machines

DC Machine Constructions

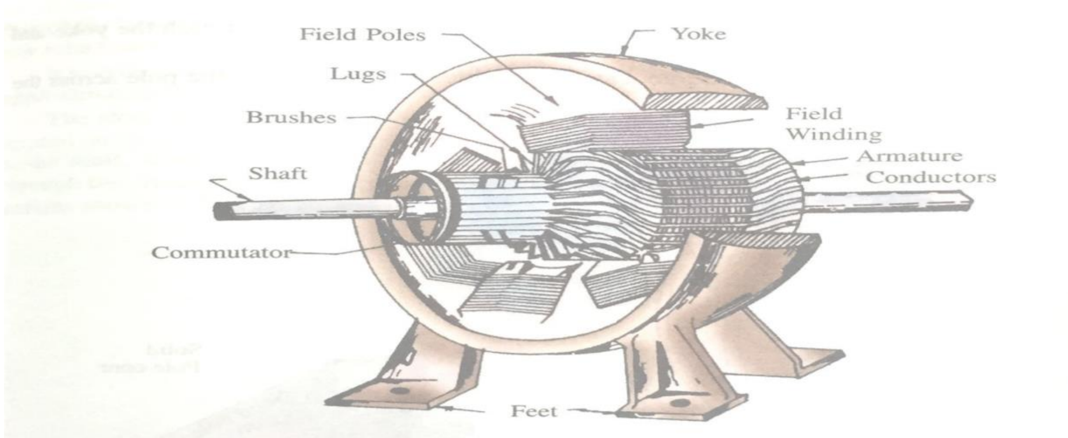


Fig. 6: DC Machine Constructions

The general construction of a DC machine shown in Fig. 6. The field windings are wound on in winding projecting poles attached to the yoke, the armature rotates between the pole living a small air gap that carries either a lap or a wave winding which is connected to the commutator. Contact winding external is made through carbon brushes (as shown in the diagram) rubbing on the commutator. Typical materials use in the construction of DC machines are Yoke; cast steel or rolled steel. Pole; high permeability steel usually laminated. Armature; high permeability, low-less steel lamination as stamping. The lamination which has a thin layer of insulation on one side are necessary to stop the flow of eddy current in the iron of the armature parallel to the shafts. The eddy current could cause over-heating and serious energy lost.

Shaft; mild steel forging

Commutator; high conductivity, hard drawn copper.

Mode of Operation

D.C machine may work as generator or motor or breaker. In the generator mode, the machine is driven by a prime mover and develops electrical power. In the motor mode, power supplied to the machine electrically is converted into mechanical power has output. The breaking mode is a generator action but with the electrical power either regenerated or dissipated within the machine system developing in consequent a mechanical breaking effect.

D.C Motor

D.C motor have a broad range of speed coupled with a high efficiency over the others and can be built with speed torque characteristics to suit any particular application. This is why there are two or three times more expensive than the squirrel cage induction motor. The motors are preferable whenever their unique qualities are desirable. For example they are widely use in electric traction on rails where their dropping torque speed characteristics wide range of speed control are valuable. DC motors (up to 12MW) are used as drivers blooming and rolling mills as main propulsion on diesel electric ship. In most cars, tractions, aircraft using DC electric supply, all armatures are driven by DC motor. Small DC motor in fraction of a watt to 10^{th} of watts exhibits various automatic control applications.

DC Generator

DC generator supplies DC for industrial purposes where low voltage is required (electrolysis, electroplating and the like). In many cases, they serve as exciters for synchronous generator. There are also various special purpose DC generators (welding, train lighting) DC rotary amplifiers (control generator) e.t.c.

Classification

DC machines are built for rating from megawatt to milli-watts. They may be also classified as follows;

Industrial DC Machine

Large generators and motors for mills, crane, machine tools and general industrial drives of ratings above a few kilowatts and usually supplied from AC mains through rectifier.

Small DC Machine

Motors for hand tools, domestic equipment and similar main fed application and automobile starter motor.

Traction

Motors for railways and battery fed vehicles.

Miniature Motors

Motors of a few watts output for intermittent load not requiring precision control.

Control Machine

Machines associated with open and close control system, they are commonly provided with permanent magnet.

Special Machine

Linear machine conductors, Eddy current devices, motor with semi field winding and unconventional design.

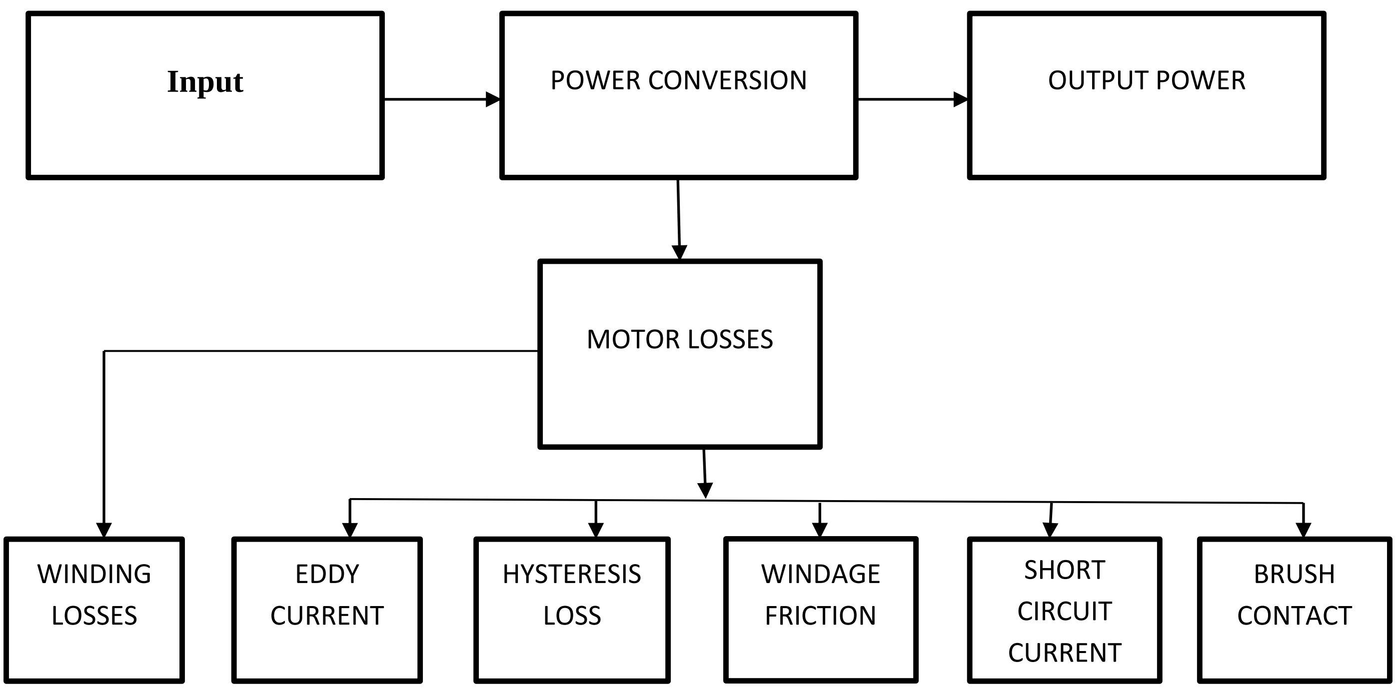
Types of DC Machine

D.C machines are classified by the way in which the field circuit is connected. These are;

i. Separately excited machine
ii Shunt machine
iii. Series machine
iv. Compound machine

Power Losses in DC Motors

DC motors used to produce mechanical power from electrical power and as such it may be viewed as an energy converter, however the motor not an ideal converter due to the armature resistances and other losses therefore it has heat losses as a byproduct of energy conversion. The power flows through the motor and the distribution of losses are illustrated below in Fig……



The figure shows that the motor losses can be rounded into two divisions, the load sensitive losses are dependent upon the generated torque and the speed sensitive losses are determined by rotation speed. Since those losses are important in establishing the limit of motor applications.

Windings

Single Layer Winding

It is the winding in which one conductor or armature coil side is placed in each armature slots such a winding is not much used.

Double Layer Winding

In this type of winding, there are 2 conductors or coil size per slots arranged in 2 layers usually one side of every coil lies in the upper half of one slot and other side lies in the lower half of some other slot at a distance approximately 1 pitch away.

Lap and Wave Winding

Two types of winding mostly employed for during type armature are known as lap and wave winding. The difference between the 2 is merely due to the different arrangement of the end connections at the front or commutator end of the armature.

The following rules however applied to both types of winding;

i. The front and back pitch are each approximately equal to the pole pitch, i.e. winding should be full pitch. This results in increase e.m.f round the coil.
   For special purposes, fractional pitch windings are deliberately used.

ii. pitches should be odd otherwise it will be difficult to place the coil (which are formerly wound) properly in the armature. For example, if y_b and y_f were both even then all the coil sides and conductors would lies either on the upper half of the slot or lower half of the slot.

iii. The number of commutator segments is equal to the number of slot or coil (or half of the number of the conductor) because the front ends of conductors are mounted to the segment with pairs.

iv. The winding should close upon itself i.e. we start from a given point and moves from one coil to another, then all conductors should be traversed and we should reached the same again without a break or discontinuity in between. The main difference between the lap and wave windings is;

Introduction to AC Motors.

There are two basic types of A.C Machines, which are Synchronous and Asynchronous. The latter is usually referred to as Induction machines which are further sub-divided into slip ring and squirrel cage induction machine.

A synchronous machine is one in which a slightly constant relation between the speed n and the supply frequency.

$$F = np \text{ or } n = f/p$$

Where p is the number of pole pairs.

The Synchronous machine is excited by direct current which is fed to the exciting winding from a D.C power current or from a special D.C machine called the exciter.

An induction machine is one in which the speed n, for a given frequency (f) depends on the load, which consequently there exist a relationship.

$$F \neq pn$$

In an induction machine the magnetic field created by an A.C supplied by an A.C both synchronous and induction machine possess ever and mg generated is a motor or a generator.

Synchronous machine are mostly used as alternatives for the production of AC power at electric power stations. There are also mostly used as synchronous motor and as synchronous condenser which are synchronous motor operated without load to improve the other factor.
Induction machine are mostly used as motor.

Poly Phase Induction Machine
Because of its simple ranged construction and good operating characteristics, the induction machine is the most commonly use. It consists of two parts: The Stationary part (Starter) and the Rotating part (Rotor).
The Starter is connected to A.C supply. The rotor is not connected electrically to the supply, but has current induced in it by heat. The rotor current is produced by induction the basis for the name of this class of machine. At standstill, the induction motor behaves like a transformer, where the starter is sometimes referred to as the primary and rotor as secondary of the machine.

Classification Induction Motors
Induction motors are classified into two (2) categories: Squirrel cage and Phase wound rotor or Slip ring.
Both machine operates on same basic principle and has the same starter construction.

General Principles of Induction Machine
Off all the AC motors the poly-phase induction motor is the one which is extensively used for various kinds of industrial drives. It has the following main advantage and disadvantage.

Advantages
It has a very simple and extremely rugged construction. (especially squirrel cage type)
It lost is low, and it's very reliable.
It has high efficiency, in normal running conditions no brushes is needed hence frictional force are reduced.
A reasonably good power factor of $cos\theta$=0.8, n = 0.96
It requires minimum maintenance.
Its starting arrangement is simple especially for squirrel cage type motor.

Disadvantages
It speed cannot be varies without scarifying some of its efficiency.
It's like a DC shunt motor, its speed decreases with increase in load.
Its starting torque is somehow inferior to that of a DC shunt motor.

Advantages of Cage motors over Slip Ring Motors
Lesser materials are used for the rotor winding.
It has small inherent 1^2 R loss.
It has better power factor
It has high efficiency, so long as the cage resistance doesn't have to be augmented to obtained adequate starting torque.
No slip-ring or starting rheostat.

Linear Motors
A linear motor is an electric induction motor which produces straight – line motion (not rotating) by means of linear stator and rotor placed in parallel. In linear motor the stator and rotor unrolled so that instead of

producing a torque (rotation), it produces a linear force along it length. Linear motors are not necessarily straight.

Areas of Application of Linear Motors.

i. Propelling the shuttle in looms.
ii. Used for sliding doors and various actuators
iii. Baggage handling and can even drive large – scale bulk materials transport solutions.
iv. Linear motor is often used on launched rollercoasters.
v. Used to create rotary motion, for example, they have been used at observatories to deal with the large radius of curvature.

Circle Diagram of AC Machine

The circle diagram is the graphical representation of the performance of the electrical machine drawn in terms of the locus of the machine's input voltage and current. The circle diagram can be drawn for alternators, synchronous motors, induction motors and transformers. It was first conceived by A. Heyland in 1894 and B. A. Behrend in 1895.

For any AC machine and a given phasor diagram, we can draw its corresponding circle diagram, which gives the corresponding parameters- efficiency, slip at max. torque, operating slip, copper losses at any load, regulation, operating power factor, etc. on performing certain test like open circuit and short circuit tests, performance parameters of the machine is noted and the corresponding no-load current, pf are used to build the vector diagram. It converts power, voltage and current scales into length units to draw it. It is drawn to predetermine the machine parameters without any mathematical calculations.

The Heyland diagram is an approximate representation of the circle diagram applied to induction motors, which assumes that stator input voltage, rotor resistance and rotor reactance are constant and stator resistance and core loss are zero.