# MAINTENANCE AND REWINDING OF 3-PHASE SQUIRREL CAGE INDUCTION MOTOR

BY

**OMAMARAH, KATE**

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## DECLARATION

I OMAMARAH KATE, declares that this project was done by me for the award of degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

.................................... 23/06/2010

OMAMARAH KATE
Student

Date

.................................... 06072010

Dr. J. Tsado
Project Supervisor

Date

....................................

....................................

Engr. Dr. Y. A. Adediran
H. O. D

Date

# DEDICATION

This project is dedicated to the Almighty God for his grace and mercy all through my academic pursuit

# ABSTRACT

This project deals with repairs and maintenance of 0.75kw burnt three phase induction motor with analysis on the cause of burnt. The rewinding process involves taking of data,stripping the winding, insulating the stator, winding of coils, placing the coils in the slots, connecting the coils, testing the winding, varnishing and baking.Thereafter, the motor was tested with continuity test as 0.005Ω per phase, short circuit test as 5MΩ per phase and insulation resistance test as 0.6MΩ indicating that the motor has been restored to its proper working condition.

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# CHAPTER ONE

## INTRODUTION

The squirrel cage induction motor is an electrical machine which converts electrical energy into mechanical energy. In the squirrel cage induction motor, the rotor receive electric power by induction in exactly the same way as the secondary of a 2-winding transformer receives its power from the primary. That is why it's called an induction motor.

The squirrel cage induction motor consists essentially of two parts namely the stator and rotor.

The stator is the stationary part of the motor that receives the three phase supply from the main, while the rotor receives it power by induction. The stator and rotor winding built are mounted in a structure of laminated steel plates. The steel plates are pressed on the rotor shaft and are insulated from each other every place except the shaft.

The rotor bars which are made of heavy bars of copper, aluminium or alloy are permanently short-circuited on themselves hence it's not possible to add any external resistance in series with the rotor circuit for starting purposes.

The rotor slots are usually not quite parallel to the shaft but are purposely given a slight skew to help make the motor run quietly by reducing the magnetic hum and in reducing the locking tendency of the teeth to remain under the stator teeth due to direct magnetic attraction between the stator and rotor.

The three phase squirrel cage induction motor is used extensively in various kinds of industrial drives, residential purpose. The knowledge of repair, maintenance and rewinding of this all importance electrical machine cannot be over emphasize for electrical engineering practices.

Since in actual practice, handling induction motor is a must. The induction motor are tested and evaluated periodically to determine their conditions and to identify minor problems before they develop into major problems.

The types of maintenance carry out on the squirrel cage induction motor are classified into physically inspection and refurbishment. Under the physical inspection, it entails inspecting the motor for signs of physical damage; inspect the motor mounting equipment to make sure it's adequately installed.

The electric motors occasionally develop problems which may be due to long usage (i.e. wear), mal-operation, voltage fluctuation bearing stiffness, short circuit, open circuit moisture, ground fault and over load. These motor can be recondition whenever they are bad.

It is the aim of this project to refurbish a burnt electric motor with detail procedures.

## 1.1 MAINTENANCE

Maintenance is the act of keeping something in good condition by checking or repairing it regularly. It is described as keeping a system, machine e t c in a working condition.

Basically, Electrical maintenance is to ensure the same performance level of units, equipment, plants, and system as provided by the work plan and design with specification from regulation and standards.

## 1.2 AIMS AND OBJECTIVES

This project is aimed at repairing and maintaining of a burnt three-phase induction motor, analysing the cause of burnt and using electrical maintenance principle to restored the burnt three phase induction motor back to normal operational standard in order to increase availability and minimise disruption of production and loss product caused by breakdown.

## 1.3 METHODOLOGY

Many separate steps are involved in rewinding and maintenance of three-phase induction motor which includes.

a. Taking data
b. Stripping the winding
c. Insulating the stator
d. Winding of coils
e. Placing the coils in the slots
f. Connecting the coils
g. Testing the winding
h. Varnishing and baking

# CHAPTER TWO

## LITERATURE REVIEW

## 2.1 ELECTRIC MOTOR HISTORY AND PRINCIPLES

The electric motor in its simplest terms is a converter of electrical energy to useful mechanical energy. The electric motor has played a leading role in the high productivity of modern industry, and it is therefore directly responsible for the high standard of living being enjoyed throughout the industrialized world [1].

The beginnings of the electric motor are shrouded in mystery, but this much seems clear: The basic principles of electromagnetic induction were discovered in the early 1800's by Oersted, Gauss and Faraday, and this combination of Scandinavian, German and English thought gave us the fundamentals for the electric motor. In the late 1800's the actual invention of the alternating current motor was made by Nikola Tesla, a Serb who had migrated to the United States. One measure of Tesla's genius is that he was granted more than 900 patents in the electrical field. Before Tesla's time, direct current motors had been produced in small quantities, but it was his development of the versatile and rugged alternating current motor that opened a new age of automation and industrial productivity [1].

An electric motor's principle of operation is based on the fact that a current-carrying conductor, when placed in a magnetic field, will have a force exerted on the conductor proportional to the current flowing in the conductor and to the strength of the magnetic field. In alternating current motors, the windings placed in the laminated stator core produce the magnetic field. The aluminium bars in the laminated rotor core are the current carrying conductors upon which the force acts.

The resultant action is the rotary motion of the rotor and shaft, which can then be coupled to various devices to be driven and produce the output [1].

Many types of motors are produced today. Undoubtedly, the most common are alternating current induction motors. The term "induction" derives from the transference of power from the stator to the rotor through electromagnetic induction. No slip rings or brushes are required since the load currents in the rotor conductors are induced by transformer action.

The induction motor is, in effect, a transformer - with the stator winding being the primary winding and the rotor bars and end rings being the movable secondary members [1].

LEESON Electric also produces permanent-magnet direct current motors. The DC motor is the oldest member of the electric motor family. Recent technological breakthroughs in magnetic materials, as well as solid state electronic controls and high-power-density rechargeable batteries, have all revitalized the versatile DC motor. Both AC and DC motors must be manufactured with a great deal of precision in order to operate properly. LEESON and other major manufacturers use laminated stator, rotor and armature cores to reduce energy losses and heat in the motor. Rotors for AC motors are heat treated to separate the aluminium bars from the rotor's magnetic laminations. Shaft and bearing tolerances must be held to ten thousandths of an inch. The whole structure of the motor must be rigid to reduce vibration and noise. The stator insulation and coil winding must be done in a precise manner to avoid damaging the wire insulation or ground insulation. And mountings musts meet exacting dimensions. This is especially true for motors with NEMA C face mountings, which are used for direct coupling to speed reducers, pumps and other devices [1].

The electric motor is, of course, the very heart of any machine it drives. If the motor does not run, the machine or device will not function. The importance and scope of the electric motor in modern life is attested to by the fact that electric motors, numbering countless millions in total, convert more energy than do all our passenger automobiles. Electric motors are much more efficient in energy conversion than automobiles, but they are such a large factor in the total energy picture that renewed interest is being shown in motor performance. Today's industrial motors have energy conversion efficiency exceeding 95% in larger horsepower. This efficiency, combined with unsurpassed durability and reliability, will continue to make electric motors the "prime movers" of choice for decades to come [1].

## 2.2 MAINTENANCE

The maintenance works is classified base on the activities carried out on particular equipment, system or an installation, be it lighting circuits or machinery equipment [2]. These maintenance works can be broadly divided into two. These are planned maintenance and unplanned maintenance [2].

### 2.2.1 UNPLANNED MAINTENANCE

Unplanned maintenance refers to unplanned emergency maintenance.

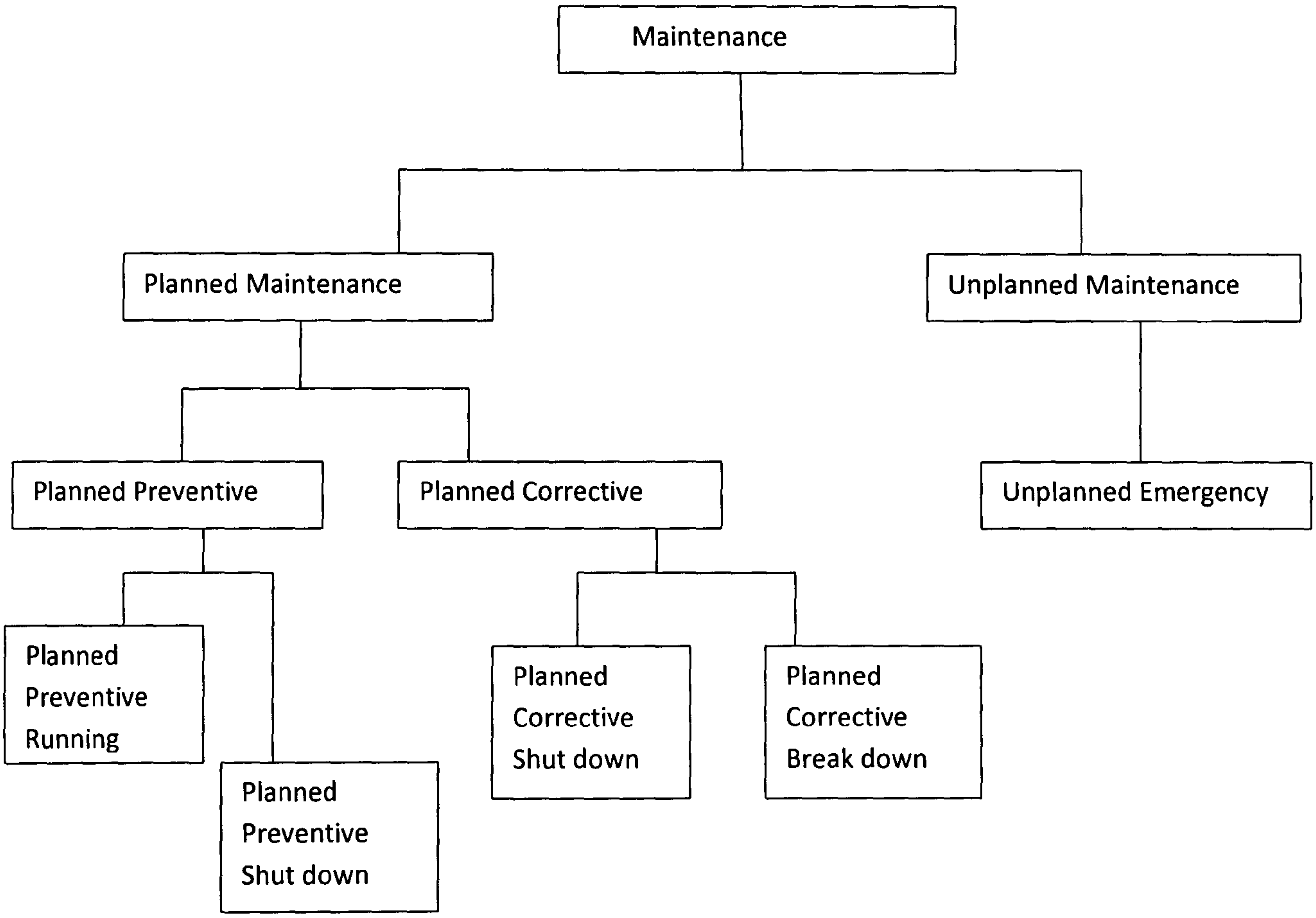



Fig 2.1: GRAPHICAL REPRESENTATION OF MAINTENANCE

A typical sequence of electrical maintenance tasks comprises of fault localization, fault isolation, fault correction, replacement or reassembling.

### 2.2.2 PLANNED MAINTENANCE

The planned maintenance is divided into two main classes. These are planned preventive maintenance and planned corrective maintenance [1]. Planned maintenance enables the work load of the maintenance task to be reasonably forecast for sometimes ahead. It is a combination of preventive and scheduled maintenance, it is logical in that inspection reports of faults both the ones that are apparent and incipient are noted, and remedial action is under taken according to priority and production requirement. Actually planned maintenance is not a specific type of maintenance, but it represents the application of maintenance tackled in a scientific manners.[1]

Planned maintenance visualizes the work contained in a job and estimate the time, materials, and cost involved in doing the job. Thus it averages the availability of manpower, materials, spares and tools required for the job. When comparing estimated cost with budget expenditure it allows times to correct any excesses which may appear. [1]

## 2.3 REPAIRS

Repair can be described as an aggregate part of maintenance. It is a corrective maintenance action that is carried out on any installation, (part or whole) equipment or system in order to restored such an item back to normal operational standard repairs is usually carried out on failed item or installation repair cover all works to be performed on a plant, system, or an installation or a simple unit of equipment after a breakdown [2].

## 2.4 REFURBISHING

Refurbishing of an induction motor is an aggregate part of maintenance. It is a corrective maintenance action that is carried out on an induction motor in order to restore such induction motor back to it normal operational standard.

Refurbishment is usually carried out on failed induction motors. It covers all works such as cleanup, rewinding etc performed on the induction motor to bring it back to it normal operating condition.[4]

## 2.5 ELECTRICAL MACHINES

Electrical machines are machines that link an electrical energy system to a mechanical energy system by providing a reversible means of energy flow in its magnetic field.[3]

### 2.5.1 CLASSIFICATION OF ELECTRICAL MACHINES

Electrical machines are classified into two, those using Direct current which is refer to as D.C machine and those using alternating current which is called A.C machine.

The D.C machines are divided into D.C motor and D.C generator, while A.C machine are divided into A.C motor and A.C generator.[3]

### 2.5.2 A.C MOTOR

The A.C motors are group into synchronous motors or asynchronous motors based on their mode of operation. They are also classified into single phase motor or three phase motor base on the mode of current used for their operation, they are also classified based on their speed into

i. Constant speed,
ii. Variable speed and

iii. Adjustable speed and finally they are classified according to their structural features into:

a. Open.
b. Enclosed.
c. Semi-enclosed.
d. Ventilated.
e. Pipe-ventilated.
f. Riveted frame.

### 2.5.3 INDUCTION MOTOR

In the induction motor, the conversion of electrical power into mechanical power takes place in the rotating part of the motor called rotor. The rotor receive it electrical power by induction in exactly the same way as the secondary of a 2-winding transformer receives its power from the primary winding.[3]

## 2.6 CONSTRUCTION OF INDUCTION MOTOR

The three phase induction motor has three main parts namely:

i. A rotating part called rotor
ii. A stationary part called stator
iii. End plates which are flattened to the frame of frame of the stator by means of screws or bolts.

### 2.6.1 STATOR

The stator of an induction motor is the same as that of a synchronous motor on generator. Its made up of a number of stampings, which are slotted to receive the winding. The stator carries a 3-phase winding and is fed from a 3-phase supply. It is wound for a definite number of poles and the exact number of poles is determined by the requirement of speed, the greater the number of poles the lesser the speed and vice versa. The stator windings when supplied with 3-phase currents produced a magnetic flux which is of constant magnitude but which revolves at synchronous speed given by the relation (Ns=120F/P). Thus revolving magnetic induces an e.m.f in the rotor by mutual induction.[3]

### 2.6.2 ROTOR

The rotor is the rotating part of induction motor, and are of two parts

i. Squirrel cage rotor and

ii. Phase wound or wound rotor

#### 2.6.2.1 SQUIRREL CAGE ROTOR

The motors employing this type of rotor are known as squirrel cage induction motors. This type of rotor has the simplest and most rugged construction imaginable and is almost indestructible. The rotor consist of a cylindrical laminated core with parallel slots for carrying for rotor conduction which are not wires but consist of heavy bars of copper, aluminium or alloys. One bar is placed in each slot; rather the bars are inserted from the end when semi-closed slots are used. The rotor bars are braced or electrically welded or bolted to two heavy and stout short-circulating end-rings their giving a squirrel cage construction. The rotor bars are permanently short-circuited on themselves; hence it is not possible to add any external resistance in series with the rotor circuit for starting purposes. The rotor slots are usually not quite parallel to the shaft but are purposely given a slight skew. This helps in two ways : To help to make motor run quietly by reducing the magnetic hum and to helps in reducing the locking tendency of the rotor for instance the tendency of the rotor teeth to remain under the stator teeth due to direct magnetic attraction between the two.[3]

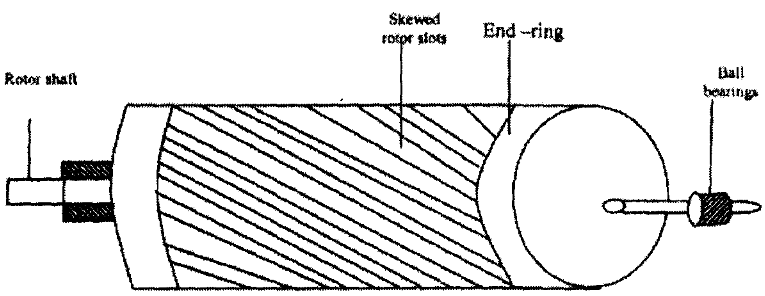



**Fig 2.2: Rotor of an induction motor**

### 2.6.2.2 PHASE-WOUND ROTOR

This type of rotor is provided with 3 phase double layer distributed winding consisting of coils. The is wound for as many poles as number of stator poles and is always wound 3-phase even when the stator is wound 2-phase. The three phases are starred internally the other three winding terminals are brought out are connected to three insulate slip rings mounted on the shaft with brushes resting on them.[3] These three brushes are further externally connected to a 3-phase star-connected rheostat. This makes possible the introduction of additional resistance in the rotor circuit during the starting period for increasing the starting torque of the motor when running under normal conditions the slip-rings are automatically short-circuited by means of a metal collar, which is pushed along the shaft and connects all the rings together. Next the brushes are automatically lifted from the slip-rings to reduce the frictional losses and the wear and tear hence it is seen that under moral running conditions, the wound rotor is short circuited on itself just like the squirrel-cage rotor.[3]

## 2.7 PRINCIPLE OF OPERATION OF AN INDUCTION MOTOR

The principle of operation of a motor as an electrical machine is that it converts electrical energy into mechanical energy by means of applying voltage through the primary which is the stator winding mounted in the slots. Three phase supply is applied through the winding displaced in space by 120 electrical degrees. They produce a resistant magnetic flux of constant magnitude which rotates at synchronous speed this flux parks through the air gap and onto the surface of the rotor and cuts the stationary rotor conductors.[5] As a result of the relative speed between the rotating flux and the stationary conductors, an e.m.f is induced in the rotor, according to faraday's first law of electromagnetic induction that states whenever a magnetic flux linked with a circuit an e.m.f is always induced in the circuit. The frequency of the induced e.m.f is the same as the supply frequency. Its magnitude is proportional to the relative velocity between the flux and the conductors between the flux and the conductor and its direction is given by Fleming's right hand rule. Since the rotor bars or conductors form a closed circuit, rotor current is produced whose direction as given by Lenz's law is such as to oppose the very cause producing it. In this case, the cause which produces the rotor current is relative velocity between the rotating flux of the stator and the stationary rotor conductor enhance to reduce the relative speed, the rotor start running in the same direction as that of the flux and tries to catch up with the rotating flux.[5]

## 2.8 SLIP

In practice, the rotor never succeeds in catching up with the stator field. If it really did then there would be no relative speed between the two, hence no rotor e.m.f no rotor current and so no torque to maintain rotation. That is why the rotor rounds at a speed which is always less than the speed of the stator field. The difference in speeds depends upon the load on the motor. The difference between the synchronous speed Ns and the actual speed N of the rotor is known as slip. It has a percentage of the synchronous speed. Actually the term slip is descriptive of the way in which the rotor slips back from synchronism.[3]

$$\% \text{ Slip } S = Ns-N/Ns \times 100$$

Sometimes Ns-N is called the slip speed obviously, rotor (or motor) speed is N=Ns (1-s).

## 2.9 FREQUENCY OF ROTOR CURRENT

When the rotor is stationary, the frequency of rotor current is the same as the supply frequency. But when the rotor starts revolving, then the frequency depends upon the relative speed or on slip speed. Let at any slip speed, the frequency of the rotor current be $f^1$ then

$$Ns-N= 120f^1/P \text{ Also } Ns=120f/P$$

Dividing one by the other, we get

$F^1/f = Ns-N/Ns = S$

$\therefore F^1=SF$

As seen, rotor current have a frequency of Fi=SF and when flowing through the individual phases of rotor winding, give rise to rotor magnetic fields. These individual rotor magnetic fields, whose speed relative to rotor is

$$= 120f^1/P =120sf/P =SNs$$

However, the rotor itself is running at speed N with respect to space. Hence, speed of rotor field in space =speed of field relative to rotor + speed of rotor relative to space =SNs+N=sNs+Ns(1-s)=Ns

## 2.10 HEATING, COOLING AND VENTILATION OF THE INDUCTION MOTOR.

As a result of energy conversion in induction motor there is energy losses, the losses occur in the core material, windings and places like bearing. Because of these losses heat is generated inside the motor. As heat is developed inside the motor its temperature rises and if it unable to dissipate heat to the surroundings its temperature will rises to an extremely high value. It is the insulating material which deteriorates first due to temperature rise. The rise in temperature depends upon the heat generation and heat dissipation. The temperature ceases to rise when the rate of heat dissipated becomes equal to heat developed. The motor has now attained its final rise in temperature. For the final temperature rise to remain well within the normal limit of the insulating material an elaborate cooling arrangement is to be designed [5].

### 2.10.1 MODE OF HEAT TRANSFER

The heat generated inside the motor is transferred to the surroundings by means of conduction, conversion and radiation.

#### 2.10.1.1 CONDUCTION

The solid parts of the motor i.e. core, windings and insulation transfer heat to the outside surface by means of conduction. The quantity of heat transferred by means of conduction can be given by the expression.

$$q_{Cond} = \frac{\theta_1 - \theta_2}{R_\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{eqn (1)}$$

Where $q_{Cond}$ = Heat transferred by conduction, W $^0$c

$\theta_1 - \theta_2$ = Temperature of the two boundaring surface

$R_\theta$ = Thermal resistance of the conducting material $^o$c/w

Heat flow equations

Equation (i) can be rewritten in terms of heat transfer rate as

$$q_{Cond} = -\theta_{th}\, s \frac{\delta\theta}{\delta x} \text{ watts}$$

Where $\left(\frac{\delta\theta}{\delta x}\right)$ is the temperature gradient in the direction of heats flow $^o$c/w

The negative sign indicates the heat flow from high temperature to low temperature [5].

### 2.10.1.2 CONVECTION

Fluid (liquid or gas/air) particles coming in contact with hot body become lighter and rises, giving place to cooler particles thereby creating a thermal head and a consequent circulation. This process is called as natural or free convection. These could be forced or artificial convection also such as blowing air over a hot body by a fan.

Convection is a complicated phenomenon depending upon a large number of variables such as temperature difference between surface and coolant, height, orientation, configuration and condition of heated surface, the viscosity and coefficient of volume expansion of fluid etc.

The amount of heat transferred in watts by natural convection can be expressed by an empirical relation [5].

$q_{Conv} = hs (\theta_1 - \theta_2)$ n watt

Where h = convection heat transfer constant, depending one shape and other conditions of the heated body as mentioned above.

S = surface area of the heated body in $m^2$

$\theta_1$ = Temperature of the heated body in $^0$c.

$\theta_2$ = Temperature of the fluid or content in $^0$c.

n = a constant depending upon conditions of the emitting surface, varying between 1.0 to 1.7.

### 2.10.1.3 RADIATION

In case of conduction and convection the heat transfer take place through a medium, but in radiation the heat transfer involves the mechanism of propagation of electromagnetic energy. For a small spherical radiating body inside a large and or black spherical cavity, heat radiated per unit surface areas may be given by Stefan – Bothzmann law.

$q_{rad} = 5.7 \times 10.8 \qquad e(T_1^4 - T_2^4)$ watt/m$^2$.

Where e = coefficient of emissivity

= 1 for perfect black body

< 1 for other bodies

$T_1$ and $T_2$ are the absolute temperatures of the emitting surface and the ambient medium respectively in $^0$K [5].

## 2.11 MOTOR UNDER HEATING

Consider a situation at any time t from beginning in a specific short time "dt," a small temperature – rise dθ takes place.

The heat developed during this small interval = Q dt

The heat stored = weight $x$ specific heat $x$ temperature difference

$= G\ c_p\ d\theta$

During this interval, the temperature of the surface rises by θ ever the ambient medium.

The heat dissipated =

Specific heat dissipation $x$ surface area $x$ temporize $x$ time = $\lambda\ s\ \theta$ dt.

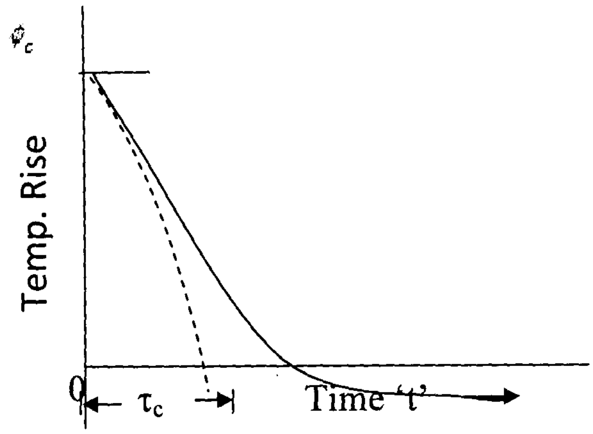
According to heat balance equation,

Heat produced = heat stored + heat dissipated.

$Q\ dt = G\ cp\ d\theta + s\ \lambda\ \theta\ dt$ [5].

## 2.12 MOTOR UNDER COOLING

When load on the machine is lowered thereby reducing the losses, or there is complete shutdown of the motor, leading to stoppage of generation of heat, the temperature of the motor will fall and the temperature time curve is again exponential in nature. See fig below




$$\theta = \theta c\,(I - e^{-et/\tau_c}) + \theta_1\, e^{-e\lambda/\tau_c}$$

Where cooling time constant, $\tau_c$, may be different from heating time constant, $\tau_h$

## 2.13 TYPES OF COOLING

i. **Inner cooler (direct cooled) winding**

   A winding which has either hollow conductors or tubes, which form an integral part of the winding, though which the coolant flows.

ii. **Open – circuit cooling**

   A method of cooling in which the coolant is drawn from the medium surrounding the motor, passes through the motor and then returns to the surrounding medium.

iii. **Closed – circuit cooling system**

A method of cooling in which a primary coolant is circulated in a closed circuit through the motor and if necessary, through a heat exchanger. Heat is transferred from the primary coolant to the secondary coolant either through the structural parts or in the heat exchanger [5].

## 2.14 TYPES OF ENCLOSURE

The scheme of ventilation is closely related to the type of motor enclosure. The various types of enclosure as per is 4722 – 1968 are

**(a). Open type**: There is no protection of any type and no restriction to ventilation. The example in this type of enclosure are;

1. Open pedestal (OP) the rotor is carried on pedestal bearings mounted, on the bed plate.

2. Open-end bracket (OEB). Here, the bearings form part of the end shields which are fixed to the stator housing the air is in free contact with the stator and rotor through wide openings in the end shields.

**(b). Protected type:** The example in this is screen protected motor (SP), the protection may be screen or by fine – mesh covers.

**(c). Drip, splash and hose proof type:** protected type motor where the end shield ventilation opening are designed to exclude falling water or dirt, vertically in the first case, at any angle between the vertical and $100^0$ from it for the second and jets of water / liquid in the third case. The examples in this types are:

1. Drip proof motor (DP)
2. Splash proof motor (SPLP)
3. Hose proof motor (HSP)

**(d). Ventilated type:** the end – shields are closed type except for flanged apertures for connection to pipes along which the cooling air in or let out. The example in this types is:

(i). Pipe ventilated (PV) or Duct ventilated (DVD), with several arrangements like forced – draught (PVFD), induced draught (PVID) etc [5].

**(e) Totally enclosed type:** These are protected by enclosures without opening but are not necessarily air tight. The example in this are

1. Totally enclosed type, naturally cooled (TE)
2. Totally enclosed fan cooled. (TEFC), a totally enclosed motor with surface cooling augmented by a fan driven by the motor itself.
3. Totally enclosed separately air cooled. (TESAC), here the surface cooling is augmented by a separately driven fan.
4. Totally enclosed water-cooled. (TEWC), here the cooling is augmented by water-cooled or other liquid –cooled surfaces embodied in the motor itself.
5. Totally enclosed closed air circuit motor, here the motor is having special provision for cooling the enclosed air by passing it through its own cooler, usually external to the motor: The cooler may be using (i). Air (CACA)
   (ii). Water (CACW).

## 2.15 METHODS OF VENTILATION AND COOLING

The cooling of electrical machines by means of an air stream is called ventilation of the motor.

The cooling systems can be grouped into three types.

**1. Natural cooling**

The motor is cooled by air movements set up in the motor due to its rotation or due to the temperature difference between inside parts and the ambient air.

**2. Self cooling**

The machine is cooled by air, blown by fan integrally built with the rotor or mounted on the shaft.

**3. Separate cooling**

The motor is cooled by air, blown by fan driven by separate motor. Further, the ventilation of motor can be classified into three types according to the schemes of ventilation incorporated in the motor [5].

**1. Open circuit ventilation**

There the heat is given up directly to the cooling air, the air is being replaced continuously.

**2. Closed circuit ventilation:** In closed circuit ventilation system heat is transferred through an intermediate ventilating medium normally air or hydrogen circulating in a closed circuit between the interior of the motor and a cooler

**3. Surface ventilation:** The heat is transferred from inside of the motor, by cooling medium to the external surface of a totally enclosed motor. The external surface is being cooled by natural means or mainly by air blown by fan [5].

## 2.16 COOLING – AIR CIRCUIT

The ventilating system can be further classified into four types in accordance with the provision of cooling ducts and how the air passes over the heated parts of the machine [5].

i. Radial
ii. Axial
iii. Combined radial and axial
iv. Multiple inlets.

## 2.17 COOLING OF TOTALLY ENCLOSED MOTOR.

In a totally enclosed motor the inside air has no connection with the outside. Therefore the heat developed inside the motor is dissipated into the atmosphere through the external surface of the frame. i.e by surface ventilation the outer heated surface having ribs is normally not left to cooling by natural means otherwise the heat dissipation is poor leading to low rated motor. The heated outer surface is cooled by blast of air by a shaft mounted fan. Now two types of fan cooling are adopted [5].

a. As shown in fig 1, Shaft mounted fans external to the working parts of the motor blows air over the carcass through a space between the main housing and a thin cover plate. Internal air circulation is produced by an internal fan, this avoids the temperature gradient across the air gap.
b. Another arrangement is shown in fig 2, an internal fan circulates the heat to the carcass. Air is also blown over the outside of the carcass to improve the

dissipation. This outer fan is enclosed by another cover in order to secure required direction of air flow.

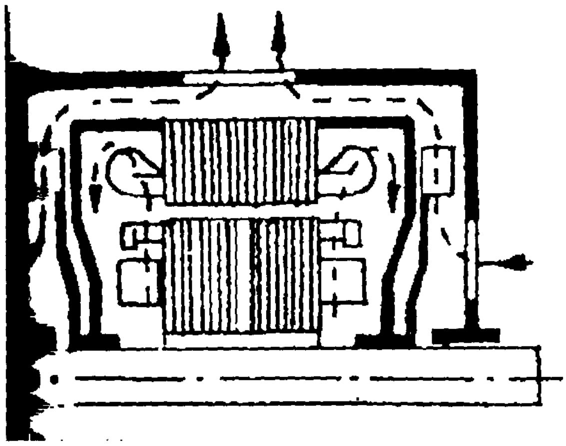


Fig 1 External shaft fan mounted circulator

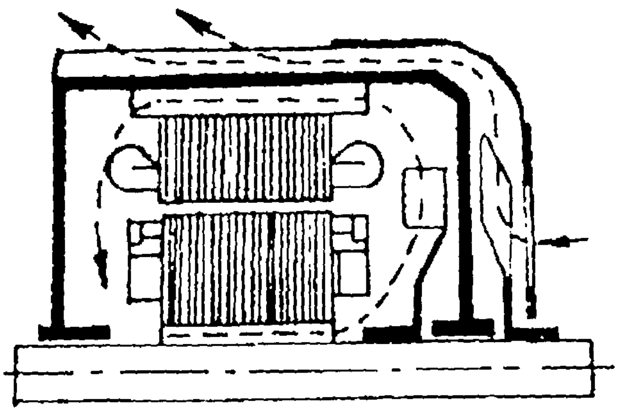


Fig 2 Internal fan circulator

## 2.18 MAGNETIZATION CHARACTERISTICS OF INDUCTION MOTOR

Each specimen of a material has a unique B-H curve, but it is a general practice to use average curves. The magnetic circuit data essential to the handling of saturations is given by the open – circuit magnetization curves or the saturation curve of the apparatus. For digital computation work some analytical relationship between B and H may be found out. The following expressions are useful, the choice depending upon the nature of the problem and the operating region of the curve [5].

(a) $B = \frac{aH}{1+bh}$ ........................................... eqn (i)

(b) $B = \frac{a_0 + a_1 H + a_2 H^2 +}{1 + b_1 H + b_2 H^2 +}$ .............................. eqn (ii)

Equation (i) gives reasonable approximation for higher values of B, While Equation (ii) is overall fit. For the reverse flux, only powers of H to be used.

It is the usual practice to replace the saturation curve by a number of straight lines, by choosing large number of points on the curve: the large the number of divisions more is the accuracy.

From these points a simple computer programme can be worked out in FORTRAN by which H for any given B can be determined [5].

### 2.18.1 CORE LOSSES

If the flux carried by a ferromagnetic material in a magnetic circuit is varied, magnetic losses, also called as core losses or iron losses, do occur and appear in the form of heat. The core losses have two component (i). Hysteresis loss and (ii). Eddy current loss.

### 2.18.2 HYSTERESIS LOSS

It occurs because of the cycling of the material through its hysteresis loop. The loss per cycle is proportional to the area of the hysteresis loop which depend upon the quality of the material. For sinusoidal flux density variation of peak value $B_m$ and r.m.s. value B, the hysteresis loss component of the specific loss in W/kg is

$Ph = kh\, f B_m^x$ ............................ eqn (iii)

Where

Ph = hysteresis loss in W/kg or $w/m^3$

Kh = hysteresis coefficient, depends upon the molecular structure of the material.

X = steinmetz coefficient, it varies between 1.5 to 2.5

### 2.18.3 EDDY CURRENT LOSS

It occurs because of the induction of currents circulating within the material. For sinusoidal flux density variation of peak valve $B_m$; the eddy loss component of the specific loss in w/kg is

$P_e = Ke\, f^2\, \beta m^2\, t^2$ W/kg ...................... eqn(iv)

Where Ke = Another proportionality constant depending on the volume of the magnetic material and its resistivity

t = Thickness of the lamination in metre.

The eddy current loss is reduced by using laminated steel sheet in transformer, a.c rotating machines and in armature and pole shoes of d.c machines. The lower the thickness of the lamination, the lesser will be the eddy current loss, But there is limitation as very thin sheets are difficult to handle and in rotating machines teeth would bend too easily.

The factor Ke is inversely proportional to resistivity of the material and to limit the eddy loss, high resistivity material is used.

### 2.18.4 TOTAL IRON LOSS

Total iron loss Pi = Ph + Pe

$= (K_h\, f\beta^x{}_m + Ke\, f^2\, \beta^2{}_m\, t^2)$ w/kg................. eqn (v)

X = 2, for most value

$$Pi = ( Kh\, f\beta^2_m + Ke\, f^2\, \beta^2_M\, T^2 )\ w/kg \ldots\ldots\ldots\ldots\ldots\ldots \text{ eqn (vi)}$$

## 2.19 ESTIMATION OF TOTAL MMF

The estimation of total mmf required to establish magnetization in the machine including transformer is essential for calculating the quantities like magnetizing current. For finding total mmf the magnetic circuit is divided into convenient parts magnetically in series or parallel. The dimension and configuration involve for each part has to be known. The flux density is calculated in every part and the mmf per unit length "H" is found from the B-H curve of the material concerned. The mmf per unit length multiplied by the length of the flux of that part gives the mmf. Summation of such mmfs when in series yields the total magnetic circuit mmf [5].

### 2.19.1 MMF FOR THE AIR GAP

The main quantities involved are

L = length of core, axial

$L_i$ = net iron length of core, axial

$L_g$ = air gap length, radial

$y_s$ = slot – pitch

$w_s$ = slot – width

$w_t$ = tooth – width

$w_o$ = slot – opening

$n_d$ = no of radial ventilating ducts

$w_d$ = width of each duct

**Case 1**: consider the iron surfaces on the two sides of the air gap to be smooth and the gap length to be uniform

Let $\phi s$ = flux through a slot pitch $y_s$

∴ Corresponding flux density $\beta = \frac{\phi s}{Ly_s}$ and reluctance $s_g = \frac{Lg}{\mu_0 Ly_s}$

For air gap $\beta = \mu_0 H$ as $\mu_r = 1$

mmf per mater. For air gap H = 800,000B

∴ mmf for air gap in this case

$ATg = 800{,}000\ Bl_g$

**Case II** : consider the iron surface on one side of the air gap to be smooth and slotted on the other let us assume that the flux path under this situation through air gap for one slot pitch is confined to width $w_t$

Here $B = \frac{\phi_s}{Lw_t} = \frac{\phi_s}{L(y_s - w_s)}$

reluctance $s_g$ has increased as the area of flux path has decreased

$$s_g = \frac{L_g}{\mu_o L[y_s - w_s]}$$

air gap reluctance, consider it in a slot pitch

$y_s = w_t + \delta w_s$

or

$y_s = y_s - k_c\, w_o$

$y_s$ is called as effective or contracted slot pitch

### 2.19.2 MMF FOR THE TEETH

Two difficulties arises while calculating the mmf for the teeth

a. The slot of all the machines, except very small machines, are normally parallel sided which make the teeth tapered. This means that the area through which the flux is passing in the teeth is not constant but varying and giving different values of flux easily over the length of the teeth. Further under rated condition, the tooth density is large at a section where the tooth-width is small and high magnetic saturation may result. This makes necessary a careful estimate of the mmf.

b. The teeth are normally working at high value of flux density and the mmf is thus high enough to make an appreciable flux pass through the slots and ducts too [5].

### 2.19.3 MAGNETIZING CURRENT

The sum of the mmf's required by the several parts of the magnetic circuit of given transformer or a rotating machine is to be provided by the exciting winding. The magnetizing current depends upon the total mmf required, the number of turns and how the winding is distributed.

Magnetizing current = $\frac{Total\ mmf\ required}{No.of\ turns.}$

or

$$I_M = \frac{AT}{T}$$

### 2.19.4 MAGNETIC CIRCUIT LEAKAGE

It is not possible to confine all flux to a desired path, same flux whatever small it may be, will definitely by passing through paths where it can be utilized. The flux passing through desired path and is being utilized is called useful flux where as the flux which cannot be utilized is known as leakage flux. To know the amount of leakage a term called leakage coefficient is brought in

Leakage co efficient = $\frac{Usefull\ flux + leakage\ flux}{Useful\ flux}$

$$= \frac{Total\ flux}{useful\ flux}$$

The useful flux and leakage flux may be added by superposition on the assumption that the presence of one does not affect the other. This is a wild assumption because of the presence of saturation but it has to be made to have single analysis.

Leakage flux: The leakage flux affects

i. Excitation demand of salient pole machine
ii. Leakage reactance of windings affecting the machine performance
iii. Mechanical forces between windings
iv. Voltage regulation of a.c machine and transformer

v. Commutation in d.c machines

### 2.19.5 LEAKAGE REACTANCE

Let $\phi_L$ be leakage flux per ampere linking a core of T turns.

The leakage inductance $L_L = \phi_L$ T Henry

$$= \lambda T^2 \text{ Henry}$$

Where $\wedge$ is the permeance of the leakage flux path and $\lambda = \mu_o \frac{A_L}{L_L}$

Let $\frac{A_L}{L_L} = \lambda$, permeance coefficient

$\therefore L_L = \mu_0 \lambda T^2$ Henry

Leakage reactance $x_L = 2 \pi f T^2 \lambda$ ohms

The permeance of a series of x

$$\lambda = \mu \Sigma\left(\frac{A_x}{L_x}\right) = \mu_0 \Sigma \lambda_x$$

### 2.19.6 LEAKAGE REACTANCE IN ROTATING MOTOR

Estimation of leakage flux in case of rotating motor is more difficult, compared to transformer because of their complex configuration with the advent of digital computers it has become possible to predetermine flux patterns accurately leading to precise estimation. A simpler approached through mmf and premeance leading to simpler equations has been discussed below.

**(a). Leakage in salient field poles:** Leakage flux in salient field poles can be divided into the following components

$\phi_{L1}$and $\phi_{L2}$: The leakage flux per pole between the pole shoe inner surface,

and between end surface of pole shoes respectively

$\phi_{L3}$ and $\phi_{L4}$ : The leakage flux per pole between the pole core inner surfaces,

and between end surface of pole cores respectively.

Let $f_g$ = gap mmf, $f_L$ = armature tooth mmf

$f_c$ = armature core mmf

$\therefore$ mmf across fluxes $\phi_{L1}$ and $\phi_{L2}$ = f = 2 ($F_g + F_L + F_c$,)

Thus $\phi_{L1} = 2\,\mu_o\, f \frac{L_{ps} \cdot h_{ps}}{d_{ps}}$

and $\phi_{L2} = 4\,\mu_o\, f\int_0^{1/2} w_{ps}\,\frac{h_{ps}\,.dx}{h_{ps} + \pi x}$

$$= 16 \times 10^{-7}\, f\, h_{ps} \log_e\left(1 + \frac{\pi\, w_{ps}}{2\, d_{ps}}\right)$$

The mmf across flux – paths $\phi_{L3}$ and $\phi_{L4}$ is zero at the root of the pole where it joins with the yoke and approximately = F = 2 ($F_g + F_L + F_c$) at the junction of pole core and pole shoe.

$\therefore$ the average mmf is $F/2$

Thus $\phi_{L3} = 2\ \mu_o\ ½\ F = \frac{L_{pc}\cdot\ h_{pc}}{h_{pc}}$

$$= \mu_0\ f\,\frac{L_{pc}\cdot\ h_{pc}}{d_{pc}}$$

$$\phi_{L4} = 4\ \mu_o\ ½\ f\int_0^{1/2\, w_{pc}} \frac{h_{pc}\,.dx}{d_{pc}+\ \pi x}$$

$$= 8 \times 10^{-7}\ f\, h_{pc} \log_e\left(1 + \frac{\pi\, w_{pc}}{2\, h_{ps}}\right)$$

Leakage flux between poles shoes per pole is about 20 f x $10^{-8}$ while leakage flux between pole core per pole is about 80 f x $10^{-8}$ thus flux at the back of the pole is the main flux

$\phi_m$ + 20 f x $10^{-8}$, the flux at the root of the pole is the main flux. $\phi_m$ + 20 f x $10^{-8}$ + 80 f x 10-8.

**(b) Leakage in non – salient poles**

The non-salient rotor has considerable leakage of the retaining rings clamping the overhang are made of magnetic material. The amount of leakage is dependent on the saturation flux density of the material. One of the disadvantages of this leakage is that it raises the mmf requirements of rotor teeth and core by saturating the material. Therefore non- magnetic steel is generally preferred for the retaining rings.

**(c) Leakage in armature**

The armature leakage flux owes its existence to the armature current and is affected by the type of winding and the presence of magnetic material in the proximity. The total armature flux is divided into the useful flux and the leakage flux.

The armature leakage flux can be divided into two identifiable regions.

i. Leakage flux in the overhang region

ii. Leakage flux in the gap region

The overhang leakage – it value depends on the type of end winding and on the proximity of the ferromagnetic materials.

The gap region leakage flux: This is further divided into several components like the slot leakage flux, zigzag leakage flux, differential leakage flux etc [5].

# CHAPTER THREE

# REFURBISHING OF THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

## 3.1 CHARACTERISTIC OF MOTOR

The electric motor is a three phase squirrel cage induction motor with the following characteristics:

a. Power rating = 0.75kw
b. Voltage rating = 380v
c. Frequency = 50Hz
d. Number of phase = 3 phase
e. Speed of motor = 2850r.p.m
f. Power factor = 0.75
g. Full load efficiency = 84%
h. Full load current on star connection is 2.1 amperes while 3.6 amperes on delta connection.

## 3.2 FINDINGS BASED ON EACH PARTS OF THE MOTOR

The following fault analysis procedure visual inspection, electric test, mechanical test were carry out on the motor in order to determine the nature of repair required for reconditioning of the motor.

## 3.3 STATOR

By visual inspection, the stator is made of cast iron, it's laminated to reduce losses due to eddy current and hysteresis it have 36 slots which are insulated from each other and have spaces between them for cooling. The 36 slots house the armature conducts or windings of the motor. After mechanical inspection it was discover that the stator frame and core are in good shape.

## 3.4 ROTOR

By visual inspection, the coils are arrange in the 36 slots and are burnt, the coils are connected in series, 3 coils are in series and the total number of coils equal to 6. And by electrical testing, where short circuit test was carry out it was discover that the conductor used for the windings of the different phases are short circuited it was also discover that the insulator fail.

## 3.5 SHORTED COILS

Short circuited coils cause noisy operation of the motor and smoke. This occurs when the insulating enamel on the conductor fails individual turns becomes shorted and cause the coils to become extremely hot and burn-out.

## 3.6 INSULATION FAILURE

Every winding must carry an insulation that protects the winding from other problem the major areas under which there would be problems with insulation are:

a. Operating the motor at a temperature beyond its class of insulation, if an insulator that is designed for 90°c working is used for a motor that should work under 150°c its clear that the insulation will due to the excessive temperature the winding is subjected to.
b. If insulation is hygroscopic and water drops into the motor, the winding will no longer be protected. And leaking will get to the body of the motor immediately and this will cause a failure.
c. If the insulation is not given its recommended varnish after the winding is done. It could be that after varnishing the motor is only left in the oven for short time or sometimes the timing is not followed and the motor over stay in oven, when such a motor is brought out and sent in for actual usage, the insulation will crack and this cause a failure.
d. Incomplete cleaning of the old coils could be problematic, if its not properly cleaned before rewinding. The insulation of the rewound coils could be affected by the excesses of the hard dried varnish. This could affect the insulation and result in a failure.

## 3.7 SHAFT BEARING

By visual inspection of the shaft and bearing it was discovered that they are in good condition. But trouble can occur if oil is not supplied to bearing holding the shaft, the shaft will become so hot that it will expand sufficiently to prevent movement in the bearing. In the process the bearing may weld itself to the shaft and make rotation impossible.

## 3.8 GROUNDED WINDING

When earth leakage test was carry out between the windings of the phases and the frame of the motor. The test result show that there is leakage of current between the windings and the frame of the motor, this condition will produced an electric shock and is as a result a breakage of insulation between the windings and the frame of the motor or causing of the motor.

## 3.9 SOLUTION BASE ON EACH PARTS OF THE MOTOR

### 3.9.1 STATOR

The stator of the motor has 36 slots and is in good condition

Fig. 3.1: **The Stator of the Squirrel cage Motor**

### 3.9.2 ROTOR

The rotor is a core that is made of sheets of high-grades electrical sheet steel called lamination and the shaft of the motor is attached to it and is in good working condition.

Fig. 3.2: **The Rotor of the Squirrel cage Motor**

### 3.9.3 WINDINGS

Since the windings are bad it need to be replace with exactly the same new winding.

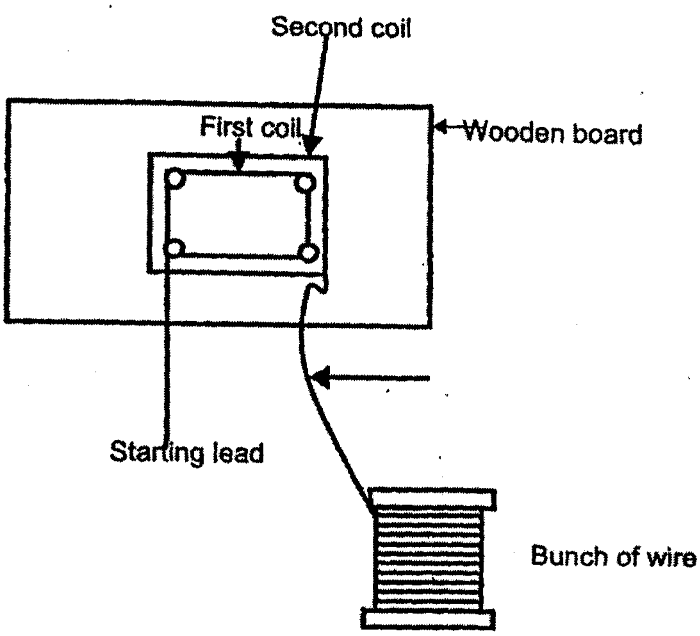



Fig. 3.3: **Preparing the first coil series**

Micrometer screw gauge is used to determined the size of the conductor used for the windings. Which diameter of the motor conductor is 0.56mm, the cross sectional area of each of the conductor is determined by using this formulae $A=\pi\ [D/2]^2$

Where A=Cross sectional area

r =Radius of the conductor

D =Diameter of the conductor

| | | |
|---|---|---|
| $A= \quad [0.56/2]^2$ | = | $3.142\times0.56^2/4 = 0.24633mm^2$ |
| Number of turn | = | 54 turns |
| Number of coil in series | = | 3 |
| Total number of turn per coil | = | 3×54 =162 turns/coil |
| Total number of coil | = | 6 coil |
| Number of coil / phase | = | Number of coil / Number of Phase |
| | = | 6/3 = 2 coils/ phase |
| Number of coil group | = | Number of poles × number of phase |
| | = | 2 poles x 3 phases = 6 group of coils |
| Number of coil in each pole | = | Number of coils / Number of poles |
| | = | 6/3 = 2 coil /pole |

Number slots for each group of coil = 36 slots/ 6 group =6 coils

Since we have 2 sides therefore the number of coil per group is 2 coils/ group.

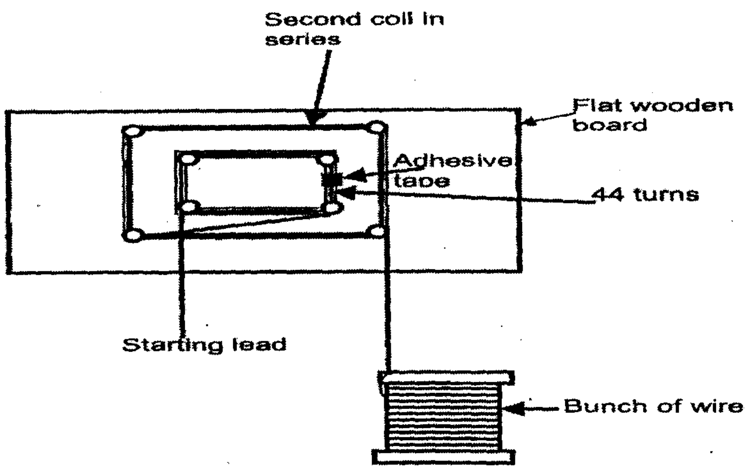



Fig. 3.4: **Preparing the first coil series**

## 3.9.4 NUMBER OF COIL AND COIL SPAN

This is determined from the total number of slots and the number of slots in motor is evenly distributed, the number of slots is 36 and the number of slots each coil occupied is 6. Therefore the number coils 36/6= 6 coils. The coil span can be determined from the number of slots and the poles that is

Coil span = 36/3 = 12

Since we are having 3 coils series, the first coil is span 1-14, the second coil is span 1-16, and the third coil 1-18. The coil span can now be said to be 1-16-18.

## 3.9.5 THE NUMBER OF POLE AND SPEED

The number of pole of the motor can be determined from the speed on the motor, for 50Hz supply, the number of poles is given below.

| | | | | | | |
|---|---|---|---|---|---|---|
| Ns | 3000 | 1500 | 1000 | 750 | 600 | 500 |
| P | 2 | 4 | 6 | 8 | 10 | 12 |

We then determined the number of pole using this expression.

Ns = 120f/p, P = 120f/ns = 6000/2850 = 2.0

Where P = Number of Poles

F = Frequency of the supply = 50Hz

Ns = Synchronous speed of the motor = 2850r.p.m

### 3.9.6 REWINDING THE THREE PHASE MOTOR

Many separate steps are involved in rewinding the three phase motor which includes.

a. Taking data.
b. Stripping the winding.
c. Insulating the stator.
d. Winding the coils.
e. Placing the coils in the slots.
f. Connecting the coils.
g. Testing the winding.
h. Varnishing and baking.

### 3.9.7 STRIPPING THE WINDING

During the process of stripping the windings the remainder of the information necessary in taking data can be obtained. Before the wires are removed from the stator, the type of connection must be recorded for instance either star or delta. This can only be achieved if one is familiar with the methods of winding three phase motor and connecting the phases and poles to one another. Large 3-phase motors have open slots in the stator. Its necessary to remove the slots wedge and move out the coil one at a time. The small and medium sized stator has semi-closed slot and stripping the winding from these stator is more difficult. Since the windings are usually hard-baked, its necessary in most cases to heat the insulating material on the winding by placing the stator in oven with temperature being controlled.

After which the winding is cut on one side of the stator and then pulled out from the other side, one coil must be saved in order to provide the pitch of coils number of turns, the size the coils are recorded.

### 3.9.8 INSULATING THE STATOR

The stator insulation should be replaced with the same insulation class as the old one used. Usually cuffed insulation is used for small to medium sized motor employing material applicable for particular motor. The cuffed insulation is sold in rolled in standard width and can be cut to sizes with a paper cutting machine or doing it manually with sharp knife and the shaped to fit the sizes of the slots.

### 3.9.9 WINDING THE COIL

The winding of the coil depends on the motor size and there are machine available for winding coil for large motors with large number of turns and many coil are series. A machine is employ in making the coil with convenience. In the case of small and medium motors a Planck of reasonable size can be employed with striking nails positions to suit the size of the coil to be wound. The coil can be wound in series (group) in this case several coils are wound before the wire is cut, the series coil can either be of the same size for instance, the same coil span or of different coil span.

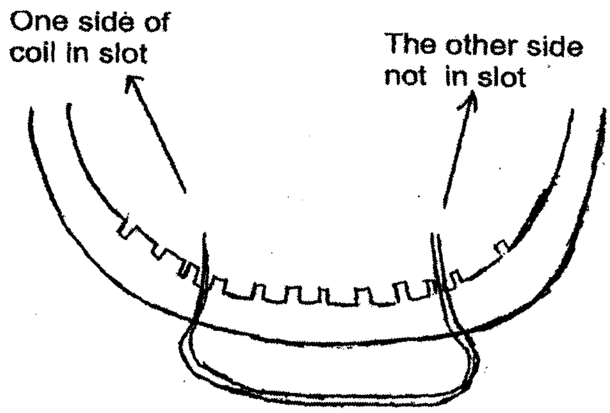



Fig. 3.5: **Starting to place one side of coil in slot before the other side**

### 3.9.10 PLACING COILS IN SLOTS

The turns of the coils are inserted one by one in to the semi-closed slots. The turns are spread out in the stator by the slots help at an angle so that all the turns can be feed into the slots by means of drawing the coil from one end of the slots to the other or by the used of a glass fibred to the coils in small quantity into the slots until the whole side enters, care must be taken to avoid drawing the wire in between the insulation and the iron core to avoid ground fault. In group winding a coil side occupies half a slot. Therefore one side of the second coil is placed beyond the first. The following coils are fitted in the same manner until the slots of a complete coil pitch hold one side of each coil before inserting the second side of each coil, its necessary to insulate it from the coil already in the slot.

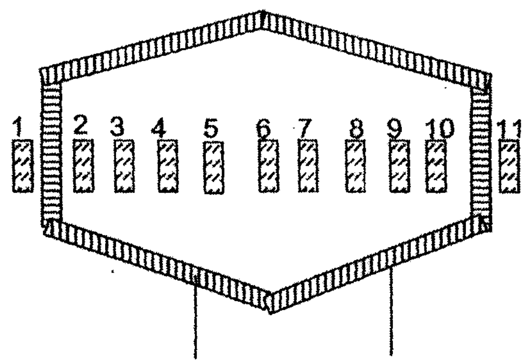



Fig. 3.6: **Method of Placing two side of each coil in slot**

To insulate between the coil sides in same slot for both open and semi-closed slot, a separator or insulator of paper width and thickness should be used to insulate between top and bottom coil sides in the slots. It should extend about 10mm beyond the slot ends when the top side is placed into the slot a wooden or formal fibred wedge is place over the top coil. This should extend 1.5mm beyond the slot ends. As each ground of coils is placed in the slots phase insulation must be used between groups varnished or plan cambric in used for this purpose.

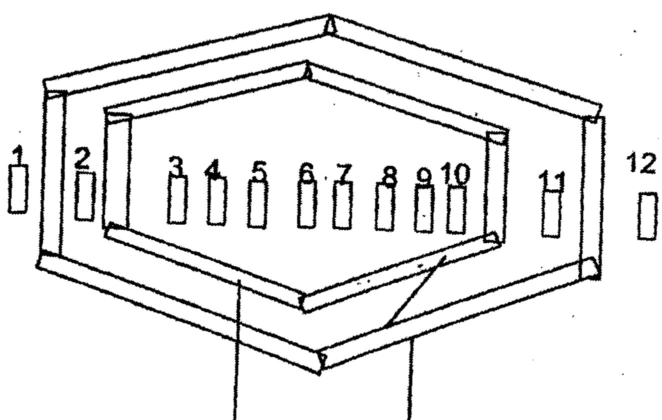



Fig. 3.7: **When two coils are placed in slot**

### 3.9.11 BAKING AND VARNISHING

When all the connections between poles of the windings have been completed and tested and the flexible leads to the power line attached and tied, the stator should be placed in a baking oven at a temperature of approximately 100°c and preheated for a short period of time approximately by one hour.

This removes moisture from the windings and increases the penetration of the varnish. The stator is then dipped into a container of insulation varnish. It is important to remainder that the varnish must be thin enough to penetrate the winding and thick enough to leave an adequate firm when baked the varnish may become thickened due to evaporation of the thinning fluid if this happens, use a thinner recommenced by the manufacturer.

After the winding has soaked in the varnish for one-half hour or until bubbling has ceased, it is removed from the container and allowed to drip. After it has stopped dripping it is again placed into baking oven and baked for several hours.

In using any type of varnish, make sure that it follows the manufacturer's recommendations. When the stator is removed from the oven, the inner surface of the core should be scraped to remove the adhering varnish so that there will be sufficient space for the rotor to turn freely.

Dipping and baking bonds the entire winding into a solid mass that is not subject to movement, it seals the windings against moisture and foreign, material and increases mechanical and dielectric strength of magnet wires. There are other types of varnishes that do not require baking and are called completely solvent less and give the same protection that ordinary varnishes provide.

### 3.9.12 ASSEMBLING

After the rewinding of the burnt coil in the three phase motor and necessary test such as continuity test, short circuit test, earth leakage test etc have been carry out on the rewind motor. The three phase motor is couple together or assembly.

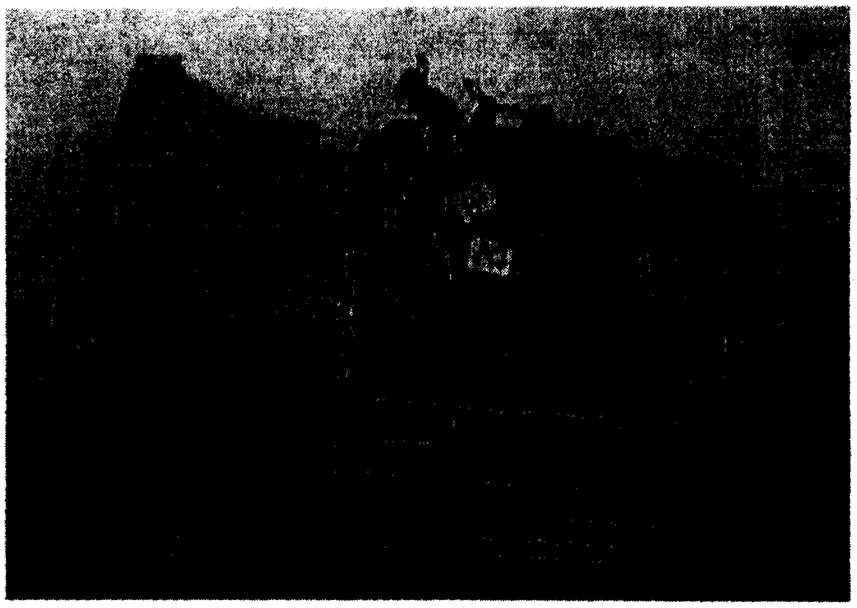


Fig 3.8 **The refurbished squirrel cage induction motor**

## 3.1O CONNECTING THE THREE PHASE MOTOR

After the three phase motor is wound with a number of coils which equal the number of slots. These coils are connected in a way to produced three separate windings each representing a phase with the same number of coils and turns.

The phase can either be connected in star or delta.

A star connected three phase motor is one in which the ends of each phase are joined together while the beginning of each phase is connected to the line as shown in the fig below

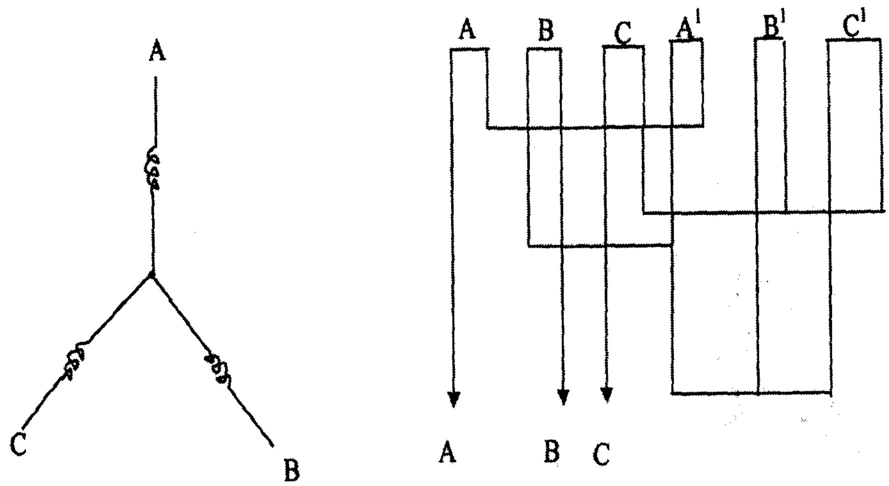



Fig 3.9 **Star Connection**

A delta connection is one in which the end of each phase as connected to the beginning of the next phase. The end of A phase is connected to beginning of the B phase. The end of B phase is connected to the beginning of C phase, and the end of C phase is connected to the beginning of A phase.

At each connection a lead is brought out to the line as shown in the figure below

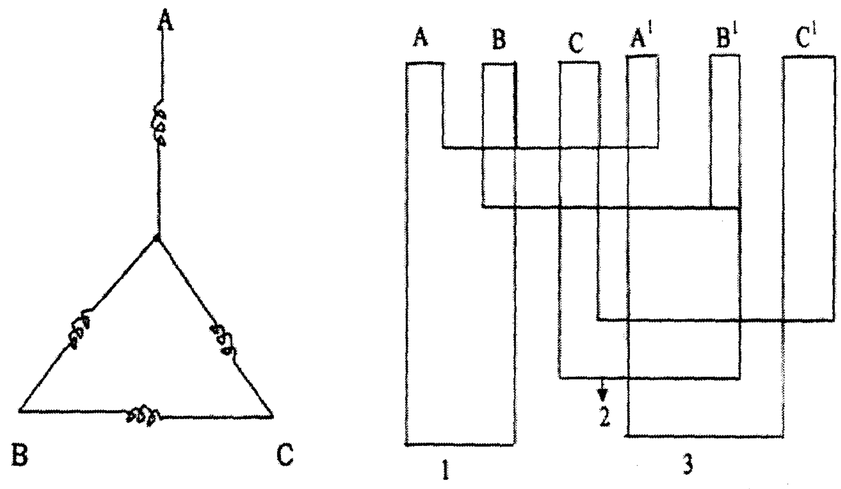



Fig 3.10 **Delta Connection**

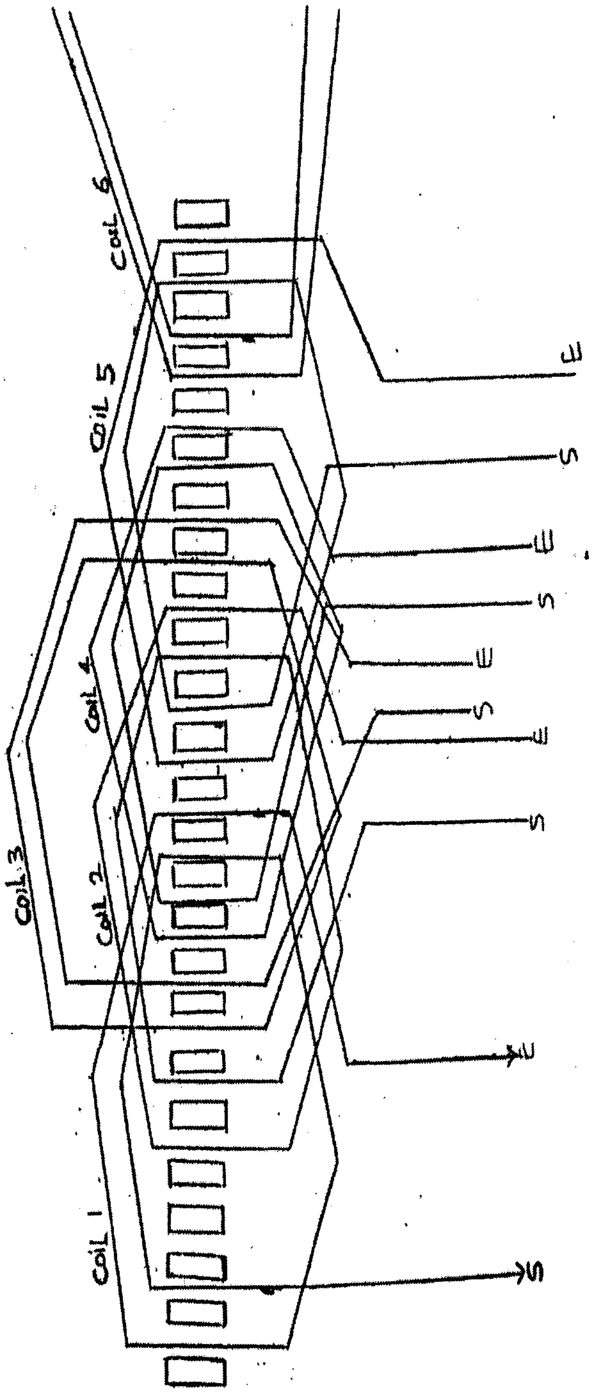
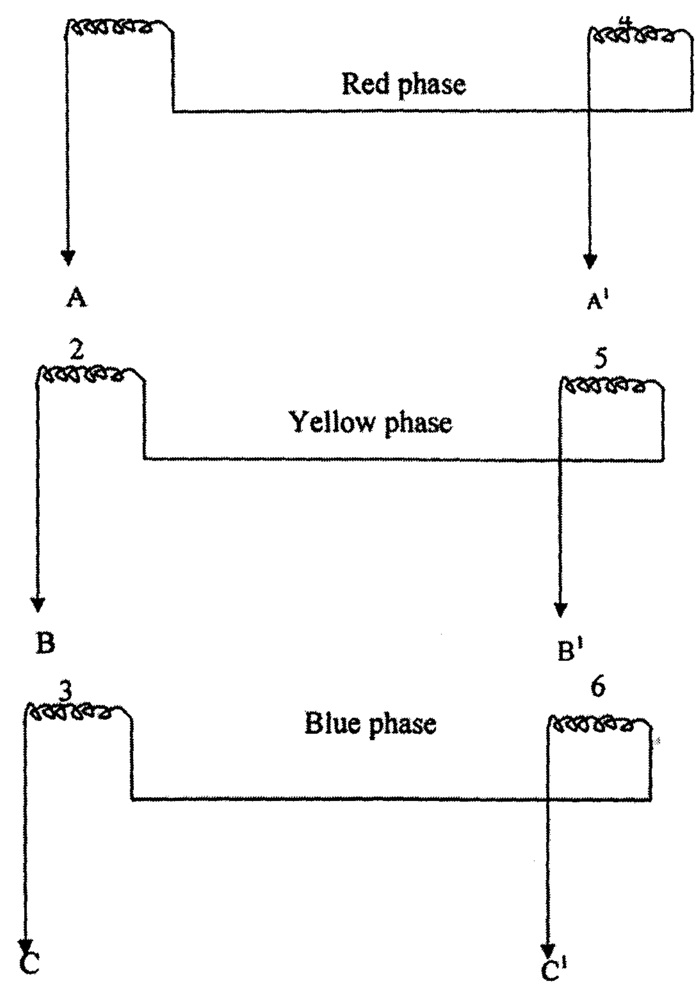



Fig 3.11 **Grouping of Coils**

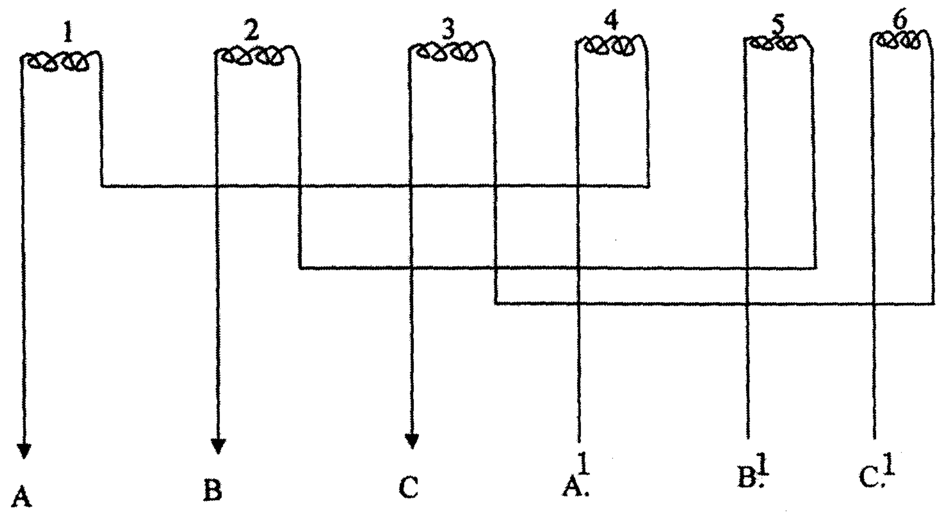
## 3.11COIL ARRANGEMENT/ GROUP CONNECTION OF COIL

This electric motor contains size coils each of the coil occupying four slots spread in a span of 1-16-18. The coils are shared into three phase groups with a phase having two coils displaced at 180°c electrical.

Each coil has two leads, start and finish. The finish of the first coil of a phase is connected to the start of the second coil of the same phase with the starting of these coil of the same phase with the starting of these coils brought out as leads of a particular phase. The other two phases being connected in the same manner.




## GROUP CONNECTION OF COILS



## 3.12 OPERATION OF ELECTRIC MOTOR

After assembling the motor, the motor was tested. Before the test was carried out, physical inspection of all the connections was carried out, all the joints were mechanically and electrically sound.

Continuity test was carried out with ohmmeter and the motor was found okay.

## 3.13 OPERATING PROCEDURE

In carrying out the operating test the following conditions were performed at the preliminary stage.

a. Turn the motor shaft by hand to make sure the rotor was free.
b. Inspection of the environment for presence of obstacle which may hinder its operation.
c. Connect the motor to the supply on the test table.
d. Then pressed the start push button the motor comes ON

When the start push button was pressed the three phase induction motor converts, electrical energy into mechanical energy by the means of applying voltage through the primary winding which is the stator winding mounted in the slots. Three phase supply is applied through the winding displaced in space by 120°. They produce a resultant magnetic flux of constant magnitude which rotates at synchronous speed. This flux passes through the air gap and onto the surface the rotor and cuts the stationary rotor conductors. As a result of the relative speed between the rotating flux and the stationary conductors, an e.m.f is induced in the rotor according to the Faraday's first law of electromagnetic induction that states, whenever a magnetic flux linked with a circuit an e.m.f is always induced in the circuit. The frequency of the induced e.m.f is the same as the supply frequency. Since the rotor is squirrel cage type the conductors are short circuited by the end rings placed at each end of the bar. The rotor current produced whole direction as given by Lenz's law is such to oppose the cause producing it which is the relative velocity between the rotating flux and stationary rotor conductors. Hence to reduce the relative speed, the rotor start running in the same direction as that of the flux and tries to catch up with the rotating flux which the rotor never achieve.

### 3.14 TOOLS USED

The tools used during the refurbishment of the three phase induction motor are set of spanner, files, chisel, mallet hammer and scraper.

Set of spanner were used during decoupling and coupling of the motor while scraper is used for cleaning the stained varnish in the core to prevent stiffness when running the motor which will add to the motor resistance.

Also hammer is used during decoupling and dressing of the winding in the slots to enable easier binding of the coils and to allow free entry of the rotor into the stator core without rubbing on the coils to avoid damage

# CHARPTER FOUR

## 4.0 TESTS, RESULTS AND DISCUSSION

### 4.1 CONTINUITY TEST

A multi meter is put on the ohm range to carry out continuity test on the three different windings for the three different phases.

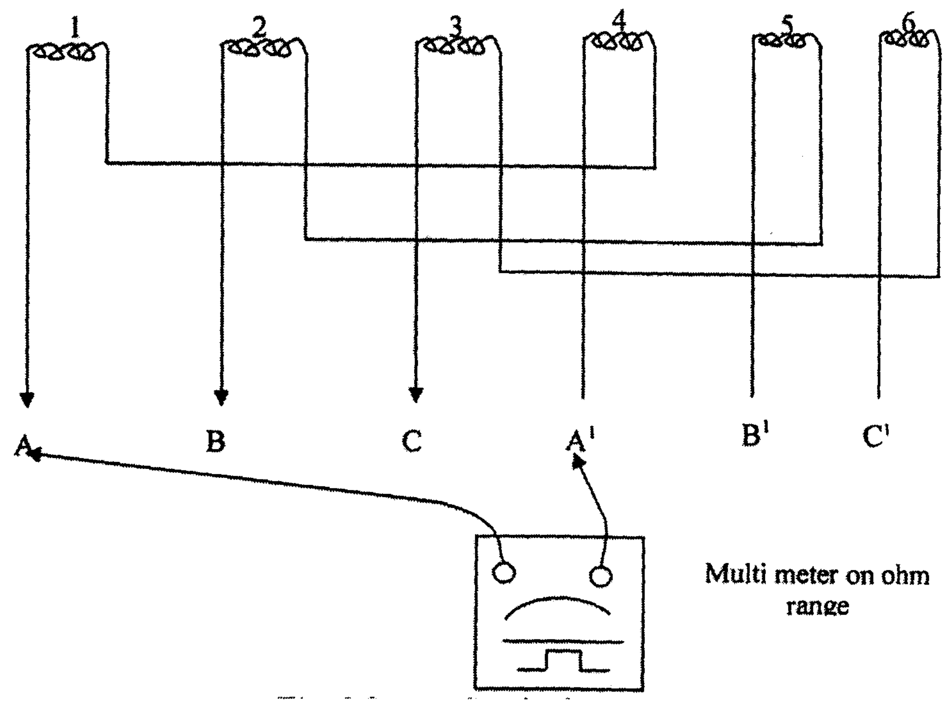



Fig 4.1

Table 4.1 CONTINUITY TEST RESULT

| S/N | Between | Result |
|---|---|---|
| 1 | Start and Finish terminal of Red Phase | 0.005Ω |
| 2 | Start and Finish terminal of Yellow Phase | 0.005Ω |
| 3 | Start and Finish terminal of Blue Phase | 0.005Ω |

The two leads of the instrument, one is place on the start of the Red phase of the motor while the other lead of the instrument is place on the finish of the same phase to confirm if the conductor that form the windings of the Red phase is continuous or not.

On carrying out this procedure on the Red phase of the motor, the multi meter reads a very low resistance almost zero. This very low resistance value show that the conductor that form the winding of the Red phase is continuous and there is no breakage of conductor or open circuit in the windings of the Red phase of the motor.

This same continuity test procedure is carry out on the remaining two phases namely the Yellow phase windings and the Blue phase windings to detect if the windings are continuous or open, while carry out the test on them, it was found that the multi meter reading of the resistance values of the Red and Blue phase windings was almost zero which confirm that both conductors windings are continuous.

### 4.2 SHORT CIRCUIT TEST

The multi meter is also put on ohm range to carry out this test on the three different phase winding to check if there is a short circuit between any of the three phase windings that make up the motor.

And also to detect if there are short circuit between any of the three phase windings and the casing of the motor.

For testing short circuit between the different three phase windings of the squirrel cage induction motor. The measuring instrument that have two leads, one lead of the multi meter is place on the start of the Red phase and start of the Yellow phase winding in the case of testing for the short circuit between the three different phases winding it can be conducted using either start or finish terminals of the three phase windings.

**Table 4.2 SHORT CIRCUIT RESULT**

| S/N | Test Between | Result |
|---|---|---|
| 1 | Red phase and the Yellow phase | 5MΩ |
| 2 | Red phase and the blue phase | 5MΩ |
| 3 | Red phase and the motor casing | 5MΩ |
| 4 | Yellow phase and the blue phase | 5MΩ |
| 5 | Yellow phase and the casing | 5MΩ |
| 6 | Blue phase and the casing | 5MΩ |

While in the case for testing between the three different phases and the casing of the motor either the start or finish of the three different phases can also be used.

In all the readings obtained for the short circuit test for various conditions, the resistance readings are very high which confirm that there is no short circuit between them.

## 4.3 INSULATION RESISTANCE TEST

The instrument used for insulation resistance test is the megger insulation tester.

The megger insulation tester consists of a hand-driven generator and a direct-reading ohmmeter mounted together in a case and provided with terminals mark

Line and Earth. For testing the insulation resistance of the 3 - $\phi$ windings of the squirrel cage induction motor. The three starts of the motor are connected together or bridged. The three finish of the motor are connected to the LINE terminal of megger insulation tester. While the earth terminal of the megger is connected to earth terminal of the motor.

The handle of the megger is rotated to generate the testing voltage, the motor insulation resistance is read from the ohmmeter scale on the megger and the value is 0.6MΩ.

The test result of the insulation resistance above is in conformity with IEE regulations E6 and E9. This result shows that the insulation resistance of the motor is okay.

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATION

## 5.1CONCLUSION

Based on financial findings, the cost of procuring a new three phase induction motor is very expensive, hence rewinding is necessary.The principles applied in the rewinding of the motor are based on electrical fault analysis procedure; visual inspection, short circuit test, continuity test, and insulation resistance test. On completion of the rewinding, the results are: continuity test as 0.005Ω per phase, short circuit test as 5MΩ per phase and insulation resistance test as 0.6 MΩ, indicating that the motor is working properly. Thus the aim of the project was achieved.

## 5.2 PROBLEMS ENCOUNTERED

I. Difficulty in getting testing equipment

II. Finding the right guage of conductor / coil.

## 5.3 RECOMMENDATION

Since squirrel cage induction motor are used in almost all industrial applications such as: rotating shaft of Compressors, pumps, Machine tool application, Laundry machine application etc. It's for this reason that the following recommendations for improvement or this particular project are made:

I. The department should make availablnd accessible more advance testing equipments.

II. More student should be encouraged to carry out project in the area of electrical maintenance in order to reduce the current trend of running electrical machines to failed.

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