Table of Contents:

Table of Figures:

Chapter One
Introduction

1.1 Introduction:

An electric generator is a device used to convert mechanical energy into electrical energy.

The generator is based on the principle of electromagnetic induction discovered by Michael Faraday.

Faraday discovered that if an electric conductor like a copper wire is moved through a magnetic field, thus an electromotive force will be induced in conductor is directly proportional with the speed of cutting magnetic flux, the density of magnetic flux and the length of the conductor. So the mechanical energy of the moving wire is converted into electrical energy, the direction of the induced electromotive force can be found by use of Fleming's right hand rule then the emf is conducted from the rotating loop of the wire.

1.1.1 Voltage:

Voltage is the electrical equivalent of mechanical potential.

The potential energy of an electrical supply is given by its voltage. The greater the voltage of a supply source, the greater it's potential to produce a current flow.

1.1.2 Current:

Electric current is referred to the flow of electrons through a conductor. Any movement of electric charge constitutes an electric current.

1.1.3 Alternating Current:

In recent years, alternating current (AC) has become increasingly popular for powering aircraft system. The advances in a modern electronics have made it possible for even light single engine aircraft to maintain small AC power systems. Larger AC power systems are now employed on virtually all modern transport category aircraft. Most of the electrical system found in these aircraft operates on AC power, although a direct current (DC) emergency system is still used.

Some of the units operated by alternating current in airplanes are instrument, florescent light, radio equipment, electric motors, navigation equipment and automatic pilot.

Chapter Two

AC Theory

2.1 AC Theory

Alternating current is defined as a current that periodically changes direction and continuously changes in a magnitude.

The practical way of generating an electromotive force (emf) by mechanical means is to rotate a conductor in a magnetic field (Fig. 2.1).

As the conductor rotates in the magnetic field, its direction of motion relative to the magnetic field is continually changing; therefore, the emf induced in the conductor is continuously changing. The emf will start at zero when the conductor is moving parallel with the lines of flux; it will rise to a maximum value when the conductor is moving at 90° to the lines of flux, before moving back to zero rising to a maximum value in the opposite direction. In this way, an alternating emf is produced which, when connected to a circuit, produces an alternating current flow.

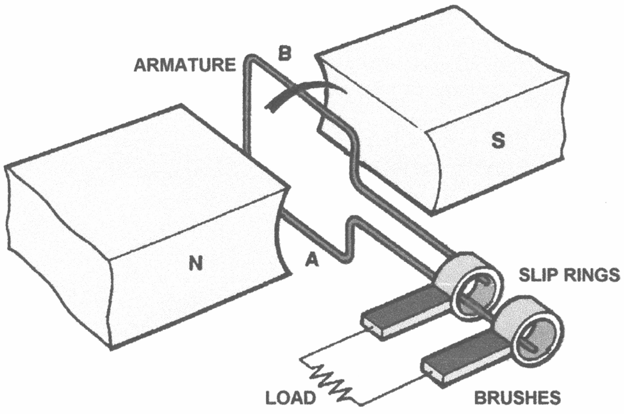

Fig. 2.1 Simple AC Generator

By making the conductor in the form of a loop, we have the basis of the simple ac generator.

All generators, both DC and AC, have this basic design. In a DC machine the output to the load is continually switched by the Commutator, so that the load current always flows in one direction. In an AC machine the output to the load is continually reversing it direction.

If the generated emf of the loop is measured and plotted as the loop rotates, the result will be as shown in the diagram below (Fig. 2.2 and Fig. 2.3)

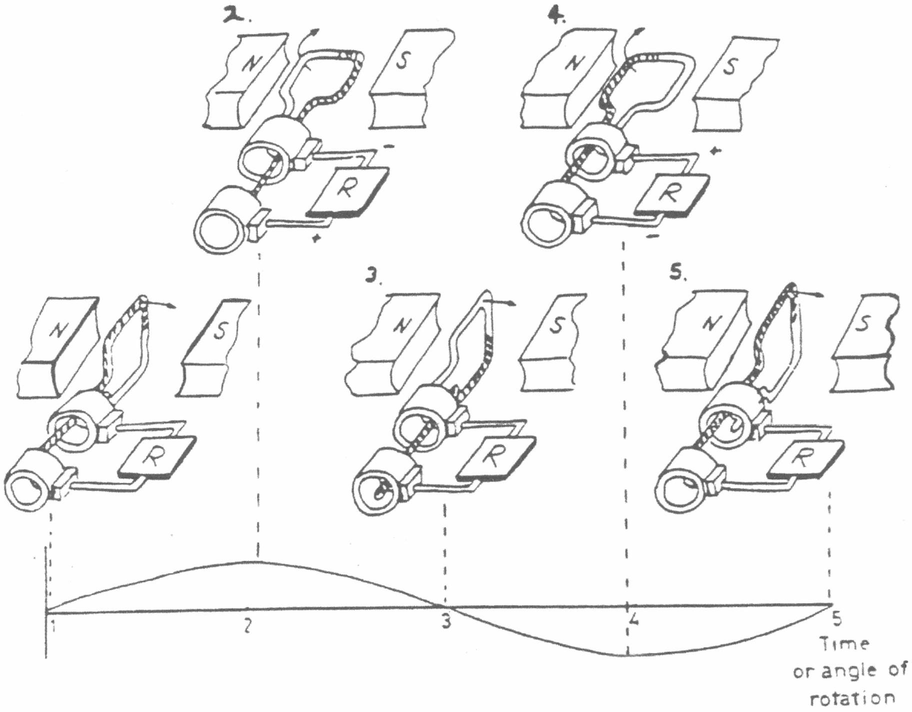

Fig. 2.2 Principles of AC Generation

It can be seen that when the conductors are moving parallel to the lines of flux, and not cutting them, the induced emf is zero. When the conductors are cutting the lines of flux at right angles, maximum emf is induced in them. By convention, the part of the waveform above the zero line is labeled positive and the part below the line is labeled negative.

2.1.1 The Sinewave:

If the conductor is rotated at uniform speed in a uniform magnetic field, the output waveform is said to be 'sinusoidal' and we refer to this type of waveform as a sine wave. There are many other wave shapes that can be generated or developed, but it is the sine wave that is used for main power supply systems.

When the conductor has completed 360° of rotation, it is said to have completed one cycle.

2.1.2 Peak and Peak-to-Peak Values:

Amplitude values and their calculation apply equally to current and voltage measurement.

2.1.3 The Peak or Maximum Value:

The maximum value attained by the wave in either direction is called the maximum value, or more usually, the peak value.

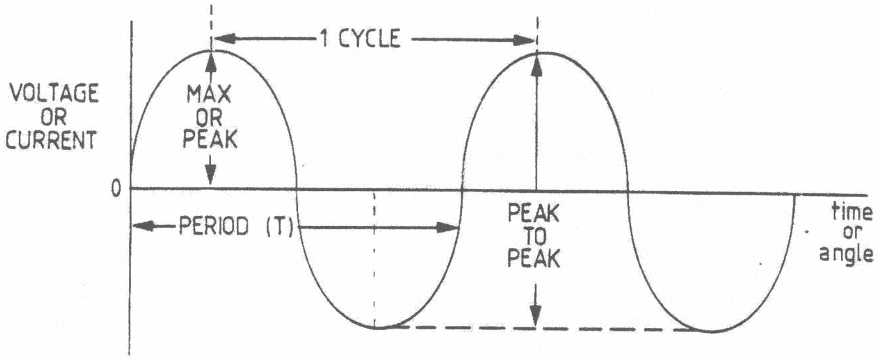

Fig. 2.3 Maximum Value

2.1.4 The Peak-to-Peak Value:

The maximum value in one direction, to the maximum in the other direction is called the Peak-to-Peak value. It must not be confused with peak value, which is measured in one direction only.

2.1.5 The Instantaneous Value:

As previously stated, the value at any instant can be calculated by multiplying the peak value by the sine of the angle (from 0°) through which the conductor has rotated.

2.1.6 Average Values:

The amplitude of an AC waveform may be defined in terms of its average values. Over one complete cycle, this would mathematically be zero (the wave goes as far positive as it does (negative) If the pulses of voltage or current are always in one direction.

2.1.7 RMS or Effective Values:

In order to determine the amount of power available from an alternating current, we must arrive at its effective value, it is obvious that effective value does not equal maximum value, because maximum value is attained only twice in the cycle even though the current during one half cycle is equal and opposite in direction to that during the other half cycle, the currents do not cancel each other; work is done whether the current is moving in one direction or the other. Therefore, the effective value must lie somewhere between the zero value and the maximum value.

The effective value of an alternating current is calculated by comparing it with the direct current. The comparison is based on the amount of heat produced by each current under identical condition since the heat produced by a current is proportional to the square of the current ($P = I^2R$),

2.1.8 Periodic Time:

The time taken to complete one cycle is called the 'periodic time' (t). It is measured in seconds or fractions of a second.

2.1.9 Frequency:

In electrical terms, frequency is the number of cycles completed in one second (cycles per second) and is expressed in Hertz (Hz).

1 Hz = 1 cycle / sec

Periodic time and frequency are related.

$T = 1/f$ and $f = 1/T$

2.2 AC Generation:

In AC generators, the rotating part of the generator is called the rotor and the stationary part is called the stator. There are three basic types

- Permanent magnet generator

- Rotating armature generator

- Rotating field generator

2.2.1 Permanent Magnet Type:

In this type the rotor of the machine is a permanent magnet and as magnet is rotated its magnetic field cut the stationary output windings producing an alternating voltage output .This type is shown in the figure below:

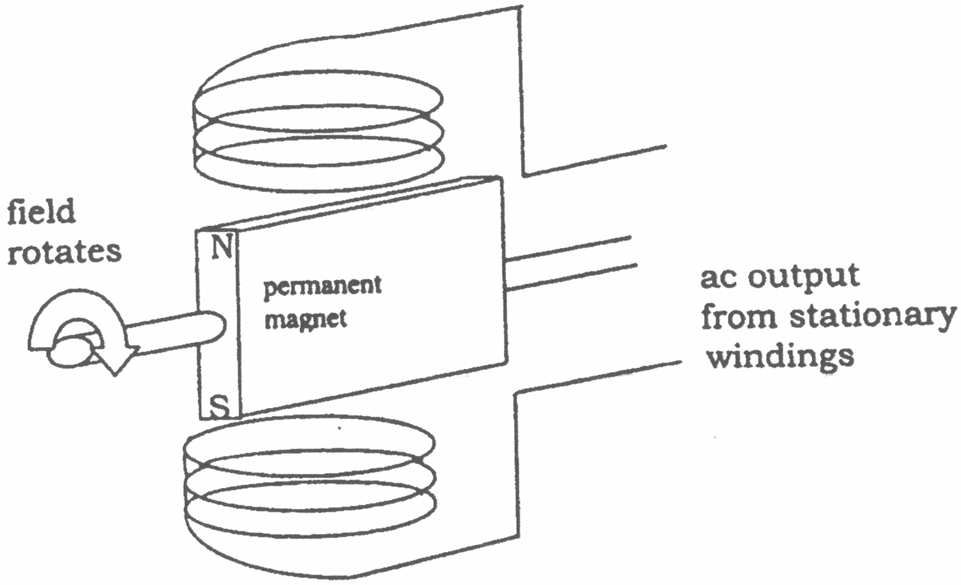

Fig. 2.4 Simple Permanent Magnet AC Generator

2.2.2 Rotating Armature Type:

This type of the machine is similar in construction to a DC generator in that the rotor rotates in a fixed field with emf picked off via slip rings. The rotor windings are laid on slots along the periphery of the rotor, the armature being laminated to reduce eddy current losses. The stator carries the DC excitation windings wound on the pole pieces to create alternate north and south poles around the stator. The figure below shows a single phase two poles machine:

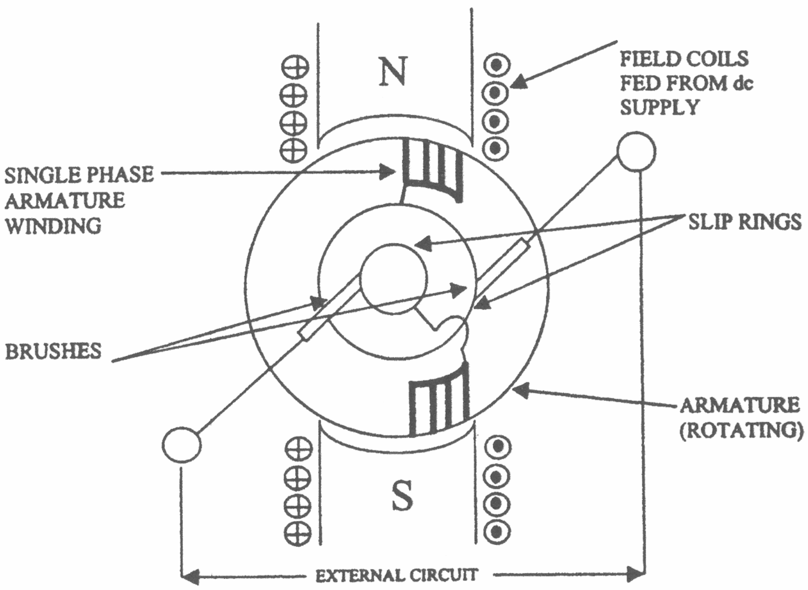

Fig. 2.5 Single Phase Two Poles AC Generator

Since an ac generator, in which a whole of the output consist of a single winding with the outer ends connected to a pairs of slip rings, is termed a single phase generator; if there were two windings at different angle connected to slip ring then this would give two outputs and would be known as a two phase generator.

And the system in which the coils are at 120 degree to each other and a three phase output is generated this type of the generator is called three phase generator this type is shown in the figure below:

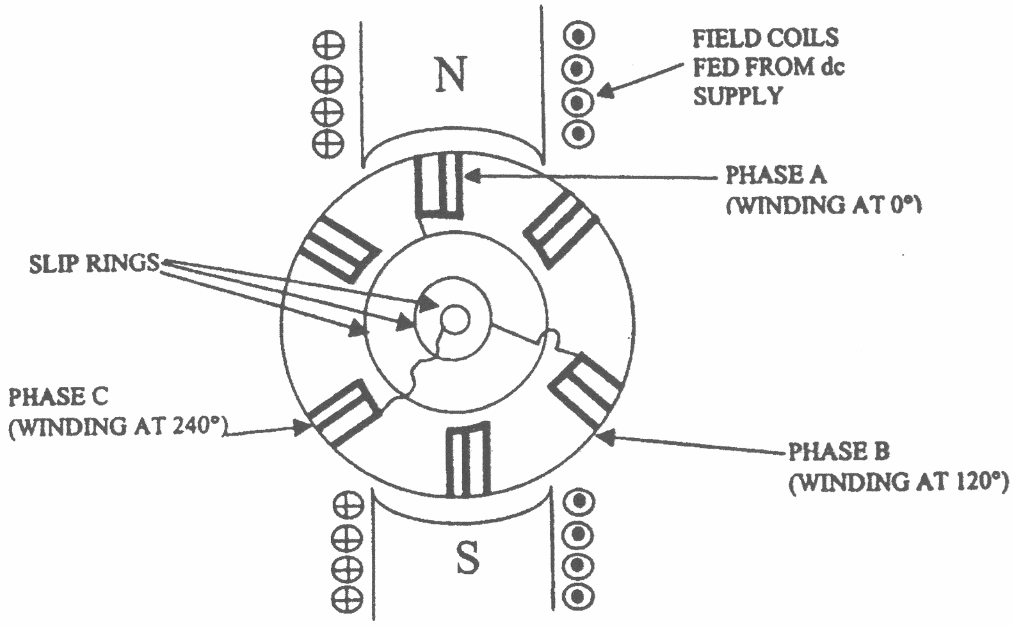

Fig. 2.6 Three Phase Two Poles AC Generator

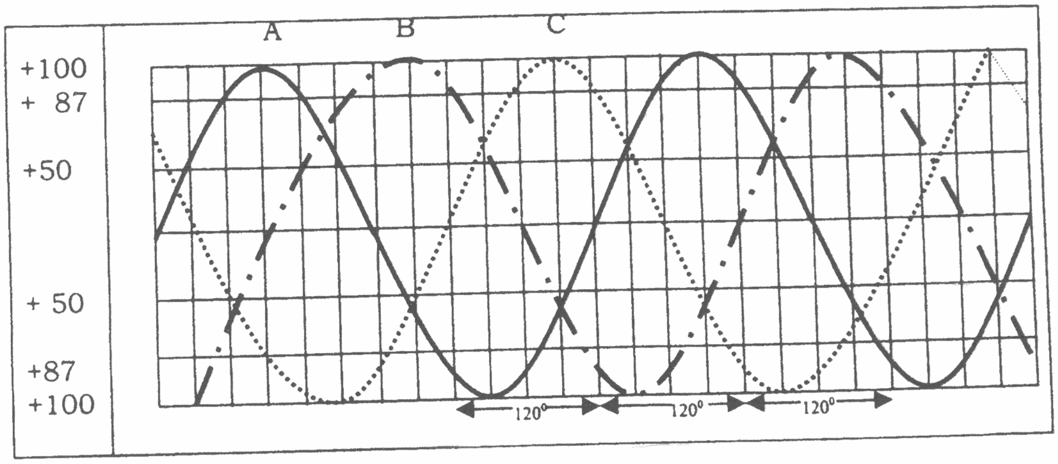

Fig. 2.7 Voltage Curve of Three Phase Generator

This type of the generator is not used as main generating source because it has following disadvantages

- As all power is taken from the rotor; the effective insulation and ventilation causes problems.

- All the (heavy) output is taken via slip rings and brushes.

- Centrifugal forces are considerable on the rotor windings.

2.2.3 Rotating Field Type:

In this type of the generator the DC field rotates and its fields cuts the stationary (output) windings on the stator. The output windings consist of a number of coils connected in series and inserted in slots in the laminated stator to give single phase output as shown in the figure below

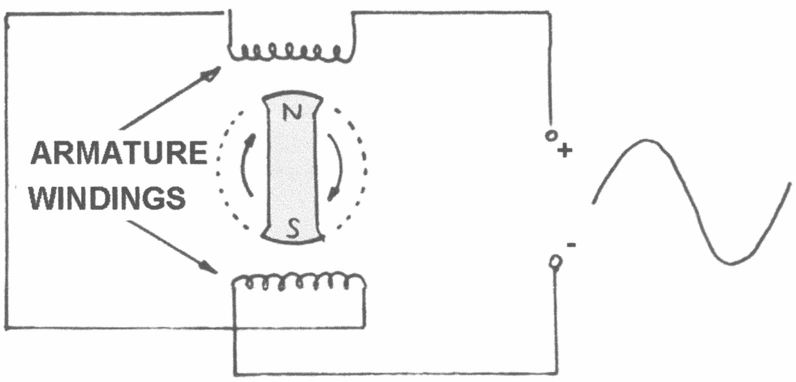

Fig. 2.8 Single Phase Rotating Field

The electromagnet is energized from a DC supply via two brushes and slip rings.

When the rotor is driven, emf's are induced in the stator windings. If the output windings are connected to a load, the load current flows. The output frequency is dependent on the speed of rotor rotation and the number of poles on the rotor.

If the generator shown was rotated at the same speed, but had two pairs of field poles, the frequency would double.

2.3 Phase:

The phase of an alternating current or a voltage is angular distance it has moved from zero angles in a positive direction.

2.3.1 Connection of Phase:

The three armature windings of a three phase generator can be connected in two ways. Firstly, the end of one winding can be connected to the start of the next, so that the three windings are connected in series to form a triangle. This form of connection is called a delta system. The delta system is a three wire system, a single wire being taken from each of the three points of interconnection. The alternative is to connect the same end of each armature winding to a common point and take the other end of each winding to an output terminal. This form of connection is called a Star system. The star system is a four wire system, as a wire is also taken from the common point to an output terminal.

2.3.2 Star and Delta Connection:

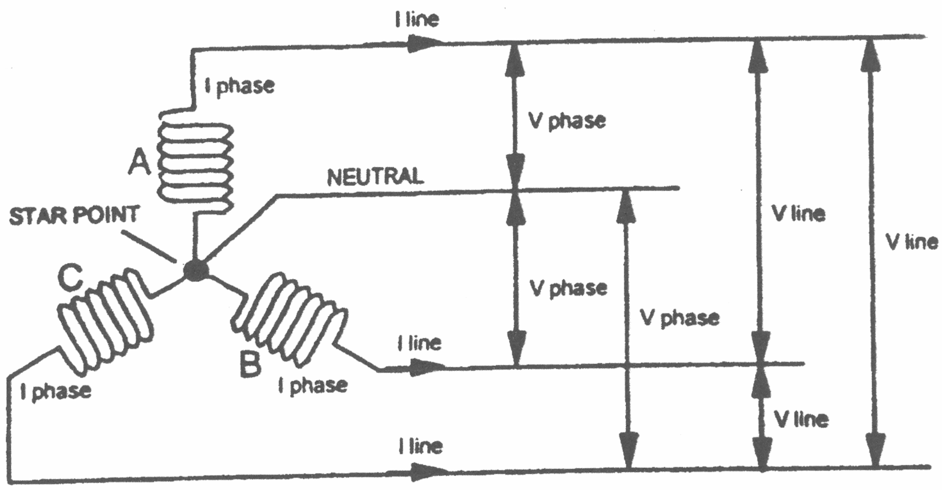

Fig. 2.9 Star Connection Generator

As shown in the figure above, in star connection the line current equal to the phase current.

The phase voltage on an aircraft generator would be 115V and the line voltage which is sum of the two phase voltage across that line, i.e. two 115V phases at 120 degree phase angle, is 200V and mathematically is the same as multiplying the phase voltage by $\sqrt{3}$.

The main advantage of the star connection is that with the neutral line two voltages are available 200V and 115V.

Another connection of three the coils is known as delta connection, in this case the three windings are connected in series to form a closed mesh, with the three output lines at the junction.

The figure of this connection is shown below:

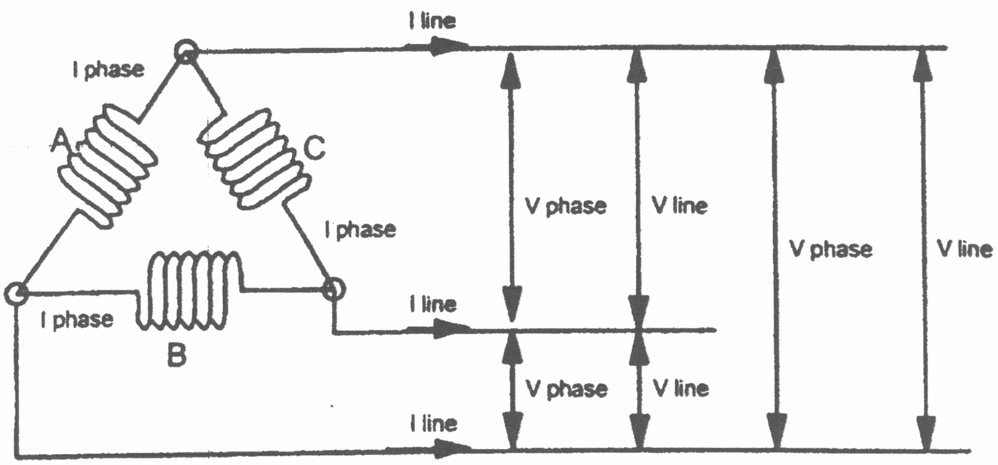

Fig. 2.10 Delta Connection Layout

In this connection the phase voltage equal to the line voltage. The delta connection does not have a neutral and cannot provide two outputs.

2.4 Alternators on the Aircraft:

The aircraft alternator is three phase Almost all alternators for aircraft power system are constructed with the a rotating field and stationary armature since a steady voltage must be provided for the aircraft electrical system, the field strength of the alternator must be varied according to load requirement. For this purpose a regulator is employed that can furnish a variable direct current to the rotor (field) winding of the alternator and a voltage regulator system is used to change this current as required to maintain a constant alternator output voltage. This variable regulator current must be supplied by a DC source.

The major differences between DC alternator and DC generator are the various design features. Since a generator has rotating armature, all the output current must be supplied through the Commutator and brush assembly. And alternator having a stationary armature can supply its output current through direct connection to the aircraft bus. This system of directly contacting the alternator output to the bus eliminates the problems caused by poor connections between a rotating Commutator and stationary brushes. At high power levels, rotating contacts are too inefficient to be practical; therefore, alternators, as opposed to the generator, are preferred on most aircraft.

2.5 Frequency Wild System:

In the frequency wild system the generators giving output a frequency depending on their rpm, which depending on the engine rpm.

These generator is preferred to DC systems because they had a better power to weight ratio and is much less affected by poor brush performance at high altitude. The output voltage of the generator is controlled by controlling the field strength of the rotating field AC generator by a signal from the regulator in the control unit which keep the voltage constant irrespective of load or speed variation.

Although such frequency variations are not suitable for the direct operation of all types of AC consumer's equipment, the output can be applied directly to resistive load circuits such as electrical de-icing systems, for the reason that resistance to alternating current remains substantially constant, and independent of frequency.

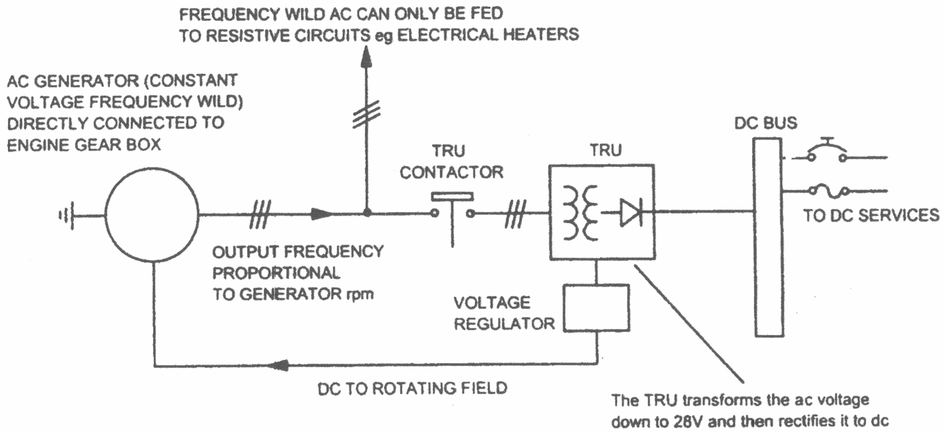

Fig. 2.11 Simplified Frequency Wild System

For the aircraft where the load is only resistive (heaters, anti-icing, windscreen heaters) then frequency wild system can be used. If circuits that are inductive or resistive are used then the frequency of supply must be constant because the impedance varies with the frequency.

For most aircraft the generator is connected to a unit called a constant speed drive unit (CSDU), this in turn is connected to the engine. The CSDU's job is to ensure the generator runs at a constant speed and hence constant frequency, irrespective of the speed of the engine. The speed of the generator is 12,000 rpm, but many aircraft have generators running at 6,000 rpm or 8,000 rpm on sum aircraft.

2.6 Constant-Speed Drive System:

In an AC power system it is usually necessary to maintain a fairly constant speed in the AC generator. This because the frequency of the AC generator is determined by the speed with which it is driven. It is especially important to maintain constant generator speed in installation in which the generators operate in a parallel. In this case it is absolutely essentially that generator speed be kept constant within extremely close limits.

In order to provide constant speed generator operation in modern AC electrical system, it is common practice to use a constant speed drive system.

CSD unit are manufactured in many designs for fit a variety of applications. The principle of operation for all CSDs is essentially the same.

The complete CSD system consist of an axial gear differential (AGD), whose output speed relative to input speed is controlled by a fly weight type governor that controls a variable delivery hydraulic pump. The pump supplies hydraulic pressure to a hydraulic motor, which varies the ratio of input rpm to output rpm for the AGD in order to maintain constant output rpm to drive the generator and maintain an AC frequency of 400 Hz.

2.7 Generator Cooling:

Owing to their compact size, most AC generators require some means of cooling during operation. The generators are typically cooled by means of ram air forced through the unit. Newer system employs oil for cooling. The oil is sent from CSD through the generator and then through an air/oil heat exchanger. The air cools the oil, the use of oil cooling allows for higher speed rotor within the generator section. A higher speed rotor means a lighter more compact generator.

2.8 Maintenance of AC Generator:

The rotor winding can be tested with an ohmmeter or continuity tester. The reading is taken with the test probes of the instrument apply to the slip rings. The stator winding can be tested by checking between the stator leads with the ohmmeter in each case. Normally, the reading will show low resistance. To test for grounded windings in the stator, the ohmmeter is connected between one stator lead and the stator frame. The ohmmeter should show infinite resistance.

To test for open windings in the stator, one test probe of the ohmmeter is connected to the auxiliary terminal or the stator winding center connection. The other probe is connected to each of the three stator leads, one at a time. The ohmmeter should show continuity in each case.

A visual inspection of an armature or field winding may give indication of defect.

Chapter Three

Prime Mover

3.1 The Prime Mover

The prime mover used to drive the generator, it is an induction motor.

3.1.1 Basic Theory:

A current carrying conductor has a magnetic field surrounding it. With the conventional current flowing away from the reader the current will be clockwise this is known as corkscrew rule. With current flowing towards the reader the field will be anti clockwise. As shown in figure below:

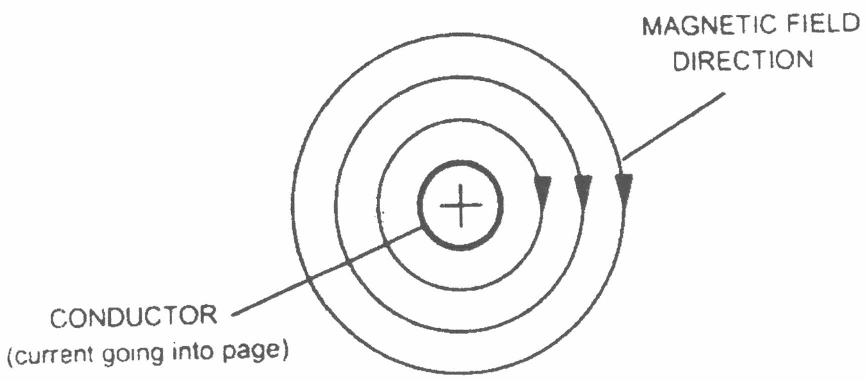

Fig. 3.1 Magnetic Field Around a Conductor

When considering the magnetic field between two poles pieces of magnet with opposite polarity the field moves from north to south as shown in fig below

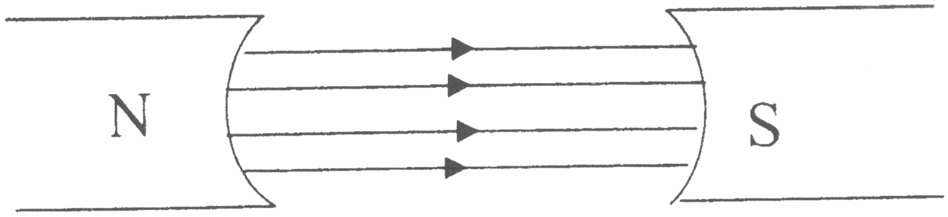

Fig. 3.2 Magnetic Field Between Two Opposite Poles of a Magnet

When current a carrying a conductor is placed within the magnetic field, the two fields cannot exist independently (conductor and poles).above the conductor flux lines move in the same direction to cause a strong field above the conductor, the field opposes each other below the conductor and therefore is weak.

The magnetic lines of flux above the conductor are in tension and try to straighten they also repel each other sideways so a force is created forcing the conductor out of the magnetic field. This operation is shown figure below

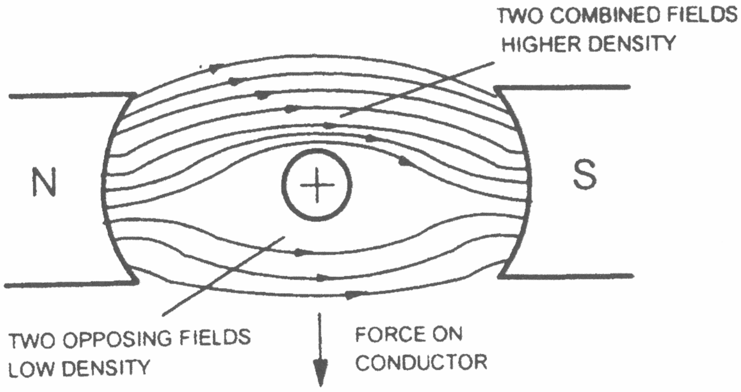

Fig. 3.3 Current Carrying Conductor in a Magnetic Field

The theory of the operation is essentially same for both single phase and three phase AC motor both types use a rotating field, but a single phase motor require starting winding or another method to produce torque for starting the motor whereas the three phase motor is self starting.

The core of the induction motor's rotor consists of an aluminum frame and sometimes it is of copper parts, so it is usually called squirrel cage; that forms the conductors for the circulating current in the rotor.

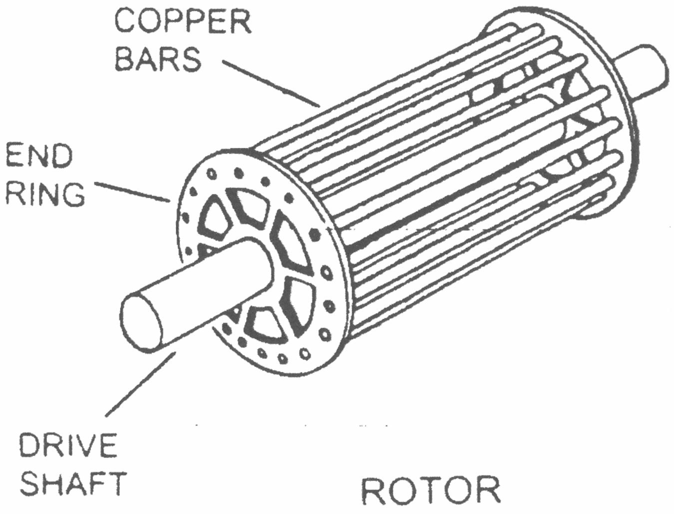

Fig. 3.4 Squirrel Cage Induction Motor

On the other hand, when the magnetic field from the stator moves across a squirrel cage of the inductor, a current is generated in squirrel cage. This current creates a magnetic field that reacts with the moving field of the stator causing the rotor to start turning. The rotor will try to "catch up" with the moving field, but cannot, in a condition known as slip.

Slip is defined as difference between synchronous speed of the stator and the rotor speed.

The rotor can never reach the synchronous speed of the stator field because, if it did, it would not cut any field line, and the torque will drop to zero. Without torque, the rotor could not turn itself.

Initially, before the rotor start moving, there is no back electromotive Force, so the stator current is high.

As the rotor speeds up it generates a back electromotive Force, which opposes the stator current.

As the motor speeds up, the torque produced balances the load and current is just enough to keep the rotor turning. The running current is significantly lower than the initial start up current because of the back Electromotive Force.

If the load of the motor is then increased the motor will slow down and generate less back Electromotive Force. This increases the current to the motor and increases the torque it can apply to the load. Thus, and induction motor can operate over a range of speed and torque. Maximum torque occurs when the rotor is spinning at about 75% of the synchronous speed.

3.1.2 Prime Mover Data:

RPM: 2800

Voltage: 220 - 240 V

Current: 4.5 A

Capacitance: 100 – 20 μF (250 – 450 V)

Frequency: 50 Hz

Weight: 18.66 Kg

Horse Power: 1 Hp

Power: 0.75 KW

Supply: Alternating current

Chapter Four

The Work Done

4.1 The Work Done

Note:

Firstly our project was to maintain a starter generator, but we could not find a powerful motor to drive that generator, the project has been changed to the AC generator, but both generators (the starter generator and the AC generator) are inspected & maintained.

4.1.1 With Respect to the Starter Generator:

The starter generator was removed from the aircraft of AN-24 from the right engine.

Firstly the starter generator is blown out with the air compressor.

The shaft of the generator was stuck and it was difficult to rotate due to dust and different ambient conditions because it stayed for a long time in the aircraft without operation.

The starter generator was lubricated by using oil; the shaft was rotated by hand during the lubrication process to ensure good lubrication this process was repeated again and again till the shaft became easy to move. And greasing made for the bearing. And the continuity check made by a digital AVO meter.

The generator brushes assemblies were removed in order to make sure that:

- Brushes for smooth travel in brush holder.

- Brushes spring for proper condition.

- Commutator surface for proper condition.

- Brushes length and degree of brush wear.

Then it was intended to use an induction motor as a prime mover which is a source that gives rotation to the starter generator.

The prime mover had given a low power, hence inspection made to determine the defect, since the defect found in the capacitor; that it had a problem of unable to start.

There upon it is intended to couple the both of starter generator and prime mover.

After all above the starter generator and the prime mover are intended to fix in a wood board by bolts.

4.1.2 Enclosed Photos:

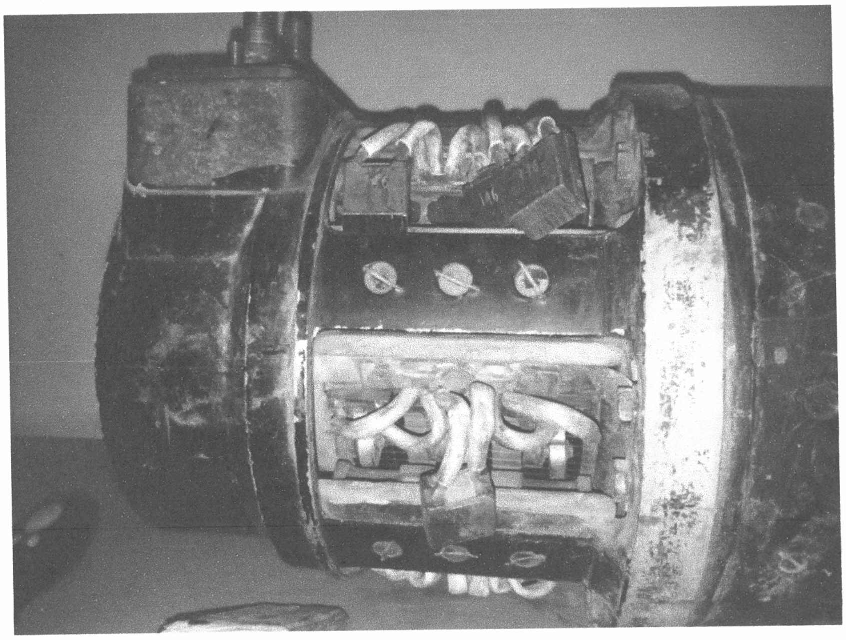

Fig. 4.1 Brushes Disassembly

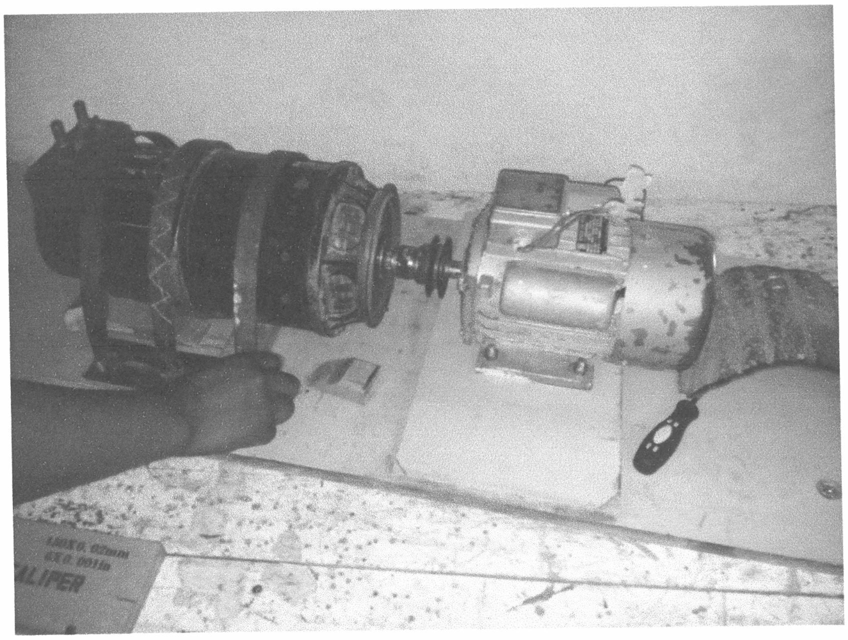

Fig. 4.2 Starter Generator During Securing

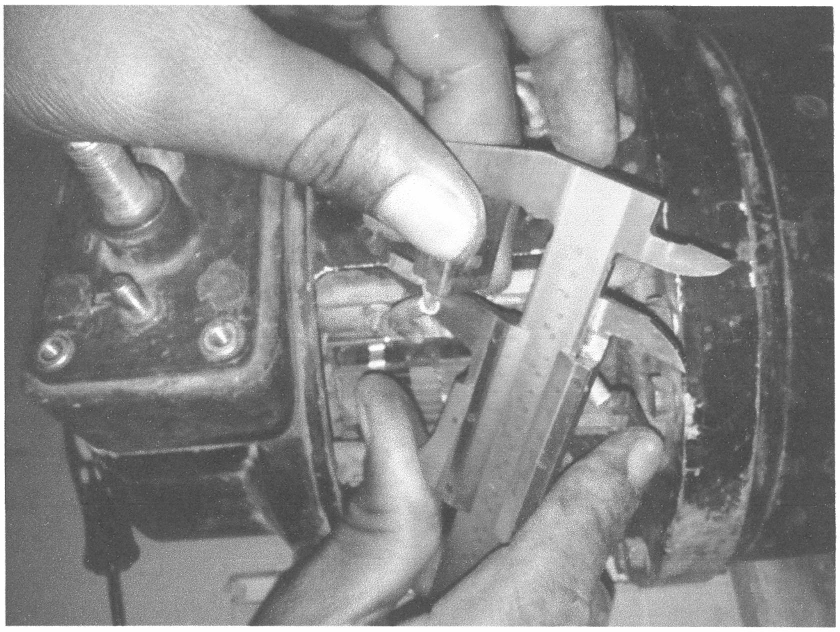

Fig. 4.3 Brushes During Measurement

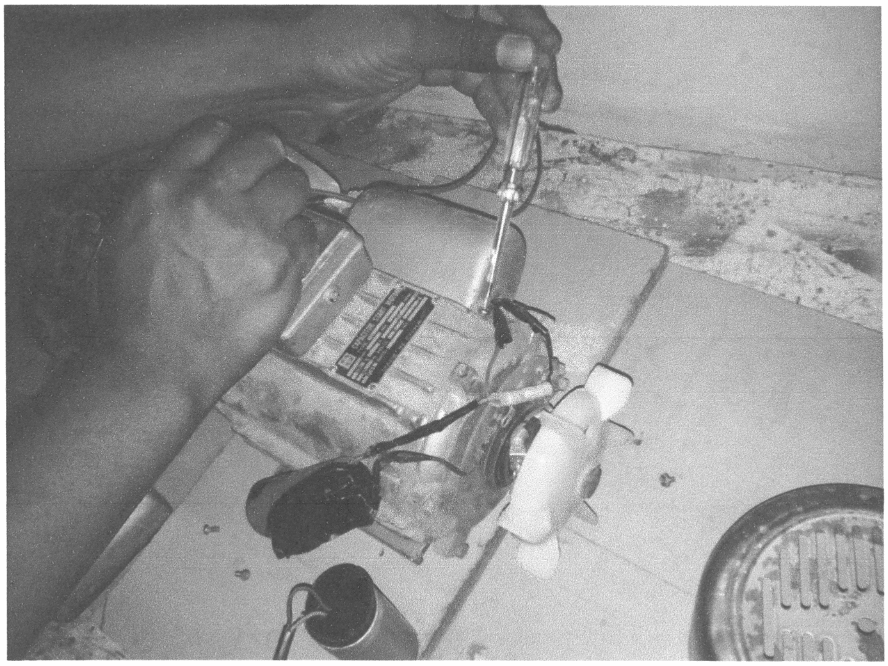

Fig. 4.4 Motor During Capacitor Replacement

4.1.2 With Respect to AC Generator:

This alternator was located on the workshop it is a three phase rotating field generator, it passed long time for this generator without any inspection, checks or maintenance made to this generator. It is intended to operate this generator by using the prime mover to provide AC source of 400 Hz for the workshop.

Firstly visual inspection done to assess it's serviceability and ability of giving output. Then a blowing out by using air compressor has been made to ensure that any dust or such has removed. The generator dismantled to make sure that there is any damage.

The AVO meter used to perform a check of continuity for both its armature winding and field winding.

There upon the shaft was not easy to rotate, in order to solve this problem the bearing of the generator was cleaned by using a gasoline and lubricated by using oil. This process was accompanied with rotating the shaft by the hand to ensure sufficient lubrication, then grease applied to the bearing. Unfortunately the generator was suffering from the problem of totally brushes damage; it was not easy to find such brushes then the decision was made to a reform a brushes of a different generator by using bench grinding. The process has gone well.

With respect to the source of excitation it is intended to use a dray cell battery, the battery is fitted together and connected each other by using a soldering and wire.

Finally the generator was ready for operation, and then it is connected to the prime mover. The output checked by using AVO meter and the indication was positive. This output is connected to a panel contains switches and indication lamps.

Photos for the Work Done in AC Generator:

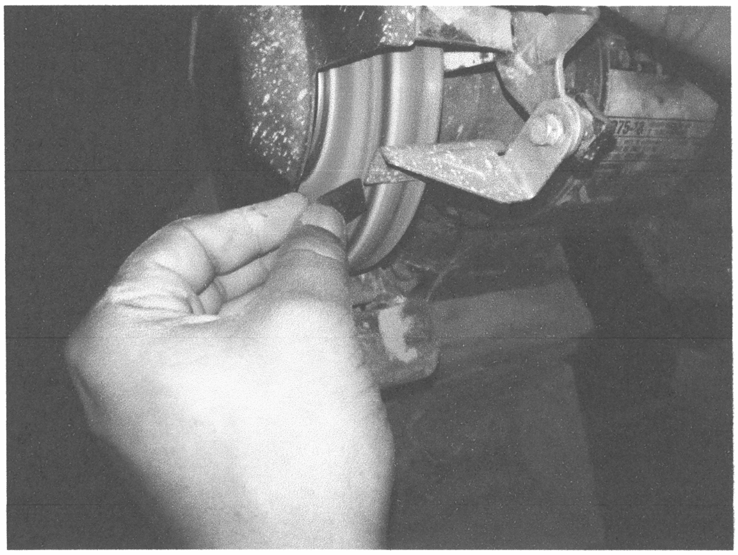

Fig 4.5 Brushes Reform

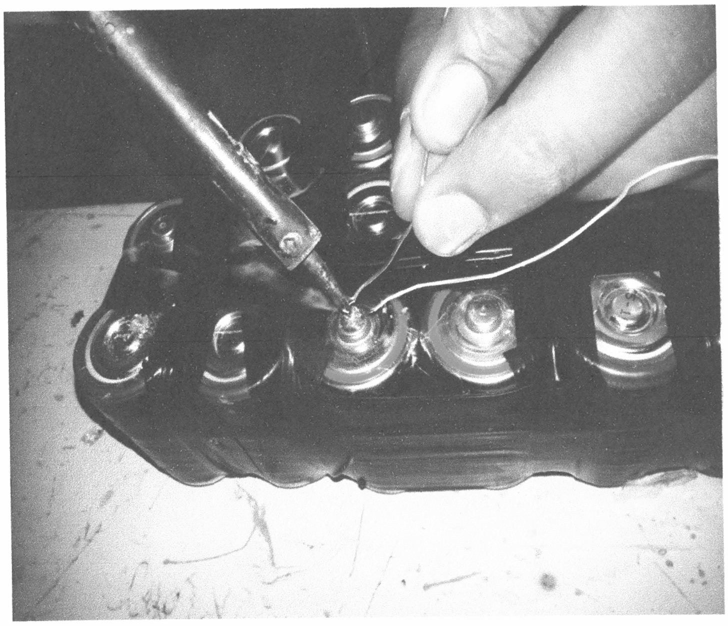

Fig 4.6 During Soldering

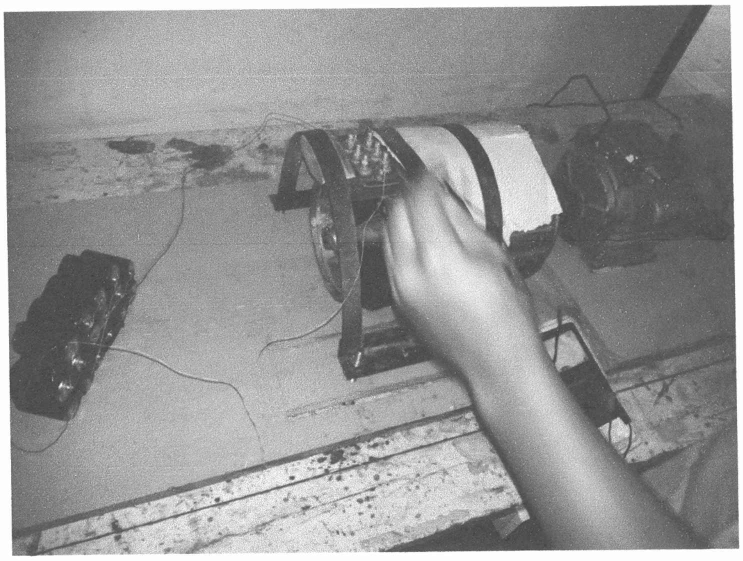

Fig 4.7 During Excitation

Chapter Five

Conclusion and Recommendations

5.1 Conclusion

Finally after maintenance procedures have been made for the generator has mentioned previously. Then the generator connected to the prime mover in order to give mechanical energy to the generator which needs it to convert to electrical energy. The prime mover ran to drive the generator. The output voltage of the generator was 117V and frequency of 175 Hz in consideration the frequency is proportional to the RPM. The greater the RPM, the greater the frequency. Thereby the aim of the project is realized which is to maintain and repair the generator including operation and serviceability check and the output voltage by using induction motor

5.2 Recommendations

As mentioned previously, problems we had experienced is to find appropriate device to give the required speed for starter generator and this made us to change the project to AC generator.

Hopefully the coming students find appropriate device to give a sufficient RPM to drive the starter generator, in order to allow it to give its required out-put voltage. And change the fixed coupling that has given us 175 Hz into belt driven to increase the speed to give 400 Hz.

5.3 References

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