**Unit 6: Electrical energy management**

**6.1 Reactive power management**

In industrial electrical distribution systems, the major loads such as incandescent lighting and resistance heating are resistive and inductive. In case of pure resistive loads, the voltage (V), current (I), resistance (R) relations are linearly related, i.e.

V = I × R and kW = V × I

Typical inductive loads are A.C. Motors, induction furnaces, transformers and ballast-type lighting. Inductive loads require two kinds of power: a) active (or working) power to perform the work and b) reactive power to create and maintain electro-magnetic fields.

Active power is measured in kW (Kilo Watts). Reactive power is measured in kVAr (Kilo Volt-Amperes Reactive).

The vector sum of the active power and reactive power make up the total (or apparent) power used. This is the power generated by the SEBs for the user to perform a given amount of work. Total Power is measured in kVA (Kilo Volts-Amperes)



Fig 1: Reactive power calculation

The active power (shaft power required or true power required) in kW and the reactive power required (kVAr) are 900 apart vectorically in a pure inductive circuit i.e., reactive power kVAr lagging the active kW. The vector sum of the two is called the apparent power or kVA. The ratio of kW to kVA is called the power factor, which is always less than or equal to unity. Theoretically, when electric utilities supply power, if all loads have unity power factor, maximum power can be transferred for the same distribution system capacity. However, as the loads are inductive in nature, with the power factor ranging from 0.2 to 0.9, the electrical distribution network is stressed for capacity at low power factors.

The solution to improve the power factor is to add power factor correction capacitors to the plant power distribution system. They act as reactive power generators, and provide the needed reactive power to accomplish kW of work. This reduces the amount of reactive power, and thus total power, generated by the utilities. The advantages of PF improvement by capacitor addition are as follows

a) Reactive component of the network is reduced and so also the total current in the system from the source end.

b) I2R power losses are reduced in the system because of reduction in current.

c) Voltage level at the load end is increased.

d) kVA loading on the source generators as also on the transformers and lines up to the capacitors reduces giving capacity relief. A high power factor can help in utilizing the full capacity of your electrical system.

Power factor improvement means cost benefits. While costs of PF improvement are in terms of investment needs for capacitor addition the benefits to be quantified for feasibility analysis are:

a) Reduced kVA (Maximum demand) charges in utility bill

b) Reduced distribution losses (KWH) within the plant network

c) Better voltage at motor terminals and improved performance of motors

d) A high power factor eliminates penalty charges imposed when operating with a low power factor

e) Investment on system facilities such as transformers, cables, switchgears etc for delivering load is reduced.

Problem1: A 10 kW motor has full load efficiency 85%. Actual input measurement at a particular reading shows 415V, 10A, PF=0.68. Find out the motor loading in%.

Solution: Actual power=10 kW

Full Load efficiency=85%

Voltage= 415 V

Current=10 A

PF=0.68

Total Power, PF==

=VA===12.5 kW

Motor loading ==0.8%

Power, P=I2R=VI=415×10=4150W=4.15 kW

Active power loading at a particular loading=× (kV) × (I) cosφ

=×0.415 ×10×0.68

= 4.89 kW

Full rated input power= =11.76 kW

Hence the motor loading ==41.58%

Problem: How does the power factor of induction motor improve with the increase in the applied load on the motor?

Solution: PF=

As the load increases, the magnitude of active power also increases. However, there is no corresponding increase in the magnetizing current or reactive power , which is proportional to the supply voltage with the result the apparent power doesn’t increase in the same way to that of active power. Therefore, the power factor improves with the increase with the increase in the applied load.

**6.2 Lighting in Households**

**6.2.1 Basic terms in lighting system**

Luminaries: It is a device that distributes, filter or transform the light emitted from or more lamps.

Illuminance: The lighting level produced by a lighting installation is usually quantified by the Illuminance produced on a specified plane. This is the ratio of luminous flux incident on an element of surface at a point of surface containing the point by the area of the element.

I Lux=1 Lumen/m2

Luminous efficacy: Ratio of luminous flux by a lamp to the power consumed by the lamp

Efficacy=

Colour rendering index (CRI): It is a measure of the degree to which the colours of surface illuminated by a given light source compare to those of the same surface under a reference light.

**6.2.2 Procedure for Assessment of Lighting Systems**

**6.2.2.1 To Determine the Minimum Number and Positions of Measurement Points**

Calculate the Room Index: =

Where L = length of interior; W = width of interior; Hm = the mounting height, which is the height of the lighting fittings above the horizontal working plane. The working plane is usually assumed to be 0.75m above the floor in offices and at 0.85m above floor level in manufacturing areas. It does not matter whether these dimensions are in metres, yards or feet as long as the same unit is used throughout.

|  |  |
| --- | --- |
| **Room Index** | **Minimum number of**  **measurement points** |
| Below 1 | 9 |
| 1 and below 2 | 16 |
| 2 and below 3 | 25 |
| 3 and above | 36 |

For example, the dimensions of an interior are:

Length = 9m, Width = 5m, Height of luminaries above working plane (Hm) = 2m

RI=1.607, so from the table the minimum number points is 16.



The points are shown in the above figure.

**6.2.2.2 Calculation of the Installed Load Efficacy and Installed Load Efficacy Ratio of a**

**General Lighting Installation in an Interior**

|  |  |  |
| --- | --- | --- |
| Step1 | Measure the floor area of | Area = -------------------- m² |
| Step2 | Calculate room index | RI = ----------------------- |
| Step3 | Determine the total circuit watts of the installation by a power meter if a separate feeder for lighting is available | Total circuit watts = -------- |
| Step4 | Calculate Watts per square metre, Value of step **3** ÷ value of step 1 | W/m² = ---------------------- |
| Step5 | Ascertain the average maintained illuminance by  using lux meter, Eav. Maintained | Eav.maint. = ---------------- |
| Step6 | Divide **5** by **4** to calculate lux per watt per square Metre | Lux/W/m² = --------------- |
| Step7 | Obtain target Lux/W/m² lux for type of the type of  interior/application and RI (2): | Target Lux/W/m² = |
| Step8 | Calculate **I**nstalled **L**oad **E**fficacy **R**atio (6÷ **7)**. | ILER = |

Table 1 : Procedure of calculation ILER

|  |  |
| --- | --- |
| ILER | Assessment |
| 0.75 over | Satisfactory to good |
| 0.51-0.74 | review suggested |
| 0.5 or less | Urgent action required |

Table 2 : Comparison of values of ILER

Comparing the values of ILER with the table, we can go for improvement in lighting in a certain building. Having derived the ILER for an existing lighting installation, then the difference between the actual ILER and the best possible (1.0) can be used to estimate the energy wastage.

Annual energy wastage (in kWh) can be calculated:

Annual energy wastage (in kWh) = (1.0 - ILER) x Total load (kW) x annual operating hours (h)

**6.3. Fans and blowers**

Fans and blowers provide air for ventilation and industrial process requirements. Fans generate a pressure to move air (or gases) against a resistance caused by ducts, dampers, or other components in a fan system. The fan rotor receives energy from a rotating shaft and transmits it to the air.

**6.3.1 Types of fans**

Fan and blower selection depends on the volume flow rate, pressure, type of material handled, space limitations, and efficiency. Generally, fans can be grouped in two categories centrifugal flow and axial flow fans.

 

Fig 2 : Centrifugal fan Fig3: Axial fan

**6.3.1.1 Centrifugal Fan**

In centrifugal fans, airflow enters in one direction and supplied in different direction. The major types of centrifugal fan are radial, forward curved and backward curved.

Radial fans have static pressures (up to 1400 mm WC) and ability to handle heavily dust laden contaminated airstreams. Because of their simple design, radial fans are well suited for high temperatures and medium blade tip speeds.

Forward-curved fans are used in clean environments and operate at lower temperatures. They are well suited for low tip speed and high-airflow work - they are best suited for moving large volumes of air against relatively low pressures. These are used mostly in low pressure HVAC applications.

Backward-inclined fans are more efficient than forward-curved fans. Backward-inclined fans reach their peak power consumption and then power demand drops off well within their useable airflow range. Backward-inclined fans are known as "non-overloading" because changes in static pressure do not overload the motor. These are chiefly used as forced draft industrial applications and sometimes HVAC as well.

**6.3.1.2 Axial fans**

In axial flow, air enters and leaves the fan with no change in direction .The major types of axial flow fans are classified as tube axial, vane axial and propeller.

Tubeaxial fans have a wheel inside a cylindrical housing, with close clearance between blade and housing to improve airflow efficiency. The wheel turn faster than propeller fans, enabling operation under high-pressures 250 – 400 mm WC. The efficiency is up to 65%. These are used in drying ovens, exhaust systems and HVAC.

Vane axial fans are similar to tube axial, but with addition of guide vanes that improve efficiency by directing and straightening the flow. As a result, they have a higher static pressure with less dependence on the duct static pressure. Such fans are used generally for pressures up to 500 mmWC. Vane axial are typically the most energy-efficient fans available and should be used whenever possible. These are chiefly used for high pressure applications including HVAC and exhaust systems.

Propeller fans usually run at low speeds and moderate temperatures. They experience a large change in airflow with small changes in static pressure. They handle large volumes of air at low pressure or free delivery. Propeller fans are often used indoors as exhaust fans. Outdoor applications include air-cooled condensers and cooling towers. Efficiency is low – approximately 50% or less. These are used in air circulation, ventilation and exhaust purposes.

**6.3.1.3 Blowers**

Blowers provide higher performance than that of fans. They can achieve pressure as high as 1.35kg/cm2. Sometimes they are used to produce vacuum for industrial vacuum systems. Depending on their method of operation, they can be classified as centrifugal blower and positive displacement blower.

 Centrifugal blowers are more like centrifugal pumps than fans. The impeller is gear-driven and rotates as fast as 15,000 rpm. Centrifugal blowers typically operate against pressures of 0.35 to 0.70 kg/cm2. In multi-stage blowers; air is accelerated as it passes through each impeller. In single-stage blower, air does not take many turns, and hence it is more efficient. One characteristic is that airflow tends to drop drastically as system pressure increases, which can be a disadvantage in material conveying systems that depend on a steady air volume. Because of this, they are most often used in applications that are not prone to clogging.

 Positive-displacement blowers have rotors, which "trap" air and push it through housing. Positive-displacement blowers provide a constant volume of air even if the system pressure varies. They are especially suitable for applications prone to clogging, since they can produce enough pressure - typically up to 1.25 kg/cm2 to blow clogged materials free. They turn much slower than centrifugal blowers (e.g. 3,600 rpm), and are often belt driven to facilitate speed changes.

**6.4 Fans performance assessment**

The fans are widely used in industry. Their assessment is needed to be done from energy savings point of view. In the field performance is determined by measurement of flow, head, and temperature on the fan side and electrical motor kW input on the motor side.

**6.4.1 Air flow measurement**

Static pressure: Static pressure is the potential energy put into the system by the fan. At the inlet to the duct, the static pressure produces an area of low pressure.

Velocity pressure: Velocity pressure is the pressure along the line of the flow that results from the air flowing through the duct. The velocity pressure is used to calculate air velocity.

Total pressure: Total pressure is the sum of the static and velocity pressure. Velocity pressure and static pressure can change as the air flows though different size ducts, accelerating and de-accelerating the velocity. The total pressure stays constant, changing only with friction losses. The illustration that follows shows how the total pressure changes in a system.



Fig5: Static, velocity and total pressure

Various parameters such as velocity pressure and total pressure are measured using a pitot tube and a manometer. When the inner and outer tube ends are connected to a manometer, we get the velocity pressure. For measuring low velocities, an inclined tube manometer instead of U tube manometer is used.

**6.4.1 Measurements and calculations**

**Velocity pressure/velocity calculation**

When measuring velocity pressure the duct diameter (or the circumference from which to calculate the diameter) should be measured as well. This will allow us to calculate the velocity and the volume of air in the duct. In most cases, velocity must be measured at several places in the same system. To determine the average velocity, it is necessary to take a number of velocity pressure readings across the cross-section of the duct. The velocity should be calculated for each velocity pressure reading, and the average of the velocities should be used. Do not average the velocity pressure; average the velocities. For best results, one set of readings should be taken in one direction and another set at a 90 ° angle to the first. For square ducts, the readings can be taken in 16 equally spaced areas. If it is impossible to traverse the duct, an approximate average velocity can be calculated by measuring the velocity pressure in the center of the duct and calculating the velocity. This value is reduced to an approximate average by multiplying by 0 .9.

**Air density calculation**

To calculate the velocity and volume from the velocity pressure measurements it is necessary to know the density of the air. The density is dependent on altitude and temperature.

Gas Density =

Where, toC = temperature of gas/air at site condition

**Velocity calculation**

The velocity can be determined from the equation:

Velocity v, m/s =

Cp = Pitot tube constant, 0.85 (or) as given by the manufacturer

∆p = Average differential pressure measured by Pitot tube by taking measurement at number of points over the entire cross section of the duct.

γ = Density at air/gas at test condition,

**Volume calculation**

The volume in a duct can be calculated as following way

Volume Q, m/sec = Velocity v, m/sec ×Area, m2

##### **6.4.2 Fan efficiency**

Fan efficiency can be represented either in terms of mechanical efficiency or static efficiency.

The mechanical efficiency is given as

Fan mechanical efficiency, ηmechanical= ×100

Similarly, static efficiency is given by

Static efficiency, ηstatic= ×100

Static efficiency expression is same as the mechanical efficiency except that the outlet velocity pressure is not added to the fan static pressure.

**6.4.5 Energy Savings Opportunities**

Minimizing demand on the fan

1. Minimising excess air level in combustion systems to reduce FD fan and ID fan load.

2. Minimising air in-leaks in hot flue gas path to reduce ID fan load, especially in case of kilns, boiler plants, furnaces, etc. Cold air in-leaks increase ID fan load tremendously, due to density increase of flue gases and in-fact choke up the capacity of fan, resulting as a bottleneck for boiler / furnace itself.

3. In-leaks / out-leaks in air conditioning systems also have a major impact on energy efficiency and fan power consumption and need to be minimized.

The findings of performance assessment trials will automatically indicate potential areas for improvement, which could be one or a more of the following:

1. Change of impeller by a high efficiency impeller along with cone.

2. Change of fan assembly as a whole, by a higher efficiency fan

3. Impeller derating (by a smaller dia impeller)

4. Change of metallic / Glass reinforced Plastic (GRP) impeller by the more energy efficient hollow FRP impeller with aerofoil design, in case of axial flow fans, where significant savings have been reported

5. Fan speed reduction by pulley dia modifications for derating

6. Option of two speed motors or variable speed drives for variable duty conditions

7. Option of energy efficient flat belts, or, cogged raw edged V belts, in place of conventional V belt systems, for reducing transmission losses.

8. Adopting inlet guide vanes in place of discharge damper control

**6.5 Pump**

A pump is a mechanical device in which a fluid, gas or liquid, is lifted or forced against an external pressure. They can be classified according to their basic operating principle as dynamic or displacement pumps.

Dynamic pumps operate by developing a high liquid velocity and converting the velocity to pressure in a diffusing flow passage. Dynamic pumps can be sub-classified as centrifugal and special effect pumps.

While a positive-displacement pump operates by forcing a fixed volume of fluid from the inlet pressure section of the pump into the discharge zone of the pump. Displacement pumps can be sub-classified as rotary or reciprocating pumps.

**6.5.1 Advantages and disadvantages of dynamic and displacement pumps**

Dynamic pumps usually have lower efficiencies than positive displacement pumps, but also have lower maintenance requirements. Dynamic pumps are also able to operate at fairly high speeds and high fluid flow rates.

These pumps generally tend to be larger than equal-capacity dynamic pumps. Positive-displacement pumps frequently are used in hydraulic systems at pressures ranging up to 5000 psi. A principal advantage of hydraulic power is the high power density (power per unit weight) that can be achieved. They also provide a fixed displacement per revolution and, within mechanical limitations, infinite pressure to move fluids. Although, positive displacement pumps are generally more efficient than centrifugal pumps, the benefit of higher efficiency tends to be offset by increased maintenance costs.

**6.5.2 Centrifugal Pumps**

Since, worldwide, centrifugal pumps account for the majority of electricity used by pumps, the focus of this discussion is limited on centrifugal pump. Centrifugal pumps operate at high speeds and usually direct connected to the driver so that the transmission losses are small. These types of pumps are usually used when relatively high pressure and large capacity are desired. There are minimum numbers of moving parts which reduces the maintenance and increase the working time, other advantages of centrifugal pumps are its smaller size and its low installation costs.

A centrifugal pump has a very simple design. The two main parts of the pump are the impeller and the diffuser. Impeller, which is the only moving part, is attached to a shaft and driven by a motor. Impellers are generally made of bronze, polycarbonate, cast iron, stainless steel as well as other materials. The diffuser houses the impeller and captures and directs the water off the impeller. Water enters the center (eye) of the impeller and exits the impeller with the help of centrifugal force. As water leaves the eye of the impeller a low-pressure area is created, causing more water to flow into the eye. Atmospheric pressure and centrifugal force cause this to happen. Velocity is developed as the water flows through the impeller spinning at high speed. The water velocity is collected by the diffuser and converted to pressure by specially designed passageways that direct the flow to the discharge of the pump, or to the next impeller should the pump have a multi-stage configuration.

The pressure (head) that a pump will develop is in direct relationship to the impeller diameter, the number of impellers, the size of impeller eye, and shaft speed. Capacity is determined by the exit width of the impeller. The head and capacity are the main factors, which affect the horsepower size of the motor to be used. The more the quantity of water to be pumped, the more energy is required.



Fig 6: Centrifugal pump

**6.5.2.1 Hydraulic power, pump shaft power and electrical input power**

Hydraulic power Ph = Q (m3/s) x Total head, hd - hs (m) x ρ (kg/m3) x g (m2/s) / 1000

Where hd - discharge head, hs – suction head, ρ - density of the fluid, g – acceleration due to gravity

Pump shaft power Ps= Hydraulic power, Ph x pump efficiency, ηPump

In order to have energy efficiency in pumping systems, we need to match the pumps with the loads. Otherwise the system will run at very poor efficiency. Moreover, efficiency in the pump could be dropped due to deposits in the impellers over a prolong period of time. Therefore, performance assessment will reveal faults in the system and corrective measure can be taken.

**6.5.2.2** **Performance Terms and Definitions**

**Pump Capacity,** Q = Volume of liquid delivered by pump per unit time, m3/sec

Q ~ N, where N- rotational speed of the pump and

Q ~ D2, where D- diameter of the impeller

Total developed head**,** H= The sum of suction and discharge pressures

The pump head represents the net work done on unit weights of a liquid in passing from inlet of the pump to the discharge of the pump.

There are three heads in pumps namely (i) potential head, (ii) velocity head and (iii) friction head. The frictional loss in a system of pipes, valves and fittings as a function (roughly as the square) of the capacity flow through the system.

**System resistance:** The sum of frictional losses in resistance & total static head.

**Pump Efficiency:** Fluid power and useful work done by the pump divided by the power input in the pump shaft.

Pump efficiency=

Field testing

**Flow Measurement, Q**

Some of the measurement methods for large water flow are given below

(A) Tracer method BS5857

(B) Ultrasonic flow measurement

(C) Tank filling method

(D)Installation of an on-line flow meter

**A. Tracer method**

In this method, a tracer of sodium chloride is injected to the cooling water for a few minutes at an accurately measured constant rate. A series of samples is extracted from the system at a point where the tracer has become completely mixed with the cooling water.

Mass flow rate, qcw = q1 C1/C2

Where qcw = cooling water mass flow rate, kg/s

q1 = mass flow rate of injected tracer, kg/s

C1 = concentration of injected tracer, kg/kg

C2 = concentration of tracer at downstream position during the ‘plateau’ period of constant concentration, kg/kg

**B. Ultrasonic Flow meter**

It is based on Doppler Effect and measurements can be taken without disturbing the system. This method is very sensitive. So, scales and rusts in the pipes may influence the results.

## C. Tank filing method

In open flow systems such as water getting pumped to an overhead tank or a sump, the flow can be measured by noting the difference in tank levels for a specified period during which the outlet flow is stopped.

## Installation of an on-line flow meter

If the application to be measured is critical and periodic then installing an on-line flow meter will give hassle free flow measurement.

**Determination of total head, H**

Suction head (hs): This is taken from the inlet pressure gauge readings.

Discharge head(hd): This is taken from the discharge side pressure gauge.

Total head, H=hs-hd

**Determination of hydraulic power**

Hydraulic power in kW, Ph= [Q× (hd-hs) ×ρ×g]/1000

Where Q= Discharge, m3/s

hd-hs=Total head, m

ρ=Density of fluid, kg/m3

g=Acceleration due to gravity, m/s2

**Measurement of motor input power**

The motor input power Pm can be done by using a portable power meter.

**Pump shaft power**

The pump shaft power Ps is calculated by multiplying the motor input power by motor efficiency at the existing loading.

Ps = Pm x ηMotor

**Pump efficiency**

This is arrived at by dividing the hydraulic power by pump shaft power

ηPump =

**Problem 1**: In a household, a centrifugal pump is used to pump water to the 3rd floor. During performance testing following results came

Pump flow, Q = 0.30 m3/s

Power absorbed, P (Motor input) = 100 kW

Suction head (Tower basin level) h1 = +1 M

Delivery head h2 = 25 M

Type of drive = Direct coupled

Motor efficiency at the operating loading = 88 %

Density of water = 1000 Kg/ m3

**Solution:** Flow delivered by the pump ,Q = 0.30 m3/s

Total head,m (h2 -(+h1)) ,H = 26 M

Liquid Horse power =

= [0.30 × 26 ×1000 ×9.81]/1000

= 76.518 kW

Actual power consumption = 200 kW

Overall system efficiency = 76.518/200 = 38.25%

Pump efficiency = 38.25/0.88 = 43.47 %

**6.6. Electric motors**

An electric motor is an electromechanical device that converts electrical energy into mechanical energy. They operate through the interaction of magnetic fields and current-carrying conductors to generate force. The reverse process, producing electrical energy from mechanical energy, is done by generators such as an alternator or a dynamo. Electric motors are found in applications as diverse as industrial fans, blowers and pumps, machine tools, household appliances, power tools, and disk drives. They may be powered by direct current, *e.g.*, a battery powered portable device or motor vehicle, or by alternating current from a central electrical distribution grid or inverter. As these motors are common in our day to day life, their performance assessment is a must to save a great deal of energy. when a motor is running, the two important parameters are efficiency and power. The efficiencies of induction motors remain almost constant between 50% to 100% loading. With motors designed to perform this function efficiently; the opportunity for savings with motors rests primarily in their selection and use. When a motor has a higher rating than that required by the equipment, motor operates at part load. In this state, the efficiency of the motor is reduced. Replacement of under loaded motors with smaller motors will allow a fully loaded smaller motor to operate at a higher efficiency.

**6.7 Efficiency of induction motors**

The efficiency of the motor is given by

η= 1-=

Where Pout – Output power of the motor

Pin – Input power of the motor

PLoss – Losses occurring in motor

**6.7.1 Determining the motor loading**

Motor loading can be measured by following discussed methods

1. By input power measurements

A. First measure input power **Pi** with a hand held or in-line power meter

Pi = Three-phase power in kW

B. Note the rated kW and efficiency from the motor name plate

C. The figures of kW mentioned in the name plate is for output conditions.

Input power at full rated load, Pin=

ηfl = Efficiency at full-rated load

Pir = Input power at full-rated power in kW

D. The percentage loading,

Load=×100%

**Problem 2:** The nameplate details of a motor are given as power = 20 kW, efficiency η = 0.92. Using a power meter the actual three phase power drawn is found to be 7 kW. Find out the loading of the motor.

**Solution**: Input power at full-rated power in kW, Pir = 20 /0.92

= 21.74kW

Therefore, Percentage loading = 7/21.74= 32.19%

2. By line current measurements method

This method is used when input power can not be measured and only amperage of the system could be measured.

% Load= (valid up to 75% of loading)

3. Slip method

In this method load is calculated in terms of slip. For this purpose a tachometer is required.

Load=%

Where Load = Output power as a % of rated power

Slip = Synchronous speed - Measured speed in rpm

Ss = Synchronous speed in rpm at the operating frequency

Sr = Nameplate full-load speed

**Problem3:** Given: Synchronous speed in rpm = 1600 at 50 HZ operating frequency.

(Synchronous speed = 120f/P) f: frequency, P: Number of poles

Nameplate full load speed = 1400

Measured speed in rpm = 1450

Nameplate rated power = 6.5 kW

Determine actual output power

**Solution:** Load==75%

Actual Output power=75%×6.5kW=4.875kW

**6.7.2 Determination of motor efficiency in the field of operation**

**No load test:** At no load test, we run the motor at the rated load and frequency without any shaft load. Power factor (P.F.) at no load is measured with the help of a low P.F. watt meter. Then, friction and Windage and core losses are found by subtracting I2R losses under no load from input power. To separate core and F & W losses, test is repeated at variable voltages. It is worthwhile plotting no-load input kW versus Voltage; the intercept is F & W kW loss component.

**Stator and Rotor I2R Losses: The** stator winding resistance is measured by volt-amp method.

Rotor I2R Losses= Slip × (Stator Input – Stator I2R Losses – Core Loss)

In the above equation the resistance and slip should be corrected to operating temperature. Correction factor for resistance is shown below

=

Accurate measurement of slip is possible by stroboscope or non-contact type tachometer.

**Stray Load Losses:** Stray losses are the losses that remain after primary copper and secondary losses, iron losses and mechanical losses. The largest contribution to the stray losses is harmonic energies generated when the motor operates under load. These energies are dissipated as currents in the copper windings, harmonic flux components in the iron parts, leakage in the laminate core. These losses are difficult to measure with any accuracy. IEEE Standard 112 method is difficult to use in the shop floor. While the IS and IEC standards take a fixed value as 0.5 % of output. IEEE – 112 specifies values from 0.9 % to 1.8 %.The table below gives stray losses of motors based on rating

|  |  |
| --- | --- |
| **Motor Rating** | **Stray Losses** |
| 1 – 125 HP | 1.8 % |
| 125 – 500 HP | 1.5 % |
| 501 – 2499 HP | 1.2 % |
| 2500 and above | 0.9 % |

Problem: The given data are for a induction motor used drive a shaft in a factory

Rated Power=34kW/HP

Voltage=415 V

Current=57 Amp

Speed=1475 r.p.m

Insulation class=F

Frame=LD200L

Connection=Delta

No load test data

Voltage, V=415Volt

Current, I=16.1 Amp

Frequency=50 Hz

Stator phase resistance at 30˚C=0.264 ohms

No load Power, Pnl=1063.74Watts

1. Calculate iron plus friction and Windage losses
2. Calculate stator resistance at 120˚C

R2=R1×

c. Calculate stator copper losses at operating temperature of resistance at 1200C

d. Calculate full load slip(s) and rotor input assuming rotor losses are slip times rotor input.

e. Determine the motor input assuming that stray losses are 0.5 % of the motor rated power

f. Calculate motor full load efficiency and full load power factor

Solution:

a) Let Iron Plus friction and Windage loss, Pi+fw

No load Power, Pnl =1063.74 Watts

Stator Copper loss, P st -30 ˚C (Psc.cu)

=3 × (16.2 / √3)2 × 0.264

=68.43 Watts

Pi + fw = Pnl – Pst.cu

= 1063.74 – 68.43

= 995.3 W

b) Stator Resistance at 1200C,

R120˚C=0.264×

=0.354 ohms per phase

c) Stator copper loss at full load, Pst.cu120˚C

=3× (57/) 2×0.354

1150.1Watts

d) Full load slip

s= (1500-1475)/1500

=0.0167

Rotor Input, Pr= Poutput/ (1-S)

=34000× (1-0.0167) =34577.4 Watts

The friction and Windage losses really are part of the shaft output; however, in the above calculation, it is not added to the rated shaft output, before calculating the rotor input power. The error however is minor.

e) Motor full load input power, P input

= Pr + Pst.cu 1200C + (Pi + fw) + Pstray

= 34577.4 + 1150.1 + 995.3 + (0.005\* × 34000)

= 36892.8 Watts

Where, stray losses = 0.5% of rated output (assumed).

Measurements of stray losses are very difficult and not practical on test bed that is why stray losses have been assumed.

f) Motor efficiency at full load

Efficiency=×100=×100=92.2%

g) Full load PF== =0.9

**6.7.3 Performance Evaluation of Rewound Motors**

Ideally, a comparison should be made of the efficiency before and after a rewinding. A relatively simple procedure for evaluating rewind quality is to keep a log of no-load input current for each motor in the population. This figure increases with poor quality rewinds. A review of the rewind shop’s procedure should also provide some indication of the quality of work. When rewinding a motor, if smaller diameter wire is used, the resistance and the I2R losses will increase.

**Questions**

1. What is reactive power? How will you manage reactive power in a electrically powered blower?

2. Define ILER and its significance.

3. Distinguish between Lux and Lumen.

4. Define room index.

5. What possible improvement measures you would look for in a general lighting system?

6. List the types of industrial fans and typical applications?

7. What are factors affecting fan performance and efficiency?

8. Briefly explain method of fan performance assessment in industry?

9. What is the common energy saving options in industrial fans / fan systems?

10. Define motor efficiency?

11. Describe the various methods by which you calculate motor loading?

12. A 20 kW rated motor is drawing actual measured power of 14 kW. If the rated efficiency is 92%, determine the motor loading?

13. What are the two factors influencing the speed of induction motor?

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