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Internal Assesment Test –V

Sub:	Testing And Commissioning of Power System Apparatus							Code:	17EE752
Date:	8/2/2021	Duration:	90 mins	Max Marks:	50	Sem:	7 B	Branch:	EEE

Answer all FIVE FULL Questions

		Marks	OBE	
			CO	RBT
1	a) State and explain the various types of enclosures for rotating Machines.? **b)** Explain the cooling operation adopted in rotating machines**?**	[5] [5]	CO3	L1
2)	State and explain various performance test and commissioning test in 3 phase induction machine?	[10]	CO4	L2
3)	Explain the procedure of low slip test and method of calculation of Xq and Xd for alternators.	[10]	CO3	L2
4)	Describe the techniques used in drying of induction motors. Explain with diagrams.	[10]	CO4	L2

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Internal Assesment Test –II

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4)	Describe the techniques used in drying of induction motors. Explain with diagrams.	[10]	CO4	L2

5)	a) Explain the sudden 3-φ S.C. test on a 3-φ generator. How to calculate Xd' and Xd" and Xd from the sudden3-φ S.C. test. b) What are the causes of vibrations in rotating machines? How are they reduced?	[6] [4]	CO3	L2
6)	a) Mention the specification of alternator. b) List and explain the steps required for installing an alternator.	[5] [5]	CO3	L2

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1.A.

Types Of Enclosure Of Electrical Machines

a) **Open Pedestal :**

Here the stator and rotor ends are open to the outside ambient air, the rotor being supported on pedestral bearings mounted on the bed plate.

b) **Open End Bracket :**

Here the bearing form part of the end-shields which are fixed to the stator housing. It has ventilations which allows air to freely circulate through the machine

c) **Protected or end cover type :**

The ventilations, provided at the end cover are of specified sizes and shapes. The end covers are protected by screen or fine mesh covers.

d) **Drip Splash or Hose Proof.**

It has openings in the endshield for cooling. The openings are small and so the drops of liquid or solids falling on the machine from vertical direction can be prevented.

e) Pipe or Duct Cooled

Here the end covers are closed except for flanged openings for connection to cooling pipes.

f) Totally Enclosed Motor

~~Let has the machine fully enclosed~~

The machine is fully enclosed but it is not completely airtight. It prevents the free exchange of air between the inside & outside of the case.

g) Weather proof : Watertight.

h) Flame proof or Explosion proof :

Used in hazardous atmosphere such as in mines, chemical factories, stores etc.

1 B.

Cooling Systems in Synchronous Machines

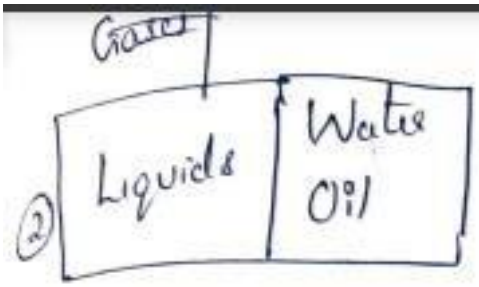
Cooling systems are required in rotating machines to remove the heat appearing in the machine. Heat is generated in the machine due to frictional losses, copper losses in stator and rotor etc. Proper cooling system is mandatory so as to protect the machine from getting damaged.

a) Air Cooling Systems

Natural Air cooling is not adequate to dissipate the large amount of heat produced in the synchronous machines. In forced air cooling systems air is forced into the machine with the help of cooling fans / blowers

The general coolants / cooling mediums used are

(1)	~~Liquid~~ Gases.	Air Hydrogen Nitrogen Carbon Dioxide



For large capacity machines, the size of cooling fans required for circulation of air increases and requires considerable power to give power supply to the cooling systems / fans. So, there is an optimum rating of the machine beyond which air cooling will not be able to keep the temperature within safe limits.

So, other gases such as hydrogen is used as an alternative.

b) Hydrogen Cooling

- Hydrogen cooled systems uses gaseous hydrogen.
- It is forced to flow inside the machine through blowers and is allowed to flow through the cooling coils inside the casing.
- Hydrogen is used mainly in turbo generators above 500 MW.
- Hydrogen gas has a higher thermal conductivity
- It has 7 times better thermal conductivity

than air.

- Hydrogen has density 1/14 times the density of air at the same temperature and pressure.

Hydrogen cooling systems ~~used~~ In Turbo Generators

- Hydrogen is used in integral circuit cooling of stator
- In rotor, Hydrogen gas is passed through rectangular tubular structures around the rotor. In stator, hollow conductors are used through which hydrogen is allowed to flow through cooling the stator conductors. to a large extend.
- The pressure of the hydrogen gas is 1.5 kg/m
  at a flow rate of 15 m^3/sec.
- Advantages of hydrogen cooling includes increased efficiency, smaller cooling systems, lesser noise, increased life operate.

c) Water cooled Systems.

- In direct water cooling, water is the cooling medium and is used to circulate through stator and rotor through cooling tubes.

- The speed of the water flow in the chillers is about 2.5 m/sec.
- Dimineralized water is used for circulating into the machine using centrifugal pump.
- Filters are used to filter water to remove the dust and dirt from machine.

Terms

Primary coolant

A medium (liquid or gas) at a lower temperature than the machine part which transfers heat from the machine by direct contact with them.
eg: Air, Water, Other liquids.

Secondary coolant

A medium at a lower temperature than the primary coolant, which removes the heat from the primary coolant using heat exchanger

Types of cooling Systems Based On The Cooling method

1. Inner Circuit Cooling
2. Open circuit cooling
3. Closed circuit cooling

1. Inner circuit Cooling (Integral cooling)

A cooling systems associated with the machine which requires partial or complete dismantling of the machine to do some maintenance in the cooling system.

eg: A winding which has hollow conductors/tubes which forms the stator windings.
The coolant is allowed to flow through the hollow windings (eg: stator windings). So, if any maintenance is required in the cooling system, the windings has to be dismantled.

2. Open circuit Cooling

- A method of cooling in which the coolant is allowed to freely circulate through the machine and is released to the surrounding atmosphere
- The coolant passes through the machine from the medium surrounding the m/c.
  It then returns to the atmosphere after absorbing all the heat from the machine.

3. Closed circuit Cooling

- The primary coolant is circulated in a closed circuit through the machine and if necessary, through the heat exchanger.
- Primary coolant is allowed ~~the~~ to circulate through the m/c. The coolant after absorbing the heat is processed, cooled and then is send to the m/c again.

This forms a closed loop

- Heat exchangers are used to transfer the heat to the secondary coolant if required.

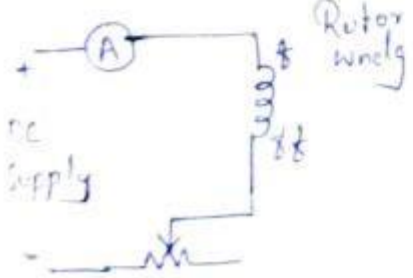
2.

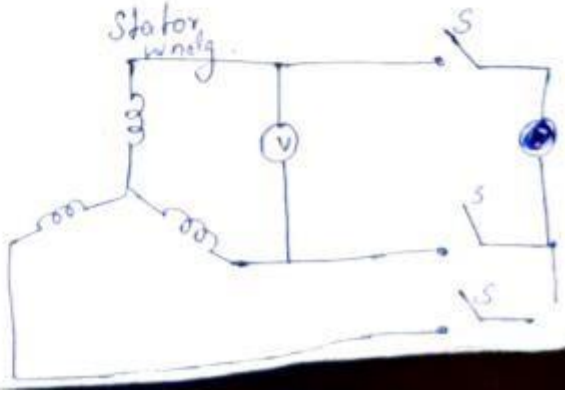
Type Tests on Synchronous Machines

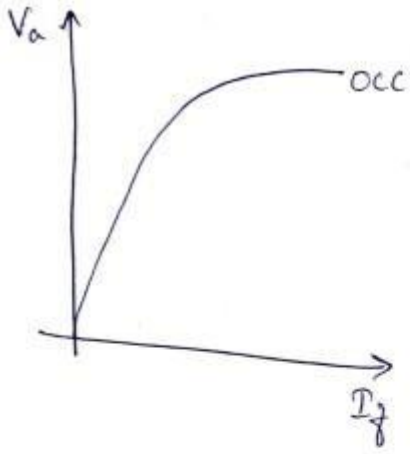
(continue...)

Open Circuit Test

- Open circuit test is also called noload; saturation test. The test is done with stator of alternator open. That is, switch S is kept open.
- For conducting the test, alternator is first driven at rated speed and the open terminal voltage is noted by varying the field current.
- This is done by varying the field rheostat ~~width~~ At different positions of field rheostat values, the I_f and V_a is noted to draw the OCC curve till V_a reaches 125% of rated voltage.



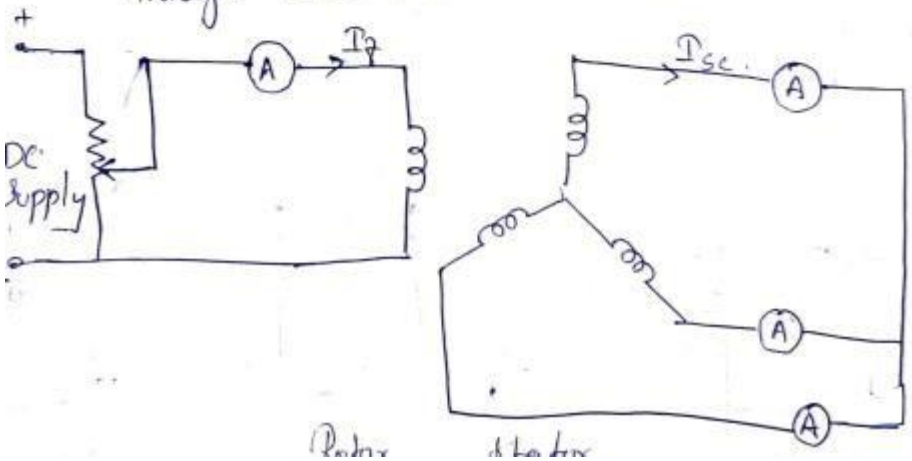




- I_f gradually increased in steps. The characteristic curve is called open circuit characteristic (OCC curve).
- Here, V_a increases till 125% of rated voltage.
- After that the system gets to saturation
- During this test, no load losses of the machine can be obtained.

② Short Circuit Test / Sustained Short Ckt Test

- Here the armature terminals are shorted through three ammeters, ~~Hera, Thomson~~



Rotor Stator

Short Circuit Ratio Of Synchronous Machine

- It is the ratio of field current required to obtain open circuit voltage, I_{foc} to the field current required for obtaining rated short circuit current when running at rated speed / syn. speed.

$$SCR = \frac{I_{foc}}{I_{fsc}} = k.$$

- SCR is a measure to of stability of alternator.
- The SCR can be calculated for each point on a grid. When the SCR value is above 1, the grid has good grid strength and will be less subject to variations in frequency.

4. Sudden Short Circuit Test.

- It shows if the mechanical design of the machine is adequate to withstand the stresses due to short circuits.
- Machine is made to run at rated speed
- The machine is supplied with no load voltage Terminal voltage at no load is as per agreement with manufacturer and purchaser.
- Short circuit is instantaneously applied by closing the ~~circuit~~ switch for a period of 3 seconds.
- The short circuits are made multiple times by making and ~~brak~~ breaking the switch
- The test is considered satisfactory if
  (a) No harmful deformation of windings takes place
  (b) If the windings withstand the high voltage test performed immediately after the instantaneous short circuit withstand test.
- This test allows protection from abnormal conditions such as (i) Switching (ii) sudden

Measurement Of Transient And Subtransient Parameters

The concept of transient, subtransient and steady state arises during short circuit faults in an alternator

When alternators is short circuited, the currents in all the three phases rises rapidly to 8-10 times the full load current

- The flux crossing the air gap is large during first few cycles.
- The current during the first few cycles are high and there reactance is high.
- This reactance is called subtransient reactance, X_d''

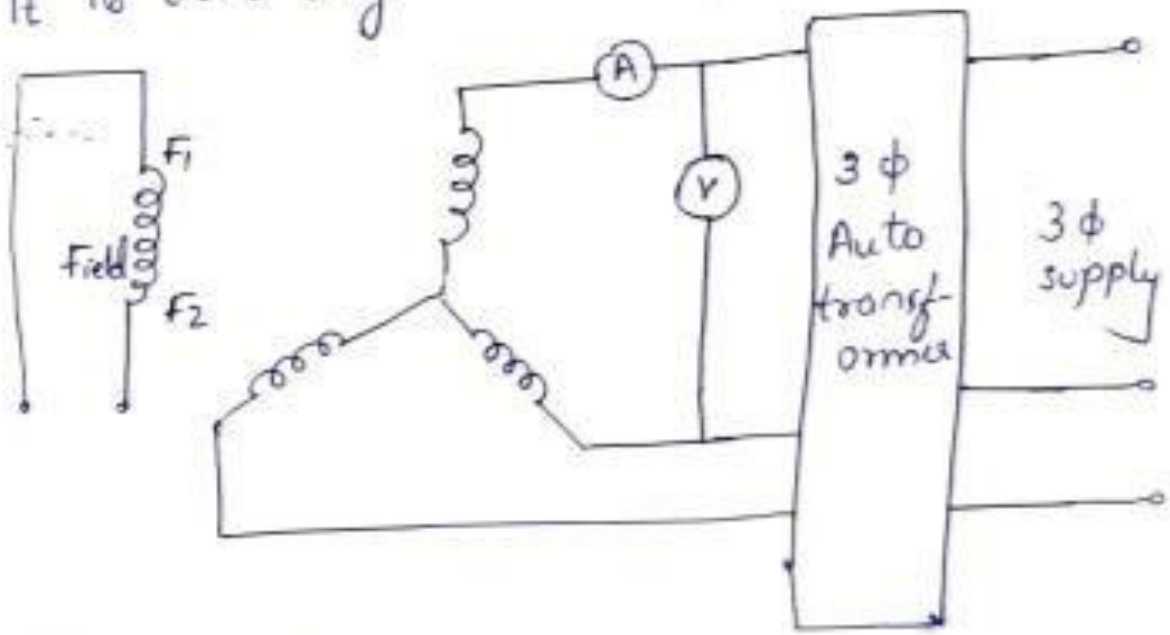
$$I = \frac{OC}{\sqrt{2}} = \frac{E_a}{X_d} \quad \text{where } X_d = \frac{E_a}{I}$$

- The first few cycles are called sub transient state
- After few cycles, the current value decreases. This period is called transient state and the reactance is called transient reactance

$$I' = \frac{OB}{\sqrt{2}} = \frac{E_a}{X_d'} \quad \text{where, } X_d' = \frac{E_a}{I'}$$

5. Slip Test

- Low slip test is done in alternator to measure the value of direct axis reactance reactance (Xd) and quadrature axis reactance(X_q
- It is done only on salient pole alternators



Procedure of test

- The field windings are kept open and a reduced voltage of (0.02 - 0.2) pu of supply voltage is applied using an auto transformer
- The ~~stato~~ rotor is allowed to run at a speed slightly less than synchronous speed.

Commissioning Test

① Measurement of Insulation Resistance.

- Measurement of insulation resistance is done using Meggar.
- IR value of
  - Stator winding to the earthed frame
  - Rotor winding to the earthed frame
  - Phase to phase winding insulation.
  - Bearing insulation.

  is measured using Meggar.
- Meggar test is done for a period of 1 minute
- The value of IR (Insulation Resistance) at 15 seconds and 60 seconds are noted.
- Meggar of 1000 V, 2500 V, 5000 V are available.
- Polarization index, PI is the ratio of IR at 60th second to that of 15 second.

$$PI = \frac{IR_{60}}{IR_{15}} > 1$$

- PI gives us the measure of extend of dryness of insulation.
- IR test is done during drying out, before HV test, during periodic maintenance testing, prior to commissioning etc.
- The value of IR should not be less than ...

$$IR_{60} \geq \frac{V_{rated}}{0.01P + 1000}$$

- where P = kW rating of machine
  IR_{60} = Insulation resistance at 60th sec.
  V_{rated} = Rated voltage

2. Measurement of DC Resistance of the winding

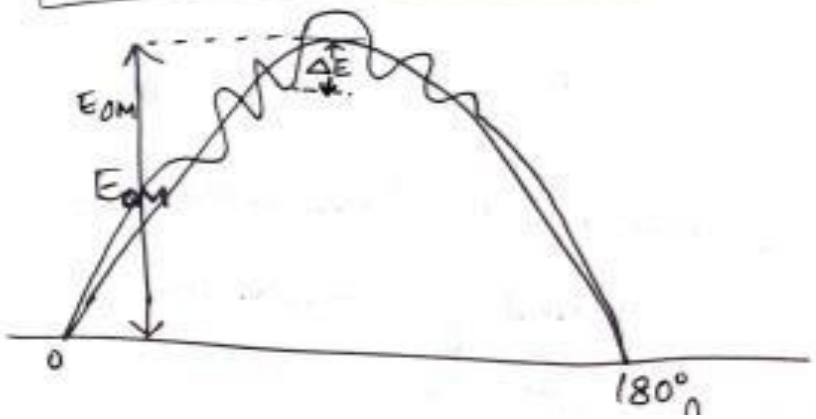
- DC resistance of the armature and field can be measured using
  - Volt ampere method
  - Bridge Method
- This is conducted at winding terminals with rotor at rest.
- So, machine is turned off for this test.
- The armature resistance for each phase has to be measured seperately.

3. Waveform Interference Test:

- For a synchronous generator with actual induced stator output voltage, the variation in the actual voltage can be identified using waveform interference test.
- Here, an equivalent ideal waveform is compared with actual stator output voltage.
- The variation in induced sine wave with an equivalent sine wave of same frequency and magnitude is obtained.
- The variation can be obtained as

a) Waveform Deviation Factor: Ratio of largest error or disturbance in the waveform to the amplitude of equivalent sine wave.

$$\text{Deviation Factor} = \frac{\Delta E}{E_{om}}$$



b) Waveform Distortion Factor

Ratio of the effective value of harmonic component ~~after~~ after eliminating the fundamental component to the effective value of the actual wave

$$\text{Distortion factor} = \frac{\sqrt{\Sigma E_n^2}}{E_{rms}}$$

ΣE_n^2 = Sum of squares of rms values of all component of voltage except fundamental.

E_{rms} = RMS value of the voltage.

c) Telephone Harmonic Factor.

- Ratio of square root of sum of squares of all series of harmonics with the weighted rms values to the rms value of voltage of the machine at no load.

$$T.H.F = \frac{100}{U}\sqrt{E_1^2\lambda_1^2 + E_2^2\lambda_2^2 + \cdots E_n^2\lambda_n^2}$$

U = RMS value of terminal voltage of the machine

E_n = RMS value of n^{th} harmonic voltage.

λ_n = Weighting ~~even~~ factor for frequency corresponding to n^{th} harmonic

d) Line charging capacity

- Line charging capacity is the reactive power of synchronous machine in KVAR while operating at zero power factor, rated voltage and field current reduced to zero. (Zero power factor can be obtained by connecting pure inductive load)
- While running as a generator, the turbine of the test generator should furnish only enough power to supply all the losses of the test generator.
- If the test generator field current cannot be reduced to zero, a series of ~~test~~ test at smaller values of excitation carried out

A curve between Ia Vs. If plotted to find the zero field current.

3.

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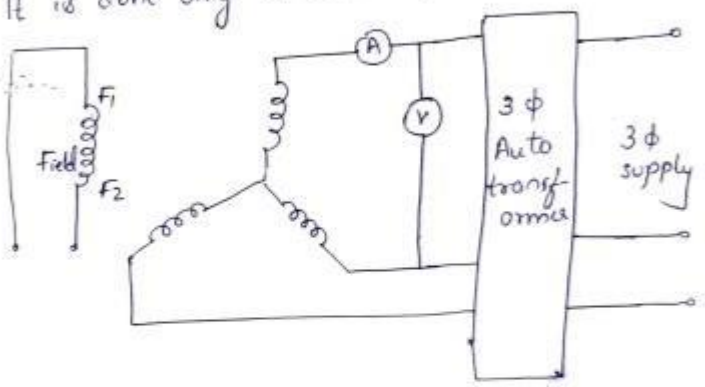
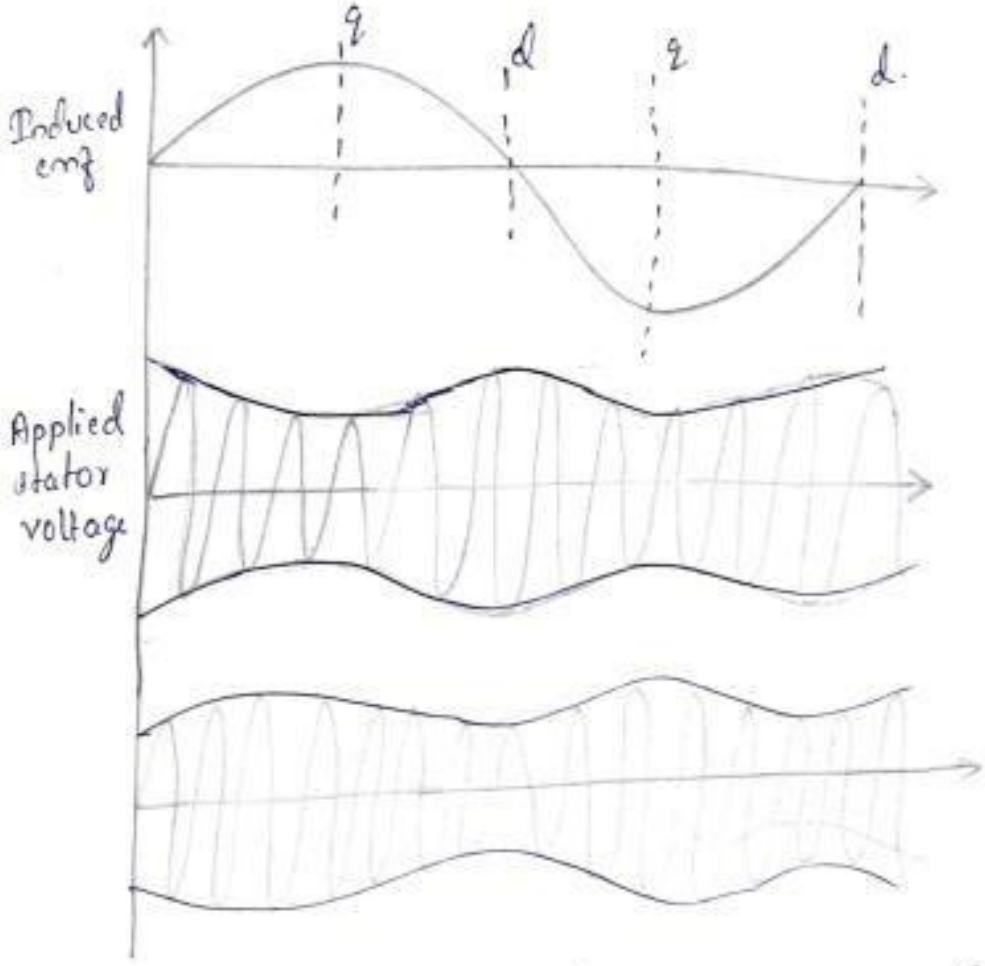


Procedure of test

- The field windings are kept open and a reduced voltage of (0.02 - 0.2) pu of supply voltage is applied using an auto transformer
- The ~~state~~ rotor is allowed to run at a speed slightly less than synchronous speed.

- We can observe after increasing the armature voltage, at some point armature voltages and current will start to oscillate to and fro
- Note down the readings V_{min}, V_{max}, I_{min} and I_{max} from voltmeter and ammeter respectively



- Case 1 : When the rotating magnetic field and rotor coincide - Direct axis

Air gap less, Reluctance less and reactance is more, I is less in that position.

This reactance is called direct axis reactance

$$X_d = \frac{V_{max}}{\sqrt{3}\, I_{min}}$$ ⇒ Direct axis reactance

- Case 2: Direction of rotating magnetic field and rotor in quadrature with each other (Quadrature axis).

- Here, air gap is more, reluctance is more, current is more. This is called quadrature axis reactance.

$$X_q = \frac{V_{min}}{\sqrt{3}\, I_{max}}$$

4.

Drying of winding

- The insulation of rotating machines will absorbs moisture from the atmosphere
  - The moisture reduces the insulation resistance
- Drying out of inductionmotorby applying the heat to the windings.
- In the first phase the insulation resistance starts decreasing due to distribution of moisture in entire insulation.
- In the second phase is a steady temperature phase over certain time and insulation resistance remains almost constant.
- In the third phase the insulation resistance increases there by indicating the moisture is removed.

Drying of Induction Motor by drying chamber & resistance method

- The ratings of heaters used for dryingis given by the equation,

$P = 0.025 (T_2 - T_1)$ kW/Vol

where,

P = kW rating of heater

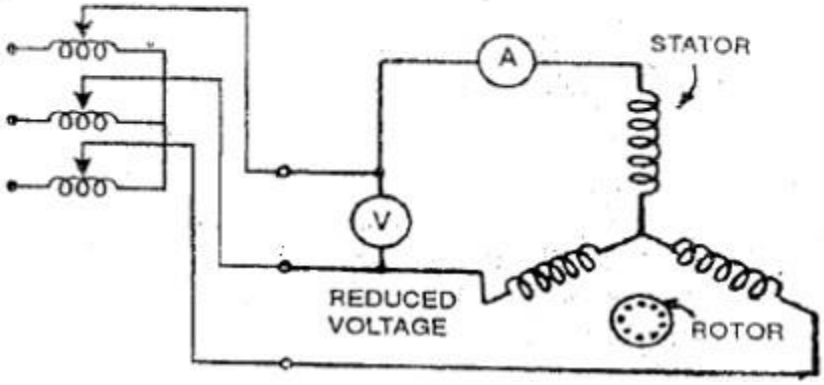
T_1 = Ambient temperature

T_2=Temperature of hot air

Vol = Volume-of air inlet m^2/min

Drying out by Circulating Short Circuit Current

- This is convenient method for drying out slip ring induction motor
- By short circuiting the rotor, large currentpasses through the windings, due to this current heat will be produced in the winding
- The current through the stator winding not to exceed 50% of the rated current.

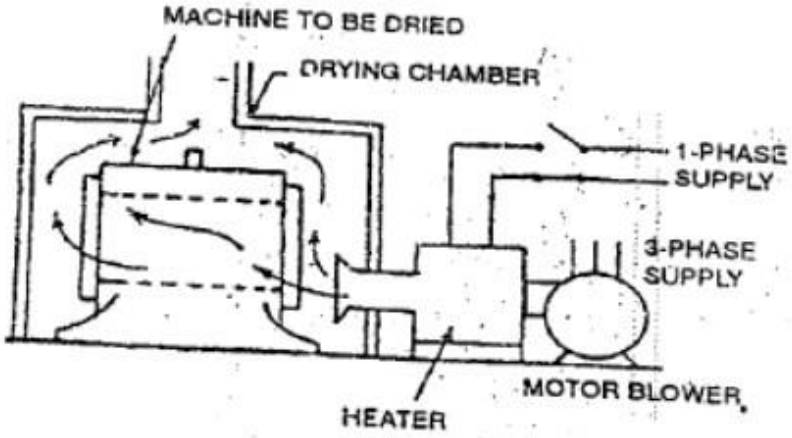


Drying by windage losses

- This method is applicable to high frequency motors having high speed.
- The inlet and outlet air ports are blocked.
- The windings gets dried by windage losses dissipated in the form of heat.

Drying of Induction Motor by drying chamber & resistance method

- The temperature is gradually raised not faster than l0°C per hour.
- It is required to preferably maintain steady temperature throughout the heating.



Drying out of induction motor by drying chamber and resistor heater

5A.

4. Sudden Short Circuit Test.

- It shows if the mechanical design of the machine is adequate to withstand the stresses due to short circuits.
  - Machine is made to run at rated speed
  - The machine is supplied with no load voltage. Terminal voltage at no load is as per agreement with manufacturer and purchaser.
  - Short circuit is instantaneously applied by closing the ~~circuit~~ switch for a period of 3 seconds.
  - The short circuits are made multiple times by making and ~~brak~~ breaking the switch
- The test is considered satisfactory if
  (a) No harmful deformation of windings takes place
  (b) If the windings withstand the high voltage test performed immediately after the instantaneous short circuit withstand test.
- This test allows protection from abnormal conditions such as (i) Switching (ii) Sudden changes in load

5B.

2. Vibration Test for Bearings

- Bearing vibration test is performed when the rotor is running at the no load condition
- Vibration is measured ~~at~~ in horizontal, vertical and axial directions.
- Velocity probe / vibrometers / accelerometer measures the vibrations.

Vibrations can be due to

i) Misalignment between motor and driven equipment.
ii) Loose foundation bolts
iii) Badly worn bearing
iv) Mechanically unbalanced rotor.
v) Bent / Cracked shaft
vi) Highly pulsating load
vii) Magnetic effects of high frequency

~~3. Measurement of Audible Noise~~

- For vibration test, rotor is then accelerated with reasonable promptness to the specified overspeed.
- Speeds can be increased till 120%, the machine has to pause at different speeds

machine has to pause at different speeds during acceleration to check for vibrations, runout of the motor, bearing conditions etc.

- The test is considered satisfactory if
  (a) No deformation observed in the rotor.
  (b) The rotor winding passes the high voltage test after acceleration
  (c) Vibrations are within permissible limits

6A.

Specification Of Synchronous Machines

- Rated Voltage : 3.3 KV, 6.6 KV, 11 KV
- Power Rating : 10 MW, 20 MW, 50 MW, 100 MW, 500 MW
- Excitation Voltage : 100 V – 1000V dc
- Excitation Current : 5-20A
- Speed : Speed in rpm is mentioned (say 3000 rpm)
- Cooling System : Forced air, Hydrogen cooled, Water cooled.
- Type of rotor : Salient pole or smooth cylindrical
- Short circuit ratio
- Class of Insulation
- Temperature limits
- Connections
- Frequency

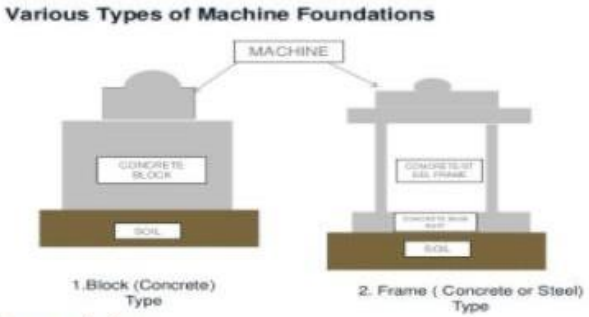
6B.

INSTALLATION

1. Physical Inspection:

- **Check for damage/missing of parts.**
- **Machines to be stored in safe place.**

2. Foundation



3. Installation of machine

Foundation Details

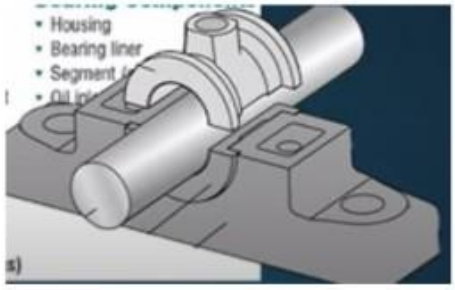
- All civil construction and foundation – fully completed before installation
- Basic dimension need to be provided by the manufacturer.
- Machine room – enough space for installation and dismounting
- Room should be clean, dry and warm
- Based on type of mounting :horizontal/vertical
- Generally alternators are mounted vertically covering two floors basement and ground.
- Provided with holes to receive fix bolts securing the bed plates.
- Holes and anchor bolts should be fixed in the concrete
- Strong construction to take the static and dynamic loads so as to prevent displacement and vibration of a running machine
- Should be separated from other columns and supporting structures of the building.

Steps in installation of a large rotating machine

- Installation of bed plate and the leveling of bed plate
- Installation of the bearing pedestals and leveling of the bearing pedestals
- Checks on stator and rotor
- Assembly of the rotor onto the shaft
- Installation of the stator
- Installing the rotor in the stator
- Checking of the air gap between

Stator and rotor

- Preparation of shaft couplings



- Mounting of shaft couplings on shaft
- Preparation of shafts and alignment of shafts.
- Installation of cooling systems
- Drying out
- Testing
- Commissioning