- For 4 pole machine, there are two cycles completed in one revolution. The rotor freq^n 'f' can be seen by oscillations of the galvanometer connected in rotor circuit

Table 1.

Sr.No	f	Time for 10 oscillation of galvano meter
1	50	10 seconds
2	50	6.66 seconds

* Procedure :-

- By changing speed by rotor resistance or by actually loading motor note down time in seconds required to complete 10 oscillation of galvanometer.

- Calculations -

For Sr. No. 1

In 10 sec : 10 oscillations } $\frac{10}{1} \times \frac{1}{10} = 1$ oscill^n
In 1 sec : 1 oscillations }

The freq^n of rotor emf $f' = 1$ cycle/sec

$$\% \text{ slip 's'} = \frac{f'}{f} \times 100 = \frac{1}{50} \times 100 = 2\%.$$

For Sr. No. 2

In 6.66 Sec = 10 oscillations } $\frac{10}{6.66} \times 1 = 1.5$
In 1 Sec = 1.5 oscillation }

$$\% \text{ slip 's'} = \frac{f'}{f} \times 100$$

$$= \frac{1.5}{50} \times 100 = 3\%.$$

- If the experiment is carried out on same machine & for same conditions & readings are taken for all the methods simultaneously & results are calculated by each method, the answers will be same

Table 2 : Result table :-

Sr.No	Method	Sr.No.1	Sr No.2
1	By tachometer	S = 2%	S = 3%
2	By stroboscope	S = 2%.	S = 3%
3	By Galvanometer	S = 2%.	S = 3%.

** ② Type Tests :-

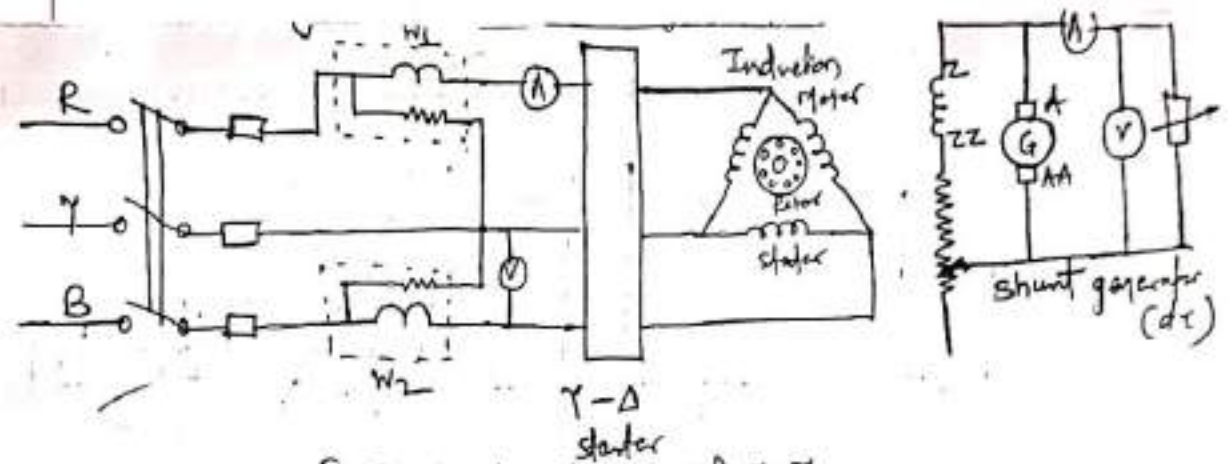
* i) Temperature Rise Test :-

- The temp. rise limits the o/p & rating of motor so it's determinations is of great importance. This test is performed to determine temp. rise on different parts of motor while running at rated conditions.
- The duration of temp. rise test is dependant on type of rating of motor. for continuous rating motors temp. rise test should be continued till thermal equilibrium is reached (i.e. temp. remains constant) for motor with short time rating the dura^n should compressed to declare short time rating.
- The temp. rise is determined by following methods :-

1. By loading I.M. with generator which is mechanically coupled to it.
2. By direct application of mechanical load.

- In both the above cases the motor is loaded up to full load. This loading is kept constant till steady state temp. condition is obtained. The temp. rise can then be calculated by resistance method. The above two methods are important.

1. By loading the I.M. with generator:-



fig② Load test of 3φ I.M.

Table 1: observation table.

Sr.No	Induction motor				D.c. Generator			
	Voltage (volt)	Current (Amp)	W1 (watt)	W2 (watt)	Speed (rpm)	Vtg (volts)	current (Amp)	W1
1.								
2.								

- Calculations:-

Motor speed = N rpm

$$\text{Slip} = \frac{NS - N}{NS} \times 100$$

Motor speed = _____ rpm

Motor I/P = $W_1 + W_2$

Generator o/p = Vdc x Idc

Generator η is known

∴ Generator I/P = $\frac{\text{Output}}{\eta}$

Motor o/p = Generator I/P

Motor η = $\frac{\text{Motor o/p}}{\text{Motor i/p}} \times 100$

Motor P.F. = $\cos\left[\tan^{-1}\frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}\right]$

2. By direct application of mechanical load :-

- This method is suitable for small & medium capacity motors due to non availability of large loading facility. Any mechanical load can be connected, but generally artificial loading arrangement is provided by brake pulley & belt or rope. Tension of rope belt can be increased to load the motor. The test set-up is shown in fig @.

shown in fig @

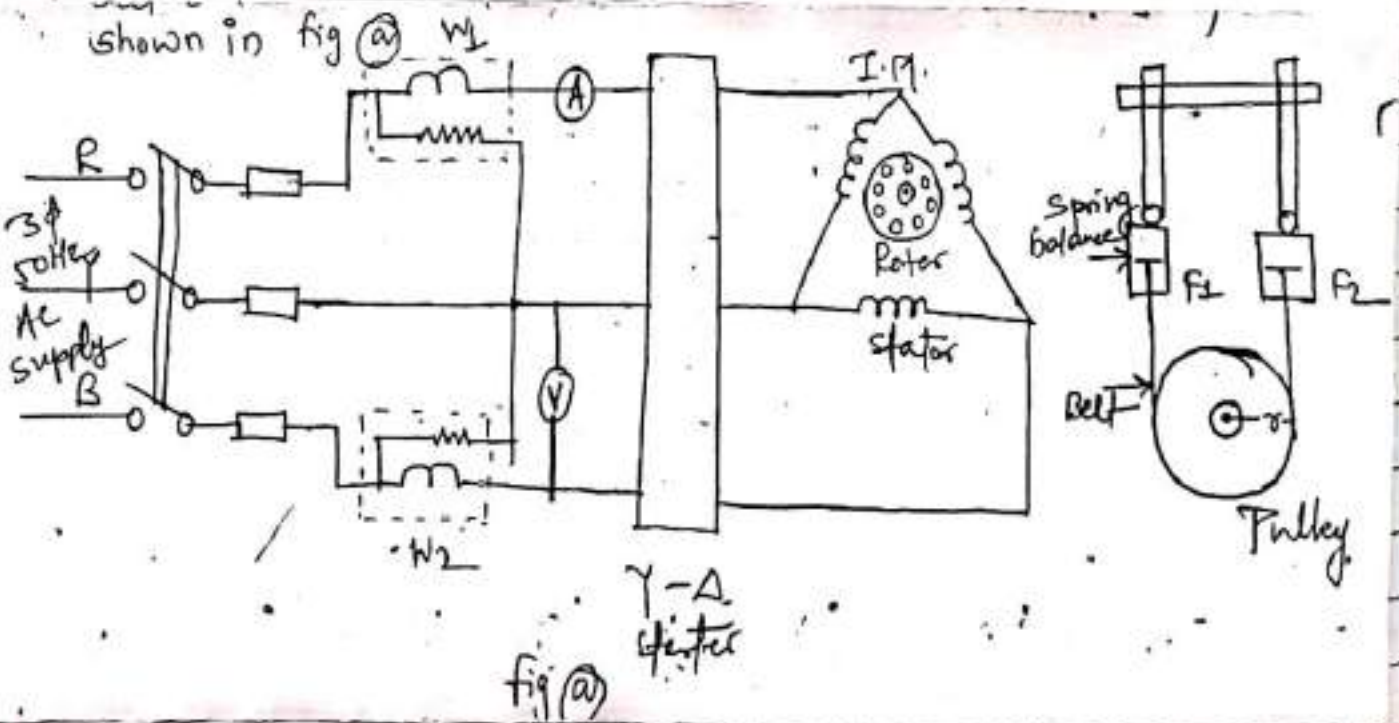


fig @

- Motor can be tested gradually increasing load by increasing (tightening) tension on belt. The spring balance readings in kg on slack & tight side of belt are noted & respective readings on I/P side of motor such as current, voltage, power are noted. Speed is measured with the help of tachometer. Finaly at full load, the load on machine is kept constant, for some time to get steady state condition of temp. Temp. then can be calculated.
- similarly, from the observations, the performance characteristics can be plotted on graph.

- Calculations :-

I/P side calculations are similar as in the previous case of loading with generator o/p is calculated as follows :-

Torque, $T = (f_1 - f_2) \times r \times 9.81$ Nm

$\text{Output} = \frac{2\pi NT}{60}$ watt (where N in rpm)

Other calculation are similar to previous case.

- Momentary Overload Test:-
- This test is applied after heat run test. The motor should be capable of withstanding momentary overload for 10 sec without stalling or abrupt change in speed. The excess load is applied gradually as per Table J.

H.P. of motor	Excess load	Duration of excess load
Upto 50 H.P.	100 %.	15 sec
Above 50 H.P.	70 %.	15 sec
Above 500 H.P.	60 %.	15 sec

**3) Special Tests:-

1) Open circuit voltage Ratio test.
2) Locked rotor readings of V+g, current, & power I/p at suitable reduced voltage.

Note:- Write a theory with circuit diagram in detail by referring previous pages.

* Testing of single phase induction Motor:-

A) Routine Tests:-

1) Insulation resistance test.
2) Winding resistance measurement test (D.C. resistance).
3) High voltage test.
4) No load test
5) Blocked rotor test
6) Quiet running test

B) Type Tests:-

1) Temperature rise test
2) Momentary overload test
3) Load test.
4) Moisture proofness test.
5) Leakage current test.
6) Pull out torque test.

A) Routine Tests

1) Insulation Resistance Test:-

- This test is generally taken after temp. rise test.
- Insuln resi. is checked by Megger (Refer I.M.)
- Insuln resi. is measured betn starting wdg. & foundation base frame.
- Insuln resi. is measured betn ~~starting~~ running wdg. (disconnecting capacitors & frame).
- If reading on megger is more than 1 MΩ, it is o.k.

2) DC resistance of winding :-

(Refer 3 Φ I.M. article)

- Voltmeter - ammeter method is used to find resistance of starting & running windings. The interconnections of winding are separated & capacitor or resistance etc. are separated.

$$\frac{\text{Voltmeter reading (V)}}{\text{Ammeter reading (I)}} = \text{Resi. of winding}$$

3) High voltage Test :-

- This test is taken after the insulation resi. measurement test. For this test following range of voltage be taken.

Low vtg. motors less than 50 volts =
Test vtg. = 500V.

- Voltage bet^n 50 to normal 250V -
Test vtg = 1000V. By this test weakness /damage of insulation is tested.

4) No load test :-

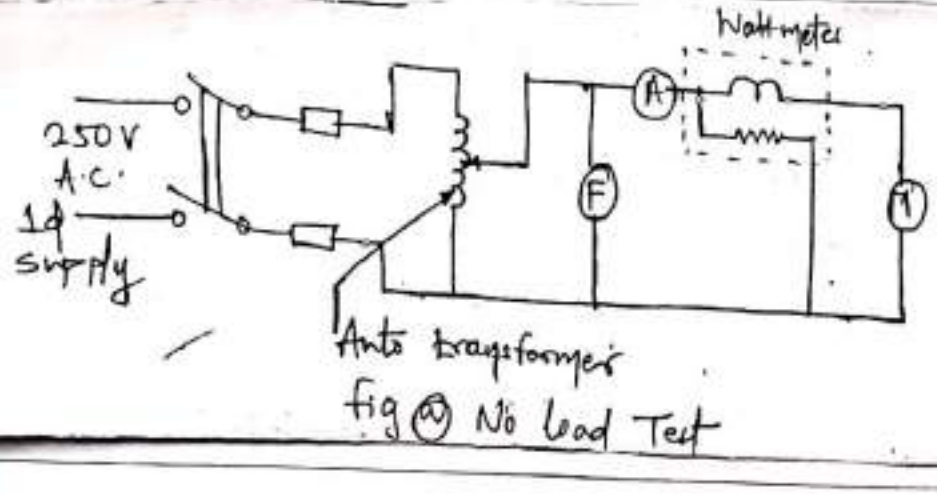


fig (a) No load Test

- Connections to the motor for no load test are shown in above ckt. diagram.

- The rated vtg to motor for no load test are shown in above ckt. diagram.

- The rated vtg. to motor is adjusted with the help of auto T/f.
- Readings of no load test are tabulated.
- Wattmeter reading ≃ Iron loss.

V	I	W	f	Speed (N)

- These values shall tally with the values commited by supplier.
- These readings are also useful to draw circle diagram of this motor.

5) Blocked rotor test :-

- The ckt. diagram for this test some as no-load test. The rotor is blocked. (not to rotate).
- care is taken that initially auto TIF is kept to it's zero position.
- The motor is started.
- slowly auto TIF is operated & vtg. is increased till ammeter reading shows the rated current of the motor.
- Operation of auto TIF is stopped & readings of respective meters are tabulated in observation table.

V	I	W	frequency
	Rated value		

- Neglecting iron loss [being small for low vtg.]

W = F.L. cu loss

From no load & block rotor tests, necessary calculations are done & a circle diagram is plotted to scale

- From circle diagram completes performance can be checked such as -

i) Losses ii) Efficiency iii) Torque

iv) Maximum torque. v) power factor.

6) Quiet Running test :-

- This test requires variable freq^n supply. The freq^n (f) & vtg. (V) are adjusted to the normal values.
- Note that motor operat^n is noiseless or noise level is below specified level.
- The test can be continued by loading motor & checking noise level which shall be below a specified level.

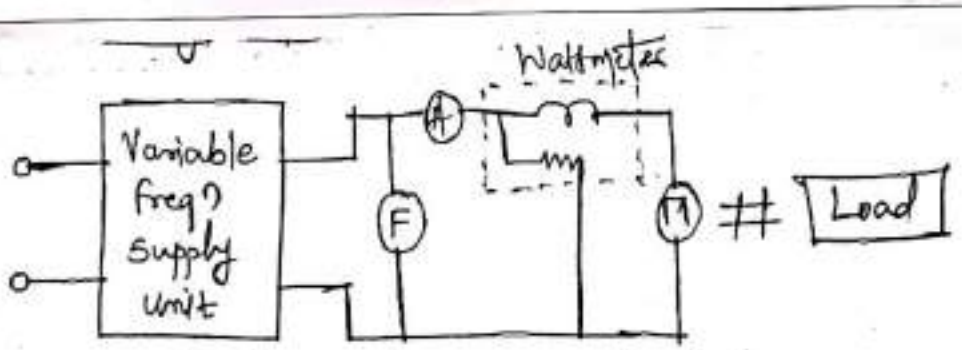


fig (a) Quiet running test

B) Type Tests :-

1) Temperature Rise Test :-

- Measuring cold winding resistance (R_1) at room temp. (t_1) & then running the motor on full load for sufficient time & then finding hot resistance (R_2) when that temp is t_2 then temp. rise is determined,

$$\frac{R_2}{R_1} = \frac{t_2 + 234.5}{t_1 + 234.5}$$

all the terms are known except t_2, t_2 is thus calculated.

- $t_2 - t_1$ is the temp. rise which shall be below specified level.
- Temp. coeff. of copper = $\frac{1}{234.5}$ at 0°c

2) Momentary overload test :-

- This test is carried out to check it's overload carrying capacity which is generally specified as -

Sr.No	Type of motor	Load	Time duration
i)	Resistance split-phase motor	1.6 F.L.	↑
ii)	Capacitor start induction run	1.6 F.L.	
iii)	Capacitor start-run	1.25 F.L.	15 seconds
iv)	Shaded pole	1.20 F.L.	↓

With this much overload for 15 seconds behaviour of motor should not be abnormal as for speed, noise, temp. rise is concerned. Motor should not stop.

Generally, this test is performed immediately after the full load temp. rise ~~test~~ test.

3) Load test :-

- This test is carried out as shown in fig. of quiet running test in which motor is supplied with a rated vtg. & freq^n. The meters, ammeter, voltmeter, wattmeter, freq^n meter are connected is the I/P side of motor as shown & load is in form of pulley & belt arrangement on the shaft.
- By tightening belt, mechanical load is increased gradually. Different readings are taken & tabulated.

Sr.No	I	V	W	F	Spring Balance		Speed N
					F1	F2	

- calculations :-

$$\text{Slip} = \frac{N_s - N}{N_s} \times 100$$

Torque T = Force x radius of pulley (r)

$$= 9.81 \times (F_1 - F_2) \times r \quad N\text{-m}$$

$$\text{O/p in watts} = 2\pi \left(\frac{N}{60}\right) T$$

$$\text{Input} = V \times I$$

$$\text{Efficiency } \eta = \frac{\text{output}}{\text{input}} \times 100$$

Thus, performance of motor is checked.

Graph is plotted from the observations.

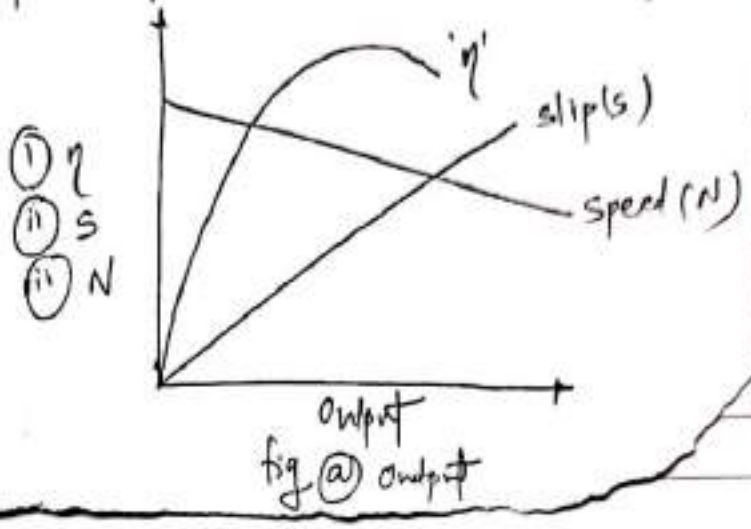


fig @ output

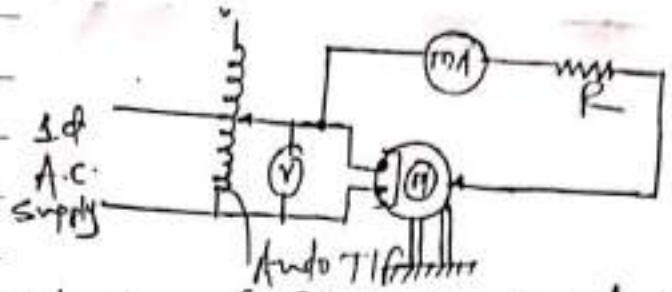
4) Moisture Proofness Test :-

- steps in this test :-
- No supply connected to motor.
- put the motor in a closed chamber in which maintain humidity as 90% & keep temp. of 42°C.
- Keep this condition for full day (24 hours)
- Take motor out of chamber & then,
- carry out insula^n resi. test. (see that insula^n resi. is not less than 1 MΩ)
- After this test take a flash over/ high Vtg. test. See that there no damage to the insulation. Then motor is ok.

5) Leakage current test:-

- The leakage current should be negligibly small so that there is no risk to the operator & machine is safe guarded. The limit for the current so measured by the external circuitary shown in diagram shall

not be more than 2.5 mA.



Procedure :- Fig(a) Leakage Current test

- Procedure :-
- The motor is applied with a vtg. = 1.1 x rated vtg. through auto T/F.
- An external ckt. consisting of a milli-ammeter & resi. R = 2000 ± 50 Ω value is connected as shown in diagram for perfect condition of insulation of motor, milli-ammeter reading should not exceed 2.5 mA.

* Preventive Maintenance of 3 phase, 1 phase I.M. :-
- In order to increase life of machine & keep it's working, satisfactory, ~~working~~ ~~from~~ it's maintenance is very imp.
- Maintenance work is carried out to prevent damage, obstacles, & breakdown of machine.
- Maintenance work is to be take care of machine to obtain satisfactory working from it.

- Maintenance prevents the ill effects which cause in future.
- Provide adequate ventilation.
- Lubricate/oil as per schedule
- Keep machine & area around machine clean & dry.
- Observe the changes in motors operating condition.
- Keeping records of maintenance checks, repairs of machine.
- Attend minor repairs before major repairs to be faced.
- Measuring electrical characteristics of motor, comparing them over a period of time to detect any changes.

* Routine Maintenance of I.M :-

- careful attention to the following routine inspectionmay help prevent serious trouble developing late.
- b. Ensure that at external cables are adequately cleated and are properly secured.
- Check the security of all electrical connections with the motor isolated from the supply. Ensure that all terminals (Terminal block) are clean and tight.
- Check and ensure that the windings and bearings are not overheating and that the motor runs quietly & smoothly.

The windings demand frequent attention if the machines are working in damp, humid or dirty situations, or in excessive temperatures,

and insulation must be kept clean, otherwise earth faults or short circuit may occur.

- Check the security for all fixing bolts, couplings, coupling guards etc
- Check that cowl intake vents are not chocked. Choked cowl intake may restrict the flow of cooling air and cause overheating. Compare the actual load current, supply voltage with the full load current. Rated voltage given on the rating plate.
- Ensure that load current does not exceed motor name plate full load current. Ensure that supply voltage and frequency is within the tolerance band specified in the catalogue/test certificate. The line voltages & currents are also to be checked to ensure balanced loading within specified limit.
- Check that the carbon brushes ~~should~~ are sitting properly on the slipring and the tension of the holders are uniform. The brushes should not vibrate in the holders when the motor is running.

Page No.:
Date:
YOUVA

* Alternator (synchronous Generator) :-

- synchronous machine 1. Generator 2 Motor
- Synchronous machines may be :
  i. Rotating field & Stationary armature type.
  ii. Stationary field & totally armature type
- synchronous machines need D.C. excitation system. Excitation Vtg. is 110 to 125 Volts D.C
- Alternator produces EMF whose magnitude is given by,

$$E_{per\ phase} = 4.44\ K_p . K_d . \phi T f$$

where, K_d = Distribution factor $\simeq 0.9$
K_p = coil pitch factor $\simeq 0.9$
ϕ = flux per pole.
f = frequency.
T = Turns per phase.

- Alternator supplies electricity to the supply system.
- If need of electricity is increased then two or more alternators can be connected to the supply system which run parallel to each other.

* Need & Advantages of parallel operation of Alternator :-

1) Load growth
- Load demand now a days is increasing due to increasing use of electric power. Existing system may not be sufficient to meet with the demand & hence additional units of alternators to be added to satisfy the increased demand.

2) Continuity of Service :-

- Instead of only one unit supplying Power many smaller units shall run on system so that if any of the unit fails the other can meet demand & continuity can be maintained.

3) Repairs :-

- The units are sometimes to be taken off from system for repair works. In it's place other unit is to be paralleled to the circuit, so that faulty unit can be taken off for repair work.

4) Maintenance :-

- As per the maintenance schedule the units are to be switched off & taken out electrically so the other unit shall continue the supply & one unit may be paralleled to the system.

5) Efficiency :-

- The machine works to it's maximum efficiency at nearly to it's full load capacity. If the demand on the system decreases, then that unit may operate at a lower load condition, at a lower efficiency. This is not economical. Hence bigger units is to be shut off & smaller unit ~~can work~~ may be introduced so that smaller unit can work to it's full capacity at higher efficiency.

* conditions for satisfactory Parallel operation of Alternators :-

- A stationary alternators must not be connected to live bus bars as it's E = 0 & hence short circuit may occur.
- The terminal vtg. of incoming alternator must be same as the bus-bar vtg (R.M.S)
- The generated frequency of incoming alternator must be same as bus-bar freq^n
- The phase-sequence of incoming alternator (3 ϕ T/F) must be same as phase sequence of bus-bar.
- The polarity of incoming alternator terminals must be same as bus-bar terminals.
- The magnitude of vtg. of alternator can be adjusted by field regulator & frequency can be adjusted by speed variation.

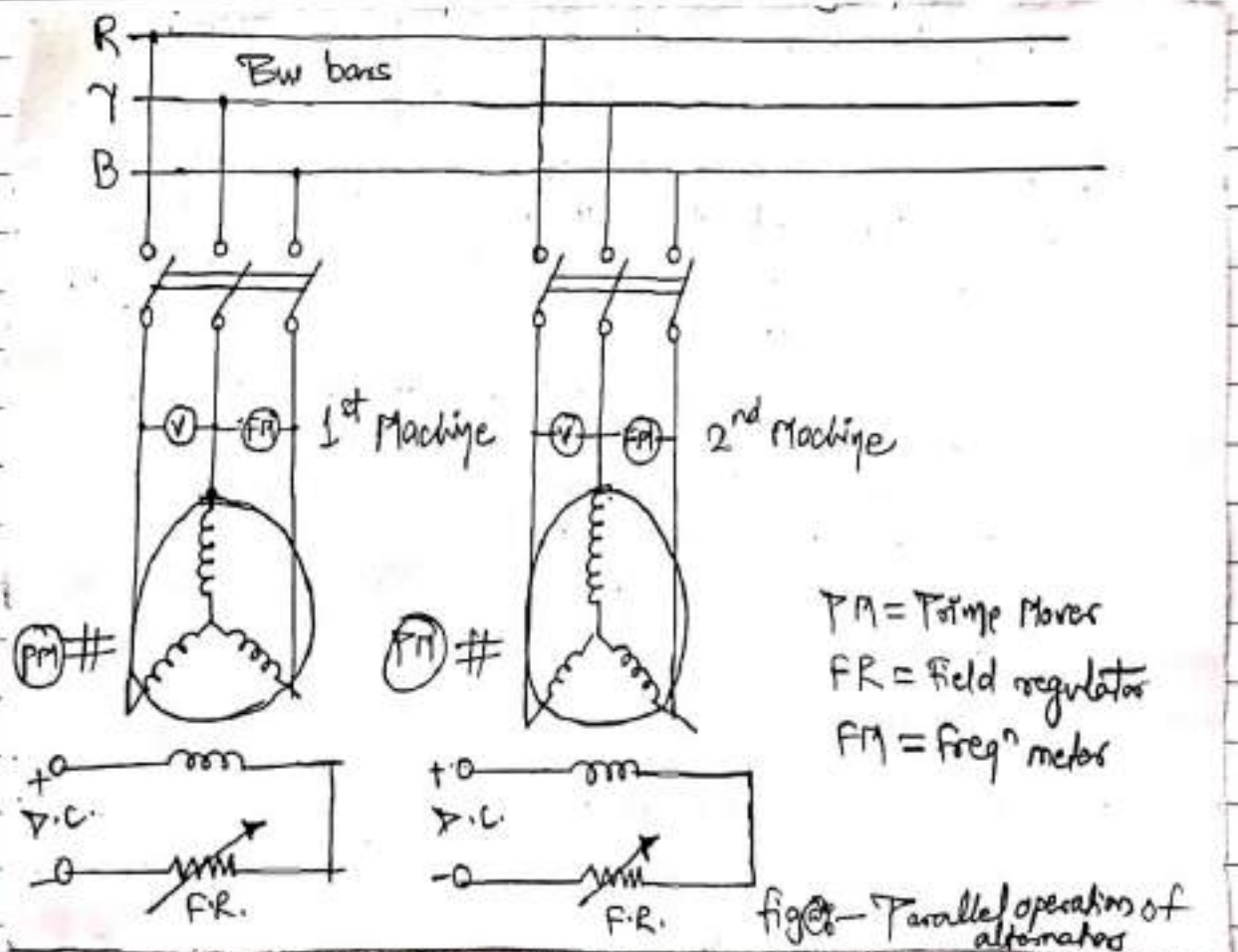


fig:- Parallel operation of alternators

* Procedure for Synchronising :-

- An incoming alternator is already working for satisfying above four conditions, the following procedure is followed in sequence.
- Start the second alternator with the help of it's prime-mover & adjust it's speed too the rated value
- The terminal vtg. of incoming alternator is increased by increasing the excitation. Thus, the terminal vtg. & also the freqn is made equal to that of the bus-bar. This is checked with the help of voltmeter & freqn meter as shown connected in the fig. @
- Check the phase-sequence of the incoming alternator to match with the phase sequence of the busbar with the help of "phase sequence indicator".
- Prior to make the synchronising switch of the incoming alternator "on", the last condition is checked any one of the following methods : (that is phase of incoming alternator vtg. must be in the same phase as of bus bar vtg.)

a) Dark lamp method b) One dark & two equally bright lamp method. c) synchroscope.

* Synchronising :-

- An incoming alternator to be connected in paralel to the existing working system on bus-bar so that it becomes synchronous to system for load sharing is called as synchronising.

* Maintenance Schedule for Synchronous Machines :-

Sr No.	Inspection frequency	Items to be inspected	Inspection notes	Action required if inspection shows unsatisfactory conditions
1.	Monthly	i) Ball & roller bearings	i) Make sure that grease or oil is not leaking out of bearing housing	If any leakage is present repair it before use.
			ii) Check the noise of bearings.	Noisy bearings if any be replaced by new one at time of shut down.
			iii) Check oil level & colour of oil	If colour become dark replace it immediately.
		ii) Brushes	i) Check length of brushes	If worn out replace them
		iii) Commutation	i) Check the commutator for roughness	When grits found out Carryout wipping of commutator with a brush or lintless cloth.
		iv) Collectors	i) Check the collectors for roughness, dust & wear	Wipe with brush / cloth.
			ii) Check if brushes are bouncing up & down on a cycle basis.	Check for collectors ring continuity.
		v) Air filters	i) Check if clogged filters.	Replace, otherwise cause of over heating.
		vi) Bolts	i) Perform visual observation for loose bolts, loose parts or loose electrical connections	Take visual observation & do the needful.
		iii) Noise and vibrations	i) Check for any unusual noise, vibration or change from previous observations.	Rectify the same.

Sl no	Inspection frequency	Items to be inspected	Inspection notes	Action required if inspection shows unsatisfactory conditions
	6 months	Bearings i) Roller & ball	Listen to all bearing, open ball bearing cap to inspect grease condition. Take samples of oil test it as suggested by manufacture.	Replace if necessary
		ii) Commutator	i) check risers for cracks ii) check end of shaft keyway & shaft fan	Do the needful
		iii) Insulation	Measure 1 min & 10 min insulating resist., calculate polarization index & compare with previous record.	Wipe deposits from brush holders stud insul^n & commutator creepage path. Remove heavy deposits from around field coil connections Blow deposits out with clean dry air. Make visual inspection for signs of overheating.
		iv) Mechanical bolts	check all electrical connections for tightness, look for signs of poor connections that is arcing, discoloration, heat etc inspect foundation for sign of cracking	Do the needful.
		v) Shaft	Check corners of exposed ends of the shaft & key way for the crack due to torsion.	Check & do the needful
		vi) Ventilation	Check clogging of screens & filters etc	Clean the same
		vii) Vibrations	Check balance & alignment	Do the needful

3.	Yearly	Bearing	Drain out housing. Remove top half of bearing housing, inspect bearing surface & rings see also bottom half of bearings	If slug (~~graft~~) is found at bottom of housing clean it.