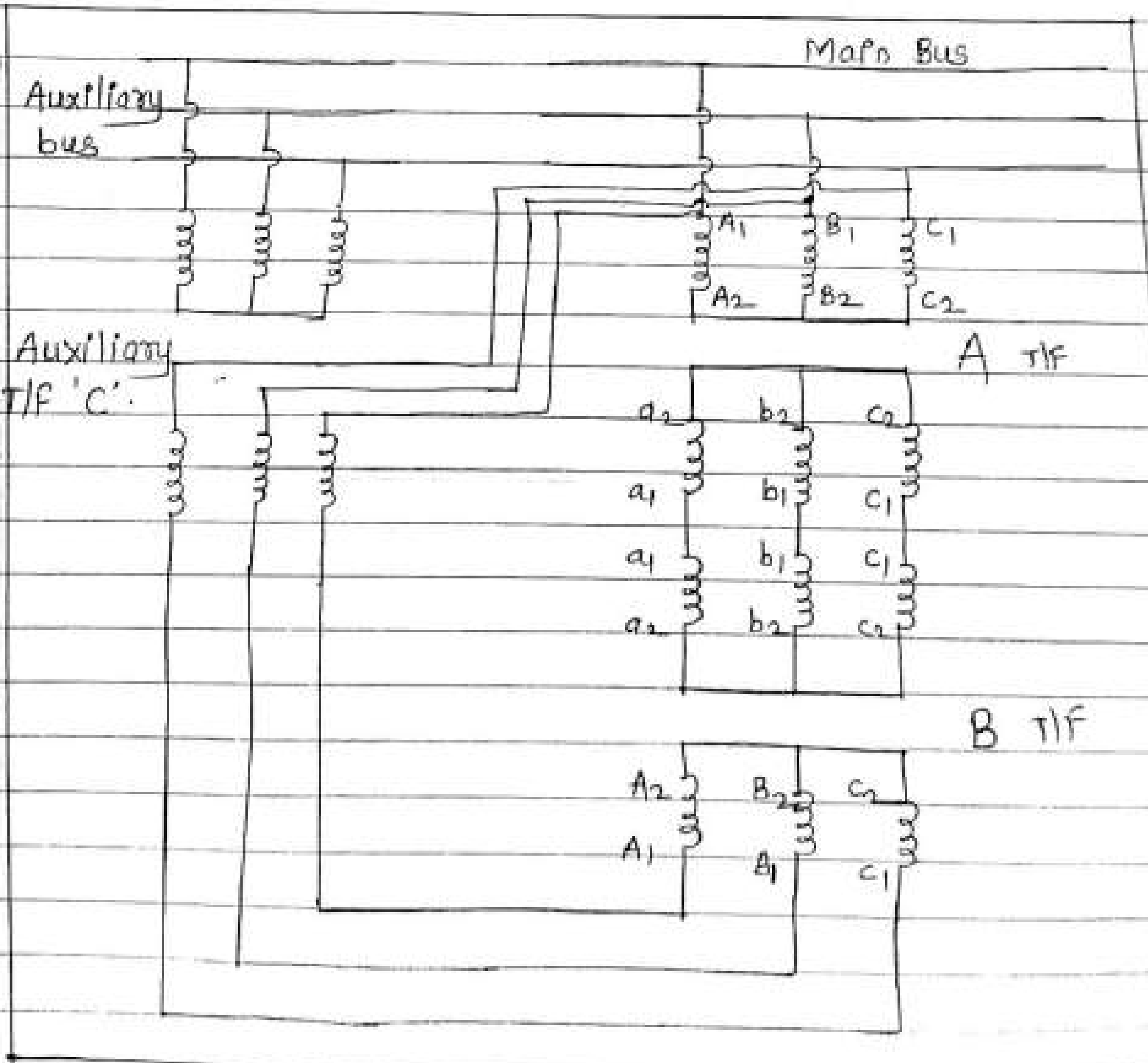
* Back to Back test on three phase star / star connected T/F

- for measuring the temp. rise by back to back method in case of three phase star / star T/F, two identical star / star connected T/Fs A & B are connected in phase opposition on secondary so that resultant voltage at secondary will be zero when no voltage is introduced from auxilliary T/F C.
- Primary windings of T/F A & B are connected to three phase main bus which supplied rated voltage to the primary windings.



- Hence, no load voltage ~~at~~ losses at normal flux density take place by connecting variable supply from auxiliary bus to primary of aux. T/F C, the current equal to full load current of T/Fs A & B is made to circulate through prim & secondary of T/Fs A & B, which will be indicated by ammeter connected say on sec ckt.
- This condition is maintained till final steady state temperature condition is reached.
- The supply is then switched off & immediately the winding resistances / phase are measured.
- From the initial value of resistance/phase & final value of resistance/phase the temp. rise can be calculated.
- The voltg from aux. bus may not be at the frequency of main bus.
- Generally, if possible low freq. is used to reduce the effect of unequal heating in both T/Fs.

## Impulse Voltage withstand Test:

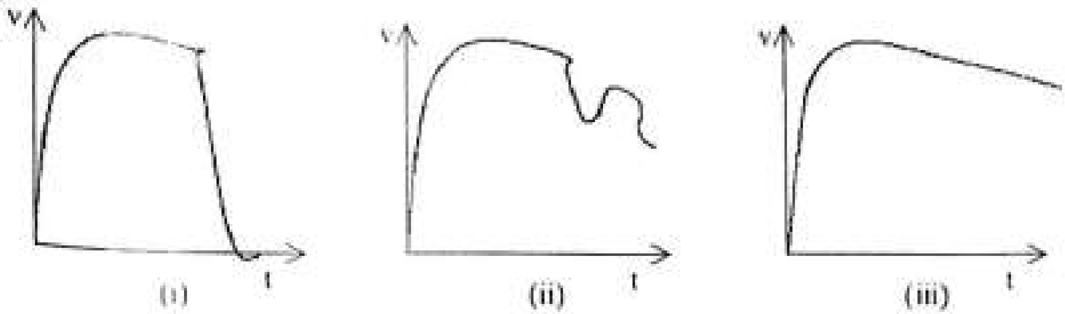



Figure - Observed impulse waveforms

These are done as tests on sample of apparatus. The impulse test level is determined by the operating level (4 to 5 times the normal operating value ) Apply on to the sample a certain number (say 10) positive impulse and 10 negative impulses of this particular value. They should withstand this voltage without any destruction.

To test the ultimate impulse strength, apply increasing amounts of impulse voltage until destruction occurs; during the tests it is necessary to see whether there is any damage. The damage may not be immediately visible, so we have it on a high frequency (single sweep and high speed) oscilloscope. In the event of complete damage, breakdown of the insulator due to the application of the impulse voltage will be indicated as in (i). If the insulator has suffered only a minor damage the wave form would show no distortion, but would show as in (ii). If there is no damage caused due to the impulse, the waveform will be complete and undistorted as in (iii).

In testing high voltage insulators whose actual breakdown is in air (i.e flashover takes place before breakdown of insulator) the porcelain itself can be tested by immersing the whole insulator in liquid of high permeability so that there would be no outside flashover, and actual breakdown of the insulator would occur.

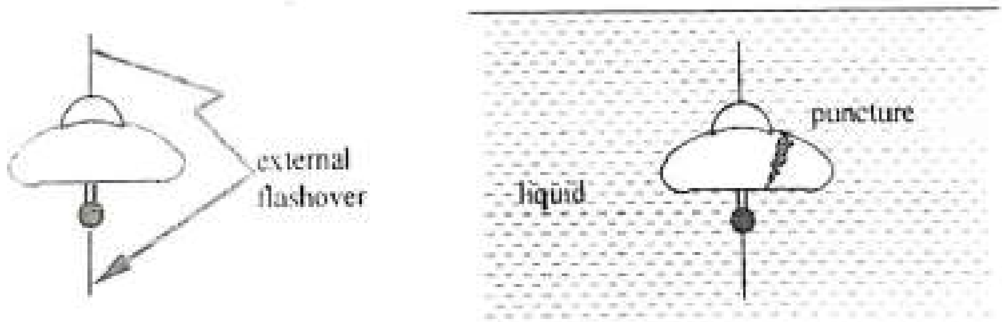



Figure - Breakdown of insulator unit

In specifying the flashover characteristic in air we give the 50% flashover characteristic. This is done as flashover occur at the same voltage on each application of the impulse. We apply different values of test voltages (impulse) and the voltage at which there is 50% probability of breakdown is taken as 50%

flashover voltage. The impulse flashover voltage also depends on the time lag of the applied impulse before flashover time lag of the applied impulse before flashover occurs. Thus we have also got to determine the time lag characteristics for breakdown.

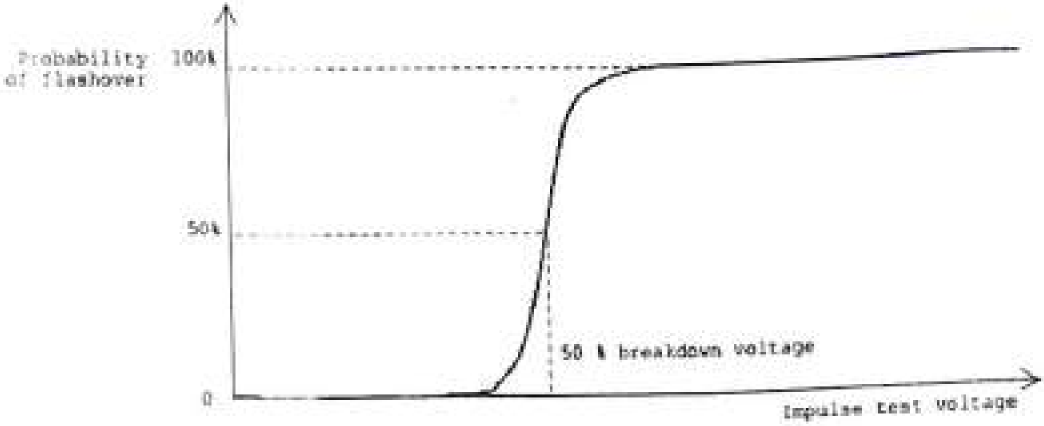
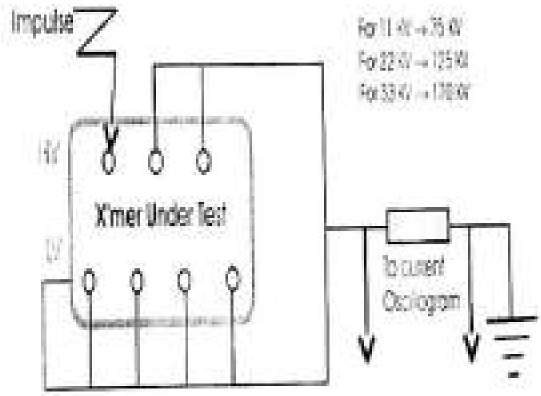



Figure - Probability of flashover



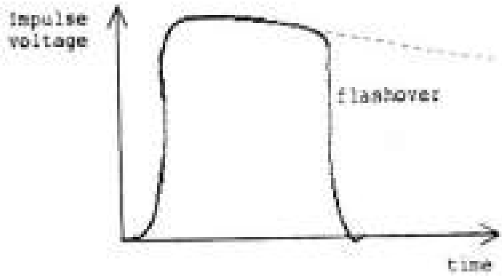
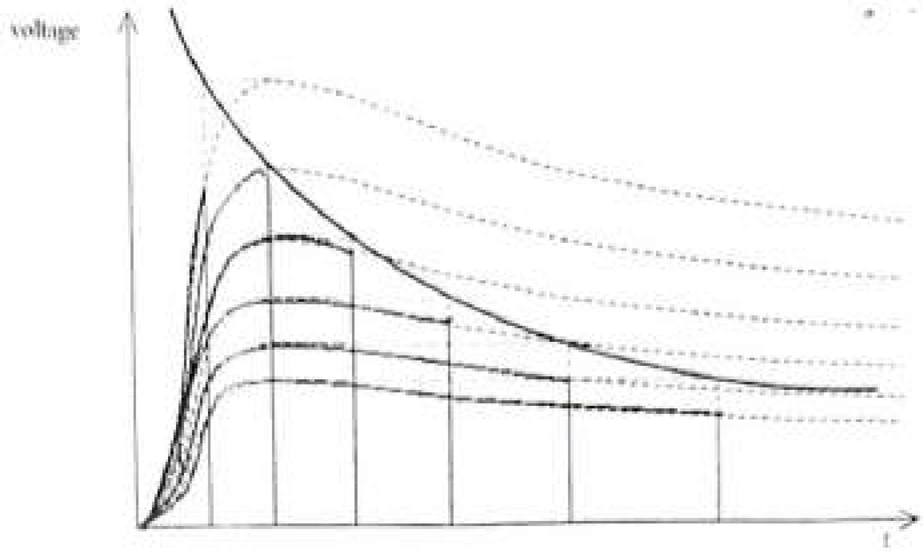




Figure - Chopped impulse waveform

If the voltage remains above a critical value long enough, flashover occurs. The time lag before flashover occurs depends on the statistical time lag and on the formation time lag. Depending on the volume of space between the gaps, and also depending on the nature of shielding, a certain time will be taken for enough free electrons to be set free. This is the statistical time lag. Once the electrons appear, depending on the voltage applied, they multiply and ionize the space. Once the space becomes conducting, flashover occurs. This is formation time lag. To determine the time lag characteristic of a device, we can use the impulse generator to generate impulses of gradually increasing amplitude and determine the time of breakdown. At each value, the test must be repeated a number of times so as to obtain consistent values.




This type of characteristic is important in designing insulators.If a rod gap is to protect a transformer. Then the breakdown voltage characteristic of the rod gap must be less than that of the transformer so as to protect it. If the characteristic cross, protection will be offered only in the region where the rod gap characteristic is lower than that of the transformer.

| System Voltage | I.E.C Impulse Withstand Voltage |
|---|---|
| 11 kV | 75 kV |
| 33 kV | 170 kV |
| 66 kV | 325 kV |
| 132 kV | 550 kV |
| 275 kV | 1050 kV |

In obtaining the breakdown characteristic of a transformer we do not attempt such tests that cause total destruction on transformers as they are expensive. What is done is we take a sample of the material used as insulators for the transformers and then apply these tests till puncture takes place. Thus the transformer characteristic is obtained by such tests on samples. To obtain one point on the voltage vs time lag characteristic we would have to do a large number of tests and take the mean, as these values vary from sample to sample. The sample would have to be surrounded by a liquid material of high permittivity so that external flashover would not occur. The impulse test voltage recommended by I.E.C. (International Electrotechnical Commission) are given in the table. The recommendation is that device when subjected to this voltage should not suffer permanent damage or minor partial damage. The voltage is set at slightly less than the withstand voltage and gradually increase to test value. About 10 positive impulses and 10 negative impulses are applied.

**Table 4.12.1 : Recommended for maintenance schedule for transformers of capacities less than 1000 kVA (as per IS 1886-1967)**

| Sr. No. | Inspection frequency (2) | Items to be inspected (3) | Inspection notes (4) | Action required if inspection shows unsatisfactory conditions |
|---|---|---|---|---|
| 1. | Hourly | Load (amperes) | Check against rated figures | - |
| 2. | do | Voltage | do | - |
| 3. | Daily | Dehydrating breather | Check that air-passages are clear. Check colour of active agent. | If silicagel is pink, change by spare charge. The old charge may be reactivated for use again. |
| 4. | Monthly | Oil level in transformer | Check transformer level. | If low, top up with dry oil. Examine transformer for leaks. |
| 5. | Quarterly | Bushings | Examine for cracks and dirt deposits | Clean or replace |
| 6. | Half yearly | Non-conservator transformer | Check for moisture under cover | Improve ventilation, check oil. |
| 7. | Yearly | Oil in transformer | Check for dielectric strength and water content. Check for acidity and sludge. | Take suitable action to restore quality of soil. |

| Sr. No. | Inspection frequency (2) | Items to be inspected (3) | Inspection notes (4) | Action required if inspection shows unsatisfactory conditions |
|---|---|---|---|---|
| 8. | do | Earth resistance | – | Take suitable actions if earth resistance is high. |
| 9. | do | Relays, alarms their circuits etc. | Examine relay and alarm contacts, their operation, fuses, etc. Check relay accuracy etc. | Clean the components and replace contacts and fuses if necessary. Change the setting, if necessary. |
| 10. | 2 Yearly | Non-conservator | Internal inspection above core | Filter the oil regardless of condition. |
| 11. | 5 Yearly | – | Overall inspection including lifting of core and coils | Wash by hosing down with clean dry oil. |

### 4.12.1 Factors Affecting the Life of Transfosmer :

**S-11**

- If proper maintenance is not followed the working of transformer will be disturbed and minor or major faults may be developed.
- Following are the factors on which proper working and life of transformer depends :
  - (i) **Moisture :**
    Generally the transformer core and winding assembly is accommodated in the tank which is full of transformer oil.
    - If moisture comes in contact with the oil then dielectric strength of oil reduces.
    - Through oil, the moisture comes in contact with the insulation of the windings and it will be absorbed by the insulation and this will reduce the insulation strength.

26-2

| Sr. No. | Inspection frequency | Items to be inspected | Inspection notes | Action required if inspection shows unsatisfactory conditions |
|---|---|---|---|---|
| 8 | Yearly | Earth resistance | — | Take suitable actions if earth resistance is high |
| 9 | Yearly | Relays, alarms their circuits etc. | Examine relay and alarm contacts, their operation, fuses, etc. Check relay accuracy etc. | Clean the components and replace contacts and fuses if necessary. Change the setting, if necessary. |
| 10 | 2 Yearly | Non-conservator | Internal inspection above core | Filter the oil regardless of condition. |
| 11 | 5 Yearly | — | Overall inspection including lifting of core and coils | Wash by hosing down with clean dry oil. |

## 3.8.2 Maintenance Schedule for Transformer of Capacity more than 1000 KVA :

Table 3.8.2

| Sr. No. | Inspection frequency | Items to be inspected | Inspections notes | Action required if inspection shows unsatisfactory conditions. |
|---|---|---|---|---|
| 1 | Hourly | Ambient temperature. | — | |
| 2 | Hourly. | Winding temperature. | Check that temperature rise is reasonable. | Shut down the transformer and investigate if either is persistently higher than normal. |

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| Sr. No. | Inspection frequency | Items to be inspected | Inspections notes | Action required if inspection shows unsatisfactory conditions. |
|---|---|---|---|---|
| 3. | Hourly | Oil temperature | – | – |
| 4. | Hourly | Load (Amperes) | Check against rated figures. | – |
| 5. | Voltage | – | – | – |
| 6. | Daily | Oil level in transformer. | Check against transformer oil level. | If low, top up with dry oil, examine transformer for leak. |
| 7. | Daily | Oil level in bushing. | – | – |
| 8. | Daily | Leakage of water into cooler. | – | – |
| 9. | Daily | Relief diaphragm | – | Replace if cracked or broker |
| 10. | Daily | Dehydrating breather | Check that air passages are free. Check colors of active agent | If silica gel is pink, change by spare charge, the old charge may be reactivated for use again. |
| 11. | Quarterly | Bushing | Examine for cracks and dirt deposits. | Clean or replace. |
| 12. | Quarterly | Oil in transformer. | Check for dielectric strength and water content | Take suitable action to restore quality of oil. |

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| Sr. No. | Inspection frequency | Items to be inspected | Inspection notes | Action required if inspection shows unsatisfactory conditions. |
|---|---|---|---|---|
| 13. | Quarterly | Cooler fan bearings, motors and operating mechanisms. | Lubricate bearings. Check gear box. Examine contacts. Check manual control and interlocks. | Replace burnt or worn contacts or other parts. |
| 14. | Half yearly | Oil cooler. | Test for pressure. | – |
| 15. | Yearly (or earlier if the transformer can conveniently be taken out for checking). | Oil in transformer. | Check for acidity and sludge. | Filter or replace. |
| 16. | Yearly (or earlier if the transformer can conveniently be taken out for checking). | Oil filled bushing. | Test oil. | Filter or replace. |
| 17. | Yearly (or earlier if the transformer can conveniently be taken out for checking). | Gasket joints. | – | Tighten the bolts evenly to avoid uneven pressure |

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| Sr. No. | Inspection frequency | Items to be inspected | Inspections notes | Action required if inspection shows unsatisfactory conditions. |
|---|---|---|---|---|
| 18. | 2 yearly | Cable boxes | Check for sealing arrangements for filling holes. Examine compound for cracks. | Replace gaskets, if leaking |
| 19. | 2 yearly | Surge diverter and gaps. | Examine for cracks and dirt deposits. | Clean for replace. |
| 20. | 2 yearly | Relays, alarms, their circuits etc. | Examine relay and alarm contacts their operation fuses etc. check relay accuracy etc. | Clear the components and replace contacts and fuses, if necessary. Change the setting if necessary. |
| 21. | 2 yearly | Earth resistance. | - | Take suitable action, if earth resistance is high. |
| 22. | (a) 5 yearly | 1000 to 3000 kVA. | Overall inspection including lifting of core and coils. | Wash by hosing down with clean dry oil. |
| 23 | (b) 7-10 yearly | Above 3000 kVA. | Overall inspection including lifting of core and coils | Wash by hosing down with clean dry oil. |

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## * Routine Preventive Maintenance of a Transformer :-

This includes :-

A)

1) Overall visual inspection without dismantling.
2) Checking oil-level through glass window in conservator tank, cooling systems.
3) Leakages, bushings, conservator.
4) Breather, silica gel colour.

B) Following test are performed :

1) Measurement of insulation resi.
2) Transformer oil breakdown vtg test
3) Gas sample analysis from Buchhols relay.

C) Mechanical Maintenance :-

1) Tightings of fittings, nuts- bolts
2) Oil deposits, dust deposits are scraped & removed from bushing / tanks / tuber etc.
3) Silica gel removal if colour is observed to be changed from pink to blue.
4) To make up oil level in the tank by adding oil.
5) Contaminated oil to be drained out for filtering.

D) Periodic maintenance :-

This includes the following tests :-

i) Dielectric test
ii) Acidity test
iii) Crackle test
iv) Moisture containment

## * Parallel Operation of 3ϕ Transformers :-

### A) Need of Parallel Operation :-

i) Increased Demand of Power :-

During the day, Electrical energy demand is continuosly varying & when total load on existing T/F becomes more than it's rated value, in such cases to meet with requirement, another T/F is to be connected in ||el to existing T/F.

ii) Stand by unit :-

Instead of one unit if such two units are their they one will serves as a "stand by" & in emergency such as failure of one T/F, the stand by unit can be taken into service to continue the supply.

iii) Continuity of service :-

If T/F is to be taken for major maintenance & repairs, the 2nd unit can maintain the continuity of the service.

iv) Efficiency :-

If demand is very less on big capacity T/F then it will be working under loaded at a poor efficiency. In such case small capacity T/F can be put in ||el & first unit of big capacity can be taken out from service so that small capacity unit will run at it's full capacity & better eff.

### B) Conditions for Satisfactory Parallel Operation of 1ϕ T/F :-

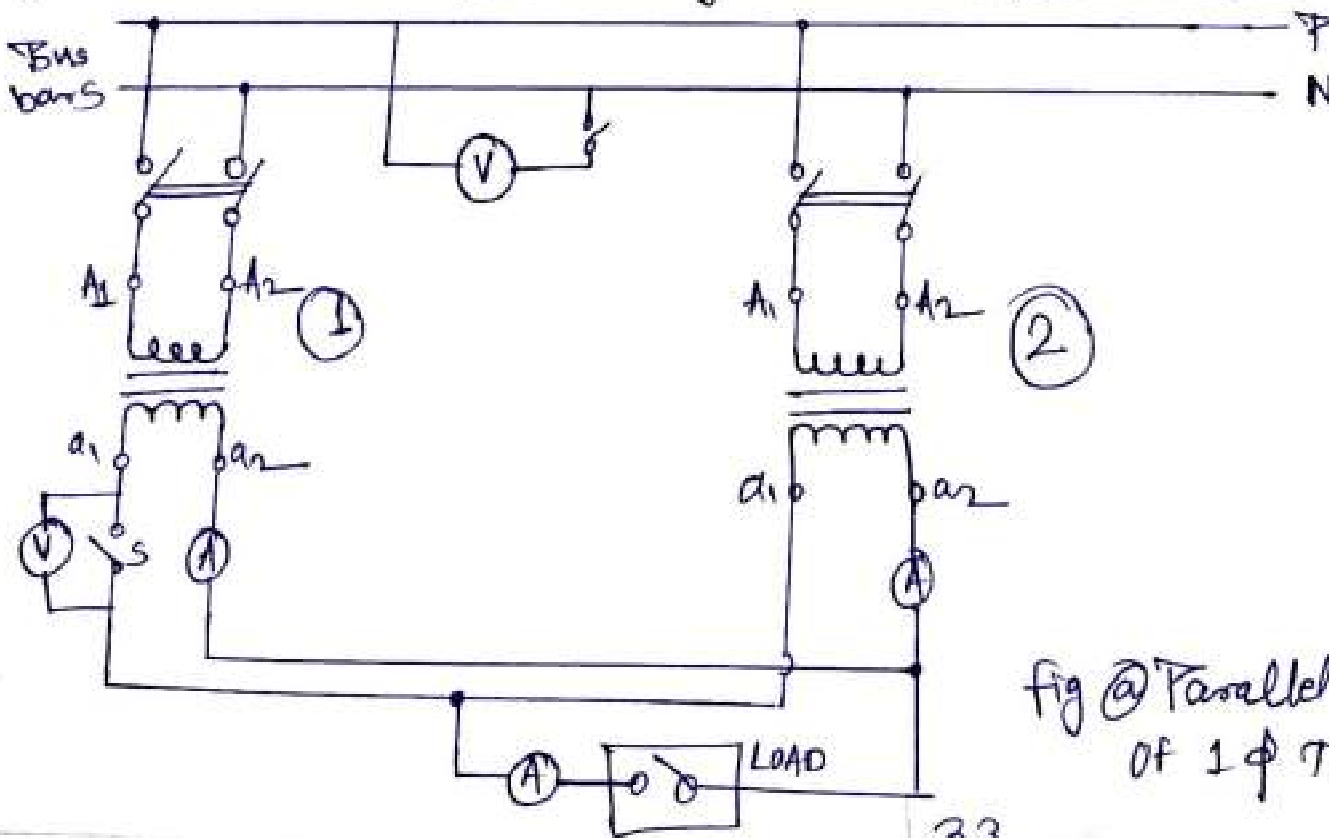


fig @ Parallel Operation of 1ϕ T/F

Conditions :-

- Voltage ratings of primary windings should be suitable for supply system voltage & freq?
- The windings must be properly connected as regards their polarities.
- Voltage ratings of primary & secondary of both T/F must be identical (i.e. they should have same turns ratio or vtg transformation ratio).
- The per unit or % impedances of both should be equal in magnitude & have same X/R ratio to avoid circulating current.
- KVA ratings of both may be same, but if not, they their % impedances should be inversely proportional to individual KVA ratings to avoid circulating current.

* Factors Affecting the Parallel Operation :-

- Wrong polarities, unequal vtg. ratio, different % impedances & impedance triangles, different vtg. ratings of T/F will affect parallel operation.
- All the condition mentioned for satisfactory parallel operation of 1ϕ T/F are also essential for 3ϕ T/F to be connected for parallel operation.

## * Parallel operation of T/F :-

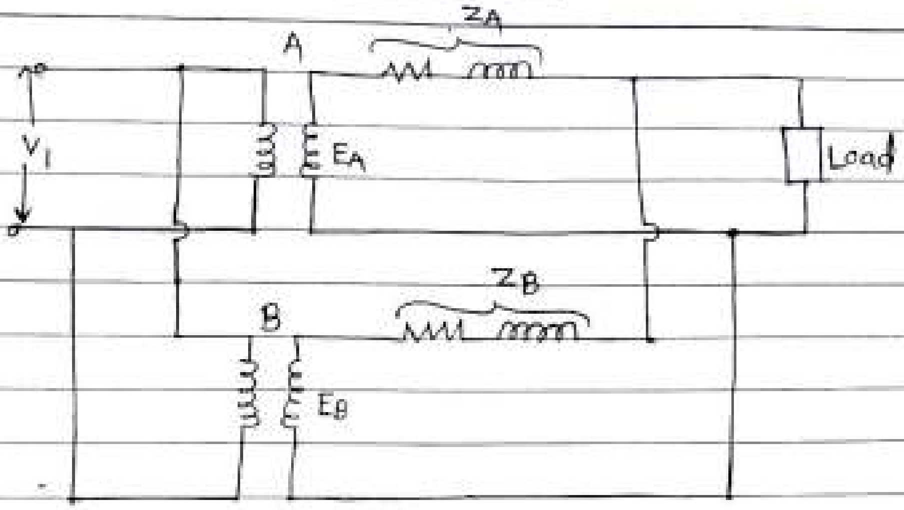


fig - ①

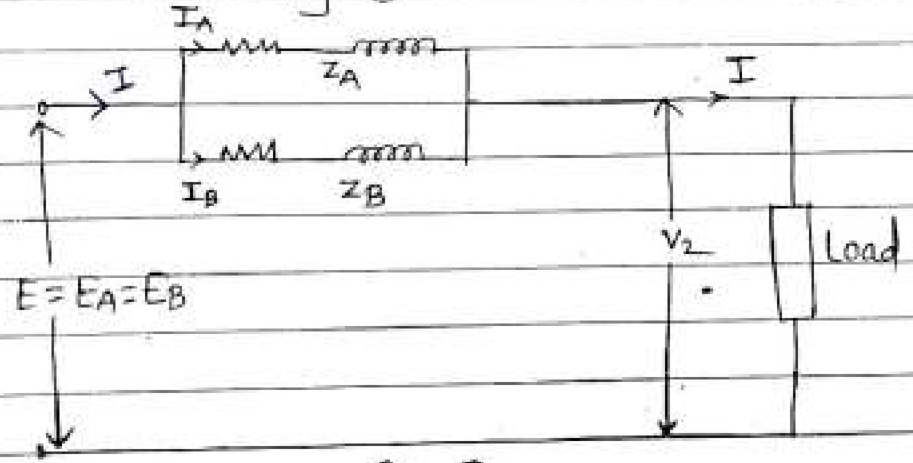


fig - ②

- Fig. shows two single-phase equal voltage ratio T/F A & B in parallel. The secondary emf of two T/Fs are equal because they have same turns ratio & have their primaries connected to the same supply.
- If the magnetising current is ignored, two T/F can be represented by their equivalent ckt referred to secondary.
- It is clear that T/F will share the total load in same way as two impedances in parallel.

Let, $Z_A, Z_B \rightarrow$ impedances of T/Fs referred to secondary.
$I_A, I_B \rightarrow$ respective currents.
$V_2 \rightarrow$ Common terminal voltage
$I \rightarrow$ Total load current.

from fig-②, it is clear that,

$$I_A + I_B = I \quad \text{——— ①}$$

$$I_A Z_A = I_B Z_B$$

$$I_A = I_B \frac{Z_B}{Z_A}$$

$$I = I_B \frac{Z_B}{Z_A} + I_B \qquad (\because I_A + I_B = I)$$

$$\text{or} \quad I = I_B \left[1 + \frac{Z_B}{Z_A}\right]$$

$$I_B = I \frac{Z_A}{Z_A + Z_B} \quad \text{——— ②}$$

similarly,

$$I_A = I \frac{Z_B}{Z_A + Z_B} \quad \text{——— ③}$$

Thus load shared by T/F is independent on load impedance but depends on T/F impedances.

* KVA carried by each transformer -

Let $S$ = total load kVA $= V_2 I \times 10^{-3}$
$S_A$ & $S_B \rightarrow$ KVA carried by T/F A & T/F B.

$$S_A = V_2 \times I_A \times 10^{-3} = V_2 \times I \times 10^{-3} \times \frac{Z_B}{Z_A + Z_B}$$

$$S_A = S \times \frac{Z_B}{Z_A + Z_B}$$

$$S_B = V_2 \times I_B \times 10^{-3} = V_2 \times I \times 10^{-3} \times \frac{Z_A}{Z_A + Z_B}$$

$$S_B = S \times \frac{Z_A}{Z_A + Z_B}$$

Therefore, $S_A$ & $S_B$ are obtained in magnitude as well as in phase from above expressions. $Z_A$ & $Z_B$ can be expressed in ohm or in p.u. If p.u. values are to be used, they should be w.r.t. common base KVA.

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* Ex. 1) Two 1-phase T/Fs with equal vtg ratio have impedance of $(0.819 + j2.503)\,\Omega$ & $(0.8 + j2.31)\,\Omega$ with respect to secondary. If they operate in parallel, how they will share a total load of 2000 kW at p.f. 0.8 lagging?

$$Z_A = (0.819 + j2.503)\,\Omega = 2.633 \angle 71.88^\circ\,\Omega$$

$$Z_B = (0.8 + j2.31)\,\Omega = 2.445 \angle 70.9^\circ\,\Omega$$

$$Z_A + Z_B = (1.619 + j4.813)\,\Omega = 5.078 \angle 71.4^\circ\,\Omega$$

$$\text{Total load KVA} = \frac{2000}{0.8} = 2500\text{ KVA}$$

$= (P + jQ)$

$$S = 2500 \angle -36.87^\circ\text{ KVA}$$

$$S_A = S \frac{Z_B}{Z_A + Z_B} = 2500 \angle -36.87^\circ \times \frac{2.445 \angle 70.5^\circ}{5.078 \angle 71.4^\circ}$$

$$S_A = 1203.7 \angle -37.37 \text{ kVA}$$

$= \text{a load of } 1203.7 \cos 37.37$

$= \underline{956.6 \text{ kW at } 0.79 \text{ p.f. lagging.}}$

$$S_B = S \frac{Z_A}{Z_A + Z_B} = 2500 \angle -36.87^\circ \times \frac{2.633 \angle 71.88^\circ}{5.078 \angle 71.4^\circ}$$

$$S_B = 1296.3 \angle -36.39 \text{ kVA}$$

$= \text{a load of } 1296.3 \cos 36.39$

$= \underline{1043.5 \text{ kW at } 0.805 \text{ p.f. lagging.}}$