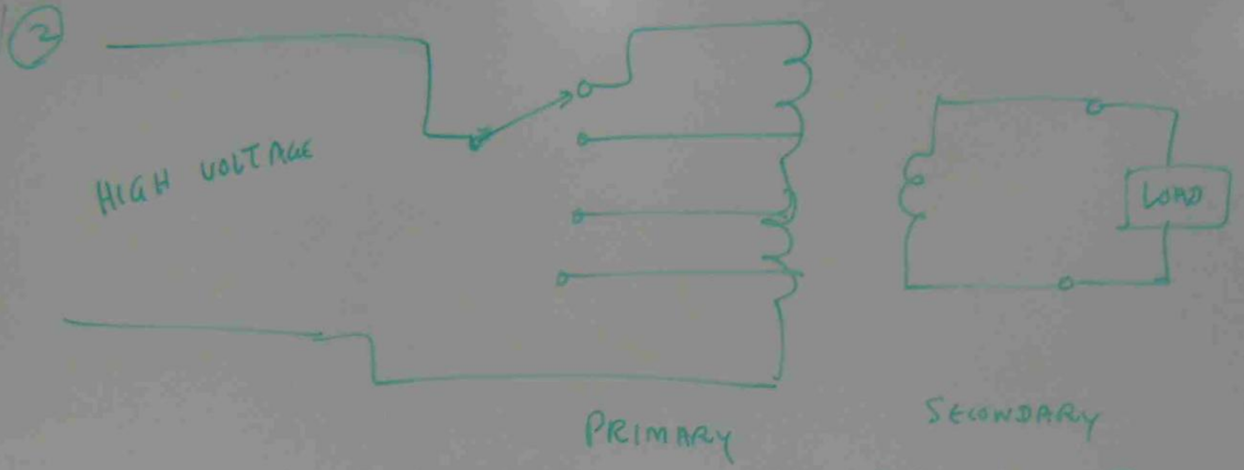
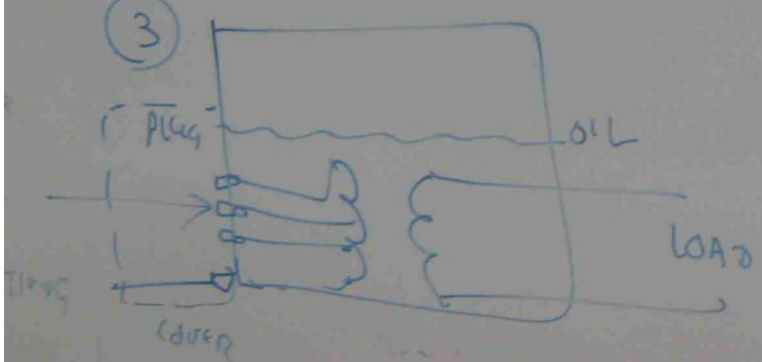
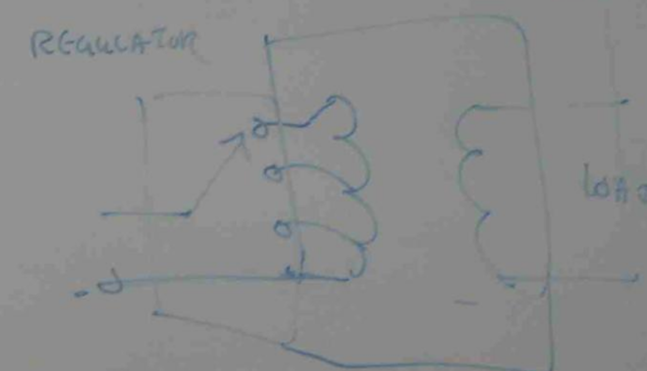
2



HIGH VOLTAGE SIDE HAS LOWER CURRENT. IT IS EASIER TO HANDLE THE LOWER CURRENT. SO VOLTAGE CHANGING IS MADE AT HIGH VOLTAGE SIDE RATHER THAN LOW VOLTAGE SIDE

3





ARRANGEMENT (1)

POWER TRANSFORMER TAPPINGS ARE TERMINATED JUST BELOW OIL LEVEL AND CHANGES ARE MADE MANUALLY BY MEANS OF SWINGING LINKS OR PLUGS ON TERMINAL BOARD

ARRANGEMENT (2)

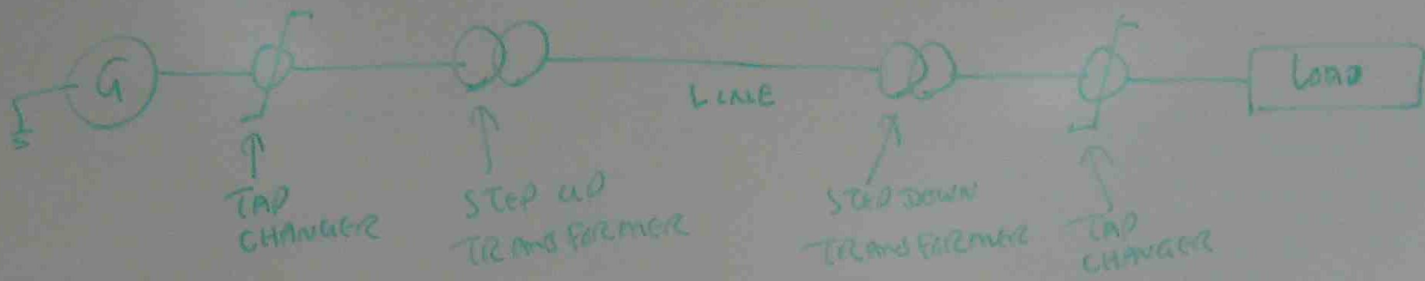
THE TAPPING SELECTOR CAN BE OPERATED FROM OUTSIDE TANK BY A ROTARY MOMENT OF SELECTOR HAND WHEEL

Q4 DESCRIBE BRIEFLY THE VARIOUS STAGES OF ON LOAD TAP CHANGING USED IN POWER SYSTEM

Q5 LIST THE TWO FUNDAMENTAL FEATURES OF NO LOAD TAP CHANGING CIRCUITS.

LOAD

4

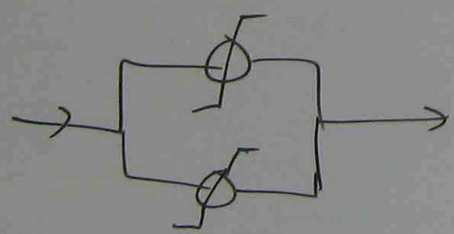


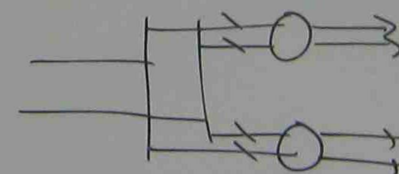
TAP CHANGERS ARE PLACED

(i) AT POWER STATION TO THE STEP UP TRANSFORMER

(ii) AT THE SUPPLY POINT TO CONTROL THE LOWER VOLTAGES TO SMALLER SUB STATIONS.

5





ALL TAP CHANGING CIRCUITS HAVE (i) SOME FORM OF IMPEDANCE WHICH IS INSERTED TO PREVENT THE SHORT CIRCUITING OF TAPPING SECTIONS AND (ii) A DUPLICATE CIRCUIT SO THAT THE LOAD CURRENT CAN BE CARRIED BY ONE CIRCUIT WHILST OTHER TAP CHANGER IS OUT OF ORDER.

Q6 BRIEFLY DESCRIBE THE EFFECT OF TAP CHANGING ON THE LIMITATION OF POWER SYSTEM OPERATION.

DUE TO THE DIFFERENT REACTANCE AT EACH TAP, THE ON LOAD TAP CHANGER HAS THE FOLLOWING IMPLICATIONS ON THE OPERATION OF POWER SYSTEM

(a) AT VARIOUS STEPS, THE SYSTEM IMPEDANCE CHANGES

(b) THE MINIMUM (AND) MAXIMUM TAPPINGS WILL INTRODUCE DIFFERENT FAULT IMPEDANCES.

3ϕ TRANSFORMER VOLTAGE REGULATION, LOSSES AND EFFICIENCY

Pb: 1000 kVA, 6600/415 V 3ϕ Δ/λ TRANSFORMER %R = 1.5 %X = 4 MAXIMUM EFFICIENCY OCCURS AT ½ LOAD

CALCULATE (a) IRON LOSS

(b) FULL LOAD EFFICIENCY AT 0.8 PF LAGGING

(c) MAXIMUM EFFICIENCY AT 0.8 PF LAGGING

$$\%R = \frac{I_{FL_{ph}} \times R}{V_{ph}} \times 100$$

FOR Δ SIDE

$$V_{ph} = V_{LINE} = 6600\,V$$

$$I_{FL} = \frac{kVA \times 10^3}{\sqrt{3} \times V_1} = \frac{1000 \times 10^3}{1.7321 \times 6600} = 87.47 \text{ Amp}$$

$$\Delta \quad I_{FL\,ph} = \frac{I_{FL}}{\sqrt{3}} = \frac{87.47}{1.7321} = 50.5 \text{ Amp}$$

$$1.5 = \frac{50.5 \times R}{6600} \times 100$$

$$R = \frac{1.5 \times 6600}{50.5 \times 100} = 1.96\,\Omega$$

$$\% X = \frac{I_{FL\,ph} \times X}{V_{ph}} \times 100$$

$$X = \frac{\% X \times V_{ph}}{I_{FL\,ph} \times 100} = \frac{4 \times 6600}{50.5 \times 100} = 5.22\,\Omega$$

$\frac{1}{2} \longrightarrow$ MAXIMUM EFFICIENCY

$$W_I = W_{C\,FL(1/2)} = 3\left[I_{FL(1/2)}\right]^2 \times R = 3\left(\frac{50.5}{2}\right)^2 \times 1.96 = 3750 \text{ WATT}$$

(b) % F

AT o

(c)

) % Full load Efficiency at 0.8 pf lagging $= \dfrac{\text{Full load output}}{\text{Full load input}} \times 100 = \dfrac{\text{Full load output}}{\text{Full load output} + W_I + W_{cFL}} \times 100 = \dfrac{\sqrt{3}\, V_L I_L \cos\phi}{\sqrt{3}\, V_L I_L \cos\phi + W_I + 3(I_{FL\,ph})^2 R}$

$$= \frac{1.7321 \times 6600 \times 87.47 \times 0.8}{1.7321 \times 6600 \times 87.47 \times 0.8 + 3750 + 3(50.5)^2 \times 1.96} \times 100 = 97.7\%$$

(c) % maximum efficiency at 0.8 pf lagging $= \dfrac{\text{maximum efficiency output}}{\text{maximum efficiency output} + W_I + W_c} \times 100$

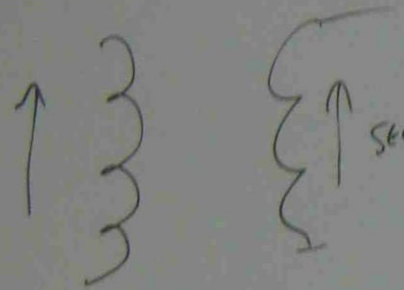
(½ load = maximum efficiency)

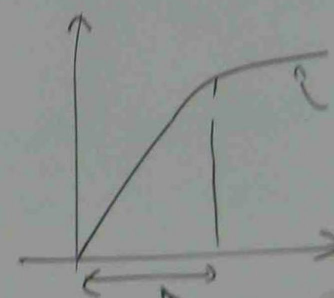
$$= \frac{\sqrt{3}\, V_L I_L \cos\phi}{\sqrt{3}\, V_L I_L \cos\phi + W_I + W_c}$$

$$= \frac{1.7321 \times 6600 \times \frac{1}{2} \times 87.47 \times 0.8}{1.7321 \times 6600 \times \left(\frac{1}{2} \times 87.47\right) \times 0.8 + 3750 + 3750} \times 100$$

$$= 98.15\%$$

UNBALANCED LOAD ON 3ϕ TRANSFORMERS



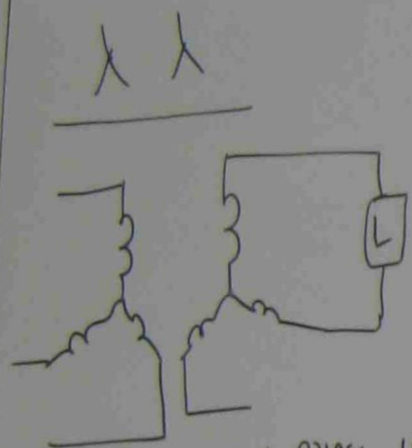


mmf - MAGNETO MOTIVE FORCE

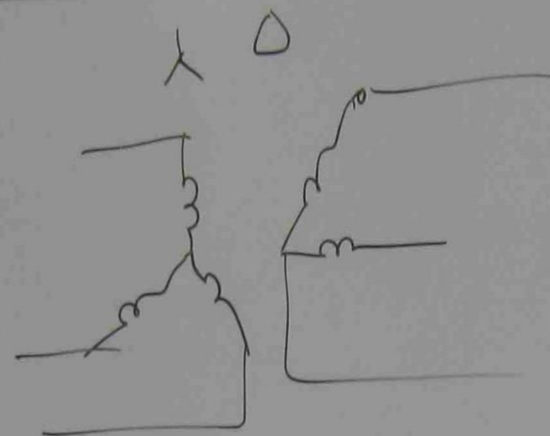
BALANCED LOADING $\quad mmf_{PRI} = mmf_{SEC} \Rightarrow \frac{N_1}{N_2} = \frac{E_1}{E_2} = \frac{I_2}{I_1}$

UNBALANCED LOADING $\quad mmf_{PRI} \neq mmf_{SEC} \Rightarrow \frac{N_1}{N_2} \neq \frac{E_1}{E_2} \neq \frac{I_2}{I_1}$

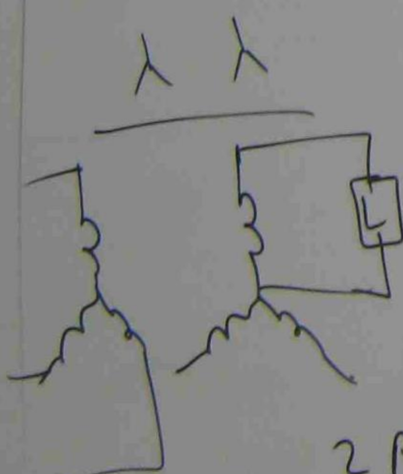
EXAMPLES OF UNBALANCED LOADING



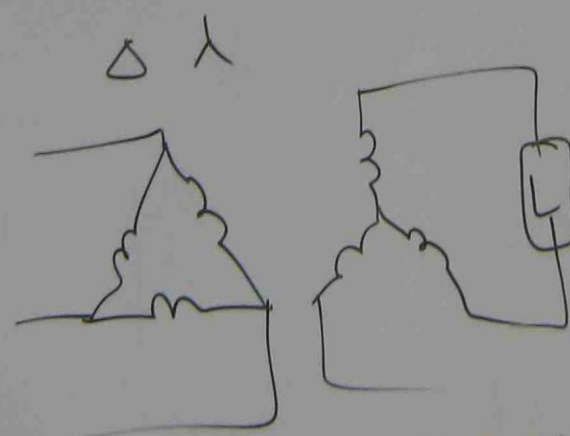
ONE PHASE IS OUT



OPEN DELTA



2 PHASES OUT



ONE PHASE OUT

(OR)

TWO PHASE OUT

IF UNBALANCED LOADING OCCURS, TRANSFORMER CAN NO LONGER FOLLOWS

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

THE SYSTEM OPERATION CAN BE DISORDER.

FOR THIS REASON, BALANCING / TRANSPOSITION OF LINE NEEDS TO BE DONE AT EVERY INTERVAL OF LINE SECTION

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(b) %.

AT

(c)

PARALLEL OPERATION of 3ϕ TRANSFORMERS

TO PARALLEL THE TRANSFORMERS, THE FOLLOWINGS MUST BE IDENTICAL

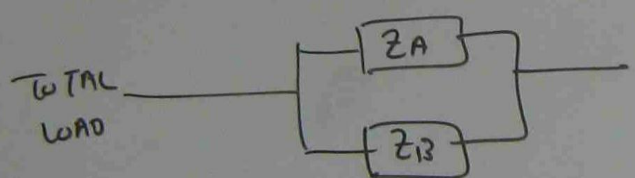
(a) VOLTAGE RATIO

(b) VECTOR GROUPING

(c) % IMPEDANCE

(d) POLARITY

LOAD SHARING of 3ϕ TR



$$TR_A\,(VA) = VA_{TOTAL} \times \frac{Z_B}{Z_A + Z_B}$$

$$TR_B\,(VA) = VA_{TOTAL} \times \frac{Z_A}{Z_A + Z_B}$$

pb TR-A $2+j5\%$ 10 MVA

TR-B $3+j7.5\%$ 20 MVA

CALCULATE (a) % IMPEDANCE OF 20 MVA TRANSFORMER TO BASE 10 MVA

(b) MVA SUPPLIED BY EACH TRANSFORMER IF LOAD IS 15 MVA AT UNITY PF

(c) WHETHER IS IT POSSIBLE TO SUPPLY 30 MVA IN COMBINATION.

(a) TRA $\rightarrow Z_A = 2+j5\%$ (10 MVA)

TRB $$Z_{NEW} = \frac{MVA\ NEW}{MVA\ OLD} \times Z_{OLD}$$

$$= \frac{10}{20} \times (3+j7.5)$$

$$Z_B = 1.5+j3.75\%$$

(b)

$$MVA_{(TR-A)} = MVA_{(TOTAL)} \times \frac{Z_B}{Z_A+Z_B}$$

$$= 15 \times \frac{1.5+j3.75}{2+j5+1.5+j3.75}$$

$$= 15 \times \frac{1.5+j3.75}{3.5+j8.75}$$

$$= 15 \times \frac{\sqrt{1.5^2+3.75^2}}{\sqrt{3.5^2+8.75^2}}$$

$$= 6.43\ MVA$$

$$MVA_{(TR-B)} = MVA_{TOTAL} \times \frac{Z_A}{Z_A + Z_B}$$

$$= 15 \times \frac{2 + j5}{3.5 + j8.75}$$

$$= \frac{15 \times \sqrt{2^2 + 5^2}}{\sqrt{3.5^2 + 8.75^2}}$$

$$= 8.57 \text{ MVA}$$

(c) $$MVA_{(TR-A)} = MVA_{(TOTAL)} \times \frac{Z_B}{Z_A + Z_B}$$

$$= \frac{30 \times \sqrt{1.5^2 + 3.75^2}}{\sqrt{3.5^2 + 8.75^2}}$$

$$= 12.86 \text{ MVA}$$

$$MVA_{(TR-B)} = MVA_{(TOTAL)} \times \frac{Z_A}{Z_A + Z_B}$$

$$= \frac{30 \times \sqrt{2^2 + 5^2}}{\sqrt{3.5^2 + 8.75^2}}$$

$$= 17.04 \text{ MVA}$$

TR-A HAS RATING 10 MVA BUT IT IS ACTUALLY TAKING 12.86 MVA. IT WILL BE OVER LOADED.

ALTHOUGH TOTAL NUMERICAL RATINGS OF TWO TRANSFORMER IN COMBINATION IS 30 MVA, THEY CAN NOT CARRY THE TOTAL LOAD 30 MVA BECAUSE THEIR DIFFERENT % IMPEDANCE CAUSES DIFFERENT LOADING ON THEM.

$$MVA\ (TR\text{-}B) = MVA_{(TOTAL)} \times \frac{Z_A}{Z_A + Z_B}$$

$$= \frac{30 \times \sqrt{2^2 + 5^2}}{\sqrt{3.5^2 + 8.75^2}}$$

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RATING AND COOLING OF TRANSFORMERS

Q1 DESCRIBE THE PRINCIPLE METHODS USED TO COOL LARGE 3ϕ TRANSFORMERS AND THE REASON FOR THEIR USE

Q2 BRIEFLY DESCRIBE THE FOLLOWING SYMBOLS AS SPECIFIED IN AS 2374 PART 2 - 1982 IN RELATION TO COOLING MEDIUM AND CIRCULATION TYPES

(i) SYMBOL FOR COOLING : O L G W A

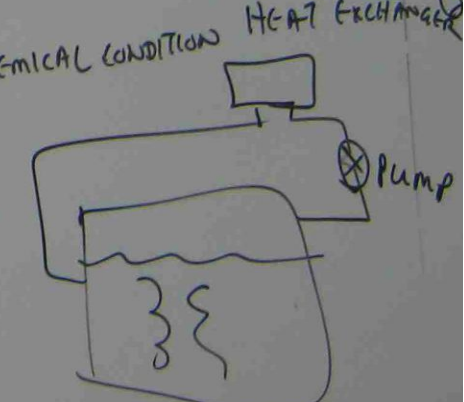
(ii) SYMBOL FOR CIRCULATING TYPE: N F D

Q1 TRANSFORMER'S OUTPUT AND LIFE DEPEND VERY MUCH ON IT'S COOLING CAPABILITY FOR THE FOLLOWING REASONS

(i) THE COPPER LOSSES IN TRANSFORMER VARIES WITH THE SQUARE OF LOAD CURRENT. EFFICIENT DISSIPATION OF HEAT CAN INCREASE THE LOAD CURRENT DELIVERED BY TRANSFORMER

(ii) THE LIFE OF TRANSFORMER IS DEPENDENT ON CHEMICAL CONDITION OF COOLING OIL AND WINDING INSULATION.

THE COOLER TRANSFORMER HAS LONGER LIFE.



Q2 (i) COOLING

O — MINERAL OIL | EQUIVALENT INSULATING OIL
L — NON FLAMMABLE SYNTHETIC INSULATING LIQUID
G — GAS
W — WATER
A — AIR

(ii) CIRCULATION

N - NATURAL
F - FORCED OIL (NOT DIRECTED)
D - FORCED OIL (DIRECTED)

-XCHANGER

Q3 - DESCRIBE THE ARRANGEMENT OF SYMBOLS USED IN COOLING METHODS

Pump

1st LETTER	2nd LETTER	3rd LETTER	4th LETTER
COOLING MEDIUM WHICH IS IN CONTACT WITH TRANSFORMER WINDING		COOLING MEDIUM WHICH IS IN CONTACT WITH EXTERNAL COOLING SYSTEM	
KIND OF COOLING MEDIUM	KIND OF CIRCULATION	KIND OF COOLING MEDIUM	KIND OF CIRCULATION