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MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

1 EXPERIMENTAL INVESTIGATION OF SIMPLE CONSTRUCTION

2 SINGLE TO THREE PHASE CONVERTER

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4 ABSTRACT

This paper shows the behaviour of three phase transformer to work as a single phase to three phase converter. The converter is to supply the three phase load by a three phase sinusoidal wave form voltage.

The converter consists of an ordinary three phase transformer and a capacitor. One coil is connected to the single phase main supply. Another coil on another limb is connected to the capacitor. Three coils, with one coil at each limb, are to supply the load by the three phase voltages.

The hybrid connections of the converter coils and capacitor are to give the 120 degrees shift between the phases, sinusoidal wave form output voltage and symmetrical values of output voltages. The value of the capacitor is chosen to give the 120 degrees shift and the sinusoidal wave form. The number of turns for each of the three output coils are also chosen to give the symmetrical values of output voltages.

The simple construction and good operating characteristics of this converter, enables it to work in light or heavy currents utilization .

INTRODUCTION

In many practical situations, it may become necessary to use 3-phase induction motors on a single phase supply system[1-4] . For example, it has been found technically and economically advantageous[1] to install initially a single wire earth return system for rural electification in remote and hilly regions. The system can be converted to a regular 3-phase power system,by the use of the converter presented in this paper at 3-phase load. A simple construction of static single to three phase converter is presented in this paper. Performance characteristics of the

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converter is investigated at no-load and when the converter is loaded by a resistive load.

SYSTEM OPERATION

Fig.1 shows the system of three phase transformer supplied from single phase supply on phase A. The shunt capacitor is connected across the terminals of phase C. Phase B is disconnected. The load of three phase may be connected to the secondary phases a, b and c. An equal turns are used for the windings A, B,C,a,b& c. Another method of winding arrangement can be used. In which, the windings A, B and C may be used only. The single phase supply may be connected to the coil A. The capacitor may be connected to coil C. The three phase load may be connected to the coils A, B and C.

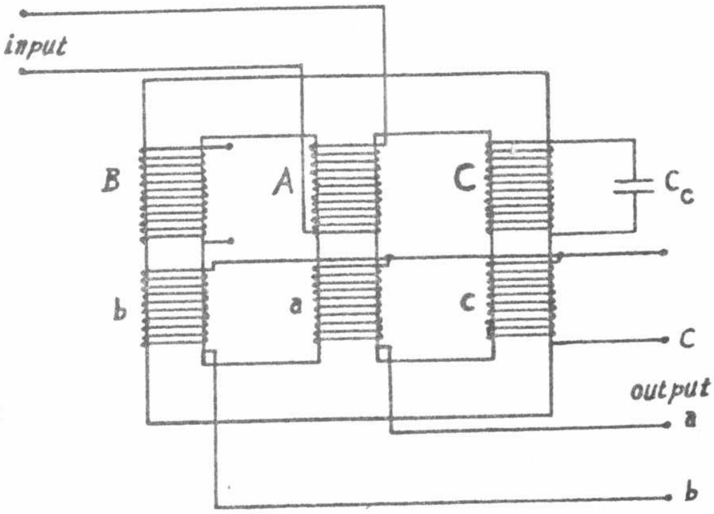

Fig.1.Construction of the converter

CONFORMING THE THREE PHASE WAVES

When the single phase voltage is applied to the converter, the three phase voltages are build up as follows;

* The single phase sinusoidal input voltage applied to the coil A, produces a sinusoidal flux in the iron core. Half value of the flux is $\emptyset_{AB}$ (Fig.2) through the limb of coil B, and the other half is $\emptyset_{AC}$ through the limb of coil C. Both flux $\emptyset_{AB}$, $\emptyset_{AC}$ are sinusoidal wave forms. A sinusoidal emf (E_C) in coil C is initially produced.

* When the capacitor is connected to E_C , a sinusoidal capacitor current I_C lead to a nonsinusoidal flux $\emptyset_{CC}$ which shifts the flux $\emptyset_{AC}$. The nonsinusoidal wave form and the shifting of $\emptyset_{cc}$ are due to the hysteresis loop of iron core.

* Thus, the total flux $\emptyset_C$ in the limb of coil C is the summation of two flux $\emptyset_{AC}$ and $\emptyset_{CC}$. Then $\emptyset_C$ is nonsinusoidal and produces

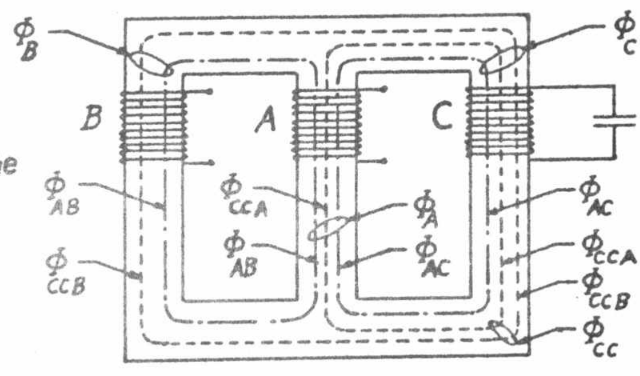

Fig.2.Flux paths of the converter at no-load

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a nonsinusoidal emf in the coils C,c.

* The flux ϕ_{CC} continuous through the limb of coil B as ϕ_{CCB} and limb of coil A as ϕ_{CCA}. Thus, the total flux in the limb of coil B (ϕ_B) may be the summation of flux ϕ_{AB} and ϕ_{CCB}. The total flux in the limb of coil A may be constant at the initial value ϕ_A, because the input current may be varied to produce a flux opposite to ϕ_{CCA} and cancels each other.

* Thus, the flux ϕ_A, ϕ_B and ϕ_C are shifted between each other as shown in Fig.3 to produce a three phase emfs.

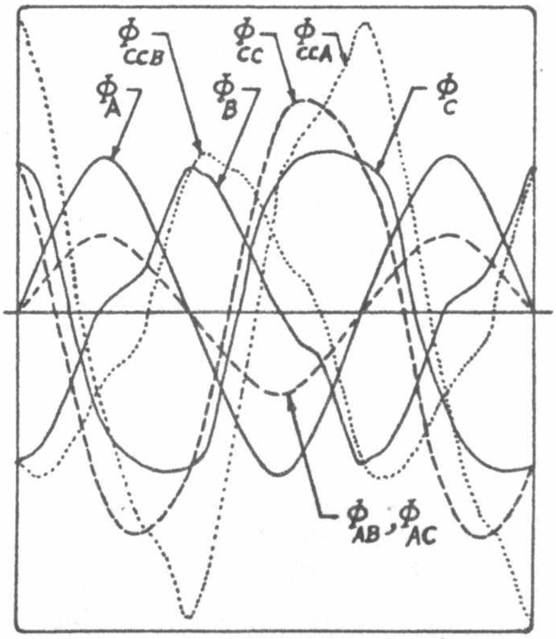

Fig.3.Wave forms of the converter flux paths at no-load

Flux paths in the iron core of the converter, indicates the following relations of flux waves

$$\phi_{AC} = \phi_{AB} = 0.5\ \phi_A \quad ,$$

$$\phi_C = \phi_{AC} + \phi_{CC} \quad ,$$

$$\phi_B = \phi_{AB} + \phi_{CCB} \quad \text{and}$$

$$\phi_{CC} = \phi_{CCA} + \phi_{CCB}$$

The waves of Fig.3 are recorded as follows;
The emf across the coil a indicates the wave of ϕ_A. Also, the emf across the coils b and c indicates the waves of ϕ_B and ϕ_C respectively.

The emf across two coils (connected in series with opposite directions), one coil on limb A and the second on limb B, indicates the wave of ϕ_{CCB} (the coil on limb A has a half number of turns of the coil on limb B, because $\phi_{CCB} = \phi_B - \phi_{AB}$).

In the same manner of recording ϕ_{CCB}, the wave of ϕ_{CC} is recorded from a two coils on the limbs A and C.

Also, the wave of ϕ_{CCA} is recorded from a two coils (with equal turns) on the limbs B and C.

EFFECT OF THE CAPACITOR VALUE AT NO-LOAD

When the capacitance value is varied, the output voltage V_a is not affected, because it is dependent on the supply voltage V_A. However, the capacitance increase lead to an increase in both voltages of phases b and c, with a higher value of the voltage in phase c than in phase b, as shown in Fig.4.

For an equal voltages of the three phase output, a capacitor of 30 μf can be used (for a 220-V on phases a,b) with a smaller turns of phase c to reduce its voltage to the 220-V.

Nearly sinusoidal output voltages are obtained for different values of the capacitance from about 15 μf to 35 μf as shown in Fig.5.

Distortion in the wave form at a capacitance lower than 15 μf (Fig.6) or higher than 35 μf (Fig.7) .

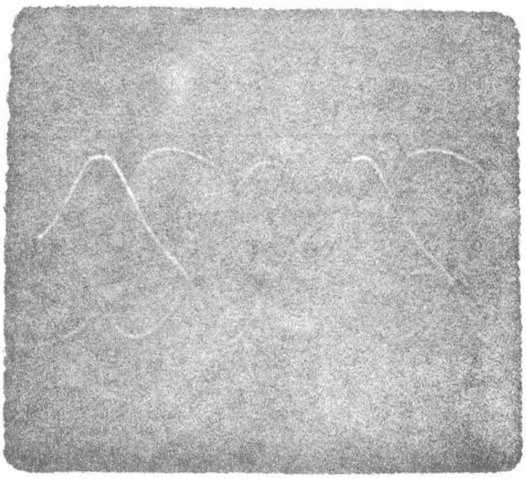

Fig.5.Output voltage wave forms at suitable capacitance of 20 μf

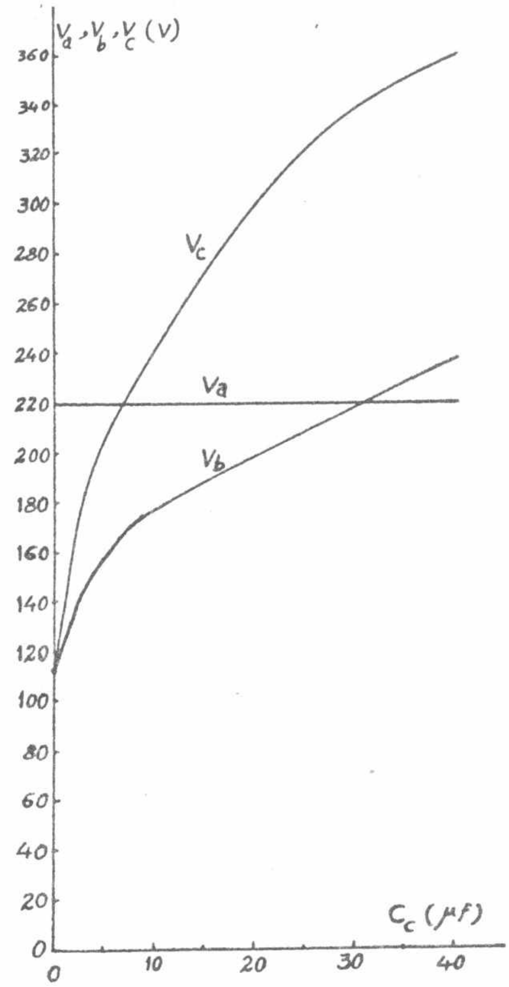

Fig.4.Variation of output voltages with the capacitance C_C

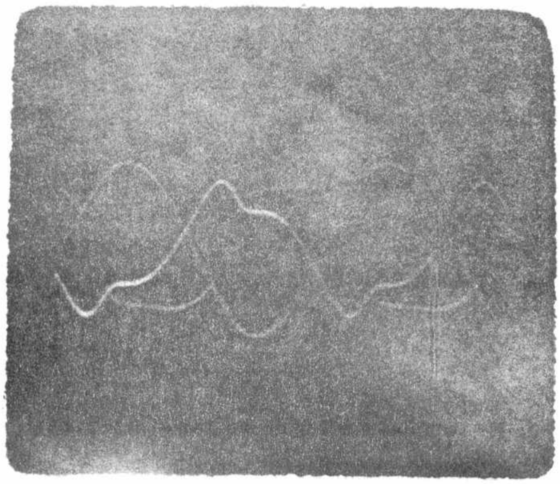

Fig.6.Output voltage wave forms at lower capacitance of 3.6μf

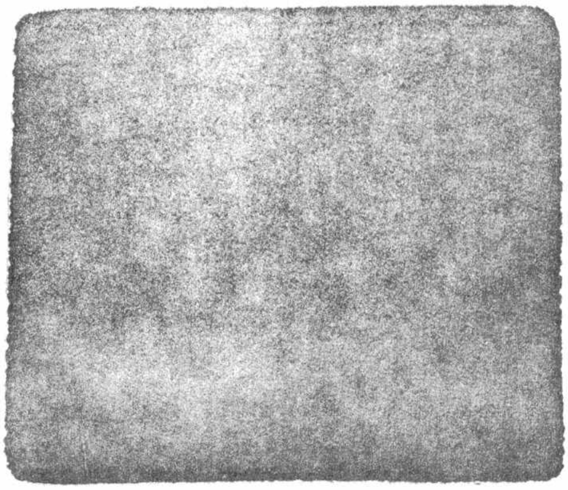

Fig.7.Output voltage wave forms at higher capacitance of 48μf

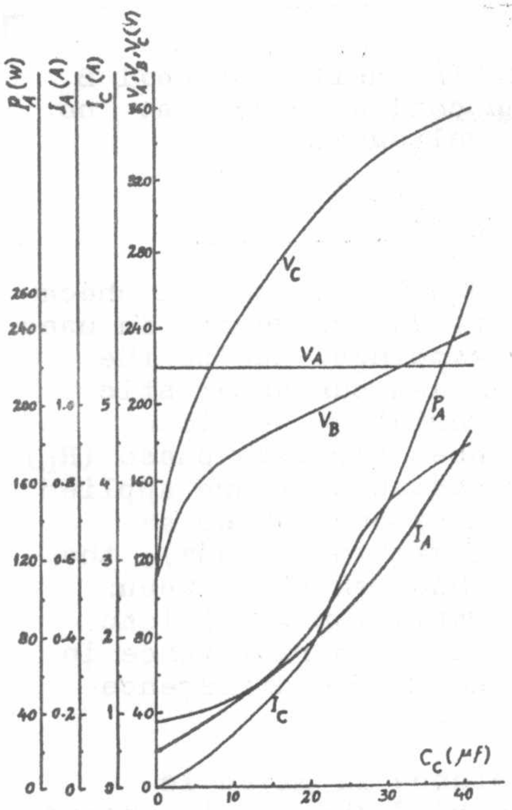

Fig.8. Variation of primary voltages, currents and power with C_C

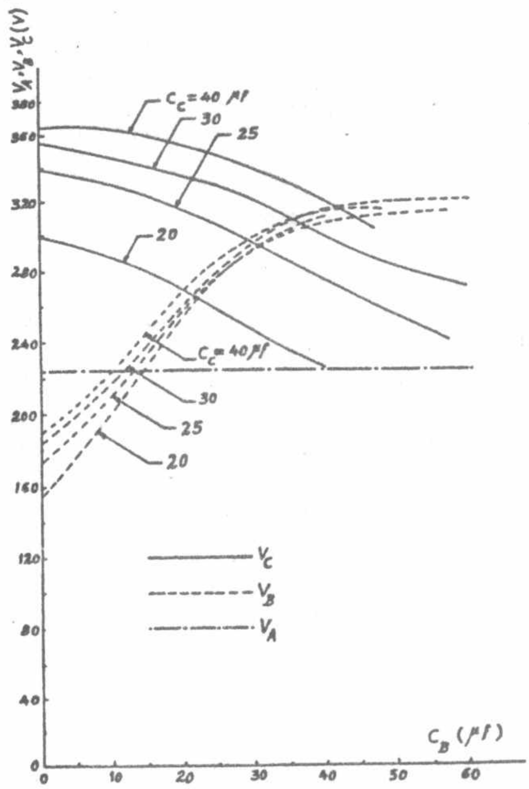

Fig.9. Variation of converter voltages with C_B at different values of C_C

The variation of primary voltages V_B, V_C are similar to that of secondary voltages V_b, V_c as shown in Fig.8. Thus, a three phase autotransformer can be used as a converter.

The input current (I_A), capacitor current (I_C) and input power (P_A) variation with capacitance value (C_C) are given in Fig.8. It is observed that the input current to the converter is smaller than the necessary capacitor current. This means that the converter input power factor is high at no-load. The input power factor reachs the unity at the suitable capacitor value.

EFFECT OF ADDITIONAL CAPACITOR

Another capacitor C_B can be connected across the coil B. The effect of C_B on the values of output voltages is given in Fig.9. The voltage V_B can reach the voltage V_C. But the wave form of V_C is distorted as shown in Fig.10. Also the converter currents and losses are increased and the efficiency is decreased. Thus, a single capacitor C_C may be sufficient to give a three phase output voltages with a suitable wave forms.

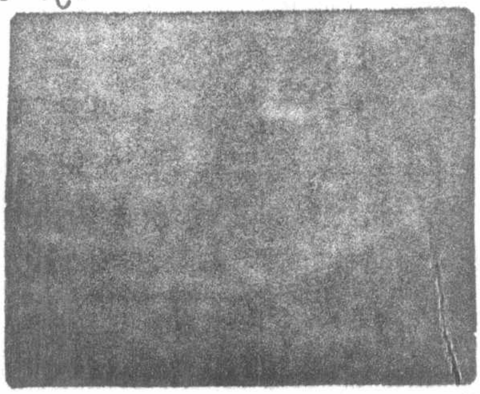

Fig.10. Voltage wave forms with C_B

The single capacitor can be connected to the coil C or coil B. But if the capacitor is connected to the coil A or coil a, no shift can be occured between the output voltages.

CONVERTER LOAD CHARACTERISTICS

Three values of the capacitor (10,20 & 30 μf) are used to check the load characteristics of the converter. The converter is used with a similar turns of the three phase windings. Due to the differences between output voltages, the load characteristic curves (Fig.11 - 13) are given with the variation of load resistance R_L. In which the load resistances for each phase (R_L) are similar. Thus, when a similar load resistances are applied to the converter output, the output voltages are varied as shown in Fig.11. At a small resistances (near to 200 ohm), the voltages V_b and V_c are reduced, and the phase shift between phases b,c is decayed. The load current variation with load resistance is given in Fig.12. For the same load resistance in each phase, the load current is differ due to the difference between phases voltage.

The load power variation with load resistance is given in Fig.13. It is observed that the load power of phase C is approximately constant during a wide range of load resistance variation. Acceptable values of the converter efficiency are obtained during the load resistance variation as shown in Fig.13.

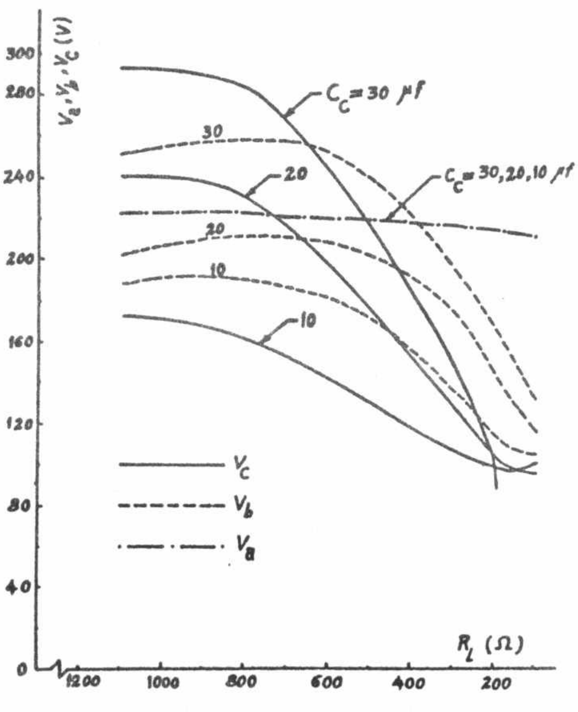

Fig.11.Output voltage variation with load resistance

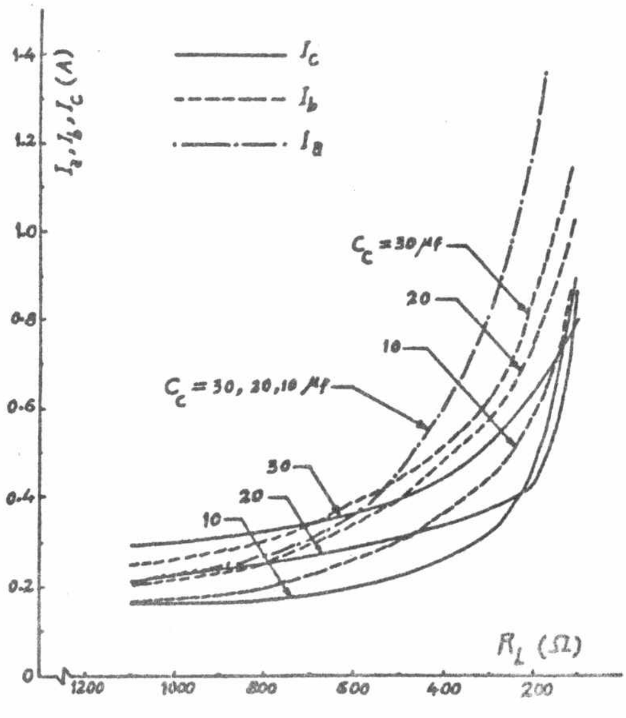

Fig.12.Load current variation with load resistance

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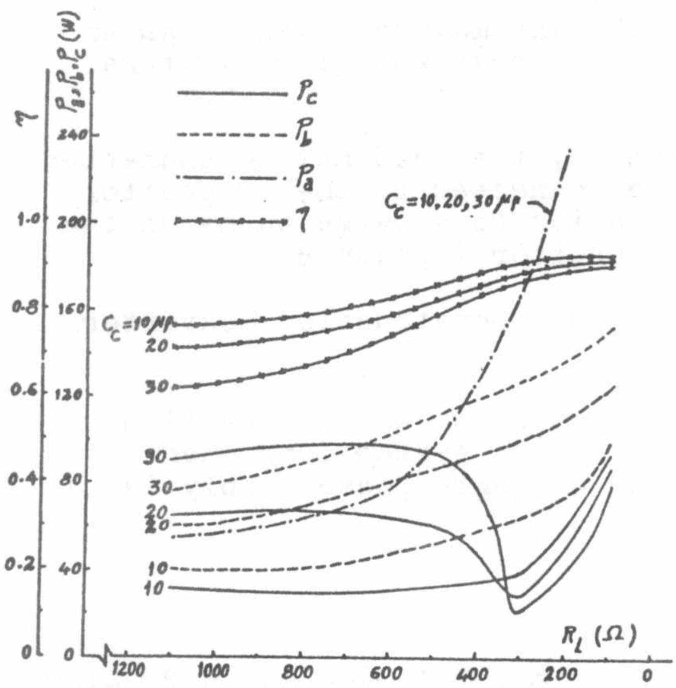

Fig.13. Variation of load power and converter efficiency with load resistance

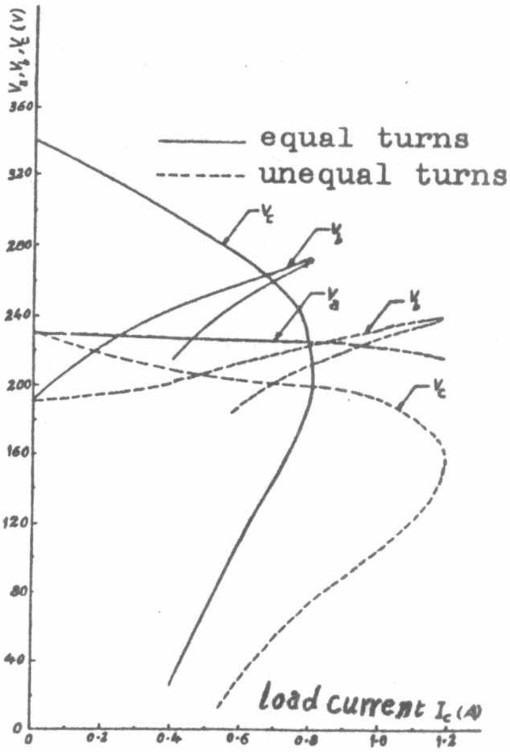

Fig.14. Load voltage variation for equal and unequal turns

LOAD VOLTAGE STABILIZATION

The load voltage is reduced for phases b, c by reducing the load resistance as shown in Fig.11. To keep the load voltages nearly constant during the variation of load resistances, the load of phase c may be connected to a small number of turns on phase c as shown in Fig.14. The number of turns on phase c may be choosen to give the load voltage of phase c equal to the load voltage of phase a.

In other words, the equalized turns of three phase coils lead to an unstable load voltages, but a tapping point on phase c (in case of autotransformer) can be used to keep the load voltages V_a , V_b and V_c constant.

Moreover, the maximum load current may be increased in case of unequal turns than with equal turns as shown in Fig.14.

CONCLUSIONS

The three phase transformer is used as a single to three phase converter. For improved characteristics, the following procedure should be taken into account ;

* Only one capacitor will be sufficient for the converter.
* The capacitor value can be chosen to give a sinusoidal output voltages with a three phase shift.

* Only three coils on the three limbs may be used (as an autotransformer) for high efficiency and low voltage regulation.

* For output voltage stabilization, the load may be connected to a small turns on the phase connected to the capacitor (phase C), while it is connected to a large turns on the phase not connected to the capacitor (phase B).

A small size can be used as a simple construction converter for light current applications.

The large size of the converter can be used in traction applications, single wire earth return system ; or when three phases are needed while only a single phase supply is available.

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