Welding Transformer: Principle, Requirement and Types

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After reading this article you will learn about:- 1. Operating Principles of a Welding Transformer 2. Requirements of a Welding Transformer 3. Types.

Operating Principles of a Welding Transformer:

In an ac welding arc the current remains nearly sinusoidal while the voltage is distorted as shown in Fig. 4.9.

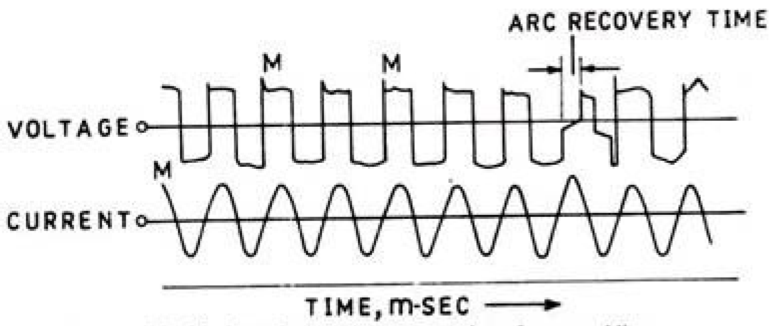


Fig 4·9 Arc voltage and current transients for a.c. welding.

Considering these transients, point M indicates the voltage required to strike an arc. The lime during which the voltage rises from zero to the voltage sufficient for re-ignition of .arc is termed as the ARC RECOVERY TIME. On the arc voltage transient it is denoted by If the arc is to be steady and quiet, the time Y should be as short as possible, because otherwise during the intervening interval the cathode might become too cold to emit adequate number of electrons and ions to reignite and sustain the arc.

One way to reduce t_1 is to raise the open circuit-voltage of the welding power source, as is evident from Fig. 4.10. Voltage curve 2 has lower peak value than the voltage curve 2. With curve 1 the arc striking voltage is E and the arc recovery time is t_1 .In the case of curve 2, with the same re-igniting voltage E the arc recovery time t_2 is considerably longer than t_1.

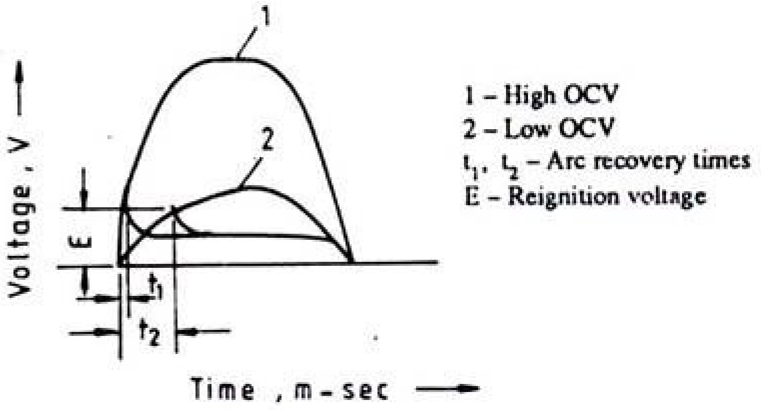


Fig. 4·10 Effect of OCV on arc recovery time in a.c. welding.

For maintaining a sustained ac arc the welding circuit should contain an inductance* which would produce a phase difference, between the voltage and current transients, of the order of 0-35 to 0-45.

When welding with low currents, the cathode loses more heat than when welding with high currents. Therefore, in the former case the arc recovery time should be as short as possible. For example, with a current of 160 to 250 amperes an arc is readily initiated when the transformer has an open circuit voltage of 55 to 60 volts while with small currents, say, 60 to 70 ampere the no load voltage of the transformer should be 70 to 80 volts.

However, an increase in the open circuit voltage may endanger the welder's safety and impair the power factor (i.e. Arc voltage/Open circuit voltage) of the welding transformer. It is therefore imperative to keep the open circuit voltage as low as possible within the applied constraints.

Requirements of a Welding Transformer:

A welding transformer should satisfy the following requirements:

1. It should have a drooping static volt-ampere characteristic.

2. To avoid spatter, the surge of the welding current during a short- circuit should be limited to the least possible above the normal arc current.

3. The open circuit voltage should not normally exceed 80 volts and in no case 100 volts.

4. The output current should be controllable continuously over the full available range.

5. The open circuit voltage should be just sufficiently high for ready initiation of an arc and not too high to impair the economics of welding.

Basic Types of Welding Transformers:

The four basic types of welding transformers are:

1. The high reactance type,

2. The external reactor type,

3. The integral reactor type, and

4. The saturable reactor type.

1. The High Reactance Type Welding Transformer:

When a transformer supplies current, magnetic fluxes are produced around its windings.

The lines of the resultant magnetic flux, ϕ, traverse the magnetic circuit and cut the primary (I) and secondary (II) windings as shown in Fig. 4.11. However, not all the magnetic flux lines do so. Some of the lines of magnetic flux due to primary current do not cut the secondary turns and vice-versa, since both have their paths in the air.

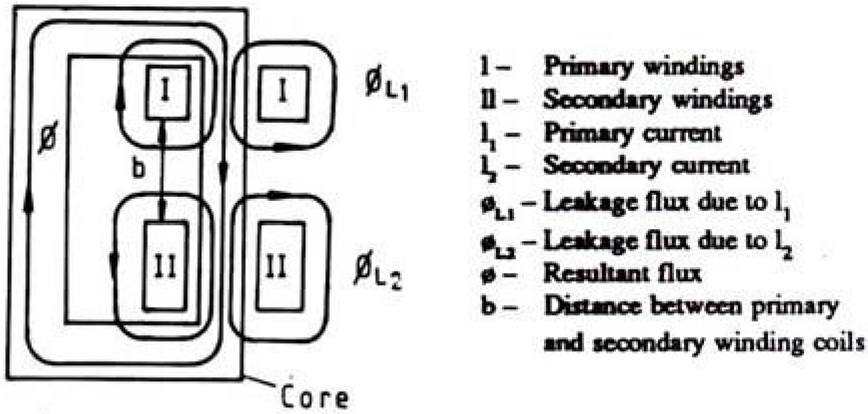
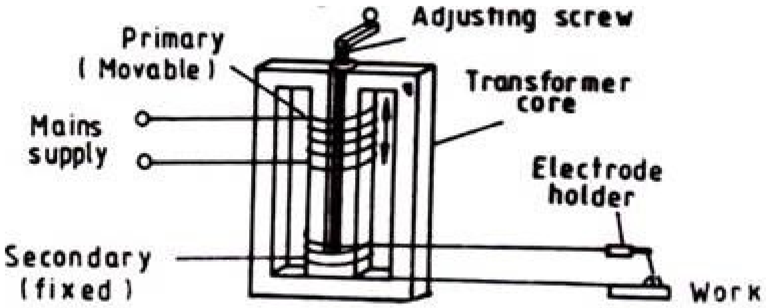


Fig. 4·11 Schematic of a high reactance type welding transformer windings.

In the diagram these partial fluxes have been marked as ϕ_{L1} and ϕ_{L2}. In other words, they are responsible for the reactance* of the coils and the respective reactive voltage drops across them. As the current increases, the leakage fluxes also increase and so does the e.m.f. of self-induction. This is why an increase in the primary or secondary current results in increase in the reactive voltage drop across the respective windings.

For a welding transformer to have a steeply drooping volt-ampere characteristic, both the primary and the secondary windings should have a high reactance i.e., they should have considerable leakage fluxes. This condition is satisfied by placing the primary and the secondary windings either on separate limbs or on the same limb but spaced some distance apart, for example, distance ‘b’ in the above figure.

Control of current in high-reactance welding transformers can be affected by three methods. One of them involves a moving primary coil as shown in Fig. 4.12. As the spacing between the windings is varied so does the reactance and hence the output welding current.



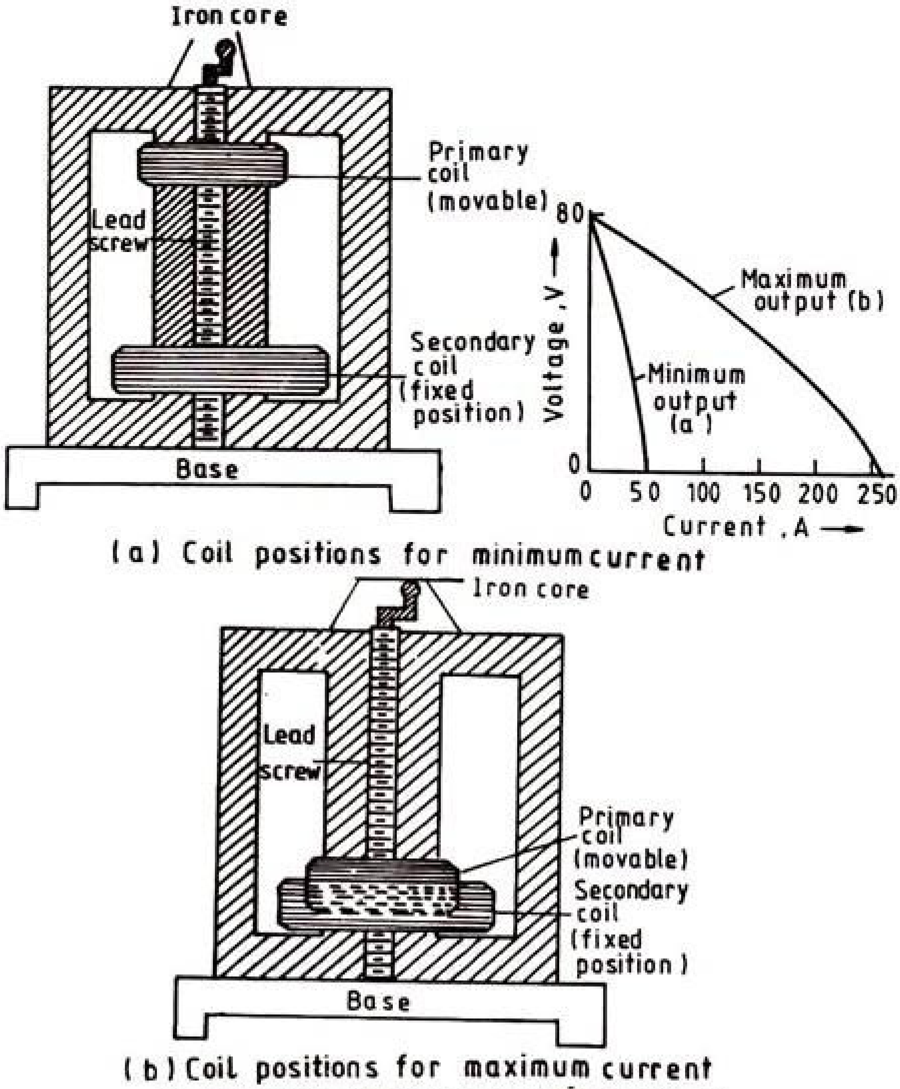


Fig. 4-12 Moving coil high-reactance welding transformer.

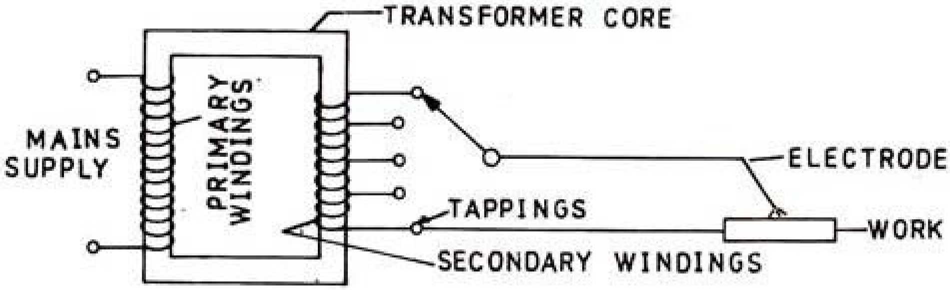


Fig. 4-13 Tapped type high reactance welding transformer.

The second method is based on the use of tapped windings either on the primary or the secondary side and the variation of the transformation ratio can be done by bringing in or out of circuit the requisite number of turns, as shown in Fig.4.13.

The third method utilises movable magnetic shunt. The position of the shunt placed in the paths of the leakage fluxes, as shown in fig. 4.14, controls the output welding current through control of reactance.

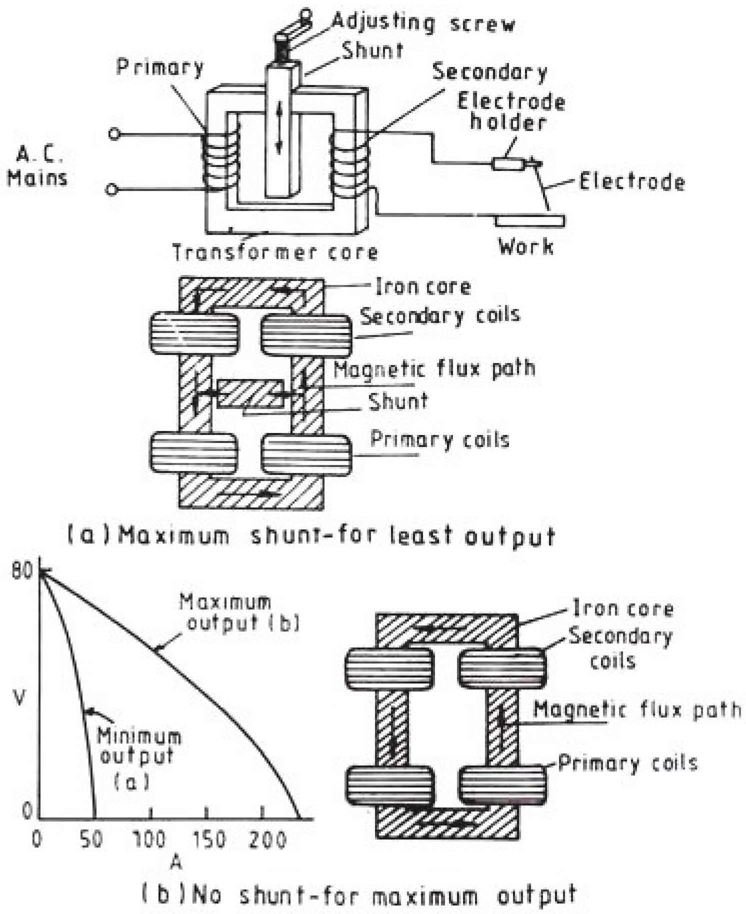


Fig. 4-14 High reactance welding transformer with movable magnetic shunt.

2. External Reactor Type Welding Transformer:

This type of welding transformer consists of a normal reactance, single phase, step down transformer and a separate reactor or choke.

The inductive reactance’s and resistances of the windings in such a welding transformer are low, so that its secondary voltage varies but a little with the welding current. The required drooping or negative volt-ampere characteristic is ensured by the reactor placed in the secondary of the welding circuit The reactor consists of a steel core and a winding wound with a wire designed to carry the maximum allowable current.

If the secondary voltage of the welding transformer is V_2, the arc voltage is V_{arc} and the total resistive cum reactive drop across the reactor is V_2 then the three quantities can be diagrammatically shown as in Fig. 4.15 and are related mathematically as follows.

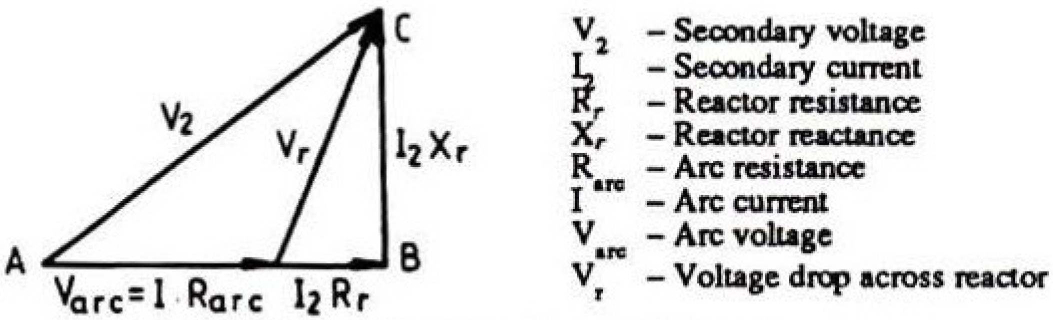


Fig. 4·15 Vector diagram relating different voltages in an external reactor welding transformer.

$$\overline{V_2} = \overline{V_{arc}} + \overline{V_r}$$

$$\overline{V_{arc}} = \overline{V_2} - \overline{V_r}$$

Thus, the arc voltage decreases with increase in current, or with increase in voltage drop across the reactor. This gives a negative or drooping volt-ampere characteristic.

Control of welding current can be achieved by two methods viz., by varying the reluctance of the reactor (the moving core reactor) or by varying the number of turns of the winding brought in circuit (the tapped reactor).

The core of the moving core reactor, as shown in Fig. 4.16, consists of a fixed portion carrying the winding, and a moving limb, which can be shifted towards or away from the fixed core by a suitable arrangement, thus varying the air gap between them. An increase in air gap adds to the reluctance of the magnetic circuit of the reactor, while its self-induction and inductive reactance drop, so that the welding current increases.

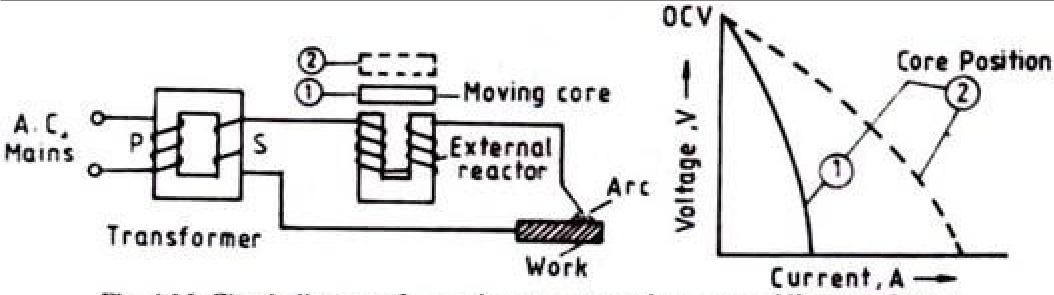


Fig. 4·16 Circuit diagram of a moving core external reactor welding transformer.

When the air gap is reduced, the reluctance of the magnetic circuit is also reduced, the magnetic flux increases, as does the inductive reactance of the coil, and the welding current drops. In this way the welding current can be adjusted very accurately and continuously.

In the tapped reactor the core is made solid but the coil is divided into a number of sections, each section having a tap brought out to the regulator point, as shown in Fig. 4.17. Moving a contact arm across the taps will vary the number of turns brought in circuit, and with that the magnitude of welding current. Thus the current is controlled in steps.

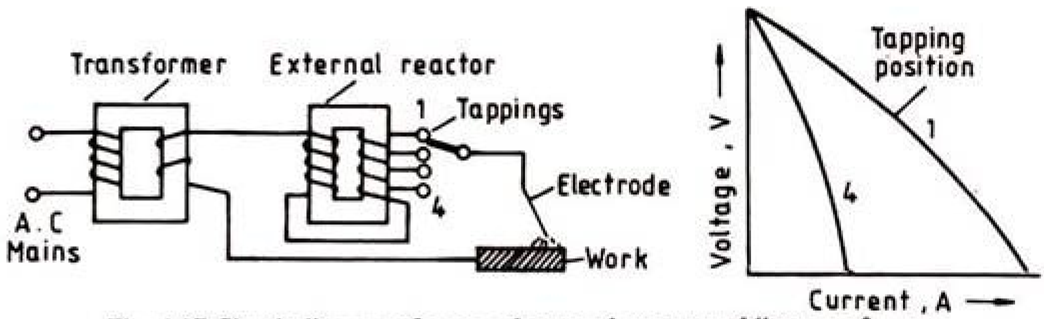
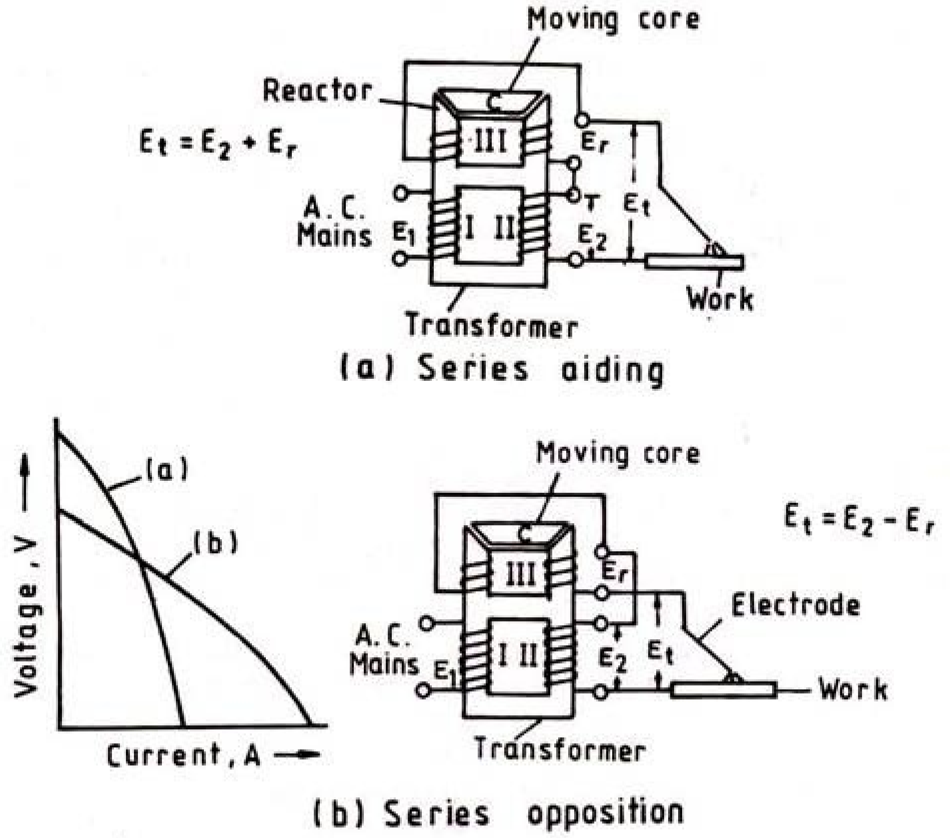


Fig. 4·17 Circuit diagram of a tapped external reactor welding transformer.

3. Integral Reactor Type Welding Transformer:

The welding transformer of the integral reactor type, shown in Fig. 4.18 has a primary winding I, a secondary winding II, and a reactor winding III. Apart from the main limbs, the core has additional limbs carrying the reactor winding. The current is adjusted by means of moving core C placed between the additional limbs.



E_1 – Primary voltage
E_2 – Secondary voltage
E_r – Voltage drop across reactor
E_t – Total voltage across welding circuit

I – Primary windings
II – Secondary windings
III – Reactor windings

Fig.4·18 Circuit diagrams of integral reactor type welding transformers.

The part that carries winding I and II is thus the transformer proper and the part carrying winding III is the reactor.

The reactor can be connected with the secondary either in series aiding, or in series opposition.

When the reactor is connected in series aiding, figure 4.18(a), the open circuit voltage of the transformer will be

$E_t + E_2 + E_r$

where E_2 is the secondary voltage of the transformer and E_r is the reactor voltage.

Series aiding connection produces a stable arc at low currents and is employed for welding thin plates.

When reactor is connected in series opposition, as shown in Fig. 4.18(b), its voltage is subtracted from the open circuit voltage of the transformer, that is,

$E_t + E_2 – E_r$

Series opposition connection is used for welding thick plates with heavy currents.

4. Saturable Reactor Type Welding Transformer:

In this welding transformer an isolated low voltage, low amperage dc circuit is employed to change the effective magnetic characteristics of the magnetic core. Thus, a large amount of ac is controlled by using a relatively small amount of dc, hence making it possible to adjust the output volt-ampere characteristic curve from minimum to maximum. For example, when there is no dc flowing in the reactor coil, it has its minimum impedance and thus maximum output of the welding transformer.

As the magnitude of dc is increased with the help of rheostat in the dc circuit, there are more continuous magnetic lines of force thus the impedance of the reactor is increased and the output current of the welding transformer is decreased. This method has the advantage of removing movable parts and flexing conductors and is often used for gas tungsten arc welding power supplies.

Fig. 4.19 shows the basics of the circuit for a simple saturable reactor power source. To achieve the desired aim of low voltage and high current the reactor coils are connected in opposition to the dc control coil.

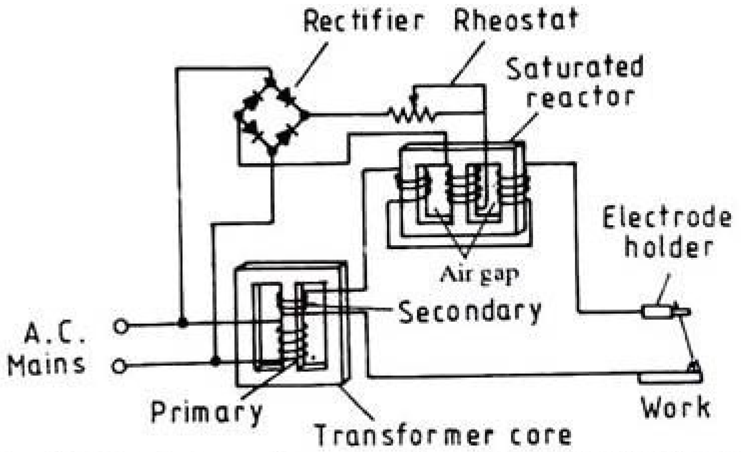


Fig. 4·19 Circuit diagram for a saturable reactor welding transformer.

With ac, the wave form for gas tungsten arc welding is quite important. Saturable reactor tends to cause severe distortion of the sine wave supplied from the transformer. Placing an air-gap, as shown in Fig. 4.19, in the reactor core is one method of reducing this distortion. Alternatively, a large choke can be inserted in the dc control circuit. Either method, or a combination of the two, will produce the desired result.

Parallel Operation of Welding Transformers:

In welding operation sometimes there is a need for current exceeding the maximum welding current obtainable from one transformer. In such a case the desired welding current can be obtained by parallel operation of two or more welding transformers.

The precaution needed for such a parallel operation is that the no-load or open circuit voltages of the transformers should be the same. This is particularly essential in the case of high reactance type welding transformers where the open circuit voltage and the transformation ratio vary to some extent according to the adjustment conditions and the control step.

When two transformers are connected for parallel operation, as shown in Fig. 4.20, the like terminals of the primary windings are to be connected to the identical line wires A, B, C of the supply mains thus ensuring the coincidence of e.m.f. phases in the secondary windings. Then the like terminals of the secondaries are to be connected in pairs as shown. Such three phase double operator transformers are marketed in India by M/s ES AB India Limited.

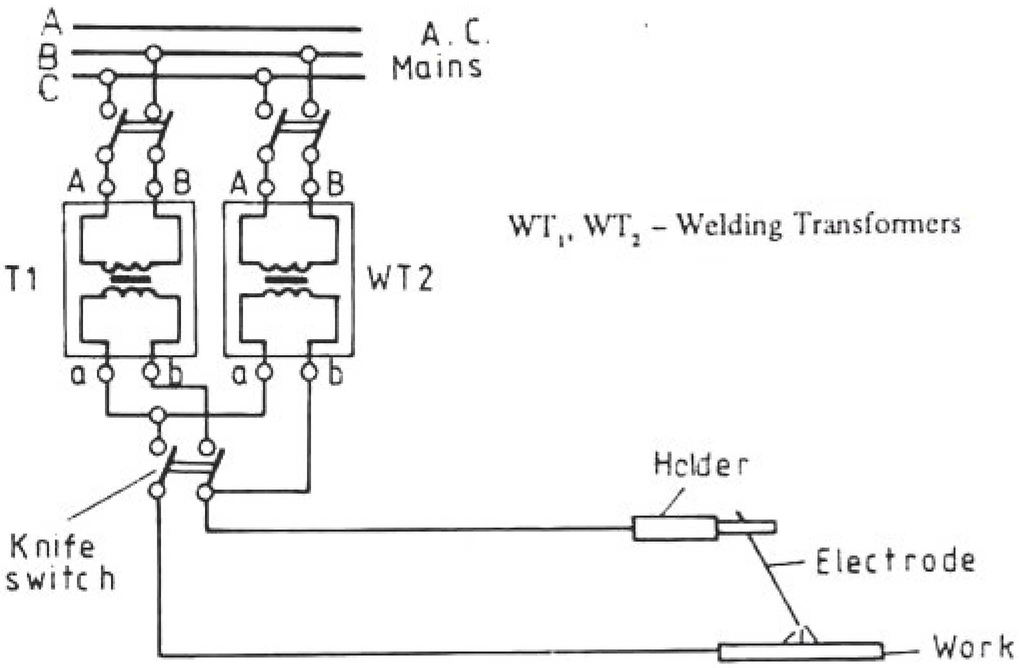


Fig. 4·20 Circuit diagram for parallel operation of welding transformers.

Multi-Operator Welding Transformers:

A multi-arc or multi-operator welding transformer system utilises a high current constant voltage power source for providing a number of welding circuits at the same time. Such a system is used when there is a large concentration of welding points in a relatively small operating area, for example, in ship-building, construction sites for power stations, refineries, and chemical plants.

A multi-operator welding transformer with a flat volt-ampere characteristic may be of the single phase or 3-phase variety. A disadvantage of a single phase multi-operator welding transformer is that it puts an unbalanced load on the 3-phase supply mains. If a multi-operator welding transformer is to have a voltage which will not vary with the load (the maximum variation should not exceed 5%) it should have low magnetic leakage, that is, a low inductive reactance.

The number of arcs or welding circuits which can be connected to a welding transformer may be found by the relationship,

$$n = I_t/I_a \cdot K$$

where,

n = number of arcs or welding circuits,

I_t = rated output current of the welding transformer,

I_a = average arc current in each welding circuit,

K = diversity factor.

The diversity factor K takes into account the fact that all the welders operating from one and the same power source do not work simultaneously. The diversity factor is related to average duty cycle and the laws of probability but is reduced as the number of welders operating from the same transformer increases. Usually K is assumed to be anywhere between 0•6 to 0•8.

Each welding station is connected through a separate variable choke (current regulator), which provides a steeply drooping static volt-ampere characteristic curve for each welding circuit. The welding circuits are connected in parallel, because with this arrangement the source is better utilised when welding with low currents, of the order of 70 to 100 amperes.

Note:

It should be noted that the welding transformers have a rather low power factor due to the fact that they incorporate coils having high inductive reactance’s. Welding transformers, therefore, must not have power ratings higher than is necessary for the performance of the assigned job. Nor should they be run at no-load for a long time.