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METHOD OF AND APPARATUS FOR ENERGIZING SELF-RECTIFYING LOADING DEVICES

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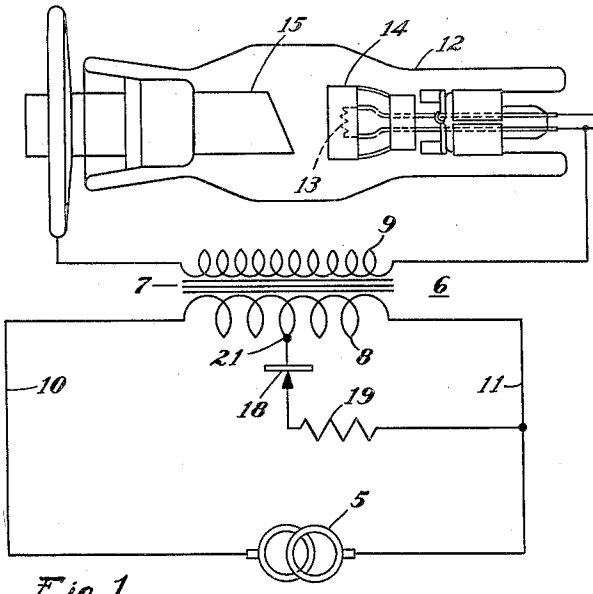


Fig. 1

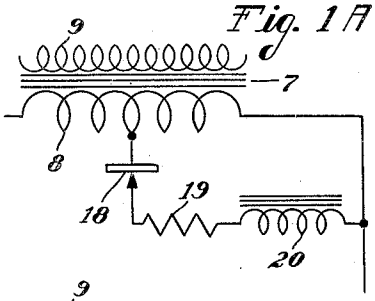


Fig. 1A

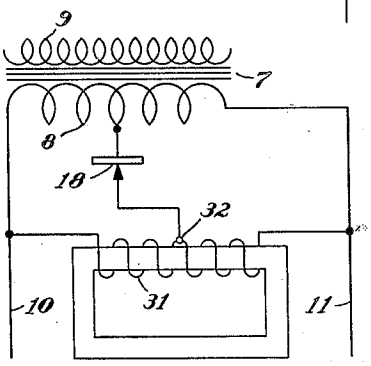


Fig. 3

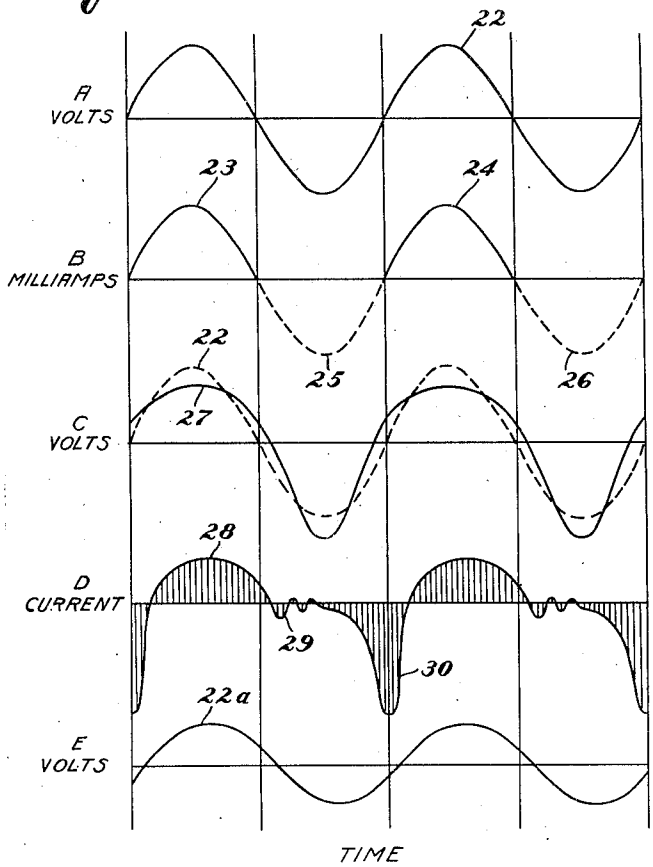


Fig. 2

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METHOD OF AND APPARATUS FOR ENERGIZING SELF-RECTIFYING LOADING DEVICES

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9 Claims. (Cl. 250—100)

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This invention relates to a method of and to apparatus for energizing self-rectifying load devices such as self-rectifying tubes.

The energization of a self-rectifying X-ray tube or like device, gives rise to an inverse voltage that appears across the X-ray tube during its non-conducting periods, which voltage tends to be considerably higher than the useful voltage that appears across the X-ray tube during its conducting periods. This condition complicates the insulation of X-ray apparatus and unsymmetrically loads the supply source. The undesirable inverse voltage effect is primarily due to the fact that the secondary winding of the transformer for energizing the X-ray tube is substantially unloaded during one-half cycle of the energizing current source while this winding is loaded by the X-ray tube with the resultant voltage drop during the remaining half-cycle when this tube is conducting.

Among the objects of the present invention are; to provide a means of and a method for compensating for the unsymmetrical form of waves created in X-ray transformers by reason of half-wave operation of the X-ray tube; to reduce the inverse voltage across the X-ray tube during the unloaded half-cycle and to accomplish these improvements without adding structure to the transformer and without increasing the volt-ampere demand on the supply line.

The various features and advantages of the invention will appear from the detailed description and claims when taken with the drawings in which:

Fig. 1 is a circuit diagram illustrating one embodiment of the invention;

Fig. 1*a* indicates how the circuit arrangement of Fig. 1 can be slightly modified;

Fig. 2 is a chart showing graphs or oscillograms useful in the understanding of the invention; and

Fig. 3 shows a modified form of the invention.

In the circuit diagram of Fig. 1, a source of alternating current 5 supplies a high tension transformer 6. This transformer has a magnetic core 7 on which there are wound the primary winding 8 and the secondary winding 9. The primary winding is connected in the primary supply circuit, being connected by the conductors 10 and 11 in series with the current source 5. The secondary circuit of the transformer includes a conventional self-rectifying X-ray tube 12 comprising a filamentary cathode 13 with its focusing element 14 and an anode 15. The cathode and anode are respectively connected to the

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terminals of the secondary winding while the cathode 13 is connected in series with a source 16 of heating current.

With the energizing arrangement thus far described, the inverse voltage appearing across the X-ray tube 12 during its non-conducting periods will be greatly in excess of the useful voltage appearing across this tube during its conducting periods, thereby manifesting an unsymmetrical wave form. This inverse voltage, unless it is reduced, has made it necessary to manufacture self-rectifying X-ray apparatus with a margin of safety in insulation that is greatly in excess of that required for protection against the useful voltage which energizes the X-ray tube.

In order to reduce this inverse voltage to a magnitude of the order of the useful voltage across the X-ray tube, an auxilliary circuit is provided in accordance with the present invention. This circuit comprises a rectifier 18, and a resistor 19 both connected in series between substantially the center point 21 on the primary winding and the conductor 11. Under certain conditions it is desirable to include a magnetic core inductor 20 in the auxiliary circuit in series with the rectifier 18 and resistor 19, as shown in Fig. 1*a*. A load connected between the center tap of a transformer winding and one terminal thereof, causes the load current due to this connection to be equally distributed in both halves of the winding. This phenomenon is utilized in my invention wherein I employ the auxiliary circuit to connect a rectified load current periodically between one terminal of the primary winding of the energizing transformer and a second point somewhere near the center of that winding.

In Fig. 1, it will be observed that the X-ray tube 12 loads the secondary winding 9 of the transformer only during each half-wave of a complete cycle, while the auxiliary circuit including the rectifier 18 together with its related load, namely resistor 19 and inductor 20, are so connected that this auxiliary circuit loads the transformer 6 for the half-cycle during which the transformer is not loaded by the X-ray tube 12. In this way, the secondary load circuit caused by the X-ray tube and the auxiliary or primary load circuit caused by the rectifier 18 together with its connected load, impose the equivalent of a full wave continuous load on the transformer 6.

The conditions prevailing during the operation of the circuit arrangement of Fig. 1 are graphically illustrated in Fig. 2 wherein graph A represents a sine curve 22 of voltage provided by

alternating current source 5. Voltage having this wave form is available at the transformer primary 8 and is also available at the terminals of the secondary winding 9 of the transformer, in the absence of a load or with a symmetrical load thereon.

In graph B, the waves 23 and 24 shown in full lines represent the load current in the secondary 9 of the X-ray transformer 6, the dotted waves 25 and 26 do not exist but are drawn in to show the form of current that would prevail in the case of a symmetrical load.

In graph C, the dotted voltage curve 22 is the same as curve 22 of graph A, that is, the unloaded or symmetrical voltage across the X-ray tube. With X-ray tube current in half-wave form, such as illustrated by 23 and 24, the transformer is loaded unsymmetrically and due to the impedance of the transformer which includes a large amount of leakage reactance, the load voltage drops off to the form shown by the full line curve 27. It will be noted that curve 27 is flattened by the load during the loaded half-cycle operation and peaked during the unloaded half-cycle of operation.

In graph D, the primary current is represented by the portion of the curve designated 28. This curve represents the load current, which is, very nearly in phase with the voltage. It also represents a small amount of oscillatory current 29 due to a transient caused in the transformer by the removal of load current. This curve further represents a very considerably peaked current 30, which is substantially 90° out of phase with the applied voltage, because of the fact that this represents only exciting current. However, the area under the negative parts of this wave curve are always equal to the area under the positive parts thereof as illustrated by the shading in this graph, so that the volt ampere load caused by such operation represents only about a fifty per cent power factor. This is, the peak 30, although it is out of phase, requires the same demand on the supply circuit insofar as amperes are concerned as does the load current 28.

In the operation of X-ray transformers and X-ray systems, the wiring and power circuit demands are base upon the volt ampere demand of the circuit. If the transformer and the connected system, is to operate efficiently and the actual watt demand is of no importance so long as the watt demand does not exceed the volt ampere demand, the cost of the actual current utilized in the operation of an X-ray machine rarely, if ever, approaches the maximum demand requirements. That is to say, power supply transformers, building wiring and fixed charge rates for X-ray machines are the determining factor in the cost of operation of X-ray radiographic machines, and, therefore, compensation methods for correcting the unsymmetrical wave forms imposed upon X-ray transformers by half-wave operations may advantageously employ more watts than usually demanded without compensators, provided the watt demand does not exceed the volt ampere demand.

It is appreciated by those skilled in the art that the so-called inverse voltage caused by the effect of unsymmetrical loading upon the circuit impedance and leakage reactance of the transformer imposed extra strains on the transformer insulation and limits the kilo-volt operation of the X-ray tube.

Referring to Fig. 1, it will be observed that with the circuit therein illustrated which symmetrically loads the transformer, and, therefore, symmetrically loads the supply line, that the effect of transformer impedance and leakage reactance is symmetric for both half-waves of operation, and, therefore, the line current takes the form 22*a* in line E of Fig. 2, and the system is caused to operate as a perfectly balanced symmetrically loaded transformer system.

In the prior art, devices have been made to compensate to some extent, the mentioned loading but they have all, without exception, employed some sort of impedance directly in series in the primary or supply circuit. However, it is well known in the X-ray transformer art, that impedance introduced in series with the primary or supply circuit increases the distortion of the unsymmetrical wave form, because of the fact that primary impedance is equivalent to leakage reactance in the transformer itself. Therefore, in these prior art devices, the compensation provided had to compensate not only for the leakage reactance of the transformer itself but also for the equivalent added effect caused by the nitroduction of impedance in the primary circuit.

In the arrangement of the present invention, however, no impedance whatever is included in series in the primary or supply circuit. Inverse voltage reduction or compensation in this arrangement is effected by an auxiliary load circuit which in no way impedes any current flow from the source 5, to the primary winding of the transformer.

The modified form of the invention disclosed in Fig. 3 is similar to that shown in Fig. 1 except that the primary load circuit has been changed. In this modification, the winding 31 of an autotransformer has its terminals connected respectively to primary supply conductors 10 and 11. The intermediate point 32 on autotransformer winding 31 is connected through the rectifier 18 with the intermediate point 21 on the primary winding 8 of the transformer 6. Otherwise this arrangement is similar to that of Fig. 1. The operation of this arrangement will be understood from the previous description.

While I have shown several forms of the invention, it will be understood that many modifications may be made by those skilled in the art without departing from the spirit of the invention.

What I claim is:

1. The method of reducing undesired inverse voltage unbalance in an arrangement including a periodically conducting and non-conducting rectifying load device energized from a transformer having a primary winding and a secondary winding connected to said device, which comprises energizing said primary winding from a source of alternating current having negligible line impedance, and applying a balancing absorption load across one-half of said primary winding during the non-conducting period of said device whereby said unbalance is reduced.

2. The method of reducing undesired inverse voltage unbalance in an arrangement including a periodically conducting and non-conducting rectifying load device energized from a transformer having a primary winding and a secondary winding, which comprises continuously supplying to said primary winding alternating current having substantially undistorted line-voltage wave

form, and alternately applying the load of said device across said secondary winding and a unidirectional balancing load across substantially one-half of said primary winding whereby said unbalance is reduced.

3. The method of reducing undesired inverse voltage in an arrangement including a periodically conducting and non-conducting rectifying load device and a cooperating transformer having a primary winding and a secondary winding connected to said device which comprises supplying to said primary winding alternating current having substantially undistorted line-voltage wave form, and applying a balancing load across substantially one-half of said primary winding during the non-conducting periods of said device.

4. In combination, a self-rectifying X-ray device which is periodically conducting and non-conducting, a source of alternating current of substantially undistorted line-voltage wave form for energizing said device, a high voltage transformer having a secondary winding connected in circuit with said X-ray device and a primary winding to the terminals of which said source of undistorted line-voltage wave form is applied, and a load circuit including a rectifying unit effectively connected across substantially one-half of said primary winding during those periods that the X-ray device is non-conducting.

5. In combination, a self-rectifying X-ray device which is periodically conducting and non-conducting, a source of alternating current for energizing said device, a high voltage transformer having a secondary winding connected in circuit with said X-ray device and a primary winding connected in a supply circuit including said source, said supply circuit being substantially devoid of any impedance unit apart from said primary winding, a balancing circuit constituting a load corresponding with that of said device, means for effectively connecting said balancing circuit across substantially one-half of said primary winding only during those periods that the X-ray device is non-conducting.

6. In combination, a self-rectifying X-ray device, a source of alternating current having substantially undistorted wave forms for energizing said device, a high voltage transformer having a secondary winding connected in circuit with said X-ray device and a primary winding connected in a supply circuit including said source, said supply circuit being substantially devoid of any impedance apart from said primary winding, and a load circuit including a rectifying unit and an impedance unit effectively connected from a central point on said primary winding to one

terminal thereof during those periods that the X-ray device is non-conducting.

7. The method of compensating for distortion of secondary voltage wave-form due to the periodic flow of direct current in the secondary of an alternating current transformer operating under half-wave secondary load which comprises supplying to the primary of said transformer alternating current having substantially undistorted line voltage wave form and drawing an external balancing load from one-half of the primary of said transformer during the half-wave period that the secondary is unloaded and during said period only.

8. The method of compensating for distortion of secondary voltage wave-form due to flow of direct current in the secondary of an alternating current transformer operating under half-wave secondary load which comprises supplying from a power line to the terminals of the primary winding of the transformer alternating current having substantially undistorted voltage wave form, and drawing an external load corresponding to that of the secondary load, from the primary of said transformer from a central primary tap thereof and one side of said line during the half-wave period that the secondary is unloaded and during said period only.

9. The method of compensating unbalanced secondary voltage wave-forms due to flow of direct current in the secondary of an alternating current transformer operating under half-wave secondary load which comprises supplying from a power line to the terminals of the primary of the transformer alternating current having substantially undistorted wave form, and drawing a balancing direct current from a central tap on said primary and one side of said line only during the half-wave periods that the secondary is unloaded.

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