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James et al.

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[54] STARTING VOLTAGE SUPPRESSOR CIRCUITRY FOR AN X-RAY GENERATOR

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315/287, 317/33 SC, 323/43.5 S

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[58] Field of Search 315/137, 291, 279, 287, 143;
250/102, 103; 317/33 SC; 323/73, 43.5 S, 44

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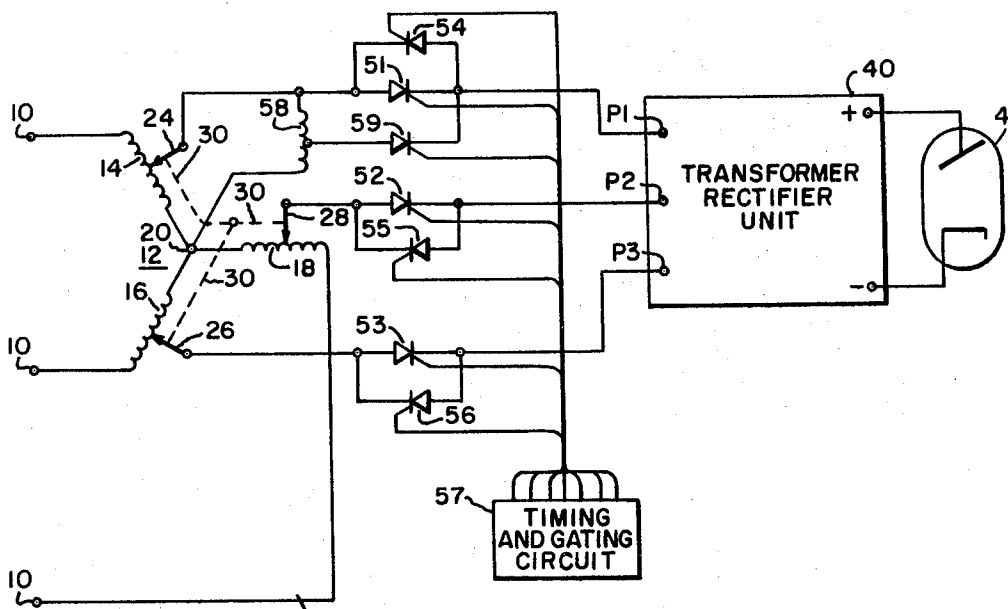
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[57]

ABSTRACT

Circuitry for eliminating or reducing overshoot of the direct current high voltage of an X-ray tube by reducing the magnitude of an initial single-phase voltage to the transformer-rectifier unit compared to the magnitude of subsequent phase voltages applied thereto during an exposure.

4 Claims, 6 Drawing Figures



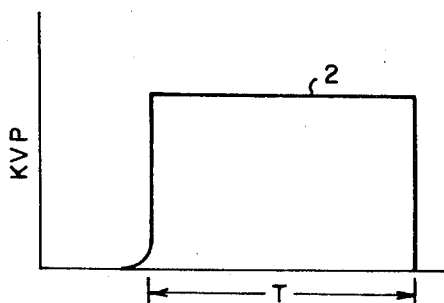


FIG. 1.

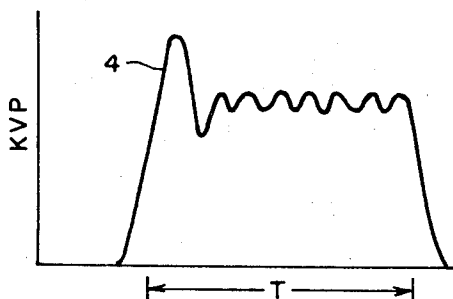


FIG. 2.

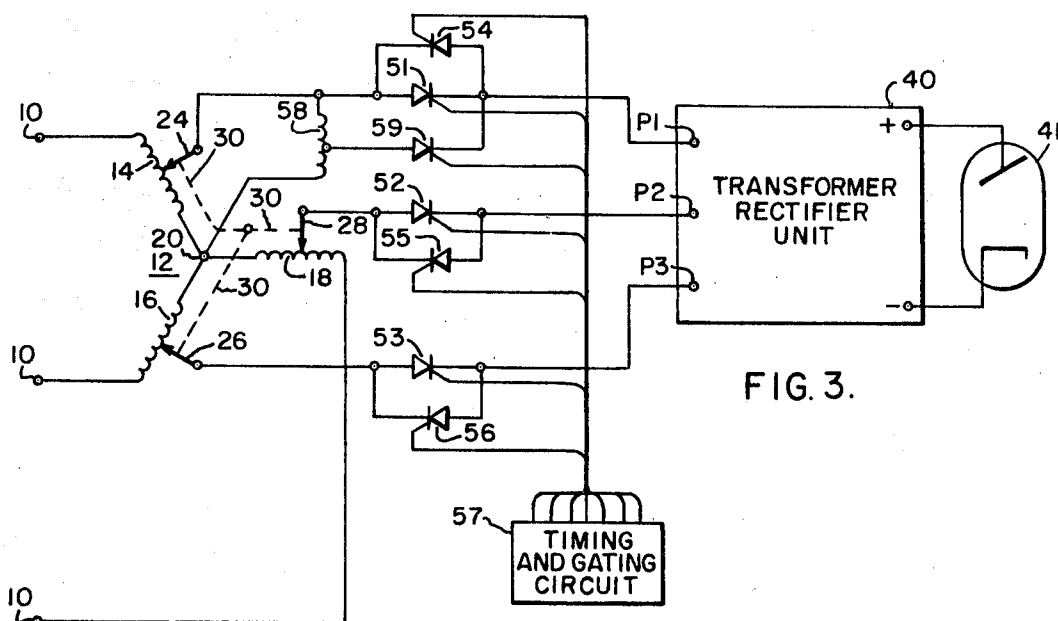


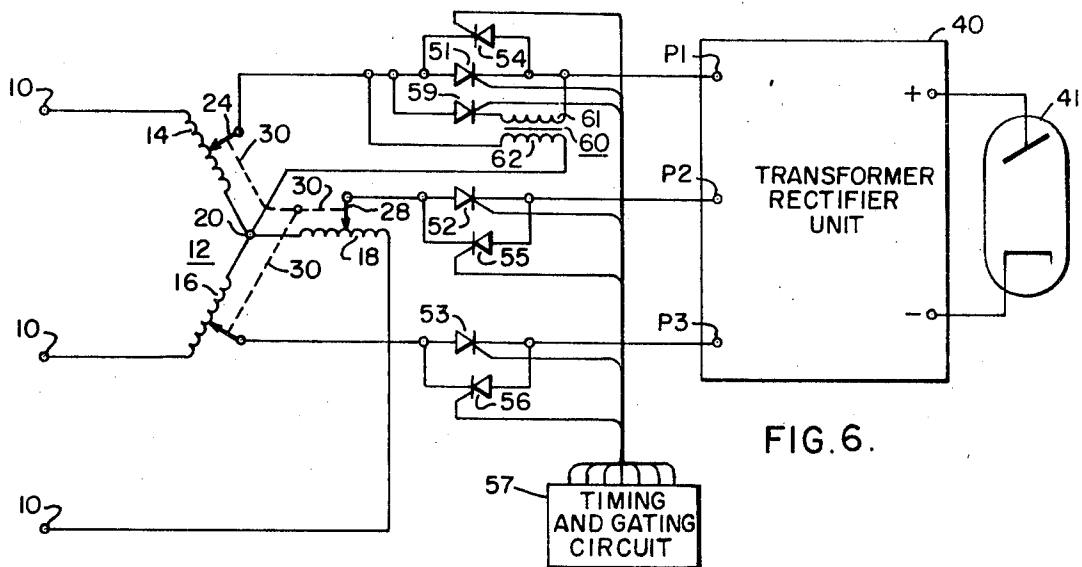
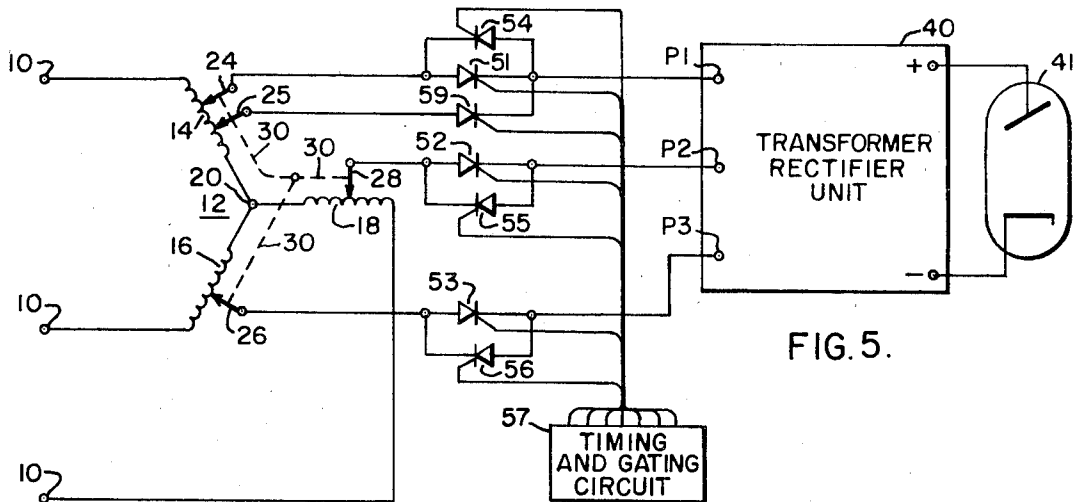
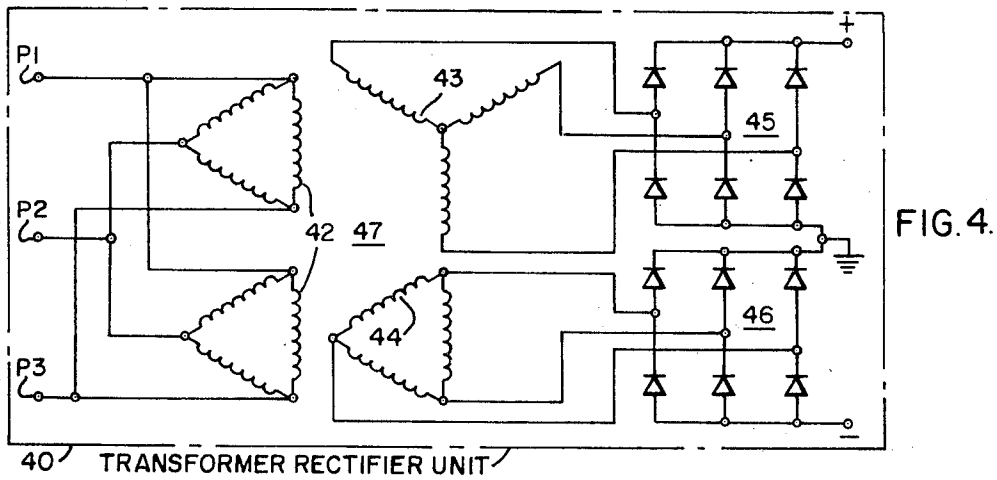
FIG. 3.

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STARTING VOLTAGE SUPPRESSOR CIRCUITRY FOR AN X-RAY GENERATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to X-ray exposure control circuitry and more particularly relates to starting voltage suppressor circuitry for eliminating or reducing overshoot of the direct current high voltage applied to an X-ray tube during an X-ray exposure to preclude overexposed radiographs and harmful overvoltage conditions.

2. Description of the Prior Art

Multiphase X-ray generators generally use a high-voltage rectified power supply which produces a direct current output across the X-ray tube with peak-to-peak ripple ranging from 5 to 20 percent for different units and various loads.

The ideal voltage output across the X-ray tube is a square wave but unfortunately upon start of an exposure a voltage overshoot occurs generally due to a combination of starting the X-ray tube on single phase which gives a higher peak voltage and/or the classical overshoot which occurs in a high-voltage rectifier circuit on the first pulse due to leakage inductance and distributed capacity in the X-ray generator. The duration of such voltage overshoot is usually 0.003 to 0.006 seconds.

The high-voltage surge can amount to a 25 percent overshoot. This is very objectionable for at least two reasons: (a) on a short time exposure of 0.003 or 0.006 the X-ray exposure will be made at a higher voltage that is set on the X-ray control and will result in overexposed radiographs and (b) the peak kilovolt settings near the top rating of the X-ray generator will cause overvoltage on the components of the equipment. The resulting overvoltage condition on the rectifiers, cables, X-ray tubes, etc., can impair the reliability of the system or require greater power handling capabilities of the equipment than is necessary for proper operation.

Therefore, an object of the present invention is to provide circuitry allowing accurate exposures even when of extremely short time duration.

Another object of the present invention is to provide circuitry for preventing overvoltage of components within the X-ray generator when operated near rated voltage.

SUMMARY OF THE INVENTION

Briefly, the present invention accomplishes the above-cited objects and other objects and advantages by providing circuitry which upon start of an exposure reduces the magnitude of the voltage input to the high-voltage rectifier circuit during an initial phase to eliminate or hold to a negligible value overshoot of the voltage to an X-ray tube. More particularly, the multiphase control input to a high-voltage transformer-rectifier unit feeding an X-ray tube is sequenced in the same way at the start of each exposure. The magnitude of the voltage of the initial phase applied to the transformer-rectifier unit is reduced compared with the magnitude of subsequent phases. The sequence is arranged to provide the desired magnitude of three-phase voltage to the transformer-rectifier unit after the transient time of voltage overshoot upon start of an exposure has passed.

BRIEF DESCRIPTION OF THE DRAWING

Further objects and advantages of the present invention will be readily apparent from the following detailed description taken in conjunction with the drawing in which:

FIGS. 1 and 2 illustrate waveforms useful in understanding the operation of the present invention;

FIG. 3 is a schematic diagram of an illustrative embodiment of the present invention;

FIG. 4 is a schematic diagram of an item utilized in the illustrative embodiment of FIG. 3;

FIG. 5 is an electrical schematic diagram of another illustrative embodiment of the present invention; and

FIG. 6 is an electrical schematic diagram of still another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The magnitude and duration of the high-voltage direct current across an X-ray tube determines the extent of an exposure. A multi- or three-phase X-ray machine generally includes a high-voltage rectified power supply which produces a high-voltage DC output across the X-ray tube having a magnitude which is a function of the phase-to-phase voltage applied to the primary of a high-voltage transformer of the transformer-rectifier unit.

The ideal voltage output across an X-ray tube would be a square wave 2 as illustrated in FIG. 1. In actual practice the output from the transformer-rectifier unit has a peak-to-peak ripple ranging from 5 to 20 percent for different units and various loads. Such an actual voltage output is as illustrated by the waveform 4 of FIG. 2. Upon initiation of an exposure the direct current voltage across the X-ray tube generally overshoots the desired magnitude. Such overshoot can be due to a combination of either starting the unit on single phase which gives a higher voltage and/or the classical overshoot which occurs in a high-voltage rectifier circuit on the first pulse due to leakage inductance and distributed capacity in the unit. The duration of such an overshoot is generally on the order of 0.003 to 0.006 seconds. The duration, of course, varies with the desired magnitude of direct current voltage to be applied across the X-ray tube and the X-ray tube anode current (load).

In some instances, it is desirable that the X-ray generator provide a very short exposure time such as in the range of the aforementioned 0.003 to 0.006 seconds. These short exposure times are desirable to avoid distortion in the radiograph as a result of motion. The high-voltage surge is undesirable when very short time exposures are to be taken since the X-ray exposure will be made at a higher voltage than is set on the X-ray control and will result in overexposed radiographs. Exposures having peak kilovolt settings near the top rating of the X-ray generator can result in overvoltage on the components of the equipment, thus impairing the reliability of the system.

FIG. 3 illustrates circuitry for preventing overshoot of kilovoltage at the start of an X-ray exposure. Terminals 10 provide means for connection of a three-phase supply to a control autotransformer 12 herein illustrated with Y-connected windings 14, 16 and 18 with a neutral path 20. Tap switches 24, 26 and 28 are gang operated by a coupling as indicated at 30. The phase-to-phase voltage output from the autotransformer 12 is as determined by controlling the positioning of the tap switches.

The transformer rectifier unit 40 connects the phase-to-phase voltage output from the control autotransformer to an X-ray tube 41.

Switching means illustrated as silicon-controlled rectifiers connect the output control voltages from the autotransformer 12 to the transformer-rectifier unit 40. Silicon-controlled rectifiers 51, 52, and 53 are located in connecting lines and poled in the same direction. Silicon-controlled rectifiers 54, 55 and 56 are connected in the same lines but poled in the opposite direction from their companion silicon-controlled rectifier.

A schematic diagram of the transformer-rectifier unit 40 is as illustrated in FIG. 4. A high-voltage transformer 47 is connected to the control autotransformer 12 via its primary windings 42 at the primary input terminals P1, P2 and P3. A Y-connected secondary 43 and delta connected secondary 44 are connected to rectifier bridges 45 and 46 to provide a high-voltage direct current output across the X-ray tube 41.

Referring again to FIG. 3 data accumulated from many oscillograms on various multiphase X-ray generators indicate that the degree of overshoot is proportional to the peak kilovolt setting on the X-ray control. The peak kilovolt output across the transformer-rectifier unit 40 to the X-ray tube 41 is a function of the phase-to-phase voltage applied to the primary 42 of the high-voltage transformer 41 in the unit 40.

The desired voltage selected at the control autotransformer 12 is connected to the transformer-rectifier unit 40 by

enabling signals from a timing and gating circuit 57 which gates selected SCR switches in a controlled sequence.

The main primary contacting or switching is controlled by SCR switches 51 through 56 which, as shown in FIG. 3 are silicon-controlled rectifiers. These could be replaced by mechanical contactors. The SCR switches are turned on in a controlled sequence in the same way at the start of each exposure. For example, switches 51 and 56 are gated ON first applying single-phase voltage across terminals P1 and P3 in the unit 40. Then 60 to 90 electrical degrees later switch 52 is gated ON followed by switches 53, 54 and 55 in the proper sequence to complete the application of three-phase voltage.

The present invention avoids voltage overshoot on the output by providing an auxiliary autotransformer 58 connected across tap switch 24 and neutral 20. A silicon-controlled rectifier 59 connects a portion of the auxiliary autotransformer 58 to the input terminal P1 of the transformer-rectifier unit 40.

In such a manner a lower voltage than that set on the control autotransformer 12 is supplied to the primary 42 of the high-voltage transformer 41 during the period that single-phase voltage is applied at the start of the exposure.

When the SCR switches are turned on in a controlled sequence in the same way at the start of each exposure the reduced magnitude of the voltage of the initial phase upon start of an exposure will eliminate or reduce the overshoot to negligible values. Then normal voltage of the magnitude selected at the control autotransformer 12 is applied with the subsequent phases.

The voltage tapped off auxiliary autotransformer 58 may be, for example, approximately 20 percent lower than the voltage at the tap switch 24. The reduced magnitude of voltage is applied to the input terminal 51 through silicon-controlled rectifier 59. The timing and SCR gating circuit 57 is arranged so that at the start of an exposure, single-phase voltage of a reduced value is applied to input terminals P1 and P3 through the gating of switches 59 and 56.

After 90 electrical degrees and before switch 54 is gated on, switch 59 is gated off. On succeeding in pulses of the proper polarity switch 51 is gated on instead of the switch 59 thus applying the full voltage set at the tap switch 24. The auxiliary autotransformer 58 could also have the same effect when connected across tap switch 28 and neutral 20 or tap switch 26 and neutral 20. When desirable, the auxiliary autotransformer 58 could also be connected from tap switch to tap switch. In each case the starting sequence would have to be altered accordingly.

An alternate embodiment of the present invention is illustrated in FIG. 5 wherein like items have been identified with identical reference characters used in FIG. 3. Referring to FIG. 5, an extra tap switch 25 is mechanically coupled to tap switch 24, replacing the auxiliary autotransformer 58, so that a fixed reduced voltage proportional to the peak kilovolt setting on the controlled autotransformer 12 is applied through switch 59. Alternatively, voltages could be tapped from the primary windings 42 associated with the input P1 to the high-voltage transformer 41 in the unit 40. Thus the auxiliary autotransformer 58 of FIG. 3 would not be required at all.

Still another illustrative embodiment is as illustrated in FIG. 6 where once again like items have been identified with identical reference characters. A bucking transformer 60 is connected with one winding 61 in series with the switch 59 and input terminal P1 with another winding 62 connected across tap switch 24 and neutral 20. The primary winding 62 could also be connected across other legs of the autotransformer 12 in a similar manner or across tap switches. The transformer 60 injects a bucking voltage which reduces the applied voltage from tap switch 24 during the first impulse upon start of an exposure.

While the present invention has been described to the degree of particularity for purposes of illustration, it is to be understood that all modifications, alterations and substitutions within the spirit and scope of the present invention are herein

to be included. For example, although silicon-controlled rectifiers have been illustrated as the means for switching it is to be understood that bidirectional semiconductor switches and even mechanical contractors may be utilized.

We claim as our invention:

1. In a multiphase X-ray generator, the combination comprising:
 - an X-ray tube;
 - transformer-rectifier means coupled to said X-ray tube, being responsive to the magnitude of a multiphase alternating current input voltage for providing a direct current voltage to said X-ray tube;
 - three-phase control autotransformer means coupled between said multiphase input voltage and said transformer-rectifier means for controlling the magnitude of the multiphase input voltage applied to said transformer-rectifier means for a desired exposure;
 - auxiliary autotransformer means connected across one phase of said control autotransformer means for reducing the magnitude of the voltage input for an initial phase upon start of an exposure; and
 - auxiliary switching means connecting said auxiliary autotransformer means to said transformer-rectifier means for applying at the start of an exposure a single-phase voltage thereto a reduced value compared to the magnitude of subsequent phase-to-phase voltages applied thereto whereby overshoot of the voltage to said X-ray tube is eliminated or held to a negligible value.
2. In a multiphase X-ray generator, the combination comprising:
 - an X-ray tube;
 - transformer-rectifier means coupled to said X-ray tube, being responsive to the magnitude of a multiphase alternating current input voltage for providing a direct current voltage to said X-ray tube.
 - three-phase control autotransformer means including a tap switch connected to each phase and ganged together, coupled between said multiphase input voltage and said transformer-rectifier means, the setting of said tap switches controlling the magnitude of the phase-to-phase alternating current voltage applied thereto for a desired X-ray exposure; and
 - another tap switch connected to one phase of said control autotransformer, coupled to said transformer-rectifier means providing a fixed reduced voltage thereto compared to the voltage setting of said tap switches for an initial phase upon start of an exposure whereby overshoot of the voltage to said X-ray tube is eliminated or held to a negligible value.
3. In a multiphase X-ray generator, the combination, comprising:
 - an X-ray tube;
 - transformer-rectifier means coupled to said X-ray tube, being responsive to the magnitude of a multiphase alternating current input voltage for providing a direct current voltage to said X-ray tube;
 - control autotransformer means coupled between said multiphase alternating current input voltage and said transformer-rectifier means for controlling the magnitude of the voltage applied to said transformer-rectifier means; and
 - bucking transformer means including a first and a second winding, said first winding being connected to said control autotransformer means and said second winding being connected to said transformer-rectifier means so as to buck the voltage of the initial phase of said input voltage from said control autotransformer means upon start of an exposure whereby the input voltage applied to said transformer-rectifier means is reduced in magnitude compared to the magnitude of subsequent phases whereby overshoot of the direct current voltage to said X-ray tube is eliminated or held to a negligible value.
4. In a multiphase X-ray generator, the combination comprising:

an X-ray tube;
transformer-rectifier means coupled to said X-ray tube,
being responsive to the magnitude of a multiphase AC
input voltage applied thereto for providing a DC voltage
to said X-ray tube;
three-phase control autotransformer means coupled
between said multiphase AC input voltage and said trans-
former-rectifier means for controlling the magnitude of
the multiphase voltage input applied thereto for a desired
exposure;
switching means interconnected between said autotrans-
former means and said transformer-rectifier means for
selectively connecting each phase of said AC input volt-
age to said transformer-rectifier means;
means coupled to one phase of said autotransformer means
for reducing the magnitude of the voltage for an initial

phase of said AC input voltage;
timing and gating means coupled to said switching means,
gating said switching means to connect the phases of said
AC input voltage to said transformer-rectifier means in a
controlled sequence in the same way at the start of each
exposure; and
said switching means further including an auxiliary switch
connecting said means for reducing the magnitude of the
voltage for the initial phase to said transformer-rectifier
means, said timing and gating means additionally being
coupled to and enabling said auxiliary switch only during
the period that said initial phase of said AC input voltage
is applied at the start of any exposure whereby overshoot
of the voltage to said X-ray tube is substantially
eliminated or held to a negligible value.

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