FERRITE BIAS REGULATOR FOR A SYNCHROTRON RESONATOR

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4 Claims

ABSTRACT OF THE DISCLOSURE

A ferrite bias regulator for a synchrotron resonator controls the resonant frequency of a ferrite tuned cavity in a synchrotron. The ferrite bias regulator supplies a regulated biasing current to a coil, inductively coupled to the ferrite material in the synchrotron cavity, thereby varying the permeability of the ferrite material so as to match or track the resonant frequency of the cavity to the frequency sweep of the particle accelerating electrical field of the synchrotron. The ferrite bias regulator has a high voltage power supply and a low voltage, high current power supply. The high voltage is supplied to overcome the back EMF of the unsaturated ferrite at the beginning of the sweep, and the high current is supplied to saturate the ferrite at the end of the sweep. Smooth current transfer is an inherent property of the regulator. The direction of the current passing through the coil is reversed every other sweep, so that the full hysteresis loop of the ferrite is utilized, thereby increasing the range of tuning frequencies obtainable from the ferrite bias regulator.

BACKGROUND OF THE INVENTION

The invention described herein was made in the course of, or under, contract W-7405-Eng-48 with the United States Atomic Energy Commission.

The invention relates generally to a power supply for a synchrotron, and more particularly to a ferrite bias regulator for a synchrotron resonator for controlling the resonant frequency of a ferrite tuned cavity in a synchrotron.

In a synchrotron the particle accelerating electrical field is obtained by exciting the synchrotron cavity with signals from a radio-frequency power source. The resonant frequency of the cavity must be tuned to match or track the frequency of the power source. One common method of tuning the cavity is a synchronous resonator which tunes the cavity by controlling the saturation, and therefore the permeability, of a ferrite material placed in the cavity. The ferrite material is saturated by passing a biasing current through a winding of coil inductively coupled to the ferrite. The particles are accelerated in the synchrotron by sweeping the frequency of the particle accelerating electrical field over a wide range. The synchrotron resonator must be capable of matching or tracking the resonant frequency of the ferrite tuned cavity to the frequency sweep of the radio frequency power source.

A synchrotron resonator tunes the cavity to the highest frequency during maximum saturation of the ferrite. The lowest tuning frequency occurs when the saturation is at a minimum, corresponding to maximum permeability of the ferrite. The back electromotive force of the ferrite is much higher at maximum permeability than at some appreciable degree of saturation has occurred. Therefore, at the beginning of the frequency sweep when the back electromotive force is greatest, a very high voltage across the coil is required to increase the saturation of the ferrite at a rate equivalent to the rate of frequency change of the particle accelerating electrical field. At the end of the frequency sweep a high current through the coil is required to further increase the saturation of the ferrite at the desired rate. Therefore, the synchrotron resonator must supply a high voltage across the coil and a high current through the coil during any single frequency sweep of the particle accelerating electrical field.

Synchrotrons commonly accelerate many particles consecutively at a very rapid repetition rate. The synchrotron resonator must cyclically supply at the same repetition rate the high voltage and high current required during a single frequency sweep of the particle accelerating electric field. The rate of saturation change of the ferrite tuning the cavity must increase as the repetition rate of the synchrotron increases. As a result, high repetition rate synchrotrons require the synchrotron resonator to supply an even higher voltage across the coil and a higher current through the coil.

One problem common to the prior art is the prior art synchrotrons utilize a single power supply in the synchrotron resonators. A single power supply capable of providing the very high voltage and the very high current required to tune the cavity at a high repetition rate synchrotron is prohibitively expensive.

SUMMARY OF THE INVENTION

The ferrite bias regulator of the present invention cyclically supplies the biasing current required to match or track the resonant frequency of a ferrite tuned cavity to the frequency sweep of the particle accelerating electric field in a high repetition rate synchrotron. The inventive ferrite bias regulator has dual power supplied. The first power supply provides a high voltage across a coil, inductively coupled to the ferrite material tuning the cavity, at the beginning of the sweep to overcome the back electromotive force of the unsaturated ferrite. The second power supply provides a high current through the coil to saturate the ferrite at the end of the sweep. Smooth biasing current transition is an inherent property of the circuitry of the ferrite bias regulator.

For any given expenditure, the dual power supplies of the inventive ferrite bias regulator enhance the magnitude of the biasing current supplied by the synchrotron resonator, thereby permitting a higher repetition rate of the synchrotron. Additionally, the control circuitry of the ferrite bias regulator reverses the direction of flow of the biasing current through the coil after every cycle of the synchrotron, thereby utilizing the full hysteresis loop of the ferrite. This increases the permeability range of the ferrite, and therefore, increases the range of frequencies through which the synchrotron cavity can be tuned.

BRIEF DESCRIPTION OF THE DRAWING

The single figure is a schematic diagram of an embodiment of the inventive ferrite bias regulator.

BRIEF DESCRIPTION OF THE INVENTION

A single embodiment of the ferrite bias regulator is shown driving a circuit load consisting of a coil 11, inductively coupled to a ferrite material (not shown). Four silicon control rectifiers 12, 13, 14, and 15, functioning as control switches, are connected in two parallel circuits with two of the rectifiers connected in series in each of the parallel circuits. Coil 11 is connected between a point...
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common to the rectifiers 12 and 14 in one of the parallel circuits and a point common to the rectifiers 13 and 15 in the other parallel circuit. A diode 16 is connected in series with a transistor modulator 17, functioning as a first current regulating device, the two parallel circuits, and a resistor 18 across a low voltage, high current power supply 19. A current limiting impedance coil 20 is connected in series with a capacitor 21 across a high voltage power supply 22. A transistor switch 23, functioning as a second current modulator, is connected in series with the transistor switch 17, the two parallel circuits, and the resistor 18 across the capacitor 21.

Current regulating circuitry for the transistor modulators 17 and 23 is comprised of a reference signal generator 24 which provides a reference signal to a summing junction 25. The summing junction 25 is a point common to the two parallel circuits, and the resistor 18. A differential amplifier 26 having a high side input connected to the summing junction 25 and a common or low side input and output connected to a point common to the resistor 18 and the capacitor 21 provides a current regulating signal from a high side output to the transistor modulator 17 and to the transistor modulator 23, through a bias cell 27. Current control circuitry for the silicon control rectifiers is comprised of a firing control 28 having a reference signal input from the reference signal generator 24. The firing control provides control signals to each of the four silicon control rectifiers 12, 13, 14, and 15.

The ferrite bias regulator operates as follows: The reference signal generator 24 simultaneously provides reference signals to the firing control 28 and to the summing junction 25. The reference signal to the firing control 28 initiates control signals to the silicon control rectifiers triggering or causing one pair of rectifiers, either 12 and 15 or 13 and 14. The reference signal to the summing junction 25 initiates a current regulating signal from the high side output of the differential amplifier 26 driving transistor modulators 17 and 23. Capacitor 21, having been charged over a relatively long period of time by the high voltage power supply 22, discharges providing a high voltage across the coil 11. Diode 16 blocks the passage of current through power supply 19. Differential amplifier 26 varies the conductivity of transistor modulators 17 and 23 according to the voltage drop across resistor 18, thereby regulating the passage of the biasing current through coil 11. This sequence is repeated for each subsequent frequency sweep of the particle accelerating electric field, except that on every other frequency sweep an alternate pair of silicon control rectifiers is closed, thereby causing the direction of current flow through the coil 11 to be reversed.

Although the current regulating circuitry of the present invention is described specifically in the above embodiment, it is to be understood that other means of regulating the flow of the biasing current from the first and second power supplies through the coil will function in a similar manner. Likewise, other means for controlling the direction of flow of the biasing current through the coil can be substituted for the current control circuitry specifically described above. It will be apparent to those skilled in the art that other modifications and changes can be made to the inventive ferrite bias regulator without departing from my invention in the broader aspects; and therefore I do not intend to limit the scope of my invention except as defined in the appended claims.

1 claim:

1. A ferrite bias regulator for controlling the saturation of a ferrite material which tunes the resonant frequency of a ferrite tuned cavity in a synchrotron to match or track a frequency sweep of a particle accelerating electric field of the synchrotron comprising in combination: a high voltage power supply, a coil adapted to be inductively coupled with associated ferrite material connected in series with the first high voltage power supply, a low voltage, high current power supply connected in series with the coil, and a current regulating means for regulating the passage of a biasing current through the coil, the biasing current adapted for controlling saturation of associated ferrite material.

2. The ferrite bias regulator of claim 1 in further combination with a current control means for reversing the direction of the biasing current flow through the coil after each frequency sweep of the particle accelerating electric field.

3. The ferrite bias regulator of claim 2 further defined in that the current regulating means is comprised of a first current modulator, a second current modulator connected in series with the first current modulator and the coil across the high voltage power supply, the first current modulator being connected in series with the coil across the low voltage, high current power supply, and a current regulating means for opening and closing the first and second current modulators thereby regulating the passage of the biasing current through the coil.

4. The ferrite bias regulator of claim 2 further defined in that the current control means is comprised of four control switches, two of the control switches being connected in series in each of two parallel circuits, the coil being connected between a point common to the two control switches in the other parallel circuit, and a control means for selectively closing two of the control switches while maintaining the other two control switches open, one of the closed control switches being in each of the parallel circuits and the two closed control switches being in series with the coil.

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