

PATENT SPECIFICATION

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(54) SYNCHRONOUS DYNAMOELECTRIC MACHINES

(71) We, SUNSTRAND CORPORATION, a corporation organised and existing under the laws of the State of Delaware, United States of America, of 4751 Harrison Avenue, Rockford, Illinois 61101, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to synchronous dynamoelectric machines, and provides in such a machine a switch for short-circuiting the main field rotor winding during induction start.

An AC voltage applied to the main stator winding of a synchronous dynamoelectric machine, employed as a motor, causes the rotor to accelerate to synchronous speed. Acceleration of the rotor occurs as the A.C. voltage is impressed on the damper bars which are used as a squirrel cage during start-up. The AC voltage is also impressed upon the main field rotor winding. When the rotor is at stand-still, or slowly rotating, high voltages tend to be developed in the main field rotor winding. These voltages are not desirable and must be minimized during start-up to prevent damage to the electronic components and windings.

The prior art discloses a number of essentially resistance-free paths for short-circuiting the main field winding of a synchronous motor during start-up. These include bypass circuits for either short-circuiting the main field or for providing a resistive bypass during start-up. Most of the circuits for shorting the main field winding employ silicon-controlled rectifiers (SCR's) and zener diodes which provide a current bypass path during the start-up of the synchronous machine. Also, centrifugal switches have been employed to disconnect the main field rotor winding from the remainder of the circuit during start-up. These have been unreliable because they use mechanical linkages and contacts, and are relatively inaccessible.

The invention provides a synchronous dynamoelectric machine having a main stator winding, an exciter field winding, and a rotor

on which is mounted a main field rotor winding and an exciter armature winding, comprising a transistor for shorting the main field rotor winding when the voltage across the main field rotor winding is of one polarity; diode means for limiting the voltage across the main field winding when the polarity of the voltage across the main field rotor winding is of the other polarity; and means for rendering the transistor inoperative when a voltage is received from the exciter armature winding. In the synchronous machine of the invention, a circuit shorts the main field rotor winding during an induction start, without the use of mechanical switches, SCR's or zener diodes. A transistor control switch is coupled across the main field rotor winding of the synchronous machine for shorting the main field rotor winding during start-up. The ON/OFF condition of the transistor is responsive to the polarity of the voltage induced across the main field rotor winding and is ON when the voltage is one of polarity and OFF when the voltage is of the other polarity. The diode means prevent excessive voltage buildup in the main field rotor winding when the transistor is OFF. When the speed of the rotor reaches a level at or near synchronous speed, current is provided to the exciter field winding. This establishes a voltage which is induced in the exciter armature winding. The voltage from the exciter armature winding biases the transistor control switch OFF. The transistor control switch remains OFF as long as current is received from the exciter armature winding. The shorting of the main field rotor winding during start-up protects circuit components and windings.

The invention is hereinafter particularly described, by way of example only, with reference to the drawings of which:

Fig. 1 depicts, in block form, the components to be mounted on the stator of a synchronous machine and, in schematic form, the improved circuit to be mounted for rotation on a rotor;

Fig. 2 is a waveform of the voltages developed by the circuit in Fig. 1; and

Fig. 3 is another embodiment of the improved rotor-mounted circuit.

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Referring to Fig. 1, three-phase voltage from an AC generator (not shown) is provided to main stator winding 10 in the well known manner when contacts 12 are closed. The voltage from the AC source is rectified and regulated by a rectifier/regulator 14. When the rotor attains a speed at or near synchronous speed, switch 15 is closed and current from rectifier/regulator is provided to exciter 16. Circuit 14 and switch 15 provide current to field winding 16 in the well known manner. The AC voltage applied to main stator winding 10 causes the rotor of the synchronous machine to rotate during start-up by well known induction principles, as by damper bars used as a squirrel cage. When a current is provided to exciter field winding 16, a voltage is induced in the exciter armature winding 18. The voltage from exciter armature winding 18, which consists of single windings 18-1, 18-2 and 18-3, is rectified by diodes 20, 22 and 24, and the resulting DC current is applied to main field rotor winding 26 to maintain synchronization of the rotor with the voltage in the main stator winding 10 for synchronous operation.

Main field rotor winding 26 is utilized near or at synchronous speed and must be short-circuited during start-up to prevent damage to electronic components, as for example diodes 20, 22 and 24. If it is not shorted during start-up, large induced currents are developed as a result of the voltage induced in the main field rotor winding 26 by main stator winding 10. The short circuit is removed from the main field rotor winding at or near synchronous speed. As the rotor rotates, lead 28 and lead 30 from main field rotor winding 26 alternately change in polarity from plus to minus as a result of the voltage induced by main stator winding 10. When lead 28 is positive, current flows through resistor 32 and provides a positive voltage at the base of transistor 34 with respect to lead 30, turning transistor 34 ON, and forward-biasing transistor 36, turning it ON to thereby short main field winding 26. Transistor 34 is an active semiconductor device having a base 34-b, emitter 34-e and collector 34-c. The base, emitter and collector of the transistor in the circuit are similarly labeled in the drawings.

For purposes of this invention, the term transistor does not include SCR's or any other member of the thyristor family of semiconductors.

When the induced voltage from the main stator winding 10 changes the polarity of the voltage in main field winding 26 (i.e., lead 28 being negative and lead 30 being positive), the voltage across main field winding 26 is limited by diodes 20, 22 and 24. Specifically, current flows from lead 30 through exciter armature winding 18, through the respective

diodes 20, 22 and 24, and returns to lead 28 of main field winding 26. Also, transistors 34 and 36 are off since their base-emitter junction is reverse-biased while the polarity across main field rotor winding 26 is reversed from that shown.

Voltage provided by exciter armature winding 18 is rectified by diodes 38, 40 and 42, providing a negative voltage with respect to lead 30 at their anode terminals. The voltage across resistor 44 is of a level sufficient to overcome the forward-biasing of the base-emitter junctions of transistors 34 and 36, turning off the transistors. The values of resistors 32 and 44 are selected so that the voltage at the base of transistor 34 is biased negatively when the voltage from exciter armature winding 18 is received. As long as a voltage is provided by exciter armature winding 18, transistors 34 and 36 will remain off, removing the short across the main field rotor winding 26.

Thus, considering the operation of the circuit from start-up to synchronous speed, a short is applied across main field rotor winding 26 for the positive portion of the voltage induced by main stator winding 10. The current flow through main field rotor winding 26 is limited by diodes 20, 22 and 24 when the voltage across main field rotor winding 26 is negative. When the rotor reaches a speed at or near synchronous speed, switch 15 becomes closed and a voltage from exciter armature 18 causes transistors 34 and 36 to be biased off.

Referring to Fig. 2, waveforms depict the operation of the circuit when a voltage is provided from exciter armature winding 18. Specifically, exciter output voltages are shown to be half-wave rectified to develop the voltage across resistors 32 and 34. The voltage across resistors 32 and 34 is the difference between the positive half-wave rectified voltage and the negative half-wave rectified voltage, as shown.

Referring to Fig. 3, an alternative rotor short-circuiting switch is shown and its operation is similar to the circuit shown in Fig. 1. The circuit is particularly useful when a single winding of the exciter armature (as single winding 18-1 disconnected from 18-2 and 18-3) is used to provide a negative bias supply. During start-up, main stator winding 10 induces a voltage in main field rotor winding 26 in a manner similar to that discussed above. The polarity of the voltage induced in main field winding 26 alternates between plus to minus on leads 28 and 30.

When the voltage on lead 28 is positive with respect to the voltage on lead 30, current flows through resistors 46 and 48, through a set of diodes 50, 52 and 54 and through a set of diodes 56, 58 and 60, and returns to lead 30 of main field rotor winding 26. The base-

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emitter junction of transistor 62 is forward-biased, rendering transistor 62 conductive to short the main field winding 26.

When the voltage induced in the main field winding 26 reverses polarity, as lead 30 being more positive than lead 28, current flows through a set of diodes 64, 66 and 68 and through a set of diodes 70, 72 and 74, returning to lead 28 of main field rotor winding 26. This limits the voltage developed across main field rotor winding 26 when lead 30 is more positive than the potential of lead 28.

The voltage developed by the individual winding 18—1 of the exciter armature winding is rectified by diodes 54 and 74, causing a voltage drop to appear across resistors 46 and 48. The voltage across resistor 48 overcomes the forward-biasing of transistor 62 as established by resistor 46, and transistor 62 turns off.

Although a single winding, 18—1, is shown connected to the circuit, it should be apparent that the other single windings, as 18—2 and 18—3 of the exciter armature winding 18, can be similarly connected, as shown by the dotted lines and components.

WHAT WE CLAIM IS:—

1. A synchronous dynamoelectric having a main stator winding, an exciter field winding, and a rotor on which is mounted a main field rotor winding and an exciter armature winding, comprising a transistor for shorting the main field rotor winding when the voltage across the main field rotor winding is of one polarity; diode means for limiting the voltage across the main field winding when the polarity of the voltage across the main field rotor winding is of the other polarity; and means for rendering the transistor inoperative when a voltage is received from the exciter armature winding.

2. A synchronous machine according to claim 1, wherein the transistor has a base, emitter and collector, the emitter and collector being connected across the main field rotor winding, and there is also provided a second transistor having a base, emitter and collector, the collector and emitter of the second transistor being connected between the base and the collector of the first transistor, the base of the second transistor being connected to the means for rendering the transistor inoperative.

3. A synchronous machine according to claim 1, wherein the transistor has a base, emitter and collector, the emitter and collector

being connected across the main field rotor winding, and the base being coupled to the means for rendering the transistor inoperative.

4. A synchronous machine according to any preceding claim, wherein the means for rendering the transistor inoperative comprise further diode means coupled to the exciter armature winding, and a first and a second resistor connected in series between the further diode means and the main field rotor winding.

5. A synchronous machine according to any preceding claim wherein the diode means are connected in series with the main field rotor winding and the exciter armature winding.

6. A synchronous machine according to claims 2 and 4, wherein the diode means comprise first, second and third diodes each connected in series with the exciter armature winding and the main field rotor winding; the further diode means comprise fourth, fifth and sixth diodes each connected to the exciter armature winding; the first resistor is connected in series with the base of the second transistor and the main field rotor winding; and the second resistor is connected in series with the base of the second transistor and the fourth, fifth and sixth diodes.

7. A synchronous machine according to claims 3 and 4, wherein the diode means comprise a first set of three diodes each connected in series with the main field rotor winding and the exciter armature winding; the further diode means comprise a second set of three diodes each connected with the exciter armature winding; the base of the transistor is connected with a junction of the first and second resistors; and third and fourth sets of three diodes are connected with each diode in series with the main field rotor winding and the exciter armature winding.

8. A synchronous dynamoelectric machine provided with a switch circuit for short-circuiting the rotor, substantially as particularly described herein with reference to Figures 1 and 2 of the drawings,

9. A synchronous dynamoelectric machine provided with a switch for short-circuiting the rotor, substantially as particularly described herein with reference to Figure 3 of the drawings.

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When the voltage induced in the main field winding 26 reverses polarity, as lead 30 being more positive than lead 28, current flows through a set of diodes 64, 66 and 68 and through a set of diodes 70, 72 and 74, returning to lead 28 of main field rotor winding 26. This limits the voltage developed across main field rotor winding 26 when lead 30 is more positive than the potential of lead 28.

The voltage developed by the individual winding 18—1 of the exciter armature winding is rectified by diodes 54 and 74, causing a voltage drop to appear across resistors 46 and 48. The voltage across resistor 48 overcomes the forward-biasing of transistor 62 as established by resistor 46, and transistor 62 turns off.

Although a single winding, 18—1, is shown connected to the circuit, it should be apparent that the other single windings, as 18—2 and 18—3 of the exciter armature winding 18, can be similarly connected, as shown by the dotted lines and components.

WHAT WE CLAIM IS:—

1. A synchronous dynamoelectric having a main stator winding, an exciter field winding, and a rotor on which is mounted a main field rotor winding and an exciter armature winding, comprising a transistor for shorting the main field rotor winding when the voltage across the main field rotor winding is of one polarity; diode means for limiting the voltage across the main field winding when the polarity of the voltage across the main field rotor winding is of the other polarity; and means for rendering the transistor inoperative when a voltage is received from the exciter armature winding.

2. A synchronous machine according to claim 1, wherein the transistor has a base, emitter and collector, the emitter and collector being connected across the main field rotor winding, and there is also provided a second transistor having a base, emitter and collector, the collector and emitter of the second transistor being connected between the base and the collector of the first transistor, the base of the second transistor being connected to the means for rendering the transistor inoperative.

3. A synchronous machine according to claim 1, wherein the transistor has a base, emitter and collector, the emitter and collector

being connected across the main field rotor winding, and the base being coupled to the means for rendering the transistor inoperative.

4. A synchronous machine according to any preceding claim, wherein the means for rendering the transistor inoperative comprise further diode means coupled to the exciter armature winding, and a first and a second resistor connected in series between the further diode means and the main field rotor winding.

5. A synchronous machine according to any preceding claim wherein the diode means are connected in series with the main field rotor winding and the exciter armature winding.

6. A synchronous machine according to claims 2 and 4, wherein the diode means comprise first, second and third diodes each connected in series with the exciter armature winding and the main field rotor winding; the further diode means comprise fourth, fifth and sixth diodes each connected to the exciter armature winding; the first resistor is connected in series with the base of the second transistor and the main field rotor winding; and the second resistor is connected in series with the base of the second transistor and the fourth, fifth and sixth diodes.

7. A synchronous machine according to claims 3 and 4, wherein the diode means comprise a first set of three diodes each connected in series with the main field rotor winding and the exciter armature winding; the further diode means comprise a second set of three diodes each connected with the exciter armature winding; the base of the transistor is connected with a junction of the first and second resistors; and third and fourth sets of three diodes are connected with each diode in series with the main field rotor winding and the exciter armature winding.

8. A synchronous dynamoelectric machine provided with a switch circuit for short-circuiting the rotor, substantially as particularly described herein with reference to Figures 1 and 2 of the drawings.

9. A synchronous dynamoelectric machine provided with a switch for short-circuiting the rotor, substantially as particularly described herein with reference to Figure 3 of the drawings.

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