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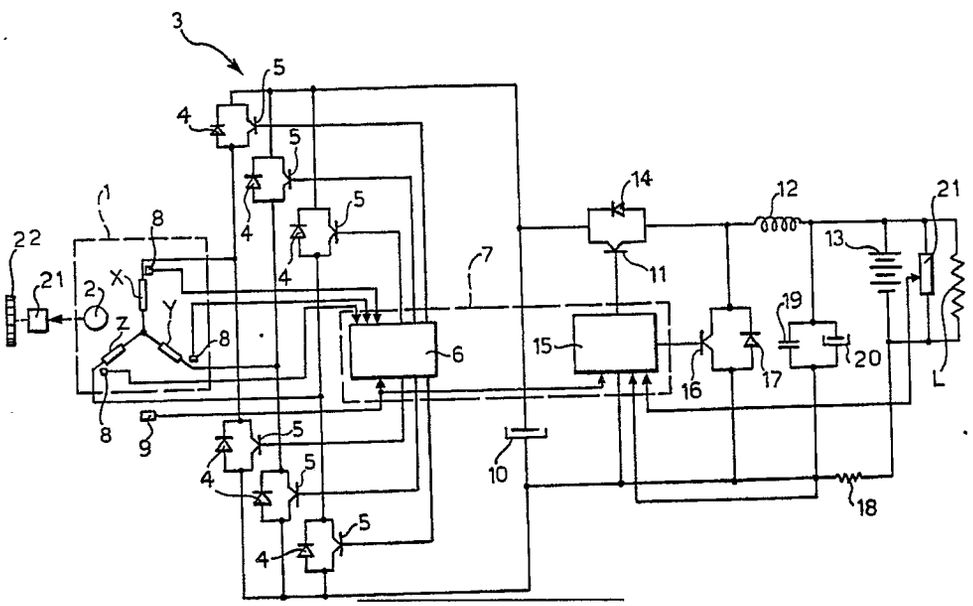
(54) An electric generator-motor system, particularly for use as a generator and starter motor in a motor vehicle.

(57) The system includes:
- a rechargeable direct-current voltage supply (13),
- a rotary electrical machine (1,2) with a polyphase armature (X,Y,Z),
- a controlled polyphase bridge circuit (3-6) adapted to act as a rectifier (4) when the electrical machine (1,2) is operating as a generator and as an inverter (5,6) when the electrical machine (1,2) is operating as a motor, and
- voltage-reducing devices (11,12,15,19,20) for reducing the voltage between the bridge circuit (3-6) and the supply (13) when the electrical machine (1,2) is operating as a generator.



EP 0 406 182 A1

AN ELECTRIC GENERATOR-MOTOR SYSTEM, PARTICULARLY FOR USE AS A GENERATOR AND STARTER MOTOR IN A MOTOR VEHICLE

The present invention relates to an electric generator-motor system, particularly for use as a generator and a starter motor in a motor vehicle provided with an internal combustion engine.

The system according to the invention is characterised in that it comprises in combination

- a rechargeable direct-current voltage supply,
- a rotary electrical machine with a polyphase armature,
- polyphase control means interposed between the electrical machine and the supply and adapted to act as rectifier means when the electrical machine is operating as a generator for supplying a rectified output current to the supply and/or a load, and as inverter means for providing the armature of the electrical machine with a polyphase current supply when the electrical machine is operating as a motor supplied with energy from the supply, and
- voltage-reducing means for reducing the voltage between the control means and the supply to a value suitable for recharging the supply when the electrical machine is operating as a generator.

Preferably, the rotary electrical machine is of the synchronous type and includes field-generator means with permanent-magnets.

The system may conveniently also include voltage-boosting means for increasing the voltage between the supply and the control means when the electrical machine is operating as a motor.

According to a further characteristic, the control means include a controlled polyphase bridge circuit piloted by an electronic control and operating unit.

Six rectifier diodes are provided in the bridge circuit, which is preferably of the three-phase type, and a respective controlled switching device, such as a transistor, is arranged in parallel with each diode.

Further characteristics and advantages of the present invention will become clear from the detailed description which follows with reference to the appended drawing which is provided by way of non-limiting example and shows the electrical layout of a system according to the invention.

With reference to the drawing, an electric generator-motor system according to the invention includes a rotary electrical machine, generally indicated 1, which is preferably of the synchronous type and has a three-phase armature whose windings are indicated X, Y and Z. These windings are connected in a star arrangement in the embodiment illustrated and are carried by a conventional stator, not shown.

The synchronous electrical machine 1 also includes a rotor 2 carrying field-generator means, preferably constituted by permanent magnets.

A three-phase bridge circuit, generally indicated 3, is connected to the armature windings of the machine 1. The circuit includes six rectifier diodes 4 each connected in parallel with the collector-emitter path of a respective transistor 5. The bases of the transistors are connected in order to corresponding inputs of a piloting circuit 6 which forms part of an electronic control and operating unit, generally indicated 7.

Sensors 8 are also connected to the piloting circuit 6 and are associated in order with the windings X, Y and Z so as to provide electrical signals indicative of the currents flowing in these windings. The sensors may be constituted, for example, by Hall-effect devices.

A speed sensor 9 is also connected to the piloting circuit 6 and provides electrical signals indicative of the angular velocity of the rotor of the electrical machine 1.

A capacitor 10 is connected in parallel with the bridge circuit 3.

A transistor, indicated 11, has its collector-emitter path arranged between the bridge circuit 3 and one terminal of an inductor 12 the other terminal of which is connected to the positive pole of a rechargeable direct-current voltage supply 13. This supply is constituted, for example, by the normal battery of a motor vehicle.

A diode 14 is connected in parallel with the collector-emitter path of the transistor 11 and has its cathode connected to the bridge circuit 3 and its anode connected to the inductor 12.

The base of the transistor 11 is connected to an output of an operating circuit 15 included in the electronic control and operating unit 7.

A further transistor, indicated 16, has its collector-emitter path connected between the junction between the diode 14 and the inductor 12 and earth. The base of this transistor is also connected to an output of the operating circuit 15 of the electronic unit 7.

A diode 17 is connected in parallel with the collector-emitter path of the transistor 16, with its cathode on the side nearest the inductor 12.

A resistor, indicated L in the drawing, represents a generic load connected to the supply 13.

A shunt resistor, indicated 18, is connected in series with the battery 13 and the load L. This resistor is also connected to an input of the operating circuit 15 and is intended to act as a sensor for sensing the current supplied to the battery 13 and the load L by the motor-generator system in operation.

Finally, two capacitors, indicated 19 and 20, are interconnected in parallel between the positive pole of the supply 13 and a terminal of the resistor 18.

A sensor for providing the operating circuit 15 with a signal indicative of the voltage supplied to the battery 13 by the system (when it is operating as a generator) is indicated 21. This sensor is constituted, for example, by a voltage divider or potentiometer in parallel with the battery.

The generator-motor system described above can conveniently be used as a generator and as a starter motor in a motor vehicle provided with an internal combustion engine. For this use, the rotor 2 of the electrical machine 1 is connected mechanically to the flywheel 22 of the internal combustion engine by means of a differential reduction unit 21 which may be of the epicyclic type or the "harmonic drive" type. When the rotor of the electrical machine 1 is acting as the driving part, the reduction unit 21 rotates the flywheel 22 at a considerbaly reduced speed in known manner. When the electrical machine is rotated by the internal combustion engine and is therefore operating as an electrical generator, the reduction unit transmits the drive from the flywheel 22 to the rotor of the electrical machine with a transmission ratio more or less equal to one.

The electronic control and operating unit 7 detects the rate of rotation of the rotor 2 of the electrical machine 1 in operation by means of a sensor 9 and, by comparing that rate with a pre-established reference, can establish whether the machine is operating as a motor or as a generator and consequently provides for the operation of the circuits 6 and 15 in the manner which will be described further below.

The operation of the above-described system when it is working as a generator will now be described.

When it is operating as a generator, the rotor 2 of the electrical machine 1 is rotated. The electrical machine therefore acts as a generator, in the manner of a normal alternator.

The piloting circuit 6 keeps the transistors 5 non-conductive. The three-phase bridge circuit 3 therefore operates as a normal passive rectifier circuit and provides a rectified output voltage which is smoothed by means of the capacitor 10.

The operating circuit 15 keeps the transistor 16 non-conductive and pilots the base of the transistor 11 in an on/off manner with a waveform whose pulse width is modulated (PWM) in dependence on the value of the voltage in the load as detected by means of the divider 21. Thus, when the transistor 11 is in the "on" condition, a current flows in the inductor 12 and towards the supply 13 and the load L. Energy is stored in the inductor 12.

When the transistor 11 is in the "off" condition, the capacitors 19 and 20 maintain the voltage in the load L, whilst the energy previously stored in the inductor 12 is recirculated through the diode 17.

The inductor 12 and the capacitors 19 and 20 together have an integrating and filtering effect on the voltage supplied to the supply 13 and the load L.

The voltage output by the bridge 3 varies according to the angular velocity imparted to the rotor 2 of the electrical machine. When the electrical machine is driven at a speed faster than a certain value, it can supply (downstream of the recitifier) a direct-current voltage higher than the nominal voltage of the battery 13. In these conditions, the circuit 15 reduces the voltage delivered to the battery in a similar way to the normal regulation circuits with which alternators used in motor vehicles are provided. However, these regulation circuits regulate the voltage supplied by modifying the current flowing in the field winding normally provided in alternators for use in motor vehicles: these regulation circuits therefore force the alternator to operate in almost short-circuited conditions and the alternator can therefore supply only a fraction of its maximum power.

In the system according to the invention, the voltage supplied by the machine to the battery is not regulated by modifying the field intensity but by choking the voltage supplied (by means of PWM). The machine is thus free to operate at voltages higher than the nominal voltage of the battery and can therefore supply a higher average power than that which can be supplied by a motor-vehicle alternator/regulator unit of similar characteristics, with a consequent net improvement in energy efficiency.

When it is working as an electric motor, however, the system according to the invention operates as follows.

The operating circuit 15 keeps the transistor 11 in the non-conductive condition and pilots the transistor 16 in an on/off manner by means of a pulsed signal whose pulse width is also modulated (PWM). Thus, when the transistor 16 is conductive, a current flows in the inductor 12 and in the collector-emitter path of the transistor 16 and energy is stored in the inductor. When the transistor 16 is cut off, the inductor 12 is connected to the capacitor 10 through the diode 14. The energy previously stored in the inductor 12 is discharged into the capacitor 10 and the voltage at its terminals gradually increases and is brought in successive steps to a value higher than that of the supply 13. When a predetermined voltage is reached in the capacitor 10, the piloting circuit 6 pilots the three pairs of transistors 5 in an on/off manner in a cyclic se-

quence with phase differences of 120°, so that the currents which are made to flow in the armature windings X, Y and Z of the electrical machine 1 have waveforms with phase differences of 120° and hence simulate a three-phase current system. The electrical machine 1 therefore acts as a motor and its rotor 2 starts to rotate.

As stated above, the bridge circuit 3 operates as a simple rectifier bridge when the system is operating as a generator but operates as a three-phase inverter when the system has to operate as a motor. For this purpose, the piloting circuit 6 may be of the type currently used for piloting so-called brushless motors.

However, the operating circuit 15 may be a normal integrated PWM modulator circuit easily obtainable commercially.

The functional synergism of some of the components of the system described above is particularly important: the operating circuit 15, the capacitor 10, the inductor 12 and the capacitors 19 - 20 form a voltage-boosting circuit when the system is called upon to operate as a motor and a voltage-reduction circuit when the system operates as a generator. The two different operating modes are achieved simply by the different piloting of the transistors 11 and 16.

The above description and the appended drawing refer to a system in which, when it is operating as a motor, a direct-current voltage supplied by the battery 13 is boosted by means of the circuit 15, the switch 12, the transistor 16 and the capacitor 10. However, for some applications, when the system is operating as a motor it is sufficient to supply the electrical machine 1 (through the inverter 3) directly with the voltage supplied by the battery. For such applications, the layout shown in the drawing may be modified by the elimination of the transistor 16 and a corresponding simplification of the circuit 15 (which now has to achieve the PWM piloting only of the transistor 11 when the system is operating as a generator). Moreover, the anode of the diode 14 must be disconnected from the cathode of the diode 17 and connected to the battery 13 so that, when the system is operating as a motor, the current supplied to the electrical machine by the battery does not pass through the inductor 12.

Claims

1. An electric generator-motor system, particularly for use as a generator and a starter motor in a motor vehicle provided with an internal combustion engine, characterised in that it comprises in combination

- a rechargeable direct-current voltage supply (13),
- a rotary electrical machine (1, 2) with a polyphase armature (X, Y, Z),
- polyphase control means (3 to 6) between the electrical machine (1, 2) and the supply (13) and adapted to act as rectifier means (4) when the electrical machine (1, 2) is operating as a generator for supplying a rectified output current to the supply (13) and/or a load (L), and as inverter means (5, 6) for providing the armature (X, Y, Z) of the machine (1, 2) with a polyphase current supply when the electrical machine (1, 2) is operating as a motor supplied with energy from the supply (13), and
- voltage-boosting means (15, 16; 10, 12) for increasing the voltage between the supply (13) and the control means (3 to 6) when the electrical machine (1, 2) is operating as a motor, and
- voltage-reduction means (15, 11, 12, 19, 20) for reducing the voltage between the control means (3 to 6) and the supply (13) to a value suitable for recharging the supply (13) when the electrical machine (1, 2) is operating as a generator.

2. A system according to Claim 1, characterised in that the electrical machine is of the synchronous type with field-generator means (2) of the type with permanent magnets.

3. A system according to Claim 1 or Claim 2, characterised in that it also includes voltage-boosting means (15, 16; 10, 12) for increasing the voltage between the supply (13) and the the control means (3 to 6) when the electrical machine (1, 2) is operating as a motor.

4. A system according to one of Claims 1 to 3, characterised in that the electrical machine (1, 2) is adapted to generate a voltage which, when rectified by the control means (3 to 6), is greater than the nominal voltage of the supply (13).

5. A system according to Claim 1 or Claim 2, characterised in that the control means comprise a controlled polyphase bridge circuit (3 to 5) piloted by an electronic control and operating unit (6).

6. A system according to Claim 5, characterised in that the bridge circuit (3 to 5) is of the three-phase type and includes six diodes (4) connected in a bridge arrangement and a respective controlled switching device (5) connected in parallel with each diode.

7. A system according to Claim 6, characterised in that each of the controlled switching devices comprises a transistor (5) with its collector-emitter path in parallel with a respective diode (4) of the bridge (3) and its base connected to a corresponding output of the electronic control and operating unit (6, 7).

8. A system according to any one of Claims 4 to 6, characterised in that the control means include sensor means (8) for sensing the current flowing in the armature (X, Y, Z) of the electrical machine (1,

2), the sensor means being connected to the electronic control unit (7) which is arranged to pilot the polyphase bridge circuit (3) in a predetermined manner in dependence on the signals supplied by the sensor means (8).

9. A system according to Claim 8, characterised in that the control means also include sensor means (9) for sensing the speed of rotation of the rotor (2) of the electrical machine (1, 2), the sensor means being connected to the electronic control and operating unit (7) which is also arranged to pilot the polyphase bridge circuit (3) in a predetermined manner in dependence on the signals supplied by the speed sensor means (9).

10. A system according to any one of Claims 5 to 7, characterised in that the voltage-reducing means comprise a first controlled switch (11) piloted by modulated-width pulses (PWM) from an electronic control and operating unit (15, 7), the first controlled switch (11) being arranged in series between the output of the bridge circuit (3) and the supply (13) and any load (L).

11. A system according to Claim 10, characterised in that an LC-type integrating and filtering circuit (12, 19, 20) is interposed between the first controlled switching device (11) and the supply (13) and any load (L).

12. A system according to Claim 11, characterised in that the integrating and filtering circuit comprises an inductor (12) connected in series with the first controlled switch (11) and a first capacitor (19, 20) in parallel with the supply (13) and with any load (L).

13. A system according to any one of Claims 10 to 12, characterised in that a second capacitor (10) is connected in parallel with the output of the bridge circuit (3).

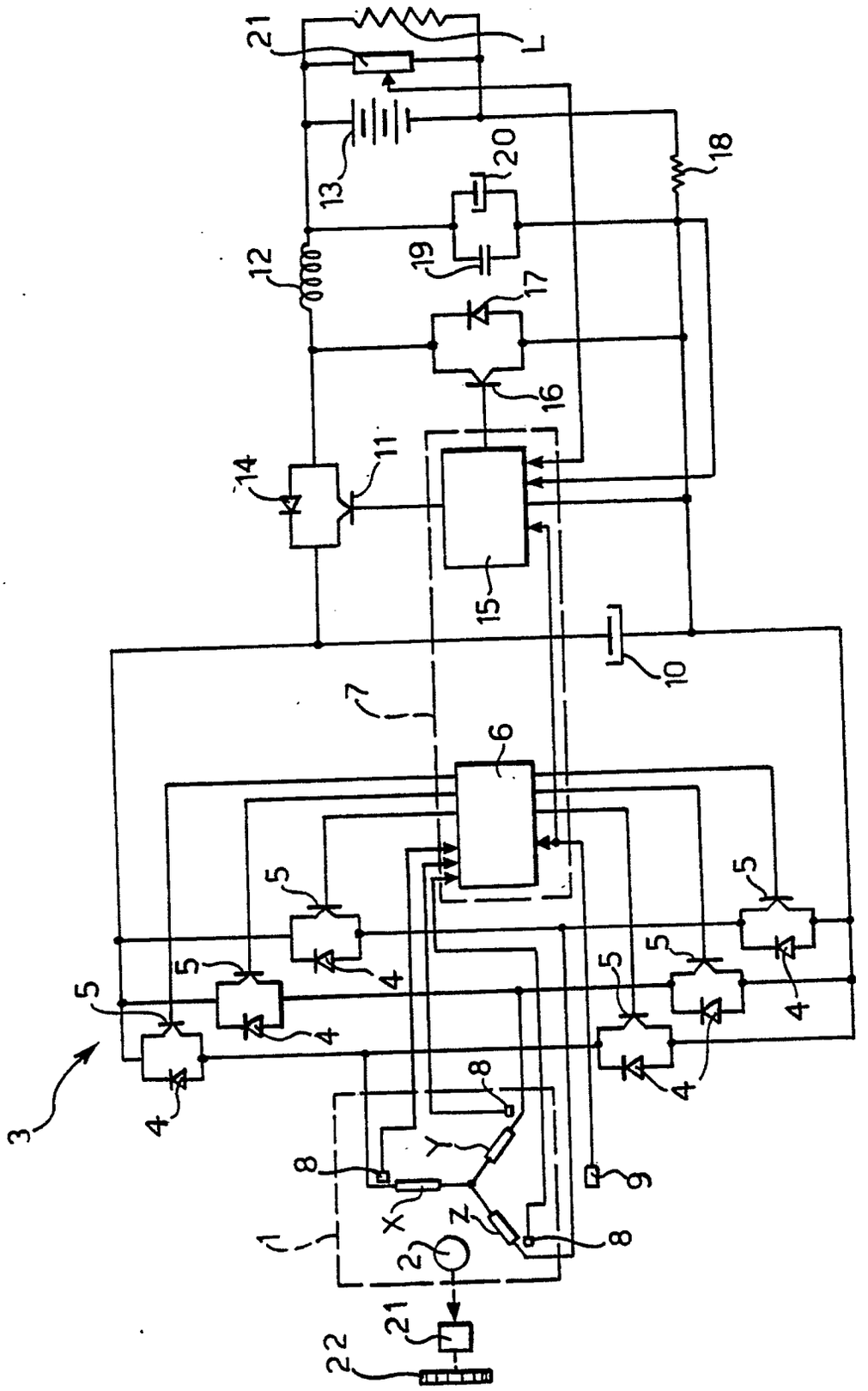
14. A system according to any one of Claims 5 to 12, characterised in that the voltage-boosting means comprise:

- a capacitor (10) connected in parallel with the bridge circuit (3),
- an inductor (12) in the path of the current between the supply (13) and the capacitor (10),
- a second controlled switch (16) arranged in parallel with the capacitor (10); the second controlled switch (16) being piloted in an on/off manner by the electronic control and operating unit (7, 15) when the electrical machine (1, 2) is acting as a motor so that, when the second switch (16) is conductive (on), energy is stored in the inductor (12) and is then discharged into the capacitor (10) when the second controlled switch (16) is non-conductive (off).

15. A system according to Claims 13 and 14, characterised in that a single capacitor (10) is connected in parallel with the polyphase bridge circuit (3) and acts as a voltage smoother when the electrical machine (1, 2) is acting as a generator and as a voltage booster when the electrical machine (1, 2) is acting as a motor.

16. A system according to any one of the preceding claims, characterised in that it also includes sensor means (21) for sensing the voltage in any load (L).

17. A system according to any one of the preceding claims, characterised in that, in order to operate as the starter motor of an internal combustion engine, the rotor (2) of the electrical machine (1, 2) is coupled for rotation with a member (22) of an internal combustion engine by means of a differential reduction unit (21).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EUROPEAN SEARCH REPORT

Application Number

EP 90 83 0291

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0260176 (VALEO) * page 4, lines 6 - 11 * * page 8, line 31 - page 9, line 26; figures 12-14. *	1, 3-12, 17.	F02N11/04
A	WO-A-8703648 (ROBERT BOSCH) * page 2, lines 17 - 30 *	2.	
A	PATENT ABSTRACTS OF JAPAN vol. 9, no. 46 (M-360)(1769) 27 February 1985, & JP-A-59 185872 (NISSAN JIDOSHA K.K.) 22 October 1984, * the whole document *		
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 179 (E-414)(2235) 24 June 1986, & JP-A-61 26500 (HITACHI LTD.) 05 February 1986, * the whole document *		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

F02N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	06 SEPTEMBER 1990	BIJN E.A.

CATEGORY OF CITED DOCUMENTS

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