AN ELECTRIC POWER SOURCE SYSTEM FOR GYROSCOPIC INSTRUMENT

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Filed: Jan. 19, 1971

Foreign Application Priority Data
Jan. 23, 1970 Japan........................................45/6193
Jan. 23, 1970 Japan........................................45/6194
Jan. 23, 1970 Japan........................................45/6195

U.S. Cl......................................................322/4, 310/74, 322/9
Int. Cl......................................................H02K 7/02
Field of Search..........................................310/74, 153; 322/4, 9; 318/150; 74/5.4, 5.7; 104/148

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Primary Examiner—Lewis H. Myers
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ABSTRACT

An electric power source system for a gyroscopic instrument in which the kinetic energy of the gyro rotor revolving at high speed is used as an induction generator during times when the normal electrical power source for the gyroscopic instrument fails and to maintain the gyroscopic instrument in its normal operative condition during the time the electrical power source is disconnected.

1 Claim, 7 Drawing Figures
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ELECTRIC POWER SOURCE SYSTEM FOR
GYROSCOPIC INSTRUMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates to an electrical power supply system for a gyroscopic instrument, and more particularly to an electrical power supply system in which electrical power is supplied to the gyroscopic instrument so that it can be driven normally even when the electric power source fails to supply power.

2. Description of the Prior Art
The interruption of the power supply for a gyroscopic instrument results in a serious matter and disrupts the proper operation of the gyroscopic instrument for a long period of time. Prior to this invention, the solution to this problem has not been known and the interruption of power has resulted in an adverse influence on the operation of the gyroscopic instrument.

SUMMARY OF THE INVENTION

Accordingly, the primary object of this invention is to provide an electrical power source system for a gyroscopic instrument which assures maintenance of normal operation of the gyroscopic instrument even when the power source is interrupted for a short period of time.

Another object of this invention is to provide an electrical power source system for a gyroscopic instrument which performs the function of a single-to-three phase converter, and enables the use of a three-phase motor with a single-phase power source and is of particular utility when employed in conjunction with a non-complex static inverter having a single-phase output.

Other objects, features and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram of a conventional induction generator in which a capacitor is inserted into each phase of a three-phase induction motor and the shaft of the induction motor is driven by another motor to supply electric power to a load;

FIG. 2 is a fundamental circuit diagram of a single-to-three phase converter;

FIG. 3 is a diagram showing the vector of a voltage between adjacent terminals of a three-phase motor;

FIG. 4 is a connection diagram showing one example of a circuit for driving the three-phase motor by a single-phase AC power source through the single-to-three phase converter; and

FIGS. 5, 6 and 7 are schematic circuit diagrams illustrating examples of a electric power source system for a gyroscopic instrument according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For a better understanding of this invention, a brief description will be given first of a gyroscopic instrument to which this invention applies.

In general, a gyroscopic instrument for determining reference for a vehicle such, for example, as a ship heading or attitude is adversely influenced by the interruption of its power supply source, even if the interruptions occur for only a short period of time. A gyroscope has a rotor of great mass which rotates at high velocity and when the power source is interrupted for a short period of time, the rotor of the gyro continues to rotate by inertia with substantially no decrease in the number of revolutions per unit of time. However, the operation of an electrical circuit accessory to the gyrooscope is not driven during interruption of the power source and the indications from the gyroscopic instrument such as the heading or attitude are no longer given. This is particularly true where the vehicle's indicated heading or attitude is controlled by an electrical follow-up servo system and during power failure external disturbances are applied to the gyrooscope to produce errors in the indicated output of the gyroscopic instrument.

Usually the vehicle's heading or attitude continuously changes during navigation and if the power interruptions end within a short period of time, the gyroscopic instrument produces erroneous indications. For example, a gyrocompass, which is the most common application of the gyroscope and is used for azimuth determination on a ship, an airplane and the like, employs a servo system to ensure that neither friction nor torque of free shafts of the gyrocompass are applied to the gyro itself. However, when the power source is cut off thus causing the servo amplifier to no longer function, the gyrocompass is subject to torque resulting from the movement of the ship, airplane or the like on which the gyrocompass is mounted, and the direction of the gyrocompass will change due to precession. An error in direction caused by such change will not be completely removed for several hours after power has been restored. Thus, even short interruptions of power exert an influence upon the functioning of the gyrocompass for many hours which results in inaccurate heading or attitude indications.

Generally, ships, airplanes or other mobile craft employ an independent electric power plant or a battery and the probability of the power interruption due to changeover of the generator or from trouble in the source is far greater than where a commercial power source is used. Accordingly, it is required that gyroscopic instruments function without being disturbed by power interruptions of short time intervals and give correct information after the power is restored. It is highly desirable to have a navigation system which does not produce errors during power interruption and which is also very accurate.

The rotor of the gyrooscope is usually driven by an induction motor which allows it to be stably driven at high speed for a long period of time.

It is well known that when the shaft of a multi-phase induction motor is driven at its synchronous speed by the external force, and, if a capacitor is connected to the terminal of the motor that the multi-phase induction motor will be caused to act as a self-excited induction generator by self-excitation due to the capacitor. When the frequency of the multi-phase induction motor is resonant with the frequency of the external driving means due to the primary self-reactance of the induction motor and the capacitance of the capacitor, it is possible to generate a self-excited frequency and power generation is achieved at a frequency depending upon the revolving speed of the generator at that time.

The rotor of the gyrooscope continues to rotate due to its great rotational inertia for a long period of time even after the power source of the motor is cut off. Accordingly, if a capacitive circuit is connected to the terminal of the motor, it is possible that during power interruption for the motor to function as an induction generator to provide power generation for supplying electrical power to the electrical accessory devices of the gyrooscope. Since the rotor keeps revolving even after interruption of power supply to the induction motor, the gyrooscope can be designed for a suitable selection of generated power and the inertia of the rotor to ensure maintenance of normal operation of the gyrocompass system for an appreciable period of time and until the number of revolutions of the rotor has substantially decreased.

A gyroscope requires that its rotor be driven at high speed and hence a power source of a relatively high frequency such, for example, as 333 Hz or 400 Hz is desirable in order to obtain these frequencies the supply power source for the gyrooscope is usually a motor-generator or a static inverter. Recent developments in semiconductor techniques renders the static inverter advantageous in efficiency, service life and size, and hence it is now widely used.

A static inverter which produces a multi-phase alternating current output directly is complicated and expensive and thus is not suitable for general demand. Therefore, it is more
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economical to change the output of a single-phase static inverter into a quasi three-phase output by the use of a single-to-three phase converter and use this signal to drive a three-phase motor.

For aircraft and warships, the signal and power source frequencies of measuring instruments and the like have been standardized at 400 Hz and such craft are usually equipped with a power source having a frequency of 400 Hz. In many cases, however, such a power source is single-phase, so that when it is used for the gyroscopic instrument a single-to-three phase converter must be interposed between the gyro and the power source.

When connecting a single-to-three phase converter to an induction three-phase motor, it is feasible to provide for power interruption by providing resonance conditions permitting the induction motor to serve as an induction self-excited generator.

FIG. 1 shows a connection diagram of a known circuit in which capacitors C are respectively connected to the phases of a three-phase induction motor M wherein its shaft is driven by another motor to provide a power supply to loads Z (==R+L). In this example, when driven at a speed higher than the synchronized one the induction motor M functions as an induction generator to supply the loads Z with power but it does not produce any reactive power. Accordingly, this induction motor cannot be used as a generator without a device for supplying reactive power to the power source side. It is known that if suitable capacitors C are connected to the stator windings of the motor M in parallel relation thereto that the motor M can be operated as a self-excited induction generator and during conditions of no load, the self-excited frequency of the generator is a synchronous frequency corresponding to the revolving speed and its self-excited voltage depends upon the capacity of the capacitors and the revolving speed.

FIG. 2 is a known fundamental circuit diagram of the single-to-three phase converter in which reference character E indicates a single-phase AC power source and C and L respectively a capacitor and an inductor for phase shifting. In this case, the single-phase of the power source E is supplied to the three-phase motor M after being converted into three-phase. Reference characters E and E respectively designate voltages across the capacitor C and the inductor L. A and B are input terminals of the single-to-three phase converter.

FIG. 3 is a diagramatic showing the phase differences in voltages derived from terminals 1, 2 and 3 of the three-phase motor M. The circuit of FIG. 2 produces voltages E and E which are respectively advanced and delayed 60 degrees relative to a reference voltage E and thus a quasi three-phase voltage is produced.

With such a circuit, it is impossible to produce a normal three-phase voltage, but in practice, the quasi three-phase voltage described above will suffice.

The condition for the realization of a quasi three-phase converter circuit for use with practical gyrocompasses is fundamentally the inclusion of the capacitor C for phase advance and the inductor for phase delay, as depicted in FIG. 2.

FIG. 4 illustrates one example of a circuit for supplying a three-phase motor M with power from a single-phase AC power source E through a single-to-three phase converter PA. In this circuit, ganged switches S and S are respectively interposed between the output terminal of the converter PA and input terminals 1 and 2 of the motor M. These switches are adapted to operate such that a switch S' interposed between one pole of the capacitor C and the terminal 2 to be closed when switches S and S are open and when the switches S and S are closed, the switch S' is open. By closing the switches S and S, a three-phase voltage such as depicted in FIG. 3 is impressed on the three-phase motor M to increase the revolving speed of the rotor R of motor M. By opening the switches S and S when the number of revolutions of the motor M has thus been increased up to its synchronous frequency causes switch S' to close as above described. At this time, a self-excited voltage is produced between the terminals 1 and 2, and, at the same time, induced voltages are respectively generated between the other terminals 2 and 3 and between terminals 3 and 1, since the capacitor C is connected between the terminals 1 and 2 of the motor M.

By inserting similar capacitors, though not shown, for phase advance between the terminals 2 and 3 and between terminals 3 and 1 as well as between terminals 1 and 2 simultaneously with the opening of the switches S, or S causes the circuit of FIG. 4 to operate in exactly the same manner as that of FIG. 1 and the self-excited voltages between the respective phases will be the same value and the synchronous frequency of the revolving speed of the motor and thus a load can be connected to each phase (refer to A and A in FIG. 6 described later).

In the example of FIG. 4, the capacitor incorporated in the aforementioned single-to-three phase converter PA may also serve as the capacitor to be interposed between the windings of the motor M at the closing of the switch S' as will be seen from the foregoing, the following conditions must be satisfied to cause an induction motor to act as an induction generator after the power source of the induction motor is cut off. These are:

1. A capacitive element or a circuit device which has a capacitive character such, for example, as a single-to-three phase converter must be inserted between the terminals of the induction motor.

2. The capacitance of the capacitive element must be selected in such a manner that the capacitance and the self-reactance of the windings of the induction motor are tuned to be resonant in an AC frequency region which is generated by the motor operating as an induction generator driven by external force at its synchronous speed.

3. The rotor of the induction motor continues to rotate substantially at the synchronous revolving speed due to the large inertia of a gyroscope.

FIG. 5 is a schematic circuit diagram showing one example of an electric power supply system for gyroscopic instruments in which a gyro motor M with rotor R is driven by a single-phase AC power source E such that when the power source E is cut off the three-phase induction motor M operates as an induction generator. In this figure reference numerals and characters similar to those in the foregoing examples designate the same elements as those mentioned above. In the illustrated example reference character G indicates a power source device including a generator or a transformer T and the voltage derived from the power source E applied to input ends A and B of a single-to-three phase converter through the transformer T. In FIG. 5 reference character A designates an electrical device accessory to the gyroscopic instrument which includes a servo system and an indicator device and so on which are necessary for the gyroscopic instrument. When the AC power source E is cut off, the gyro motor M serves as an induction generator due to the resonance of the capacitor C with the reactance between the terminals 1 and 2, as above described. The single-to-three phase converter circuit applies single-phase power to the input terminals A and B from the three-phase voltage induced between adjacent terminals of the motor M. Accordingly, the electrical device A, interposed between the terminals A and B continues its normal operation based upon power generation of the gyro motor M even if the power source is interrupted. In this case, there is the possibility that when the internal impedance of the power source device G is low relative to the induction generator M, that the power source device G will become a great load on the gyro motor M, and hence no power generation will be accomplished.

This can be avoided by providing that the circuit will be cut off at either one of the terminals A and B and terminals C and D provided on the side of the primary winding T of the transformer T when power interruption occurs. However, if the circuit A is a small load, the above circuit need not always be disconnected. It is rather necessary to prevent the "Q" of the resonance circuit from being raised by indiscr etely cutting off the circuit as this might provide an abnormally high generated
voltage. This is also true of the capacitor \( C_1 \) and the inductance \( L \) for the single-to-three phase conversion. It is necessary to select the "Q" of the resonance circuit such that the circuit can be tuned to a lower frequency band of the resonance frequency even if the number of revolutions of the rotor gradually decreases. The broken line block including the capacitor \( C \) and the inductance \( L \) in FIG. 5 indicates the single- to-three phase converter PA of FIG. 4.

FIG. 6 schematically illustrates a modified form of this invention for driving the gyroscopic instrument by using a known transistor inverter as the power source device \( G \). In this example, reference numerals and characters similar to those in FIG. 5 identify the same elements as those in FIG. 6. When supplied with power of a DC power source \( E \), transistors \( Q_1 \) and \( Q_2 \) of the power source device \( G \) are alternately turned on and off one after the other by the operation of a transformer \( T_1 \) of the power source device \( G \), producing an AC voltage \( E_{AC} \) of square wave shape as shown between both ends \( A \) and \( B \) of a secondary winding \( T_{2A} \) of the transformer \( T_2 \). Reference character \( A \) designates an additional circuit of the gyro which is similar to the circuit \( A \) but which requires a power source of a different phase from that of the circuit \( A \). In the present example the power source for the circuit \( A \) is derived from terminals \( 1 \) and \( 2 \) of the motor \( M_1 \). The voltage between the terminals \( 1 \) and \( 2 \) is used as a driving signal for a servo device or the like which is indispensable for the gyroscopic instrument. In this example an inductance \( L' \) is connected in parallel with the capacitor \( C_2 \). The inductance \( L' \) has a center tap \( b \) between one end \( a \) and one end \( 2 \), and tap \( b \) is electrically capacitive and compensates for the influence of the parallel connection of the capacitor \( C_2 \) directly to the gyro rotor. The impedances of the windings of the induction motor \( M_3 \) are at a minimum when the rotor is at a standstill and the impedances increase with an increase in the revolving speed of the rotor and becomes high when the rotor rotates at the synchronous speed. Therefore, when the capacitor \( C_2 \) for phase advance is directly connected in parallel to the motor windings as depicted in FIG. 4, the desired phase division is not achieved. However, when the load \( A_3 \) is also connected in parallel between the terminals \( 1 \) and \( 2 \) of the windings as shown in FIG. 6, the inductance \( L' \) is required for the elimination of the influence of the circuit \( A \).

It is a known technique for obtaining a stable output voltage in an induction motor to connect a capacitor to the terminals through an auto-transformer or to connect a saturable reactor in parallel to the capacitor so as to adjust a phase advancing current necessary for power generation.

Accordingly, the connection of the capacitor \( C_2 \) to the terminals of the motor through the inductance \( L' \) as shown in FIG. 6 provides an advantage that a stable output can be obtained not only in the case of the single-to-three phase converter but also when using it as an induction generator during power stoppage.

In FIG. 7 there is depicted another modification of this invention, which is an improvement to that of FIG. 6. In FIG. 7, reference numerals and characters similar to those in FIG. 6 identify similar elements. In the illustrated example, the motor can be operated as an induction generator for many hours and the voltages between the respective phases can be kept at substantially the same value. In the present example, two ganged movable switch contacts \( K_1 \) and \( K_2 \) of a relay coil \( K \) are inserted into one transmission line for a single-phase output voltage derived from the power source device \( G \). Reference characters \( K_{1H} \), \( K_{1L} \), \( K_{2H} \), and \( K_{2L} \), respectively indicate two pairs of fixed contacts for the movable switch contacts \( K_1 \) and \( K_2 \). The relay coil \( K \) is energized by the transformer \( T_1 \). When the relay coil \( K \) is energized, the movable switch contacts \( K_1 \) and \( K_2 \) contact the fixed contacts \( K_{1H} \) and \( K_{2H} \), respectively. The movable switch contact \( K_3 \) is connected in series to a capacitor \( C' \) and this series circuit is connected in parallel across the inductance \( L \). When supplied with power from the power source device \( G \), the circuit depicted in FIG. 7 performs exactly the same operation as that of FIG. 6, since the movable switch contact \( K_3 \) of the relay makes contact with the stationary contact \( K_1 \). When the power from the power source device \( G \) has been cut off, a self-excited induced voltage is generated by the three-phase motor \( M_1 \) as previously described and power is supplied to the additional electrical device \( A_1 \). At this time, the movable switch contact \( K_1 \) and \( K_2 \) of the relay are in contact with the contacts \( K_{1L} \) and \( K_{2L} \), respectively, as depicted in the figure, so that the power source device \( G \) is disconnected from the load side including the single-to-three phase converter circuit. As a result of this, neither exciting current of the transformer \( T_1 \) nor reactive current to the inverter flow and all the power from the motor \( M_1 \) is fed to the electrical device \( A_1 \). Further, the voltage balance between the respective phases is effectively maintained because the capacitor \( C' \) is inserted in parallel with the inductance \( L \) at this time as above described. This ensures a supply of proper voltage to the electric device \( A_1 \) for many hours.

As has been described in the foregoing, the present invention which is normal driving of the gyroscopic instrument in the case of temporary interruption of its power source and ensures that it is driven without any trouble even after the interruption of the power source has ended.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of this invention.

We claim:

1. An electrical power source system for a gyroscopic instrument driven by polyphase A.C. motor comprising:
a gyro rotor mounted in said gyroscopic instrument;
a polyphase A.C. motor connected to drive said gyro rotor at high speed having a plurality of windings;
a single-phase electrical power source;
a converter circuit means connected between said single-phase electrical power source and said polyphase motor for converting power from said single-phase source to polyphase power, a first capacitor in said converter circuit having a capacitance such that said capacitor resonates with the windings of said polyphase A.C. motor in the region of the frequency of said single-phase power source, and whereby said single-phase electrical power source is interrupted when said polyphase A.C. motor operates as an induction generator being driven by said gyro rotor to supply electrical power;
an electrical utilization circuit associated with said gyroscopic instrument electrically connected to said polyphase A.C. motor and energized thereby when said single-phase power source is interrupted,
a second capacitor is inserted between two of said windings of said polyphase motor which are not connected to said first capacitor, a relay connected to said single-phase source for controlling a pair of movable contacts with one disconnecting said single-phase electrical power source and said utilization electrical circuit of said gyroscopic instrument and another movable contact connected to second capacitor in circuit, whereby when said single-phase electrical power source is interrupted, the first movable contact is opened and the second movable contact is closed to disconnect said single-phase electrical power source from said induction generator.