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(54) Title: CONTROL AND PROTECTION SYSTEM FOR SINGLE-PHASE INDUCTION MOTOR AND CONTROL AND PROTECTION METHOD FOR SINGLE-PHASE INDUCTION MOTOR

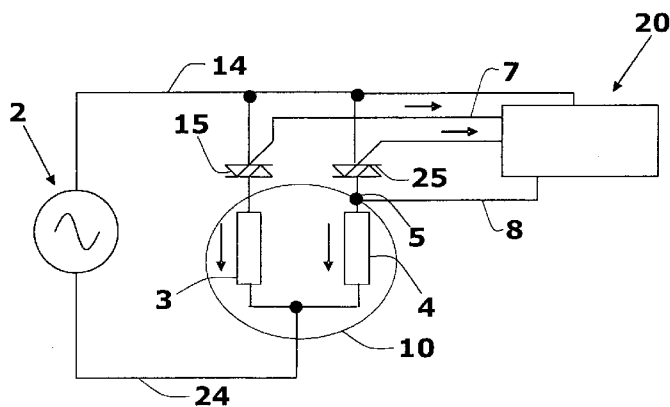


Fig. 2

(57) Abstract: The present invention refers to a control and protection system for a single-phase induction motor capable of detecting a start-up condition of the motor based on the observation of the phase difference between the currents of the main and auxiliary windings, and also of detecting any deceleration of the machine based on the observation of the phase difference existing between the current that circulates through the main winding and the voltage on the switch of the start-up winding. Said system comprises at least one electronic control circuit (20), at least one main switch (15) and at least one auxiliary switch (25), the main switch, (15) being electrically associated to a main winding (3) of the single-phase induction motor (10), the auxiliary switch (25) being electrically associated to an auxiliary winding (4) of the single-phase induction motor (10) through an electrical connection point (5), the electronic control circuit (20) being electrically associated to a trigger terminal of the auxiliary switch (25) and to a trigger terminal of the main switch (15), the electronic control circuit (20) being electrically associated to the electrical connection point (5), the control and protection system for a single-phase induction motor and the single-phase motor (10) being electrically associable to an alternating voltage source (2), the electronic control circuit (20)

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being capable of detecting a first movement condition of the single-phase motor (10) based on an angle- phasor difference measured between the currents that circulate through the main (3) and auxiliary (4) windings, and capable of detecting a second movement condition of the single-phase motor (10) based on an angle-phasor difference measured between the current that circulates through the main winding (3) and the electrical voltage on the auxiliary switch (25).

Specification of Patent of Invention for "**CONTROL AND PROTECTION SYSTEM FOR SINGLE-PHASE INDUCTION MOTOR AND CONTROL AND PROTECTION METHOD FOR SINGLE-PHASE INDUCTION MOTOR**".

The present invention refers to a control and protection system for single-phase induction motor, capable of detecting a start-up condition of the motor based on the observation of the phase difference between the currents of the main and auxiliary windings, and also of detecting any deceleration of the machine based on the observation of the phase difference existing between the current that circulates through the main winding and the voltage on the switch of the start-up winding.

Additionally, the present invention provides a control and protection method for a single-phase induction motor, capable of detecting the working conditions described above.

Description of the State of the Art

Today, electrical motors are used in an ever greater number of applications. It is known that induction motors particularly offer, in most cases, a robust solution, easy to maintain and low cost, when compared to the use of other kind of machines such as continuous current motor for the same application.

The use of frequency inverters, for example, has provided a wider gamut of applications for so-called induction motors over recent years.

More particularly, single-phase motors are widely used in household and commercial applications, although said machines are also used to generate torque in industrial applications, such as: motocompressors, pumps, ventilators, tools, among others.

An extremely relevant characteristic to be noted when using single-phase motors concerns the correct scaling of its start-up, in addition to a continuous evaluation of its working conditions, in order to guarantee that the best performance criteria are achieved.

Normally motors are started up by command devices that connect the start-up winding to the mains, until it attains a speed near to nomi-

nal. When said condition is observed, the start-up winding is disconnected from the mains.

Said command devices can be employed in various forms and arrangements. A common solution refers to the use of a start-up relay to act as command device during the start-up of the single-phase motor. In this case, the contacts of said relay, once powered by the main winding, act as providers of an electrical current for the start-up winding of the motor during its initial acceleration.

A drawback of said technique refers to the need to adjust the relay for each motor project used, making the project more complex and vulnerable to potential failures of said electro-mechanical device.

An alternative solution of the state of the art refers to the use of a centrifugal switch, which normally has a contact that is usually closed and a mechanism that is sensitive to centrifugal force. Said switch is sensitive to the turning speed of the drive axle, and is responsible for shutting down the start-up winding when the motor reaches a certain revolution.

The solution provided by the centrifugal switch has major limitations, such as the need to assemble its structure on the drive axle, or rotor, in addition to the fact that said solution must take into account the frequency of the network in which the motor will be installed.

Additionally, the centrifugal switch has the drawback of being fragile to wear, the action of particles and potential contaminants.

An additional technique uses a voltage relay to assist in the start-up of the motor, which normally has a contact that is usually closed and a coil that is sensitive to the mains voltage connected to the start-up winding of the motor. In this case, the motor also operates with a starting capacitor.

For the above solution, the current supplied to the start-up winding is controlled by said contact, such that the start-up winding is kept powered until the motor reaches a revolution near to synchronous speed.

As observed, the last solution described above has the drawback that said relay should be scaled in accordance with the project of the motor and the voltage of the mains.

A derivation of this technique consists of the electronic reading of the voltage existing on the start-up winding. Said characteristic must take into account a reference voltage to disconnect the start-up winding after accelerating the motor.

A limitation of this technique refers to the need to adjust the reference voltage at the point desired for shutting down the start-up winding, in addition to the fact that it only works with the use of a set of start-up capacitors.

Additionally, the solution adopted by the state of the art refers to the use of a timer switch to connect the start-up winding for a certain time. However, this technique has the drawback that the time needed to start the motor depends on the load condition and of the voltage supplied to the motor by the mains.

The use of a device of the PTC (Positive Temperature Coefficient) kind, which consists of a resistor having low ohmic resistance when installed at ambient temperature, interconnects the start-up winding to the mains, in order to supply an electrical current to said winding, consequently heating said resistance device.

The PTC device interrupts the current supplied to the start-up winding when the ohmic resistance is high, reflex of the accelerating of the single-phase motor and development of the synchronous speed achieved thereby.

A drawback of the use of the PTC refers to the fact that in the event of deceleration of the motor, said device will not supply a new current to the start-up winding, sequentially shutting down the single-phase induction motor by way of the motor thermal protection device. In this case, it is necessary to wait for the PTC device to cool down and then start up the motor again.

Other solutions of the state of the art, such as that disclosed in North American patent US 5808441, refers to additional solutions for the control and protection of electric motors.

Patent US 5808441 refers to a micro-processing system to con-

trol the motor, with the aim of monitoring and controlling the start-up and normal operation of a single-phase motor.

Said control is carried out by way of the phase difference measured between the mains voltage and the voltage between the main and auxiliary windings. More particularly, the invention described in the document US5808441 describes a motor control system for compressor or cooling apparatus.

A drawback of said North American art refers to the fact that said system is linked directly to the mains, which in many cases causes an inadequate working of the motor due to interferences or noise existing in the power line.

An additional drawback of the art presented in document US 5808441 refers to the use of additional sensors to measure a phase difference described below.

Based on the above, the present invention offers an innovative control and protection system for a single-phase induction motor compared to prior arts, capable of providing, efficiently, a start-up condition of the machine, as well as to evaluate a deceleration condition of the motor. Said characteristics are achieved by an arrangement not directly associated to the mains that is capable of avoiding potential noise interference from the mains, besides not using additional sensors.

Objectives of the Invention

A first objective of the present invention is to propose a control and protection system for single-phase induction motor, capable of detecting a start-up condition of the motor based on the observation of the phase difference between the currents of the main and auxiliary windings, and also of detecting any deceleration of the machine based on the observation of the phase difference existing between the current that circulates through the main winding and the voltage on the switch of the start-up winding.

A second objective of the present invention is to propose a control and protection method for single-phase induction motor, capable of detecting the start-up and deceleration conditions of the machine.

Brief Description of the Invention

The first objective of the present invention is achieved by providing a control and protection system for a single-phase induction motor comprising at least one electronic control circuit, at least one main switch and at least one auxiliary switch, the main switch being electrically associated to a main winding of the single-phase induction motor, the auxiliary switch being electrically associated to an auxiliary winding of the single-phase induction motor through an electrical connection point, the electronic control circuit being electrically associated to a trigger terminal of the auxiliary switch and to a trigger terminal of the main switch, the electronic control circuit being electrically associated to the electrical connection point, the control and protection system for a single-phase induction motor and the single-phase motor being electrically associable to an alternating voltage source, the electronic control circuit being capable of detecting a first movement condition of the single-phase motor based on an angle-phasor difference measured between the currents that circulate through the main and auxiliary windings, and capable of detecting a second movement condition of the single-phase motor based on an angle-phasor difference measured between the current that circulates through the main winding and the electrical voltage on the auxiliary switch.

The second objective of the present invention is achieved by providing a control and protection method for single-phase induction motor, the single-phase induction motor comprising a main winding and an auxiliary winding, the main and auxiliary windings being respectively associable to the main and auxiliary switches, the main and auxiliary switches each respectively having trigger terminals, said method comprising the following steps:

- electrically connect the main and auxiliary windings of the single-phase motor to a first end of the main and auxiliary switches respectively;
- connect the main and auxiliary switches to an electronic control circuit through the trigger terminals of the respective switches;
- electrically connect the electronic control circuit to an electrical connection point existing between a connection of the start-up winding and

the auxiliary switch;

- electrically connect the single-phase induction motor, the electronic control circuit and a second end of the main and auxiliary switches to an alternating voltage source;

- if the main and auxiliary windings are connected by way of the electronic control circuit, through the trigger terminals of the main and auxiliary switches, monitor after connection, by way of the electronic circuit, an angle phase difference existing between the currents that circulate through the main and auxiliary windings, by way of the voltages existing on the trigger terminals;

- if the angle phase difference, measured by the electronic control circuit, between the currents that circulate through the main and auxiliary windings, is over 40 degrees, shut down the auxiliary winding and keep the main winding connected;

- if the auxiliary winding is connected and the auxiliary winding is disconnected, monitor, through the electronic control circuit, the angle phase difference existing between the current that circulates through the main winding and the voltage on the auxiliary switch; and

- if the angle phase difference existing between the current that circulates through the main winding and the voltage on the auxiliary switch, for the auxiliary winding disconnected, is substantially less than 40 degrees, based on the reading taken by the electronic control circuit, shut down the main winding.

Summary Description of the Drawings

The present invention will now be described in greater detail, with reference to the drawings appended hereto, wherein:

Figure 1 – represents a graph highlighting the main operating conditions of a single-phase motor;

Figure 2 – represents a schematic view of the system now proposed for the control and protection of a single-phase induction motor, in accordance with the teachings of the present invention;

Figure 3 – represents a schematic view of the phase difference

between the currents that circulate through the main and auxiliary windings in two operating conditions;

Figure 4 – represents a second schematic view of the phase difference between the current that circulates through the main winding and the voltage on the auxiliary switch;

Figure 5 – represents a schematic view of some wave forms (voltage and current) present in the system;

Figure 6 – represents a second schematic view highlighting the phase angle between trigger voltages of the system switches; and

Figure 7 – represents a third schematic view highlighting the phase difference between the voltage in the trigger terminals of the main switch and the voltage on the terminals of the auxiliary winding switch.

Detailed Description of the Drawings

As mentioned previously, the object of the invention now proposed offers a control and protection system for single-phase induction motor, capable of efficiently foreseeing the start-up condition of the machine, as well as a deceleration condition of the motor.

These characteristics are achieved by way of an electronic arrangement not directly associated to the mains, conferring thereto greater immunity to noise, besides not making use of additional sensors to detect the operating conditions mentioned above.

It is known that single-phase motors essentially comprise a main winding 3 and an auxiliary winding, or start-up 4.

Normally, the main 3 and auxiliary 4 windings are connected to an alternating voltage source by means of switches. Said switches command the motor operations in start-up conditions and regime of the machine.

Figure 1 illustrates, by way of a graph, the main operating conditions of a single-phase induction motor 10, or simply single-phase motor 10, object of the present invention.

More particularly, figure 1 shows the torque curve developed by the motor, when the main winding 3, or the two motor windings, are connected to the alternating voltage source 2.

When the main 3 and auxiliary 4 windings are connected to the alternating voltage source 2, the single-phase motor 10 develops a higher torque ($T(I_p + I_a)$), as illustrated in a first operating condition of the motor 100 of figure 1, in order to execute its start-up. The second operating condition 200 of the single-phase motor 10, also illustrated in figure 1, represents its working at the moment in which only the main winding 3 is connected.

The same figure also shows the third operating condition 300 of the motor, this being the ideal moment to uncouple the auxiliary winding 4, after its start-up. The third operating condition 300 refers to the moment in which the single-phase motor 10 has reached maximum torque condition, at which point it is possible to shut down the auxiliary winding 4.

Figure 2 illustrates the control and protection system of the single-phase induction motor, in accordance with the teachings of the present invention.

In figure 2 it is possible to note that the system comprises, besides the single-phase motor 10 itself, at least one electronic control circuit 20, at least one main switch 15 and at least one auxiliary switch 25.

The electronic control circuit 20 can be comprised by a circuit, or semiconductor, micro-controlled, or even micro-processing device, capable of executing the software to evaluate the operating status of the motor in accordance with the operating conditions now proposed.

Additionally, it is provided in the present invention that said electronic control circuit 20 is equipped with peripheral devices, such as memory elements and/or data communication ports, in order to store the user program and to make data available for other devices.

The electronic control circuit 20 of the present invention is capable of taking the decision to connect, or shut down, a certain winding of the single-phase motor 10, in accordance with the operating conditions estimated thereby.

More particularly, and as already mentioned, said conditions are related to the moment of start-up of the single-phase motor 10, or even the moment at which it is decelerating.

Figure 2 also shows that a main switch 15 is electrically associated to the main winding 3 of the single-phase motor 10, the auxiliary switch 25 being electrically associated to an auxiliary winding 4 of the 25 single-phase motor 10, through an electrical connection point 5.

The electronic control circuit 20 is electrically associated to the electrical connection point 5, as shown in figure 2. As can be noted also in figure 2, the control and protection system for a single-phase induction motor and the single-phase motor 10 are electrically associable to an alternating voltage source 2, in order to supply sufficient electrical power for the start-up and regime operation of the motor 10.

The electronic control circuit 20 is associated to the alternating voltage source 2 through a first source terminal 14, as illustrated in figure 2.

An essential and innovative characteristic of the present invention refers to detecting the operating conditions of the single-phase motor 10.

In accordance with the teachings of the present invention, the electronic control circuit 20 is capable of detecting a first movement condition of the single-phase motor 10, based on an angle-phasor difference measured between the currents that circulate through the main 3 and auxiliary 4 windings. Said first movement condition is given during the start-up and acceleration of the single-phase motor 10.

Figure 3 illustrates an angle-phasor difference, in a first phase angle 11 and in a second phase angle 21, between the currents that circulate through the main 3 and auxiliary 4 windings.

Note, from figure 3, that in the first phase angle 11 the angle-phasor difference, or phases, is significantly reduced, this being the point of start-up of the single-phase motor 10. At this moment, the motor's two windings, main 3 and auxiliary 4, are connected to the alternating voltage source 2, through their respective switches. This is the first operating condition 100 of the single-phase motor 10, as illustrated in figure 1.

At the moment the single-phase motor 10 starts up, the current I_{a1} that circulates through its auxiliary winding 4 is ahead of the current I_{p1} that circulates through its main winding 3.

As the single-phase motor 10 accelerates, and nears its working revolution condition, or regime, the angle-phasor difference increases as indicated in figure 3, to the second phase angle 21. At this point, the second phase angle 21 is around 50 degrees, and the current I_{a1} that circulates through the auxiliary winding 4 is behind the current I_{p1} that circulates through the main winding 3.

Said working revolution condition, or regime, is illustrated in figure 1, and is referred to herein as second operating condition 200 of the single-phase motor 10.

An advantage of the present system, compared to prior arts, lies in the fact that the angle-phasor difference described above is a common characteristic in single-phase motors 10, and so it is not necessary to know the project requirements for the different motors to evaluate its start-up condition and acceleration.

In this sense, the use of said angle-phasor difference, or phases, between the currents that circulate through the main 3 and auxiliary 4 windings, allows the electronic control circuit 20 to evaluate the best moment for shutdown, or uncoupling, by way of the auxiliary switch 25, of the auxiliary winding 4, if the single-phase motor 10 has attained the third operating condition 300.

In this condition, the angle-phasor difference is greater or equal to 40 degrees, and is thus easily detected by the electronic control circuit 20.

Said electronic control circuit 20 is also capable of detecting a second movement condition of the single-phase motor 10, based on an angle-phasor difference measured between the current I_{p1} that circulates through the main winding 3 and the electrical voltage V_{sa} on the auxiliary switch 25.

Said second movement condition refers to a reduced speed operation of the single-phase motor 10, substantially below its nominal speed. The second movement condition can also be evaluated in an idle or blocked status of the drive axle 10.

Figure 4 illustrates the third 31 and fourth 41 phase angles rela-

ting to the second movement condition of the single-phase motor 10, object of the present invention.

In this second movement condition, note that the angle-phasor difference measured between the current I_{p1} that circulates through the main winding 3 and the electrical voltage V_{sa} on the auxiliary switch 25 is reduced in the third phase angle 31, when compared to the fourth phase angle 41.

The moment identified by the third phase angle 31 reflects the operation of the single-phase motor 10 near the idle status of the axle, whereas the fourth phase angle 41 indicates the operation of the single-phase motor 10 near the second operating condition 200.

Based on this information, the electronic control circuit 20 is capable of detecting an idle axle condition of the single-phase motor 10, by observing the phase difference between the current I_{p1} that circulates through the main winding 3 and the voltage V_{sa} existing on the auxiliary switch 25.

In this kind of operation, the present protection and control system is capable of avoiding undesirable heating of the single-phase motor 10, shutting down the machine, and also allowing it to develop a new start-up. The main 15 and auxiliary 25 switches are preferably formed by thyristors of the TRIAC kind, or equivalents, such as disclosed in figure 2 of the present application.

According to the subject matter now claimed, the electronic control circuit 20 is electrically associated to a trigger terminal 8 of the auxiliary switch 25, whereas the same electronic circuit 20 is electrically associated to a trigger terminal 7 of the main switch 15. The trigger terminal, or gate, of a TRIAC is the connection responsible for receiving a command voltage whether or not to conduct its respective thyristor.

It is normally necessary to apply short-lasting pulses to trigger the TRIAC and turn it on, and said pulse must be repeated at every semicycle start of the mains voltage, in order to maintain the thyristor in the on-state throughout the entire voltage cycle. Figure 5 illustrates instants in which the trigger currents are applied to their respective TRIACs.

In the present invention, the electronic control circuit 20 is responsible for generating a trigger current principal IGP in the main switch 15 and the auxiliary trigger current IGA in the auxiliary switch 25.

In figure 5 it is also possible to note the existence of a main voltage VGP on the trigger terminal 7 of the main switch 15, and an auxiliary voltage VGA on the trigger terminal 8 of the auxiliary switch 25, in the moment at which they are in the on-state, as well as the currents that circulate through each switch. This case refers to an electrical voltage value originating from the trigger terminals from the main 15 and auxiliary 25 switches.

According to the teachings of the present invention, the angle-phasor difference measured between the currents that circulate through the main 3 and auxiliary 4 windings, as already described, is obtained from said electrical voltage value originating from the trigger terminals of the main 15 and auxiliary 25 switches.

More particularly, the electrical voltage value originating from the trigger terminals is further capable of detecting the direction of the currents that circulate through the main 3 and auxiliary 4 windings, and also the point at which they cross zero.

It must be emphasized that the electrical voltage value originating from the trigger terminals, especially the main VGP and auxiliary VGA voltages, is around 1V when its respective thyristor is in the on-state.

Furthermore, the polarity of said voltages varies, thus allowing the direction of the currents that circulate through each TRIAC to be inferred.

Figure 6 illustrates the main VGP and auxiliary VGA voltages, observed in the trigger terminals of the main 15 and auxiliary 25 switches, as well as the angle α formed between said voltages, and in this sequence it is possible to infer by the angle between the currents that circulate through both switches. Said value is estimated by the electronic control circuit 20, in accordance with the teachings of the present invention.

As described previously, said angle α is employed by the electronic control circuit 20 to determine the moment at which the auxiliary winding 4 will be disconnected, in this case the main winding 3 only remaining

connected.

If the electronic control circuit 20 so understands, based on the phasor difference of the currents of the motor windings 10, that the angle between them is below a reference value, said circuit 20 should maintain both windings connected, in order to provide the start-up torque required for the single-phase motor 10. Preferably, said reference angle is about 30 degrees.

In alternative applications, it is possible to program the electronic control circuit 20, via software, so that it can develop a new start-up in the single-phase motor 10, if it fails to achieve the desired revolution within a pre-set time period.

An alternative embodiment, in accordance with the object of the present invention, refers to the observance of an AIV voltage angle, as illustrated in figure 7, between the voltage phase on the auxiliary switch 25, when open, and the phase of the voltage principal VGP present in the trigger terminal 7 of the main winding.

Said AIV voltage angle, when implemented via software in the electronic control circuit 20, makes it possible to evaluate the operating status of the single-phase motor 10, and more particularly whether it is working in operation, or regime, or even in low revolution or idle.

Analogously to the forms already described for the present system, when the single-phase motor 10 is in regime operation, said AIV voltage angle is substantially elevated compared to the angle of AIV voltage obtained for the motor 10 at reduced speed, offering the electronic control circuit 20 an efficient detection mechanism of the motor operating status.

It is further provided in the present invention the use and control and protection method for a single-phase induction motor. To implement said method, the single-phase induction motor 10 comprises a main winding 3 and an auxiliary winding 4, the main 3 and auxiliary 4 windings being respectively associable to main 15 and auxiliary 25 switches.

The main 15 and auxiliary 25 switches each respectively have trigger terminals, as mentioned previously. The method now proposed es-

entially comprises the following steps:

- electrically connect the main 3 and auxiliary 4 windings of the single-phase motor 10 to a first end of the main 15 and auxiliary 25 switches respectively;

- connect the main 15 and auxiliary 25 switches to an electronic control circuit 20 through the trigger terminals of the respective switches;

- electrically connect the electronic control circuit 20 to an electrical connection point 5 existing between a connection of the start-up winding 4 and the auxiliary switch 25;

- electrically connect the single-phase induction motor 10, the electronic control circuit 20 and the second end of the main 15 and auxiliary 25 switches to an alternating voltage source 2;

- if the main 3 and auxiliary 4 windings are connected by way of the electronic control circuit 20, through the trigger terminals of the main 15 and auxiliary 25 switches, monitor after start-up, through the electronic circuit 20, an angle phase difference existing between the currents that circulate through the main 3 and auxiliary 4 windings, through the voltages existing on the trigger terminals;

- if the angle phase difference, measured by the electronic control circuit 20, between the currents I_{p1}/I_{a1} that circulate through the main 3 and auxiliary 4 windings is over 40 degrees, shut down the auxiliary winding 4 and keep the main winding 3 connected;

- if the auxiliary winding 3 is connected and the auxiliary winding 4 is shut down, monitor, by way of the electronic control circuit 20, the angle phase difference existing between the current I_{p1} that circulates through the main winding 3 and the V_{sa} voltage on the auxiliary switch 25;

- if the angle phase difference existing between the current I_{p1} 30 that circulates through the main winding 3 and the V_{sa} voltage on the auxiliary switch 25, to shut down the auxiliary winding 4, is substantially less than 40 degrees, based on the reading by the electronic control circuit 20, shut down the main winding 3.

It is important to emphasize that the present system has greater

immunity to any noise from the mains, compared to prior arts, since the electronic control circuit 20 makes no use of network parameters to evaluate the operating state of the single-phase motor 10.

Lastly, the object of the invention now proposed does not need additional sensors to evaluate the operating status of the single-phase motor 10.

Having described examples of preferred embodiments, it must be understood that the scope of the present invention encompasses other possible variations, and is only limited by the content of the claims appended herein, potential equivalents being included therein.

CLAIMS

1. Control and protection system of single-phase induction motor comprising:

- at least one electronic control circuit (20),
- at least one main switch (15); and
- at least one auxiliary switch (25),

the main switch (15) being electrically associated to a main winding (3) of the single-phase induction motor (10),

the auxiliary switch (25) being electrically associated to an auxiliary winding (4) of the single-phase induction motor (10) through an electrical connection point (5),

the electronic control circuit (20) being electrically associated to a trigger terminal (8) of the auxiliary switch (25) and to a trigger terminal (7) of the main switch (15),

the electronic control circuit (20) being electrically associated to the electrical connection point (5),

the electronic control circuit (20) being electrically associated to a first source terminal (14),

the control and protection system for a single-phase induction motor and the single-phase motor (10) being electrically associable to an alternating voltage source (2),

characterized in that the electronic control circuit (20) is capable of detecting a first movement condition of the single-phase motor (10) based on an angle-phasor difference measured between the currents that circulate through the main (3) and auxiliary (4) windings, and capable of detecting a second movement condition of the single-phase motor (10) based on an angle-phasor difference measured between the current that circulates through the main winding (3) and the electrical voltage on the auxiliary switch (25).

2. Control and protection system of single-phase induction motor, according to claim 1, characterized in that the first movement condition of the single-phase motor (10) is given during its start-up and acceleration.

3. Control and protection system of single-phase induction mo-

tor, according to claim 1, characterized in that the second movement condition of the single-phase motor (10) is given during an operation of reduced speed of the single-phase motor (10) substantially below a nominal speed of the single-phase motor (10).

4. Control and protection system of single-phase induction motor, according to claim 1, characterized in that the second movement condition of the single-phase motor (10) is given during the idle axle condition of the single-phase motor (10).

5. Control and protection system of single-phase induction motor, according to claim 1, characterized in that the angle-phasor difference measured between the currents that circulate through the main (3) and auxiliary (4) windings is obtained from an electric voltage value originating from the trigger terminals (7,8) of the main and auxiliary switches (15,25).

6. Control and protection system for single-phase induction motor, according to claim 5, characterized in that the electrical voltage value originating from the trigger terminals (7,8) is capable of detecting the direction of the currents that circulate through the main (3) and auxiliary (4) windings and the point at which they cross zero.

7. Control and protection system of single-phase induction motor, according to claim 1, characterized in that the start-up winding is shut down by way of the auxiliary switch (25) in a condition in which the angle-phasor difference measured between the currents that circulate through the main (3) and auxiliary (4) windings is greater or equal to 40 degrees.

8. Control and protection system of single-phase induction motor comprising:

- at least one electronic control circuit (20),
- at least one main switch (15); and
- at least one auxiliary switch (25),

the main switch (15) being electrically associated to the main winding (3) of the single-phase induction motor (10),

the auxiliary switch (25) being electrically associated to an auxiliary winding (4) of the single-phase induction motor (10) through an electrical

connection point (5),

the electronic control circuit (20) being electrically associated to a trigger terminal of the auxiliary switch (25) and to a trigger terminal of the main switch (15),

the electronic control circuit (20) being electrically associated to the electrical connection point (5),

the electronic control circuit (20) being electrically associated to a first source terminal (14),

the control and protection system for a single-phase induction motor and the single-phase motor (10) being electrically associated to an alternating voltage source (2),

characterized in that the electronic control circuit (20) is capable of detecting a start-up condition or acceleration of the single-phase motor (10) based on an angle phase difference measured between the currents that circulate through the main (3) and auxiliary (4) windings, and capable of detecting a condition of reduced speed or deceleration of the single-phase motor (10) based on an angle phase difference measured between the current that circulates through the main winding (3) and the electrical voltage on the auxiliary switch (25).

9. Control and protection system of single-phase induction motor, according to claim 8, characterized in that the angle phase difference measured to detect a start-up condition and acceleration of the single-phase motor 10 is obtained from an electrical voltage value originating from the trigger terminals (7,8) of the main and auxiliary switches (15,25).

10. Control and protection method for a single-phase induction motor, the single-phase induction motor comprising a main winding (3) and an auxiliary winding (4), the main (3) and auxiliary (4) windings being respectively associable to main (15) and auxiliary (25) switches, the main (15) and auxiliary (25) switches each respectively having trigger terminals (7,8), characterized by comprising the following steps:

- electrically connect the main (3) and auxiliary (4) windings of the single-phase motor (10) to a first end of the main (15) and auxiliary (25)

switches respectively;

- connect the main (15) and auxiliary (25) switches to an electronic control circuit (20) through the trigger terminals (7,8) of the respective switches (15,25);

- electrically connect the electronic control circuit (20) to an electrical connection point (5) existing between a connection of the start-up winding (4) and the auxiliary switch (25);

- electrically connect the single-phase induction motor (10), the electronic control circuit (20) and a second end of the main (15) and auxiliary (25) switches to a alternating voltage source (2);

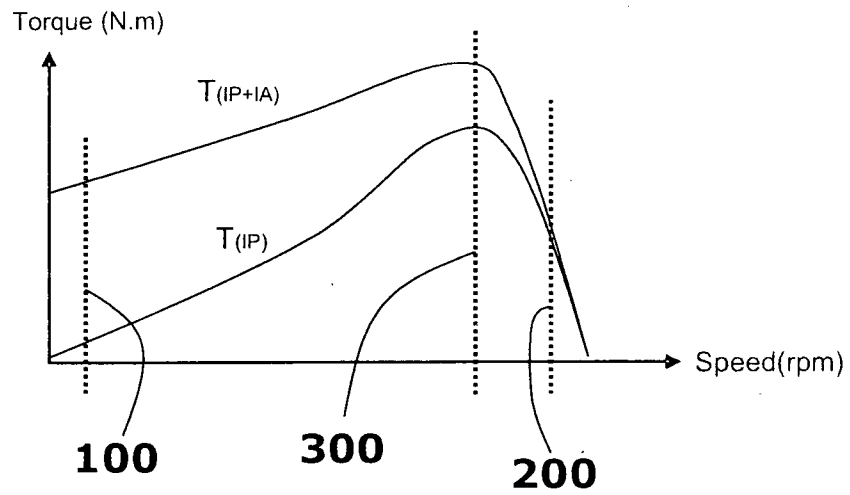
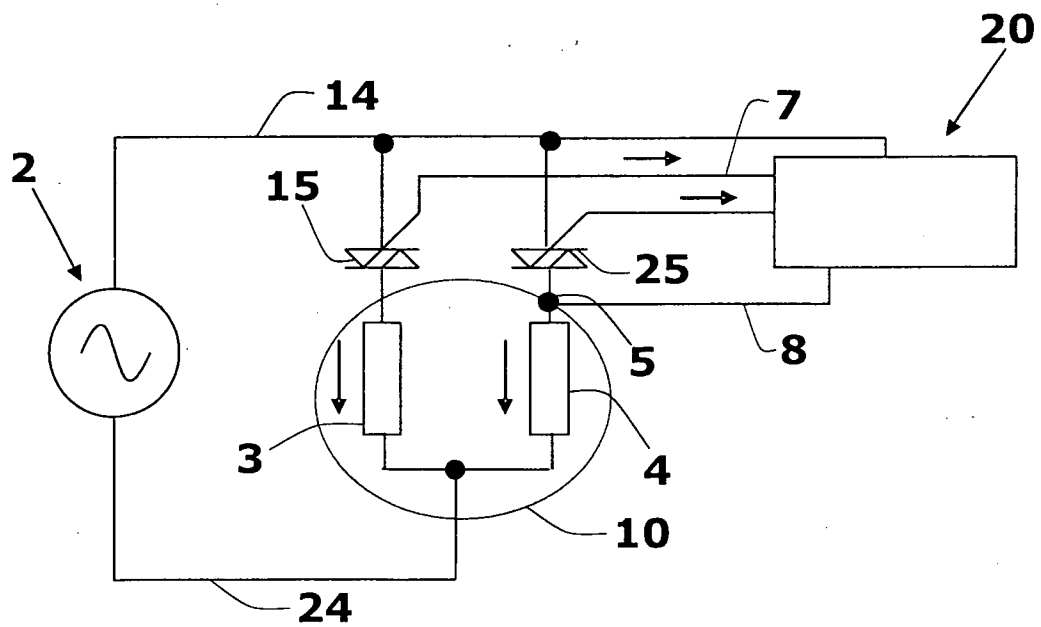
- if the main (3) and auxiliary (4) windings are connected by the electronic control circuit (20), through the trigger terminals (7,8) of the main (15) and auxiliary (25) switches, monitor after connecting, by way of the electronic circuit (20), an angle phase difference existing between the currents that circulate through the main (3) and auxiliary (4) windings, by way of the voltages existing on the trigger terminals (7,8);

- if the angle phase difference, measured by the electronic control circuit (20), between the currents (I_{p1} , I_{a1}) that circulate through the main (3) and auxiliary (4) windings is over 40 degrees, shut down the auxiliary winding (4) and keep the main winding (3) connected;

- if the auxiliary winding (3) is connected and the auxiliary winding (4) is shut down, monitor, by way of the electronic control circuit (20), the angle phase difference existing between the current (I_{p1}) that circulates through the main winding (3) and the voltage (V_{sa}) on the auxiliary switch (25);

- if the angle phase difference existing between the current (I_{p1}) that circulates through the main winding (3) and the voltage (V_{sa}) on the auxiliary switch (25), for the auxiliary winding (4) disconnected, is substantially less than 40 degrees, based on a reading by the electronic control circuit (20), shut down the main winding (3).

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**Fig. 1****Fig. 2**

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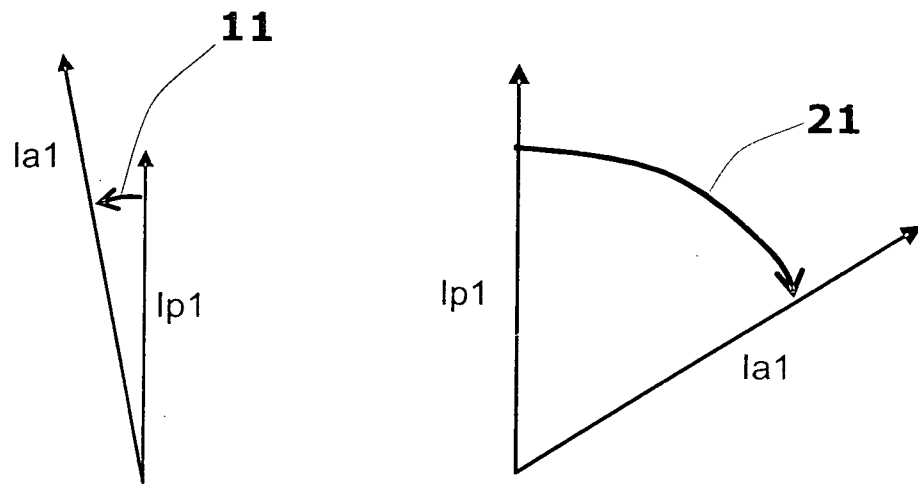


Fig. 3

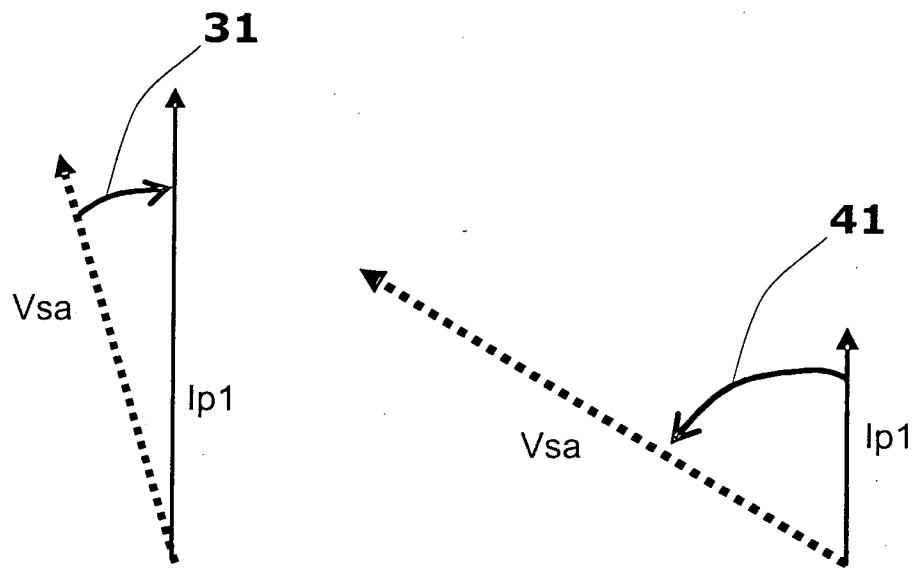


Fig. 4

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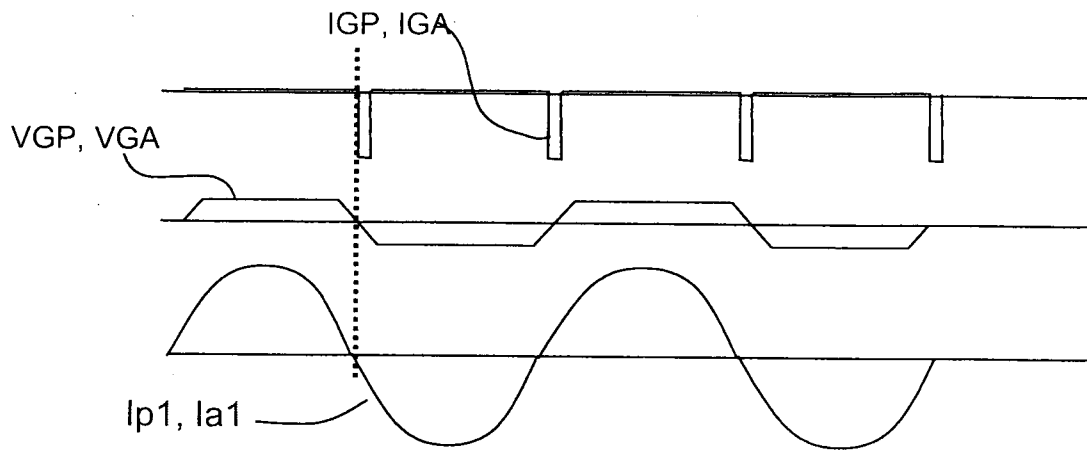


Fig. 5

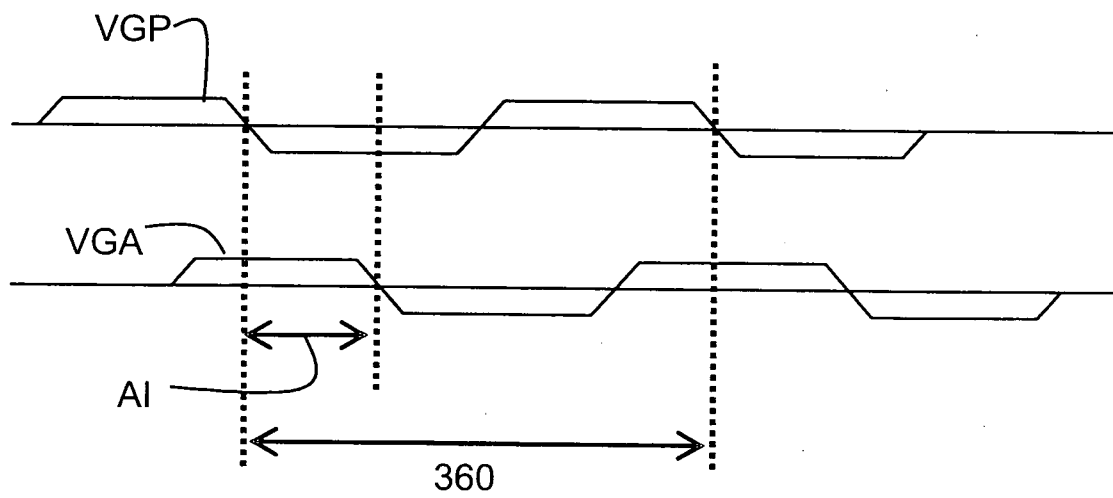


Fig. 6

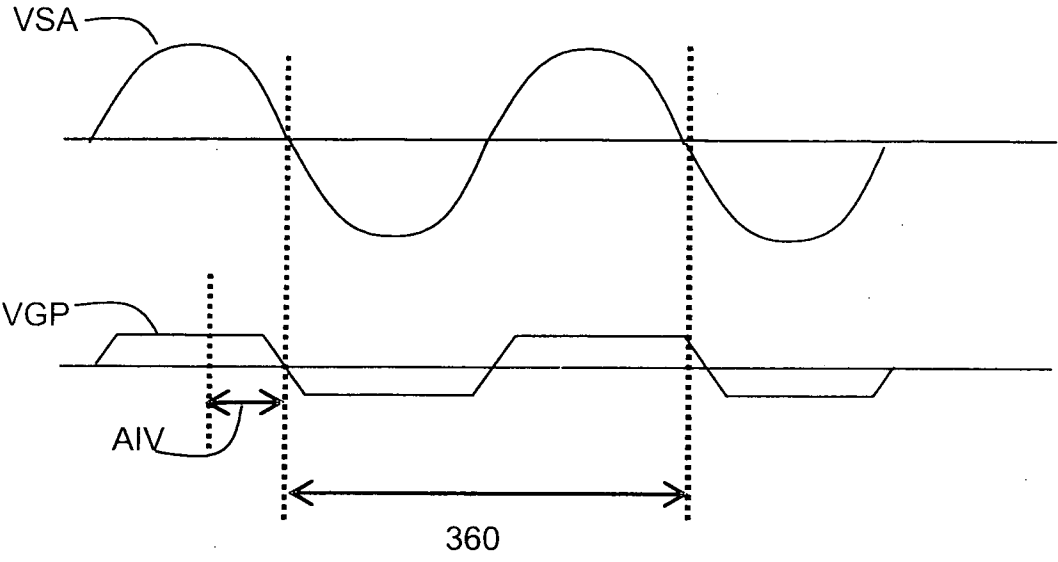


Fig. 7