

A CONTROL SYSTEM FOR A COMPRESSOR ACTUATED BY AN ELECTRIC MOTOR

The present invention relates to a control system, a method and an arrangement for motors and motor-compressors, designed for operation in a wide voltage range of the feed network.

10 Description of the Prior Art

Single-phase induction motors are widely used on motor-compressors, pumps, ventilators, household tools and appliances, and their performance thereof being sensitive to variation in the network voltage. The capability of overcoming the load at the start, the efficiency, the heating and the
15 maximum power supplied depend on the dimensioning thereof and on the voltage range to which they are subjected, this voltage being imposed by the network.

The dimensioning of these motors basically consists in defining the amount of electrical steel and the electric-conductor mass (copper mass),
20 wherein the larger the amount of material employed the better the performance of the motor and the higher the maximum power that can be extracted from it continuously. The nominal operation voltage of the motor is defined by the characteristics of the windings, and it is necessary to define the minimum voltage which the motor runs in order to keep the capability of overcoming
25 the specific load torque. For a given winding, as the voltage applied to the electric motor increases, the power that can be extracted will increase. On the other hand, the maximum voltage that can be applied to the motor is defined by the maximum temperature which the materials employed withstand, determining the condition of maximum voltage of use.

30 As it becomes necessary to dimension the electric motor to operate at a maximum voltage that is quite higher than the minimum voltage, that is to say, the greater the relation between the maximum and the minimum

voltage the larger the additional amount of material required for making this motor project feasible, which makes it more expensive.

Thus, motors employed under conditions in which the network voltage varies within a broader range are more expensive than motors used
5 under conditions in which the network has little variation.

In general, in less developed countries, due to ecological limitations, feed networks have serious limitations in their dimensioning, with the consequent loss in quality of the energy, having a poor voltage regulation, much floating, with periods of very high voltage when there so little demand,
10 and quite low voltages when many loads are connected.

As an example, a feed network with a nominal voltage of 230 V and high quality of energy, typically varies its voltage in a range of -10 to +15%, whereas in a network of low quality of energy, the variation may be in the range of -30 to +35%.

15 Thus, on markets where there are economical restrictions, there is usually an unfavorably conjunction of factors, on the one side the low quality of electric energy and on the other the demand for more economical products, which makes difficult or unfeasible the design of motors suitable for these applications.

20 The prior art in this filed is described in Patent Document WO 2005053147, where one designs an electric motor in order to work with a nominal voltage of operation or value of root mean square voltage, also called as effective value that is lower than the minimum value expected in the feed network voltage. The aim of this configuration allows the possibility of
25 always feed the motor, and for this purpose suffice it that the value of the controlled voltage should be lower than the value of the minimum network voltage. However, this configuration does not enable one to build the electric motor with dimensions smaller than the conventional ones, nor does it foresee correction of the level of voltage to be applied in order to compensate
30 losses resulting from harmonics.

Brief description and objectives of the invention

The present invention foresees a control system, an electronic

control assembly with an electric motor, a method and arrangement for motors and motor-compressors for enabling operation in a wide voltage range, making use of little material, specifically steel and copper, such a configuration enabling the use, for instance, of small-size compressors, making possible a number of cooling solutions, wherein the size is of particular relevance. As an example, the utilization of a compressor carcass of smaller size or lower height, which enables greater utilization of the space in the cooler, greater ease in assembling it, besides requiring a smaller amount of material and, therefore, being more economical.

Thus, according to the teachings of the present invention, the control system, assembly, method and arrangement for motors and motor-compressors designed for operation in a wide range of voltage of the feed network is constituted by an electronic control that receives the voltage supplied by the feed network and feeds the windings of the electric motor or motor-compressor for cooling, limiting the voltage to an effective value close to the value of the expected minimum voltage for the feed network, so as to enable the motor to have the capability of overcoming start and load operation torques, independently of the feed network having a rise in the voltage to its maximum expected value. When the feed network voltage exhibits a value higher than the minimum expected, the electronic control will limit the voltage supplied to the motor to a value close to the minimum expected in this feed network.

Among the objectives of the present invention, one is to provide systems employing single-phase induction motors capable of operating in a wide voltage range, while keeping full torque performance when the electric feed network exhibits voltage at its minimum level.

Another objective of this invention is to provide systems employing single-phase induction motors capable of operating in a wide voltage range, preventing the overheating of the materials when the electric feed network exhibits voltage at its maximum level.

A further objective of the present invention is to provide systems employing single-phase induction motors capable of operating in a wide vol-

tage range, while keeping the efficiency performance substantially high, even when the feed voltage is at its highest level.

Still another objective of the present invention is to provide systems employing single-phase induction motors capable of operating in a wide
5 voltage range with a reduced cost.

The control system, method and arrangement for motors and motor-compressors basically consists in associating an electronic control capable of regulating the voltage supplied to a motor with windings and magnetic core suitably dimensioned to fully meet the start and operation torques at
10 the minimum expected voltage for the electric energy network, wherein the electronic control incorporates the method of limiting the effective voltage on the motor windings, so as to maintain its capability of meeting the minimum torques specified for the application, independently of the rise in feed network voltage to values higher than the minimum voltage expected for the network.

These objectives are achieved by means of a control system for
15 controlling a compressor actuated by an electric motor, the system comprising an electronic control and at least one power switch electrically connected to the feed network voltage, the feed network voltage floating from a minimum network voltage, the power switch interconnecting the network voltage to windings of the electric motor and means in order to measure the voltage
20 of the feed network voltage and a controlled voltage applied to the windings of the electric motor, the electronic control being configured to periodically actuate the power switch, so that the constantly controlled voltage will be essentially close to the minimum network voltage expected for the network
25 voltage.

The objectives are further achieved by means of an assembly of electric induction motor and electronic control, the assembly being electrically connected to a feed network voltage that floats from a minimum network voltage, the electric motor being dimensioned to operate essentially in a voltage
30 range close to the minimum network voltage expected for the network voltage.

Another way of achieving the objectives of the present invention

is through an arrangement for motor-compressors, formed by a compression mechanism, coupled to an electric induction motor, the electric induction motor being fed by a controlled voltage, the controlled voltage being regulated by an electronic control, from a feed network voltage, the network voltage floating from a minimum network voltage, the arrangement being dimensioned to operate essentially in a voltage range close to a minimum network voltage expected for the feed network.

A further way of achieving the objectives of the present invention consists of a control method for controlling an electric motor, the electric motor being fed by a controlled voltage obtained from a network voltage, the network voltage floating from a minimum network voltage, the method comprising steps of continuously measuring the value of the network voltage, and decreasing the value of the controlled voltage to a level essentially close to the minimum network voltage expected and keeping it at this level.

Brief description of the drawing

The present invention will now be described in greater detail with reference to an embodiment represented in the drawing. Figure 1 shows a block diagram of the control system and arrangement for motors and motor-compressors, designed for operation in a wide range of voltage from the feed network, according to the teachings of the present invention.

Detailed description of the figure

As can be seen from figure 1, the control system for controlling a compressor actuated by an electric motor of the present invention comprises an electronic control 10, which is constituted by a processing unit electrically associated with at least one power switch 5, the power switch 5 being electrically connected to a network voltage V_{AC} . The power switch 5 interconnects the feed network voltage V_{AC} to windings (not shown) of the electric motor 2, the electronic control 10 being configured to periodically actuate the power switch 5, so that one can control the level of the network voltage V_{AC} to a level of a controlled voltage V_C .

Measurement means for measuring network voltage 11 and for measuring controlled-voltage 12 are also foreseen for measuring the network

voltage V_{AC} and the controlled voltage V_C , respectively.

Operationally, the electronic control 10 receives the information of the voltage value present in the feed network (network voltage V_{AC}) and of the voltage applied onto the windings of the motor (controlled voltage V_C),
5 and on the basis of this information it periodically activates electronic switches so as to apply a constant effective voltage to the motor windings, in other words, so that the controlled voltage V_C will always be essentially close to the minimum network voltage V_{AC-MIN} expected for the network voltage V_{AC} .

The electronic switches or power switches 5 used may be of the
10 TRIAC type or others that enable the conduction and interruption of the alternating current applied to the windings of the electric motor 2. If the switch is of the TRIAC type, the periodic actuation of the switch will take place at a moment delayed with respect to the crossing of the current through the value zero, at each cycle of the network voltage, and the longer this delay the greater the relation between the feed network effective value and the value applied
15 to the motor winding.

Adjustment of the level of the controlled voltage V_C to variations in the network voltage V_{AC}

When a TRIAC is used, there is a cut in the V_{AC} wave form, which
20 is originally sinusoidal and ceases to be sinusoidal, with cuts that, as they are increased, begin to generate a number of harmonics, which will gradually increase as the cut of the wave becomes larger, that is to say, as the value of the network voltage V_{AC} becomes higher and farther away from the value of the minimum network voltage V_{AC-MIN} , a situation in which one should further
25 cut the sinusoidal wave, so that the value of the controlled voltage V_C will reach the value of the minimum network voltage V_{AC-MIN} .

With the cuts that occurred in the network voltage V_{AC} to reach a level of controlled voltage V_C to levels close to the level of minimum network voltage V_{AC-MIN} , as the harmonics rise the current harmonics within the windings of the electric motor 2 will also increase and generate, within the elec-
30 tric motor, various torque curves that will cause some braking of on the rotor, generating heating and specially losses in the motor torque, and such loss of

torque should be compensated for depending on the losses caused by the harmonics.

In order to compensate for this, according to the teachings of the present invention, one should then raise the level of the controlled voltage V_C to a value higher than the value of the minimum network voltage V_{AC-MIN} proportionally to the value of the feed network voltage V_{AC} , so as to compensate for effects of loss of torque of the electric motor 2 through the harmonic contents of the voltage. This increment in the voltage to compensate for secondary effects caused by the harmonic contents of the voltage applied to the motor can be determined theoretically from the electric models of the motor and of computer simulation routines, as well as determined empirically from bench assays, by checking the performance of the electric motor 2. Since these are secondary effects, this compensation is generally dispensable.

As a general rule, one can consider that the difference between the value of the minimum network voltage V_{AC-MIN} and the controlled voltage V_{AC} will be proportional to the difference between the network voltage V_{AC} and the minimum network voltage V_{AC-MIN} expected, since the necessary compensation has a substantially linear behavior depending on the level of cut of the network voltage V_{AC} by the TRIAC and the consequent increase in the amount of harmonic components.

In terms of practical implementation according to the teachings of the present invention, one should configure the electronic control 10 so that the controlled voltage V_C will be essentially close to the value of the minimum network voltage V_{AC-MIN} , and the closer to this value the network voltage V_{AC} measured by the network-voltage measuring means 11 is, the closer to the minimum network voltage V_{AC-MIN} the level of the controlled voltage V_C should be kept. From the opposite point of view, one should configure the electronic control 10 so that the controlled voltage V_C will be essentially close to the value of the minimum network voltage V_{AC-MIN} , and the farther away the network voltage V_{AC} measured by the network-voltage measuring means 11 is from this value, the farther away from and above the value of the minimum network voltage V_{AC-MIN} the level of the controlled voltage V_C should be.

A further way of actuating according to the teachings of the present invention, one can establish that the difference between the value of the minimum network voltage V_{AC-MIN} and the controlled voltage V_C should be proportional to a level of cut effected by the power switch 5 in the network voltage V_{AC} to reach the level essentially close to the minimum network voltage V_{AC-MIN} expected.

In this way, the necessary compensation in the level of the controlled voltage V_C will take place, so that one can eliminate the effects resulting from the appearance of harmonic components, as described before.

10 Compensation for heating effects

As it is known, as the cuts at the level of the network voltage V_{AC} rise, this will raise the harmonic contents of the signal, generating a heating of the electric motor 2. However, such an effect is significantly smaller in comparison with the level of heating when one applies the value of the full sinusoidal of the network voltage V_{AC} to the motor 2, that is to say, without cuts made by the TRIAC, since in this situation of full sinusoidal wave, saturation of the iron would occur, generating losses in copper.

The present invention will solve this problem, inasmuch as no loss is generated in the motor, i.e., no heating is generated any longer. The heating resulting from the harmonic components as a function of the decrease of the network voltage V_{AC} for the level of controlled voltage V_C is significantly smaller if compared with the level of heating that would occur if the full sinusoidal of the network voltage V_{AC} is applied, so that, for practical purposes, one could consider that in the system of the present invention no heating occurs, whereas in the art of applying the full level of the network voltage V_{AC} , heating occurs.

Construction in assemblies of electric motor and electronic control and arrangements for motor-compressors

Bearing in mind that the concepts of the present invention are particularly applicable in cooling systems, one foresees the construction in the form of assembly of the electric induction motor 2 and of the electronic control 10, as well as an arrangement for motor-compressors, formed by a

compression mechanism, coupled to the electric induction motor 2, making the same control effected according to the constructiveness applied to the system of the present invention, that is to say, the electric motor 2 is dimensioned to operate substantially in the voltage range close to the minimum
5 network voltage V_{AC-MIN} expected for the network voltage V_{AC} , that is, within the same concepts applied to the system of the present invention.

Thus, the arrangement of the motor to operate in conjunction with this electronic control and method consists in dimensioning the windings of the motor so as to provide a torque value sufficient to overcome the highest
10 load required by the application, in a voltage equal to the minimum expected voltage for the feed network in question. In this way, the motor will be capable of operating without problems even when the feed network voltage is at its minimum value, and in this condition the electronic control will not be limited to the voltage coming from the network, which allows it to be fully applied
15 to the motor.

Further, in applications where the electric motor 2 is actuating a motor-compressor 1 for cooling, the sizing of this compressor 3 will enable the gas compression mechanism and the electric motor 2 to be installed on a smaller carcass, since the electric motor will have a significantly reduced size
20 with respect to the motor sized for a compressor designed according to the prior art. This motor-and-pump assembly according to the proposed technique in the present invention will not present additional heating in the periods in which the application network is exhibiting voltage higher than the minimum voltage expected for the network, facilitating the maintenance of the
25 temperature ranges of the electric and mechanical assembly of the compressor, in values that are acceptable for the efficiency performance of the compressor 1 and durability of the materials, which will make it possible to provide a quite compact light-weight motor-compressor to operate in severe conditions with a wide variation of the electric network voltage, employing conventional materials and with reduced cost.
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Sizing of the electric motor 10

As to the sizing of the motor, since the electric motor 5 operates

at a decreased level of voltage and since it is designed to operate at the level of the minimum network voltage V_{AC-MIN} foreseen in the network, the motor should be suitably dimensioned, that is, with reduced dimensions.

In this way, taking as an example a feed network that exhibits
5 minimum network voltage V_{AC-MIN} decreased by 30% below the usually fore-
seen nominal one, the winding of the electric motor 2 will have its number of
turns reduced to operate with 30% of undervoltage, which consists in a de-
sign different from that intended for a feed network exhibiting only 10% of
reduction of the voltage with respect to the nominal value. In conjunction with
10 this reduction in the number of turns, one also dimensions the magnetic core
so as to operate, under the condition of the minimum value of feed network
voltage V_{AC-MIN} , with the highest possible level of induction, respecting the
minimum efficiency required for application, which will lead to a significant
reduction in the volume of magnetic material employed, since this sizing can
15 be made only by considering this minimum value of network voltage, not by
considering the maximum value expected for the feed network any longer,
which could be up to 35% higher than the nominal value.

Further taking as a basis the above example, in the feed net-
works where one operates with a range of -30% below the minimum feed
20 network voltage V_{AC-MIN} of the network voltage V_{AC} and +35% above the net-
work voltage V_{AC} , this results in about 20% reduction in copper and about
33% reduction in steel, which are necessary to construct the electric motor 2.
Further taking as a basis the variation of -30% to +35% in the network vol-
tage V_{AC} , it is possible to obtain a decrease in the range of about 20 – 25%
25 decrease in the motor height.

Option for operation in bi-volt

Bearing in mind the characteristics of the present invention, it is
possible to make the electric motor 2 a bi-volt one. For this purpose, if the
controlled voltage V_C is modulated for the double of the minimum voltage
30 V_{AC-MIN} , for example, it would be possible to construct a system capable of
adjusting automatically and operate connected either to a 220V network or to
a 127V network. Although the motor operates with less efficiency at high vol-

tage, it would still be possible to operate it, for example, without heating and overload problems.

On the basis of the teachings of the present invention, one can achieve the desired objectives, and it is possible to manufacture a compressor with a significantly decreased volume and, at the same time, to have a product that operates in a wide range of network voltage values V_{AC} , including the configuration of a bi-volt product.

Preferred embodiments having been described, it should be understood that the scope of the present invention covers other possible variations, being limited only by the contents of the accompanying claims, which include the possible equivalents.

CLAIMS

1. A control system for a compressor actuated by an electric motor, the system comprising:

- 5 - an electronic control (10);
 - at least one power switch (5) electrically connected to the feed network voltage (V_{AC}), the feed network voltage (V_{AC}) floating from a minimum network voltage (V_{AC-MIN}); and
 - a power switch (5) interconnecting the feed network voltage (V_{AC}) to
 - 10 windings of the electric motor (2);
- the control system being characterized in that the electronic control (10) is configured to periodically actuate the power switch (5), so that the controlled voltage (V_C) will always be essentially close to the minimum network voltage (V_{AC-MIN}) expected for the feed network voltage (V_{AC}), the assembly formed by the compressor (3) and the
- 15 electric motor (2) is dimensioned to operate essentially close to the minimum network voltage (V_{AC-MIN}), the control system further comprising network voltage measurement means (11) and controlled voltage measurement means (12) to measure the feed network voltage (V_{AC}) and the controlled voltage (V_C), respectively.

2. A system according to claim 1, characterized in that the electric motor

20 (2) is dimensioned to operate essentially in a voltage range close to the minimum network voltage (V_{AC-MIN}) expected for the network voltage (V_{AC}).

3. A system according to claim 2, characterized in that the electronic control (10) keeps the controlled voltage (V_C) essentially close to the value of the minimum network voltage (V_{AC-MIN}), and the closer to this value the network voltage

25 (V_{AC}) measured by the voltage measurement means (11) is, the closer to the value of the minimum network voltage (V_{AC-MIN}) the level of the controlled voltage (V_C) will be.

4. A system according to claim 2, characterized in that the electronic control (10) keeps the controlled voltage (V_C) essentially close to the value of the minimum network voltage (V_{AC-MIN}), and the controlled voltage (V_C) being kept farther

30 away from the value of the minimum network voltage (V_{AC-MIN}) in a proportional manner to the difference between the minimum network voltage (V_{AC-MIN}) and the network voltage (V_{AC}) measured by the voltage measurement means (11).

5. A system according to claim 2, characterized in that the difference between the value of the minimum network voltage (V_{AC-MIN}) and the controlled voltage

35 (V_C) is proportional to the difference between the network voltage (V_{AC}) measured and the minimum network voltage (V_{AC-MIN}) expected.

6. A system according to claim 2, characterized in that the difference

between the value of the minimum network voltage (V_{AC-MIN}) and the controlled voltage (V_C) is proportional to a level of cut effected by the power switch (5) in the network voltage (V_{AC}), to reach the level essentially close to the minimum network voltage (V_{AC-MIN}) expected.

5 7. A system according to claim 6, characterized in that the electronic control (10) is configured to operate in a controlled voltage (V_C), having double the level of the minimum network voltage (V_{AC-MIN}).

8. An assembly of electric induction motor (2) and electronic control (10), characterized by being electrically connected to a feed network voltage (V_{AC}), the feed
10 network voltage (V_{AC}) floating from a minimum network voltage (V_{AC-MIN}),

the electric motor (2) being dimensioned to operate essentially in a voltage range close to the minimum network voltage (V_{AC-MIN}) expected for the network voltage (V_{AC}), the assembly being further configured such that the electronic control (10) keeps the controlled voltage (V_C) essentially close to the value of the minimum network
15 voltage (V_{AC-MIN}), and the controlled voltage (V_C) being kept farther away from the value of the minimum network voltage (V_{AC-MIN}) in a proportional manner to the difference between the minimum network voltage (V_{AC-MIN}) and the network voltage (V_{AC}) measured by the voltage measurement means (11).

9. An assembly according to claim 8, characterized in that the electronic
20 control (10) applies a controlled voltage (V_C) to the electric motor (2), the controlled voltage (V_C) being limited to a value essentially close to the minimum network voltage (V_{AC-MIN}).

10. An arrangement for motor-compressors, formed by a compression mechanism, coupled to an electric induction motor (2), the electric induction motor (2)
25 being fed by a controlled voltage (V_C), the controlled voltage (V_C) being regulated by an electronic control (10), from a feed network voltage (V_{AC}), the feed network voltage (V_{AC}) floating from a minimum network voltage (V_{AC-MIN}).

the arrangement being characterized in that the motor-compressor (1) is sized to operate essentially in a voltage range close to a minimum network voltage.
30 (V_{AC-MIN}) expected for the feed network.

11. An arrangement for motor-compressors according to claim 10, characterized in that the electronic control (10) limits the controlled voltage (V_C) applied to the electric motor (2) to a level essentially close to the minimum network voltage (V_{AC-MIN}) expected.

35 12. An arrangement for motor-compressors 11, characterized in that the electronic control (10) is configured to operate in a controlled voltage (V_C) having double the level of the minimum network voltage (V_{AC-MIN}).

13. A method for controlling an electric motor (2) applied to a compressor (3), the electric motor (2) being fed by a controlled voltage (V_C) obtained from the feed network voltage (V_{AC}), the feed network voltage (V_{AC}) floating from a minimum network voltage (V_{AC-MIN}), the method being characterized by comprising the steps of:

- 5 - continuously measuring the value of the feed network voltage (V_{AC}) by means of a network-voltage measuring means 11 and an electronic control (10);
- continuously measuring the value of the controlled voltage (V_C) by means of a measuring controlled-voltage (12) and the electronic control (10);
- and
- 10 - reducing the value of the controlled voltage (V_C), proportional to a level of cut effected by a power switch (5) in the network voltage (V_{AC}), to a level essentially close to the minimum network voltage (V_{AC-MIN}) expected and keeping it at this level.

14. A method as defined in claim 13, characterized in that, in the step of keeping the level of the controlled voltage (V_C) close to the level of the minimum network voltage (V_{AC-MIN}), the closer to this value the measured feed network voltage (V_{AC}) is, the closer to the value of the minimum network voltage (V_{AC-MIN}) the level of the controlled voltage (V_C) will be kept.

15. A method according to claim 13, characterized in that, in the step of keeping the level of the controlled voltage (V_C) close to the level of the minimum network voltage (V_{AC-MIN}), the farther from this value the measured feed network voltage (V_{AC}) is, the farther above the value of the minimum network voltage (V_{AC-MIN}) the level of the controlled voltage (V_C) will be kept.

16. A method according to claim 14, characterized in that, in the step of keeping the level of the controlled voltage (V_C) close to the level of the minimum network voltage (V_{AC-MIN}), the difference between the value of the minimum network voltage (V_{AC-MIN}) and the controlled voltage (V_C) should be proportional to the difference between the feed network voltage (V_{AC}) measured and the minimum network voltage (V_{AC-MIN}) expected.