

METHOD AND APPARATUS FOR FORMING
A REFERENCE VOLTAGE AMPLITUDE FOR A THREE-PHASE
INVERTER SUPPLYING A SQUIRREL CAGE MOTOR

5 The present invention concerns a method and apparatus for establishing the amplitude of a reference voltage for a three-phase inverter supplying a squirrel cage motor.

10 The frequency-controlled a.c. motor is the most advanced design for controlled speed drives, used for example, in lifts. With frequency control the efficiency is constantly high at any motor speed, and the mains power factor is nearly 1. Frequency control is applicable in gearless lifts and in lifts with gear
15 transmission, and at any speed. Moreover, it is possible to use for the motor a simple and reasonably priced squirrel cage motor. In lift applications, an inverter implemented with transistors is best suited for use in frequency control because transistors
20 enable the highest switching frequency to be achieved among presently existing power electronics components. GTO thyristors may also be contemplated, but their use is somewhat more cumbersome than that of transistors due to the components required for the
25 switching guard circuits which must be used with GTO thyristors.

Experience has revealed that a good strategy for controlling a squirrel cage motor is to keep the magnetic flux constant. As a rule, inertia is associated with magnetic flux. If the magnetic flux changes, a time constant is introduced into the system. Stabilization of the magnetic flux may be obtained by keeping the magnetic flux in either the stator, the rotor or the air gap constant. The most advantageous procedure is that in which the magnetic flux of the stator is kept constant because the risk of saturation of the components in the motor's magnetic circuit is then at its minimum.

It is present practice, in forming the reference voltage for an inverter, to use current feedback in which the current drawn from the inverter output is measured. The drawback of current feedback is slow response. This slow response is caused by the fact that in current feedback the inductances of the motor give rise to time constants. The control loop is as a rule slower the greater the number of time constants in it. Moreover, current measuring elements are expensive because they must also be able to measure direct current.

The object of the present invention is to eliminate the drawbacks mentioned.

In accordance with a first aspect of the present

invention, there is provided a method for the formation of the amplitude of a reference voltage for a three-phase inverter that supplies a squirrel cage motor, wherein said amplitude is formed by finding, in a
5 predetermined constant flux curve family representing the squirrel cage motor in question and in which family of constant flux curves the motor's rotor current frequency appears as a parameter, a curve from which the amplitude of the motor's stator voltage,
10 which corresponds to the frequency of the motor's stator voltage, is obtained, i.e. the inverter reference voltage, so that the magnetic flux in the stator will be constant.

When the method of the invention is applied, no
15 expensive current measuring elements are needed to form the reference voltage.

In an advantageous embodiment of the method of the invention, the substantially U-shaped constant flux curves are approximated by forming the legs of
20 the curve, relating to both directions of rotation of the motor, linearly except for low stator voltage frequencies, where the non-linear range at said low frequencies is approximated with a horizontal line portion. The height of said line portion is found by
25 combining the minimum of the base curve and a factor proportional to the frequency of the rotor current.

The invention also provides an apparatus for performing the method wherein, for the formation of the amplitude of the inverter reference voltage, with the exception of low stator voltage frequencies, the apparatus comprises a summing unit in which the stator voltage frequency is combined with a correction component proportional to the rotor current frequency; an absolute value amplifier in which the absolute value of the amplitude in the case of negative frequencies is formed; an adjustment means by which the correction component proportional to the rotor current frequency can be adjusted; and, for the approximation of the non-linear portion at said low frequencies, a first summing unit in which the horizontal portion approximating the minimum of the curve is formed, in the case of low positive stator voltage frequencies; a second summing unit, wherein the amplitude value obtained from the first summing unit is added to the minimum value of the base curve in the case of low negative stator voltage frequencies; an adjustment means by which the correction component proportional to the rotor current frequency can be adjusted; a further adjustment means by which the minimum value of the base curve can be adjusted; and a plurality of diodes and a diode threshold error correction circuit for the formation of the amplitude

in various parts of the curve.

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

5 Fig. 1 shows the constant flux curve family representing a squirrel cage motor;

 Fig. 2 illustrates the linear approximation of the constant flux curve family representing the squirrel cage motor; and

10 Fig. 3 shows a curve family calculator for implementing the present invention.

 The method of the invention for forming the amplitude A_s of the inverter's reference voltage is explained by first considering the constant flux curve
15 family, representing a squirrel cage motor, shown in Fig. 1. The curve family of Fig. 1 represents the amplitude A_s of the motor's stator voltage, i.e. the inverter's reference voltage, as a function of frequency f_s , for various rotor current frequencies
20 f_{r0} to f_{r4} , when the magnetic flux of the stator is constant. With the value of the rotor current frequency $f_r = 0$ we obtain the base curve f_{r0} , its minimum being the minimum value of the reference voltage amplitude. The substantially U-shaped curves
25 of the family comprise linear portions constituted by high positive and negative stator voltage

frequencies, f_s , and non-linear portions constituted by low positive and negative stator voltage frequencies f_s .

The present curve family calculator calculates the amplitude A_s of the inverter reference voltage, using the linear approximation of the constant flux curve family depicted in Fig. 2. The linear approximation is accurate enough to represent the constant flux curve family in lift operation. Moreover, setting up, or commissioning, the curve family calculator implemented with linear approximation is simpler than that of an analog calculator which calculates the curve family exactly.

The curve 0 in Fig. 2 is the approximation of the base curve $fr0$ of Fig. 1. The minimum of the curve 0 is A_0 . This voltage A_0 is in force when the rotor current frequency fr is zero. If the horizontal axis is interpreted so that negative stator voltage frequencies f_s refer to the other direction of rotation, the absolute value of the straight line has to be taken in order that the voltage will also be correct with negative frequencies f_s . If a correction component A_1 proportional to the rotor current frequency fr is added to the curve 0 and the absolute value taken, an approximation is obtained for the curve family of Fig. 1, with the exception of low

stator voltage frequencies f_s .

At low stator voltage frequencies f_s , the height of the bottom of the curve is proportional to the rotor current frequency f_r augmented by the minimum, A_0 , of the base curve. The whole approximate curve i
5 can be formed by combining the curve of stator voltage frequencies f_s having a high absolute value, with the curve of stator voltage frequencies f_s having a small absolute value.

10 In Fig. 3 a curve family calculator is shown implementing the linear approximation of a constant flux curve family as illustrated in Fig. 2. The stator voltage frequency f_s and the rotor current frequency f_r , which constitute the inputs of the
15 calculator are formed by a technique with which a person skilled in the art is familiar and is not part of the subject matter of this invention. The operation of the curve calculator of Fig. 3 is considered next.

In the case of stator voltage frequencies f_s
20 with a high absolute value, the reference voltage amplitude A_s is formed by combining the stator voltage frequency f_s , with the correction component A_1 found from the rotor current frequency f_r and which can be adjusted with a trimmer TR_1 , in a summing unit 1.
25 The reference voltage amplitude A_s' thus obtained is conveyed, in the case of positive stator voltage

frequencies f_s , to a diode D1 and to a diode threshold error correction circuit 5, from the output of which, the amplitude A_s is obtained. Hereafter, the amplitude A_s is conveyed, for example, to a reference oscillator, where the reference voltage of the inverter can be formed. The reference voltage can be applied to control, for instance, a pulse width modulator. The diode threshold correction circuit 5 consists of an amplifier 6, a diode D5 and a resistor R1. The formation of the reference voltage, as well as the operation of a diode threshold error correction circuit 5, is obvious to a person skilled in the art. With negative stator voltage frequencies f_s , the amplitude is first carried to an absolute value amplifier 2, where a positive amplitude is obtained from the negative amplitude, and then via a diode D2 to the diode threshold error correction circuit 5.

At low stator voltage frequencies f_s , the amplitude A_s of the reference voltage is obtained by carrying a correction component, formed from the rotor current frequency f_r , to a summing unit 3, where the correction component is combined with the minimum A_0 of the base curve. In the case of positive values of the rotor current frequency f_r , the amplitude A_s' is obtained from the summing unit 3. This amplitude consists of the sum of the correction component A_2

and the minimum value A_0 of the base curve, as shown in Fig. 2. The amplitude A_s' passes through a diode D_3 to the diode threshold error correction circuit 5. In the case of negative values of the rotor current frequency f_r , the correction component is again combined with the minimum A_0 of the base curve in a summing unit 4. The amplitude A_s' thus obtained is conducted to the correction circuit 5. The correction component A_2 that is formed from the rotor current frequency f_r can be adjusted with a trimmer TR_2 . The minimum A_0 of the base curve can be adjusted with a trimmer TR_3 .

It is obvious to a person skilled in the art that various embodiments of the invention are not exclusively confined to the example presented in the foregoing, instead of which they may vary within the scope of the claims following hereinafter.

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CLAIMS

1. A method for the formation of the amplitude of a reference voltage for a three-phase inverter that supplies a squirrel cage motor, wherein said amplitude
5 is formed by finding, in a predetermined constant flux curve family representing the squirrel cage motor in question and in which family of constant flux curves the motor's rotor current frequency appears as a parameter, a curve from which the amplitude of the
10 motor's stator voltage, which corresponds to the frequency of the motor's stator voltage, is obtained, i.e. the inverter reference voltage, so that the magnetic flux in the stator will be constant.
2. A method as claimed in claim 1, wherein the
15 required substantially U-shaped constant flux curves are approximated by forming the legs of the curve, corresponding to both directions of rotation of the motor, to be linear with the exception of low stator voltage frequencies, and wherein the non-linear
20 portion at said low frequencies is approximated by a horizontal line portion, the height of which is found by combining the minimum value of the base curve and a factor proportional to the rotor current frequency.
3. An apparatus for performing the method of claim 1
25 wherein, for the formation of the amplitude of the inverter reference voltage, with the exception of



-11-

low stator voltage frequencies, the apparatus comprises a summing unit in which the stator voltage frequency is combined with a correction component proportional to the rotor current frequency; an absolute value

5 amplifier in which the absolute value of the amplitude in the case of negative frequencies is formed; an adjustment means by which the correction component proportional to the rotor current frequency can be adjusted, and, for the approximation of the non-linear

10 portion at said low frequencies, a first summing unit in which the horizontal portion approximating the minimum of the curve is formed, in the case of low positive stator voltage frequencies; a second summing unit, wherein the amplitude value obtained from the first

15 summing unit is added to the minimum value of the base curve in the case of low negative stator voltage frequencies; an adjustment means by which the correction component proportional to the rotor current frequency can be adjusted; a further adjustment means

20 by which the minimum value of the base curve can be adjusted; and a plurality of diodes and a diode threshold error correction circuit for the formation of the amplitude in various parts of the curve.

4. A method for forming the reference voltage

25 amplitude for a three-phase inverter substantially as hereinbefore described with reference to the



-12-

accompanying drawings.

5. Apparatus for forming the reference voltage amplitude for a three-phase inverter, substantially as hereinbefore described with reference to and as
- 5 illustrated in the accompanying drawings.

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