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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)
COMMONWEALTH OF AUSTRALIA

Patent Act 1952

CONVENTION APPLICATION FOR A STANDARD PATENT

I/WE, KONE ELEVATOR GMBH, a limited liability company of Rathausstrasse 1, CH-6340 Baar, Switzerland

hereby apply for the grant of a Standard Patent for an invention entitled PROCEDURE AND MEANS FOR CONTROLLING THE CONTROL VOLTAGE OF A THREE-PHASE INVERTER SUPPLYING AN A.C. MOTOR

which is described in the accompanying complete specification.

This application is made under the provision of Part XVI of the Patents Act 1952 and is based on an application for a patent or similar protection made

in Finland on 19 March 1986

No. (861143)

Our address for service is: F.B. RICE & CO.,
28A Montague Street,
Balmain N.S.W. 2041

Dated this 5th day of December 1986

KONE ELEVATOR GMBH

By: [Signature]

Registered Patent Attorney

To: The Commissioner of Patents

COMMONWEALTH OF AUSTRALIA
COMMONWEALTH OF AUSTRALIA
Patents Act 1952-1969

DECLARATION IN SUPPORT OF A CONVENTION
APPLICATION FOR A PATENT OR PATENT OF ADDITION

In support of the Convention Application made by

KONE Elevator GmbH, of Rathausstrasse 1, CH-6340 Baar, Switzerland

(hereinafter referred to as the applicant) for a Patent

for an invention entitled:

"Procedure and means for controlling the control voltage of a three-phase inverter supplying an a.c. motor"


1. Vilkko Virkkala, member of Board

of Purjetuulenkuja 11, 00850 Helsinki, Finland

of and care of the applicant company

do solemnly and sincerely declare as follows:

1. I am authorised by the applicant for the patent to make this declaration on its behalf.

2. The basic application as defined by Section 141 of the Act was made in Finland on the 19th day of March 1986, by Kone Oy

3. Matti KAHKIPURO, Kauppalankatu 3, 05800 Hyvinkää, Finland

2. Urpo STEN, Koppelonkuja 1-3 C 14, 05800 Hyvinkää, Finland

3. Pekka NUMMI, Siippoontie, 01900 Nurmi, Järvi, Finland

4. Pekka HYTTI, Urheilukatu 4 C 41, 05800 Hyvinkää, Finland

5. Harri HAKALA, Palvelinkatu 15 A 2, 05830 Hyvinkää, Finland

are the actual inventors of the invention and the facts upon which the applicant is entitled to make the application are as follows:

The applicant is the assignee of the invention from the said actual inventors.

4. The basic application referred to in paragraph 2 of this Declaration was the first application made in a Convention country in respect of the invention the subject of the application.

DECLARED at Hyvinkää this 20th day of November 1986.

KONE Elevator GmbH

Vilkko Virkkala

Member of Board

To: THE COMMISSIONER OF PATENTS.
A procedure for controlling the control voltage of a three-phase inverter supplying an a.c. motor, in said inverter the power stage being implemented using semiconductor switches, and in said voltage control the output voltage (UA) of each inverter phase being measured, characterized in that the control voltage of the pulse width modulator in each phase of the inverter is controlled with a voltage regulator, and that the control voltage obtained as output of the voltage regulator is formed from an actual value voltage formed of the output voltage (UA) of each inverter phase and of the reference voltage (Va).
control voltage ($V_{a'}$) of the pulse width modulator can be produced from the actual value voltage and the reference voltage ($V_a^*$).
Complete Specification for the invention entitled:
PROCEDURE AND MEANS FOR CONTROLLING THE CONTROL VOLTAGE OF A THREE-PHASE INVERTER SUPPLYING AN A.C. MOTOR

The following statement is a full description of this invention including the best method of performing it known to us:-
PROCEDURE AND MEANS FOR CONTROLLING THE CONTROL VOLTAGE
OF A THREE-PHASE INVERTER SUPPLYING AN A.C. MOTOR

The present invention concerns a procedure and a means for controlling the control voltage of a three-phase inverter supplying an a.c. motor, in said inverter the power stage being implemented using semiconductor switches, and in said voltage control the inverter output voltage of each phase being measured.

The frequency-controlled a.c. motor is the most advanced design, for instance, in lift use. With frequency control, the efficiency is high at all motor speeds, and the mains power factor is nearly 1. Frequency control is appropriate for both geared and gearless lifts, and at all speeds. Moreover, a simple and moderately priced squirrel cage motor can be used for the motor. In lift use, a transistor inverter implemented with transistors is best suited for frequency control because it is possible with transistors to achieve the highest switching frequency among existing power electronics components. GTO thyristors may also be contemplated because they have approximately equal switching times, but main current switching is more complicated than with transistors because of the required switching guards.

If in the inverter pulse width modulation is applied with a comparator in sinusoidal and triangle voltage comparison without feedback, the current which the inverter supplies to the motor is not sufficiently sinusoidal for instance for lift use because in the rectified intermediate voltage circuit, whence the three-phase a.c. voltage supplying the motor is obtained by rectification with the inverter, the voltage is not constant, and also for the reason that a semiconductor switch does not follow the control without delay. A third factor causing an error is that differential voltage which is caused by the voltage existing across the power electronics component used as semiconductor switch, compared with the voltage occurring with the other direction of current when the
diode which lies in parallel with the semiconductor switch is conducting. In practice, the errors give rise to vibration in the motor, which for instance in lift operation impairs the performance of the lift and causes discomfort to the passengers.

Presently, current feedback is a procedure known in the state of the art in inverter technology as a method for improving the curve shape. The drawback of current feedback is slow response. This is caused by the fact that in current feedback the motor inductances introduce time constants. The control loop is as a rule the slower the greater the number of time constants. Moreover, current measuring elements are expensive because they are required to be able to measure also direct current.

With the aid of the present invention, it is possible to eliminate the above-mentioned drawbacks. The procedure of the invention for controlling the control voltage of a three-phase inverter supplying an a.c. motor is characterized in that the control voltage of each phase of the inverter’s pulse width modulator is controlled by a voltage regulator, and that the control voltage obtained from the output of the voltage regulator is produced from an actual value voltage formed from the output voltage of each inverter phase and from a reference voltage. Since in controlling the inverter voltage control is employed instead of current control, faster control is achieved since, unlike current control, voltage control involves no delay caused by inductive phenomena.

An advantageous embodiment of the procedure of the invention is characterized in that from the output voltage of each inverter phase an actual value voltage is formed in that with the voltage measured at the output is combined, to constitute a synthetic zero level, an a.c. voltage varying at a frequency three times the basic frequency, and which is obtained by combining the positive and negative voltages of the pulsating d.c. voltage obtained by full-wave rectifying the three-phase voltage.

An advantageous embodiment of the procedure of the invention is also characterized in that the control voltage, obtained as output
from the voltage regulator of each phase, is formed from the actual value voltage formed from the output voltage of each inverter phase and from the reference voltage in that of the actual value voltage and the reference voltage is formed their difference, which is amplified and superimposed on the reference value.

An advantageous embodiment of the procedure of the invention is also characterized in that for inverter is used a transistor inverter in which the transistors serving as semiconductor switches are controlled for producing the output voltages of the transistor inverter.

An advantageous embodiment of the procedure of the invention is also characterized in that for inverter is used a GTO thyristor inverter in which the GTO thyristors serving as semiconductor switches are controlled for producing the output voltages of the GTO thyristor inverter.

The means applying the procedure of the invention, comprising an inverter output voltage measuring element, is characterized in that, for controlling the control voltage of the pulse width modulator in one inverter phase, the means comprises an actual value voltage forming circuit in which from the voltage measured at the inverter output can be established an actual value voltage, and a reference voltage forming circuit in which from the actual value voltage and the reference voltage can be formed the control voltage for the pulse width modulator.

An advantageous embodiment of the means applying the procedure of the invention is characterized in that the actual value voltage forming circuit is mainly implemented with a summing unit combining the positive voltage and negative voltage of a pulsating d.c. voltage obtained by full-wave rectification of the three-phase voltage, and with a summing unit combining the voltage measured at the inverter output and the a.c. voltage obtained as described.

An advantageous embodiment of the means applying the procedure of the invention is also characterized in that the reference voltage
forming circuit is mainly implemented with a differential unit comparing the actual value voltage and the reference voltage, an amplifier integrating said difference, and a summing unit, by the aid of which the differential obtained as described can be superimposed on the reference value to become a control voltage taking into account the momentary state of the a.c. motor.

An advantageous embodiment of the means applying the procedure of the invention is also characterized in that the inverter is a transistor inverter in which transistors serve as controlled semiconductor switches in the power stage.

An advantageous embodiment of the means applying the procedure of the invention is also characterized in that the inverter is a GTO thyristor inverter in which GTO thyristors serve as controlled semiconductor switches in the power stage.

When the voltage regulator of the invention is used, the ripple of the voltage is, due to the synthetic zero level, less of a detriment than in the case that a sinusoidal voltage is formed with reference to the mains zero. Moreover, in the regulator of the invention the differential signal produced from the actual value and reference value voltages is amplified and superimposed on the reference voltage. By the superpositioning principle faster control is achieved than by carrying the entire voltage control through the integrating amplifier of the regulator.

The invention is described in the following more in detail with the aid of an example, referring to the drawing attached in which

Fig. 1 presents the voltage regulator of the invention.

Fig. 2 shows the formation of the synthetic zero level.

Fig. 3 presents an a.c. motor drive comprising a three-phase transistor inverter with voltage regulators according to the invention.
In the following the operation of the voltage regulator 1 of the invention working in phase A is described with the aid of Figs 1, 2 and 3. The voltage regulators in phases B and C are similar to the voltage regulator 1 in phase A. In Fig. 3 is presented an a.c. motor drive in which a transistor inverter provided with voltage regulators 1 of the invention is employed. The inputs of the voltage regulator 1 are the voltage \( V_a \), measured at the inverter output with the measuring element 8, and the reference voltage \( V_{a\ast} \). The forming of the reference voltage represents technology with which a person skilled in the art is familiar and it is not part of the subject matter of the present invention. From the output of the voltage regulator 1, the control voltage \( V_{a\prime} \) of the pulse width modulator is obtained. The pulse width modulator 2 controls through the delay circuit 3 and a control means 4 the transistor TI in the main circuit 6 of the inverter. The transistors TI-T6 supply the a.c. motor 7. The power returning from the motor goes to the resistor R2.

The design of the voltage regulator 1 is presented in Fig. 1. The voltage regulator is composed of an actual value voltage forming circuit 9 and a circuit 10 forming the control voltage \( V_{a\prime} \) of the pulse width modulator. In the actual value voltage forming circuit 9, the summing unit 11 produces a synthetic zero level. The synthetic zero level is obtained by combining the positive voltage \( pU_1 \) and negative voltage \( nU_1 \) of the pulsating d.c. voltage, appearing across the capacitor \( C_4 \) and which has been obtained by full-wave rectifying, with the diode rectifier bridge 5, from the three-phase mains, which have the phase voltages \( U_R, U_S \) and \( U_T \), to become the a.c. voltage \( V_0 \). The positive voltage \( pU_1 \), the negative voltage \( nU_1 \) and the a.c. voltage \( V_0 \) formed of these are depicted in Fig. 2. In the summing unit 12, the synthetic zero level a.c. voltage \( V_0 \) is combined with the voltage \( V_a \) measured at the inverter output.

In the pulse width modulator reference voltage forming circuit 10, the differential unit 13 forms the difference of the actual value voltage and the reference voltage \( V_{a\ast} \), said difference being controlled by an integrating amplifier 14. The differential unit...
13 consists of a summing unit with one of its two inputs negative. The gain of the amplifier 14 can be changed with the aid of a trimmer TM1. In the summing unit 15, the reference voltage \( V_{a*} \) and the correction component produced from the difference of the reference voltage \( V_{a*} \) and the actual value voltage are superimposed to become the control voltage \( V_{a'} \) of the pulse width modulator.

In order that the desired pulse width modulation might be obtained, the modulator 2 has to be controlled with this voltage. The modulator 2 is composed of a triangular wave generator 16 and a comparator 17. The triangular wave generator 16 is common to all phases A, B and C. The modulating digital signal is obtained at the output A and its complementary signal, at the output A'. The signal A controls the transistor of the inverter T1, and the signal A' controls the transistor T2.

It is necessary in this context to take into consideration the effect of storage time. That is, when the base current is removed from a transistor carrying current, the transistor remains conductive about another twenty microseconds. During that time the transistor operating as the pair to the other must not be opened, as a short-circuit would otherwise ensue. The transistor ceases to be conductive only after the charge on the base has dissipated. In Fig. 3, an asymmetric delay 3 has been introduced in the control of the transistor T1 with the aid of a hysteresis gate 18 so that the other transistor T2 might not open before the transistor T1 has ceased to conduct. The delay of this circuit is determined by the product of resistor R1 and capacitor C1. The diode D1 is needed in order that there might be no delay in the switch-off operation.

The control means 4 of the transistor T1 has two floating power sources. A negative supply is required in order to have a powerful negative base current for rapid switch-off. The two floating voltages are produced with rectifier diodes D2-D9 and filtering capacitors C2 and C3. The power supply of the control means 4 is a high-frequency chopper power supply 19, the secondary of its transformer TR1 having enough windings to provide the requisite floating power supplies. Energy is supplied from the transformer...
An optoisolator 20 supplies over the resistor R3 the end stage transistors T8 and T9. Said transistors constitute a dual emitter follower circuit.

The diode D10 is a so-called Baker diode. It prevents the power transistor proper, T1, from becoming saturated. This reduces and stabilizes the storage time. Furthermore, the switch-off power of the transistor is reduced due to the diode. The resistor R3 is needed for the Baker diode D10 to operate correctly. The control signal of the control means is inserted at the point a. The point O/E represents the ground of the oscillator electronics. The diode D11 is the protective diode for the optoisolator 20.

The power supply of the main circuit 6 of the four-quadrant transistor inverter is in the present instance obtained by full-wave rectifying the phase voltages UR, US and UT of the three-phase mains with the diode bridge 5. In this way, a fixed intermediate voltage is produced across the capacitor C4. From the intermediate voltage is produced, by pulse width modulation, a three-phase voltage UA, UB and UC with controlled frequency and amplitude. This controlled three-phase power controls the motor 7.

The diodes D12-D17 are zero diodes constituting current paths for inductive currents while the transistor connected in parallel with the diode is switched off. The braking energy goes to the braking resistance R2 controlled by the braking transistor T9.

It is obvious to a person skilled in the art that various embodiments of the invention are not restricted to the example presented in the foregoing, but may vary within the scope of the claims to be presented below. In addition to a transistor inverter implemented with transistors, a GTO thyristor inverter using GTO implemented with GTO thyristors is an example of another possible application of the voltage regulator of the invention.
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. A procedure for controlling the control voltage of a three-phase inverter supplying an a.c. motor, in said inverter the power stage being implemented using semiconductor switches, and in said voltage control the output voltage (UA) of each inverter phase being measured, characterized in that the control voltage of the pulse width modulator in each phase of the inverter is controlled with a voltage regulator, and that the control voltage (Va') obtained as output of the voltage regulator is formed from an actual value voltage formed of the output voltage (UA) of each inverter phase and of the reference voltage (Va*).

2. Procedure according to claim 1, characterized in that from the output voltage (UA) of each inverter phase an actual value voltage is formed in that with the voltage (Va) measured at the output is combined, to constitute an artificial zero level, an a.c. voltage (VO) varying at a frequency three times the basic frequency, this a.c. voltage being obtained by combining the positive voltage (pU1) and the negative voltage (nU1) of a pulsating d.c. voltage full-wave rectified from a three-phase voltage.

3. Procedure according to claim 1 or 2, characterized in that the control voltage (Va') obtained as output of the voltage regulator of each phase is formed of the actual value voltage formed of the output voltage (UA) of each phase and the reference voltage (Va*) in that of the actual value voltage and the reference input voltage (Va*) the difference is formed and this difference is amplified and superimposed on the reference value (Va*).

4. Procedure according to claim 1, 2 or 3, characterized in that for inverter is used a transistor inverter in which the transistors (T1-T6) serving as semiconductor switches are controlled for producing the output voltages (UA,UB,UC) of the transistor inverter.

5. Procedure according to claim 1, 2 or 3, characterized in that for inverter is used a GTO thyristor inverter in which the GTO...
thyristors serving as semiconductor switches are controlled for producing the output voltages of the GTO thyristor inverter.

6. A means intended for applying claim 1, comprising an output voltage measuring element, characterized in that, for controlling the control voltage of the pulse width modulator in one phase of the inverter, the means comprises an actual value voltage forming circuit in which an actual value voltage can be produced from the voltage (Va) measured at the inverter output, and a control voltage forming circuit in which control voltage forming circuit the control voltage (Va') of the pulse width modulator can be produced from the actual value voltage and the reference voltage (Va*).

7. Means according to claim 6, characterized in that the actual value forming circuit is mainly implemented with a summing unit combining the positive voltage (pUI) and the negative voltage (nUI) of a pulsating d.c. voltage full-wave rectified from a three-phase voltage and with a summing unit combining the voltage (Va') measured at the inverter output with the a.c. voltage (VO) thus obtained.

8. Means according to claim 6 or 7, characterized in that the control voltage forming circuit is mainly implemented with a differential unit comparing the actual value voltage and the reference voltage (Va*), with an amplifier integrating said difference, and with a summing unit, with the aid of which superimposed on the reference value (Va*) to become a control voltage (Va') taking into account the momentary state of the a.c. motor.

9. Means according to claim 6, 7 or 8, characterized in that the inverter is a transistor inverter in which the controlled semiconductor switches in the power stage are transistors (T1-T6).

10. Means according to claim 6, 7 or 8, characterized in that the inverter is a GTO thyristor inverter in which the controlled
semiconductor switches in the power stage are GTO thyristors.

Dated this 5th day of December 1986

KONE ELEVATOR GMBH
Patent Attorneys for the Applicant
F.B. RICE & CO.
Fig. 3