ABSTRACT

ELECTRONICALLY COMMUTATED ELECTRICAL MOTOR HAVING A CALIBRATED MOTOR TORQUE CONSTANT

The present subject matter describes an electrically commutated electrical motor (1) having a stator (10) and a permanent-magnetically designed rotor (12). The electronically commutated electrical motor (1) also has a control unit (24) that is connected to the stator (10) and configured to actuate the stator (10) for generating a magnetic rotary field. The control unit (24) is configured to detect a voltage induced in at least one stator coil (14, 16, 18) of the stator (10) and to determine a motor torque constant in dependence of a rotational speed signal representing a rotor rotational frequency of the rotor (12). The control unit (24) is configured to detect a frequency content of the motor torque constant and to actuate the stator (10) for generating a torque in dependence of the frequency content, in particular a frequency amplitude, of the motor torque constant.

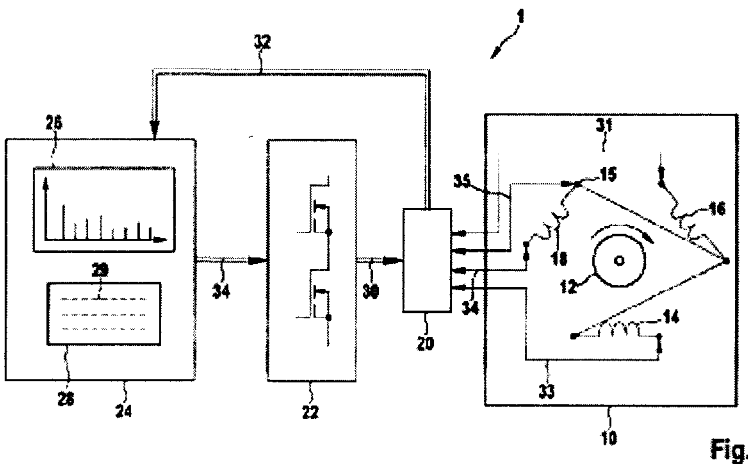

Fig. 1

I/We claim:

1. An electrically commutated electrical motor (1) comprising:

   a stator (10);

   a permanent-magnetically designed rotor (12); and

   a control unit (24) that is connected to the stator (10) and that is configured to actuate the stator (10) for generating a magnetic rotary field, wherein the control unit (24) is configured to detect a voltage induced in at least one stator coil (14, 16, 18) of the stator (10) and to determine a motor torque constant representing an achievable torque in dependence on a rotational speed signal representing a rotor rotational frequency of the rotor (12);

   characterizing in that,

   the control unit (24) is configured to detect a frequency content (45, 60, 62, 64, 66) of the motor torque constant and to actuate the stator (10) for generating a torque in dependence of the frequency content (45, 60, 62, 64, 66), particularly a frequency amplitude (60, 62, 64, 66), of the motor torque constant.

2. The electric motor (1) as claimed in claim 1, wherein the control unit (24) is configured to generate a Fourier transform (45) of the motor torque constant by Fast Fourier transform, and to actuate the stator (10) in dependence of the Fourier-transformed motor torque constant.

3. The electric motor (1) as claimed in claim 2, wherein the control unit (24) is configured to carry out an order analysis of the Fourier-transformed motor torque constant and to actuate the stator (10) in dependence of a signal parameter, particularly a signal amplitude of at least one order (60, 62, 64, 66) of the frequency content (45) of the motor torque constant.

4. The electric motor (1) as claimed in one of the claim 2 or 3, wherein the control unit (24) is configured to actuate the stator in dependence of only odd orders (60, 62, 64, 66) of the motor torque constant.

5. The electric motor (1) as claimed in any one of the claim 3 or 4, wherein the control unit (24) is configured to generate a time-dependent and/or rotor-position-dependent profile of the motor torque constant by inverse Fourier transform of the Fourier-transformed motor torque constant and to actuate the stator (10) in dependence of the time and/or rotor-position-dependent profile.

6. The electric motor (1) as claimed in any one of claim 3 or 4, wherein the control unit (24) is configured to generate a time-dependent and/or rotor-position-dependent profile of the motor torque constant by selective order filtering of inverse Fourier transform of the Fourier-transformed motor torque constant and to actuate the stator (10) in dependence of time and/or rotor-position-dependent profile.

7. The electric motor (1) as claimed in one of the preceding claims, wherein the control unit (24) is configured to electrically actuate the stator (10) in dependence of a predetermined rotor angle range, particularly 90° or 60° to control the motor torque constants.

8. A method (70, 72, 74, 76) for controlling an electronically commutated electric motor (1) having a stator (10) and a permanent magnet formed rotor (12), wherein the method comprises:

detecting a motor torque constant representing producible torque of the electric motor, in dependence of induced voltage during rotational movement of the rotor (12);

detecting a frequency content (45) of the motor torque constant; and

controlling the stator (10) in dependence of the frequency content, particularly a frequency amplitude, of the motor torque constant of the stator (10) for generating a torque.

9. The method as claimed in claim 8, wherein the method further comprises generating a Fourier transform (45) of the motor torque constant by FFT analysis, and controlling the stator (10) in dependence on the Fourier-transformed motor torque constant.

10. The method as claimed in one of the claim 8 or 9, wherein the method comprises carrying out an order analysis of the Fourier-transformed motor torque constant, and controlling the stator (10) in dependence of at least one signal parameter, particularly a signal amplitude, at least of the order (60, 62, 64, 66) of the motor torque constant.

11. The method as claimed in any one of claims 8 to 10, wherein the controlling the stator (10) is carried out in dependence of only odd orders (60, 62, 64, 66) of the motor torque constant.

12. The method as claimed in any one of claims 8 to 11, wherein the method further comprises generating a time-dependent and/or rotor-position-dependent profile of the motor torque constant by inverse Fourier transform of the Fourier-transformed motor torque constant, and controlling the stator (10) in dependence of the rotor-position-dependent profile.

13. The method as claimed in any one of claims 8 to 11, wherein the method further comprises generating a time-dependent and/or rotor-position-dependent profile of the motor torque constant by selective order filtering of the inverse Fourier transform of the Fourier-transformed motor torque constant, and controlling the stator (10) in dependence of time and/or rotor-position-dependent profile.

Dated this 11th day of April 2012

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To
The Controller of Patents
The Patent office at New Delhi

Applicant(s) Name: **ROBERT BOSCH GmbH** ORIGINAL Sheet No.: 1

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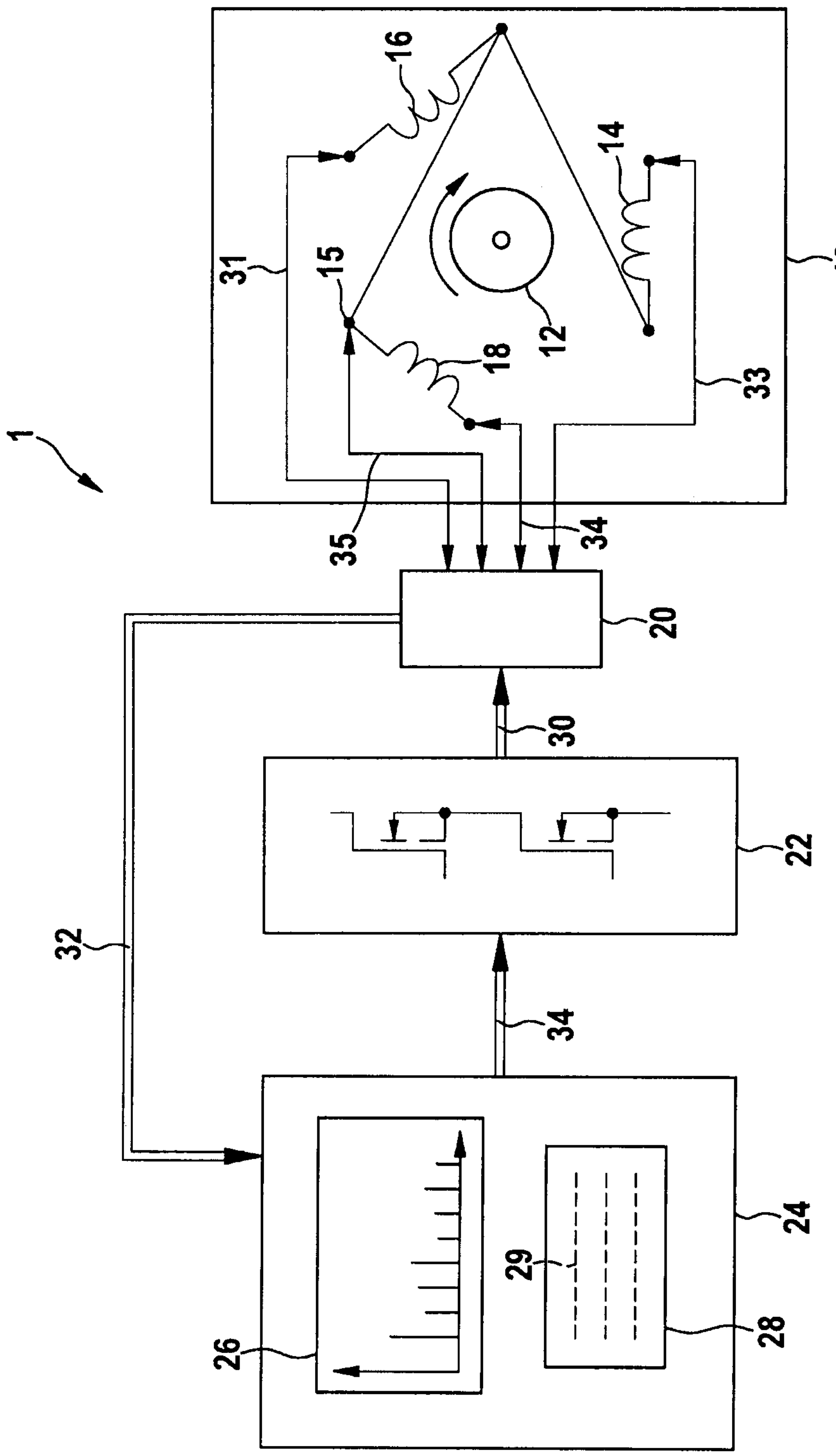
Fig. 1



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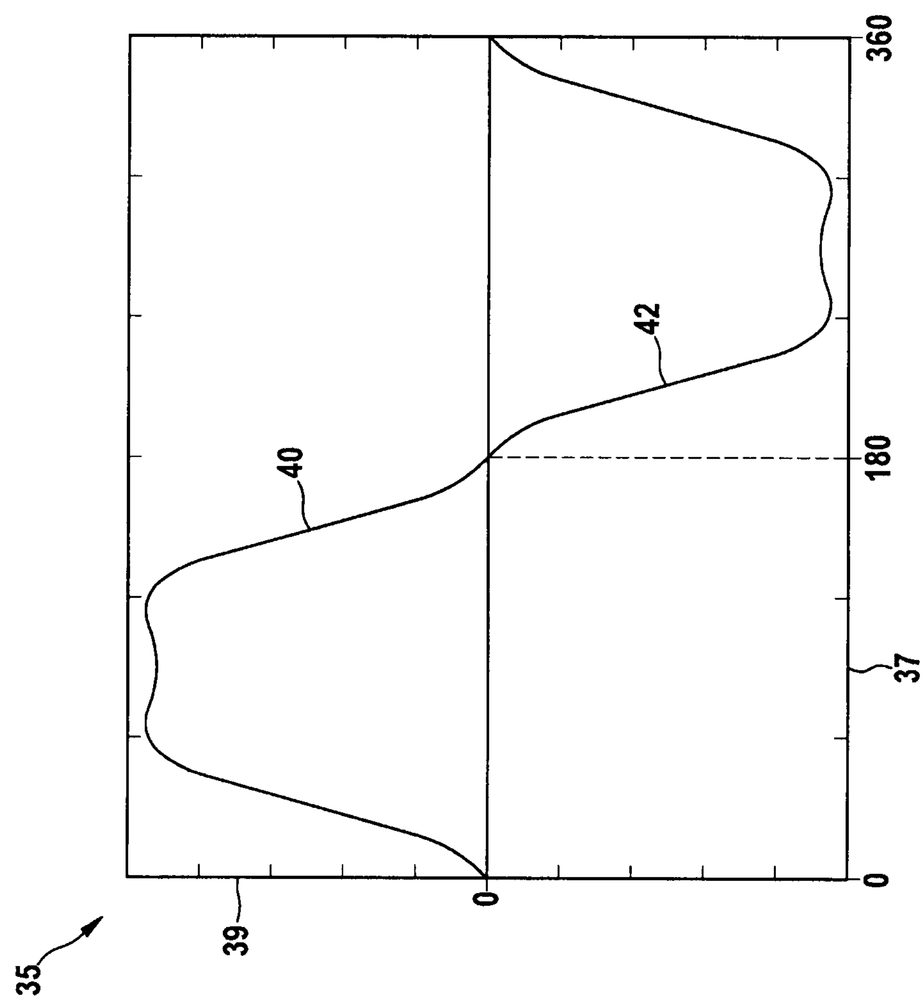

Fig. 2

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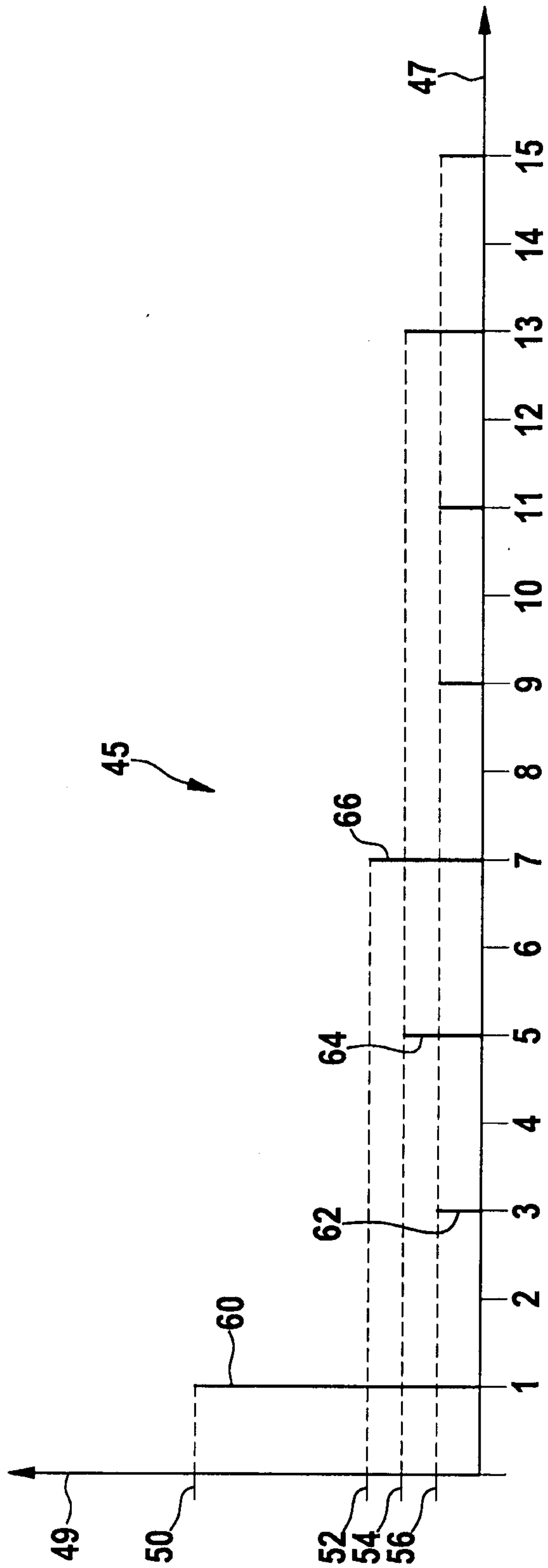
Fig. 3



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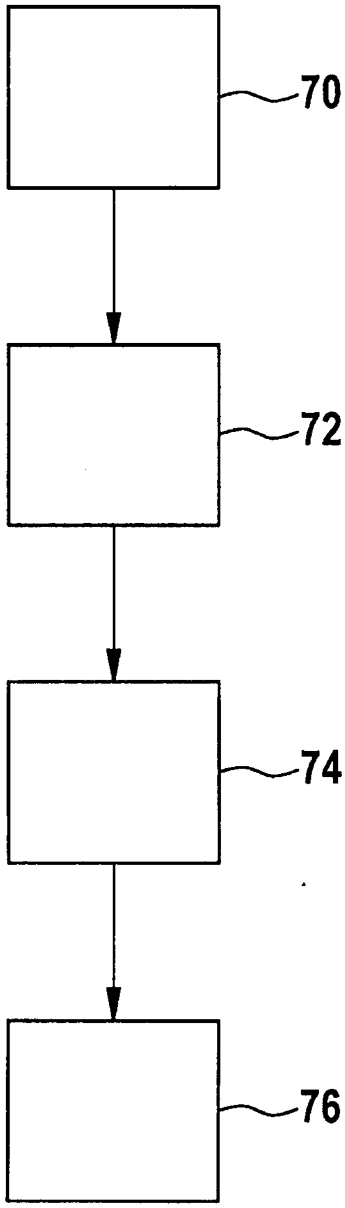

Fig. 4

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TECHNICAL FIELD

The present subject matter relates to an electronically commutated electric motor having a stator and a permanent magnetically designed rotor.

BACKGROUND

The document DE 10 2007 020 068 A1 describes a method and a device for determining a motor torque constant of an electric motor, where the motor torque constant of the electric motor is determined during operation of the motor in dependence of induced voltage generated by the electric motor.

SUMMARY

This summary is provided to introduce concepts related to an electronically commutated electrical motor having a stator and a permanent-magnetically designed rotor, and the concepts are further described below in the detailed description. This summary is neither intended to identify essential features of the claimed subject matter nor is it intended for use in determining or limiting the scope of the claimed subject matter.

In one embodiment, the subject matter describes an electrically commutated electrical motor. The electrical motor includes a stator, a permanent-magnetically formed rotor, and a control unit. The control unit is connected to the stator and is configured to actuate the stator for generating a magnetic rotary field. The control unit is further configured to detect a voltage induced in at least one stator coil of the stator and to determine a motor torque constant representing an achievable torque in dependence on a rotational speed signal representing a rotor rotational frequency of the rotor. The control unit is configured to detect a frequency content of the motor torque constant and to actuate the stator for generating a torque in dependence of the frequency content, particularly a frequency amplitude, of the motor torque constant.

In another embodiment, the subject matter further describes a method for controlling an electronically commutated electric motor having a stator and a permanent magnet formed rotor. The method includes detecting a motor torque constant representing producible torque of the electric motor, in dependence of induced voltage during rotational movement of the rotor, detecting a frequency content of the motor torque constant, and controlling the stator in

dependence of the frequency content, particularly a frequency amplitude, of the motor torque constant of the stator for generating a torque.

BRIEF DESCRIPTION OF THE FIGURES

The detailed description is described with reference to the accompanying figures. Some embodiments of system and/or methods in accordance with embodiments of the present subject matter are now described, by way of example only, and with reference to the accompanying figures, in which:

Fig. 1 shows an embodiment for an electric motor, in accordance with the present subject matter.

Fig. 2 shows an embodiment of a waveform, which represents a portion of a rotor circulation in the area of a stator coil across location-dependent motor torque constant.

Fig. 3 shows a spectrum which has frequency components of the motor torque constant shown in Fig. 2.

Fig. 4 shows an embodiment of a method for operating an electronically commutated electric motor shown in Fig. 1.

DETAILED DESCRIPTION

According to the present subject matter, an electronically commutated electric motor is provided with a control unit that is configured to detect a frequency content of the motor torque constant, and to actuate a stator for generating a torque in dependence of the frequency content, particularly a frequency amplitude, of the motor torque constant.

The electric motor has a rotor position sensor and/or a speed sensor. The rotor position sensor is configured to detect a rotor position of the rotor and to generate the rotor position signal representing the rotor position. The speed sensor is configured to detect the rotor rotational frequency of the rotor and to generate the speed signal representing the rotor rotational frequency.

By detecting the frequency content of the motor torque constant, a rotor magnetic field strength and thus the motor torque constant influencing factors can be accurately detected. Also, the electronically commutated electric motor has advantageous manufacturing tolerances, such as an eccentricity of the stator coils, locally-shifted permanent magnets, electrical tolerances of components, in particular of the stator coils, mutually different magnetization of the permanent magnets, mutually different magnetic field gradients of the stator coils, and a temperature-dependent magnetic field strength of magnetic components, for example, the permanently magnetic rotor can be detected. For example, the material for ferrite at low temperatures in the range of 40 degrees Celsius has a magnetic field strength smaller than at 20 degree Celsius. The neodymium material includes a smaller magnetic field strength than at 20 degrees Celsius at high temperatures, for example at 120 degrees Celsius. The elector motor can, for example, be easily calibrated during operation, so that the obtained torque is detected over rotor circulation and the determined motor torque constant can be used or stored to further drive the stator.

In an embodiment, the electronically commutated electric motor may electrically determine the motor torque constant via a rotor rotational frequency, more preferably detect through at least a portion of a rotor rotational frequency electrically in particular for a stator coil 120 degrees, or more preferably only 90 degrees or for three stator coils 60 degrees. Such detection takes place while detecting an engine operating the mechanical and / or electrical efficiency of the electric motor via the determination of the motor torque constant.

The motor torque constant is achieved with the torque of the electric motor as follows in relation:

(1) Pelectrical = Uind*Istring

(2) Pmechanical = M.ω

(4) M = Istring*B*l* r

with:

Uind = induced voltage

P = Power

M = torque

ω = angular frequency

B = magnetic flux density

l = length of a current-carrying conductor of the stator

r = distance of the conductor from a rotor axis of the rotor

The equivalence of electrical and mechanical performance is obtained for the induced voltage Uind

(5) $U_{ind} = M.\omega/I_{string} = \omega.B.l.r$

The factor occurring together in (5) and (4)

(6) $k = B*l*r$ is called the motor torque constant.

In an embodiment of the electric motor, the control unit is configured, particularly by Fast Fourier transformation, to generate a Fourier transform of the motor torque constant, and to actuate the stator in dependence of the Fourier transform motor torque constant. Accordingly, at least one or a plurality of frequency components, particularly orders are detected from a frequency spectrum of the motor torque constant and the stator is controlled in dependence on at least one of the frequency component, particularly an amplitude or a power spectral density of the frequency component.

In an embodiment of the electric motor, the control unit is configured, particularly by order filter to perform an order analysis of the Fourier transform motor torque constant in dependence of the speed signal representing the rotor rotational frequency and to actuate the stator in dependence of a signal parameter, particularly a signal amplitude of at least one order of the frequency content of the motor torque constant. Thus a temperature-dependent loss of the torque is detected by frequency analysis, particularly Fourier frequency analysis, preferably FFT analysis (FFT: Fast Fourier Transform).

In an embodiment of the electric motor, the control unit is configured to actuate the stator in dependence of odd orders or odd harmonics of the motor torque constant, particularly only in dependence of odd harmonics of the motor torque constant. This may be advantageous to save computing time of the effective motor torque constant.

In an embodiment of the electric motor, the control unit is configured to generate a time-dependent and/or rotor-position-dependent profile of the motor torque constant by means of inverse Fourier transform of the Fourier-transformed motor torque constant, and to actuate the stator in dependence of the time and/or rotor-position-dependent profile. A number of matrix operations, at least one matrix operation from the control unit is performed for generating the position-dependent profile of the motor torque constant during time-dependent operation of the motor, based on a rotor rotation.

The control unit is configured to generate a time-dependent and/or rotor-position-dependent profile of the motor torque constant by means of selective order filtering of inverse Fourier transform of the Fourier-transformed motor torque constant, and to actuate the stator in dependence of time and/or rotor-position-dependent profile.

In an embodiment of the electric motor, the control unit is configured to electrically actuate the stator in dependence of a predetermined rotor angle range, preferably 120 degrees, more preferably 90 degrees, particularly preferably 60 degrees, to control the motor torque constant. The period of an induced voltage for a stator coil is composed from the waveforms of the induced voltages of three stator coils during a rotor angular portion of 60 degrees. Thus, the induced voltages of three stator coils is determined over a rotor angular portion of 60 degrees in order are to put together the induced voltage for an average stator coil characteristic by means of addition of the waveforms of the three stator coils. Thus the computing time and/or measurement time can be saved, and mirror symmetry of a signal of the induced motor voltage, and the motor torque constant can be utilized. In an embodiment, the control unit is configured by a microprocessor, a microcontroller or an FPGA (FPGA field-programmable gate array).

In another embodiment of the electric motor independently or in addition to the previously described variant with a Fourier transformer, the control unit determines the motor constant by a low pass filter, which is phase-shift-free. For this purpose, the control unit applies the same or same filter twice successively in time to the timing signal of the motor torque constant, or the induced voltage, preferably first in a forward direction, then apply in the reverse direction. Thereby the amplitudes of frequency components can be adjusted only in the frequency spectrum. The low pass filter is for example a FIR filter (FIR: Finite Impulse Response).

The present subject matter also relates to a method for controlling an electronically commutated electric motor having a stator and a particular permanent magnetically formed rotor, particularly the above-described electric motor. In the method, motor torque representing producible torque of the electric motor is detected particularly in dependence of an induced voltage during rotational movement of the rotor during an operation of the electric motor. A frequency content of the motor torque constant is detected, and the stator is controlled in dependence of the frequency content, particularly a frequency amplitude of the motor torque constant, for generating a torque

In an embodiment, a Fourier transform of the motor torque constant is generated in the method by means of FFT analysis, and the stator is controlled in dependence of the Fourier-transformed motor torque constant.

Furthermore, an order analysis of the Fourier-transformed motor torque constant is performed in the method by an order filter and the stator is controlled in dependence of a signal parameter, particularly signal amplitude of at least an order of the controlled motor torque constant. An order is a harmonic higher frequency of a fundamental frequency.

In an embodiment of the method, the stator is controlled in dependence of only odd orders of the motor torque constant.

In another embodiment of the method, a time-dependent and/or rotor-position-dependent profile of the motor torque constant is generated by means of inverse Fourier transform of the Fourier-transformed motor torque constant and the stator is controlled in dependence of the rotor-position-dependent profile.

In an embodiment of the method, a time-dependent and/or rotor-position-dependent profile of the motor torque constant is generated by means of selective order filtering of a Fourier inverse transform of the Fourier-transformed motor torque constant and the stator is controlled in dependence of the time-dependent and/or rotor-position-dependent profile.

The present subject matter is explained hereinafter with reference to figures and other embodiments. Further embodiments and/or implementations result from the features mentioned in the dependent claims and/or the description of the figures mentioned in the features.

Fig. 1 shows an embodiment for an electric motor 1. The electric motor 1 comprises a stator 10. The stator 10 has three stator coils, namely, a stator coil 14, a stator coil 16 and a stator coil 18 which are arranged together to move a rotor 12 of the electric motor 1 by means of a rotating magnetic field into rotary motion. The rotor 12 of the electric motor 1 is formed in this embodiment in a permanent-magnetic manner. The electric motor 1 also has a power output stage 22 which is connected on an output side 30 via a connection to a terminal 20 for the stator 10. The terminal 20 is connected via a connection line 33 to a first terminal of the stator coil 14. The terminal 20 is also connected via a connection line 34 to a first terminal of the stator coil 18, and via a connection line 31 to a first terminal of the stator coil 16. The second terminals of the stator coils 14, 16 and 18 are each connected to a common star terminal 15. The star terminal 15 is connected via a connection line 35 with the terminal 20.

The terminal 20 is also connected via a connection 32 to a control unit 24 of the electric motor 1. The control unit 24 can determine induced voltages over the connection 32, the terminal 20 and the connection lines 31, 33, 34 and for example in addition the connection line 35 of the stator coils 14, 16 and 18 respectively in the stator coils 14, 16 and 18. Orders of third degree or multiples of the third degree, for example, a sixth or ninth order can be detected over the star terminal 15. The stator coils 14, 16 and 18 can be energized over the terminal 20 and the connection line 30 from the power output stage 22 for generating the rotating magnetic field. The control unit 24 has its output connected via a connection 34 with the power output stage 22 and is configured to control the power output stage 22 for energizing the stator coils 14, 16 and 18 such that the rotating magnetic field for rotary movement of the rotor 12 can be generated by means of the stator coils 14, 16, and 18.

The control unit 24 is configured to determine an induced voltage over the connection 32 and the terminal 20 to the stator coils 14, 16 and 18 and convert these from analog-to-digital signals. The control unit 24 is configured, in a further step, to divide the previous analog to digital converted induced voltages in each case by the rotor rotational frequency of the rotor 12 and thus a motor torque constant for each strand is calculated, which is determined for each stator coil of the stator coils 14, 16 and 18. The determination, particularly the calculation of the motor torque constant can be carried out as follows:

n-1 n-1

(7) ak = Δα- £Ku(j-Aoc)-cos(k-j-Aoc) und bk = Δα- £Ku(j-Aoc)-sin(k-j-Aoc)

with

ak, bk = Fourier coefficients

Ku = motor torque constant for a stator coil of string U

2Π

k = wave number, k = , mit λ= wave length

λ

n = number of samples over a period

In vector notation, the frequency vector of the motor constant can be calculated as the matrix [F]:

(8)

$$[F]=\begin{bmatrix} a1 \\ \vdots \\ am \\ b1 \\ \vdots \\ bm \end{bmatrix}=\begin{bmatrix} \Delta\alpha\cdot\cos(1\cdot 0\cdot\Delta\alpha) & \cdots & \Delta\alpha\cdot\cos(1\cdot(n-1)\cdot\Delta\alpha) \\ \vdots & \ddots & \vdots \\ \Delta\alpha\cdot\cos(m\cdot 0\cdot\Delta\alpha) & \cdots & \Delta\alpha\cdot\cos(m\cdot(n-1)\cdot\Delta\alpha) \\ \Delta\alpha\cdot\sin(1\cdot 0\cdot\Delta\alpha) & \cdots & \Delta\alpha\cdot\sin(1\cdot(n-1)\cdot\Delta\alpha) \\ \vdots & \ddots & \vdots \\ \Delta\alpha\cdot\sin(m\cdot 0\cdot\Delta\alpha) & \cdots & \Delta\alpha\cdot\sin(m\cdot(n-1)\cdot\Delta\alpha) \end{bmatrix}\bullet\begin{bmatrix} Ku(0\cdot\Delta\alpha) \\ \vdots \\ Ku((n-1)\cdot\Delta\alpha) \end{bmatrix}=[FFT]\bullet[K]$$

with

[K] = motor constant vector

[FFT] = operator of a discrete-time Fourier transform.

By reducing a sensed rotor angular range, for example, preferably 90 degrees or 60 degrees, a reduced motor torque constant Kr can be used as vector:

(9) $$[Kr]=\begin{bmatrix} Ku(0\cdot\Delta\alpha) \\ Kv(0\cdot\Delta\alpha) \\ Kw(0\cdot\Delta\alpha) \\ \vdots \\ Ku((n_2-1)\cdot\Delta\alpha) \\ Kv((n_2-1)\cdot\Delta\alpha) \\ Kw((n_2-1)\cdot\Delta\alpha) \end{bmatrix}$$ with

Ku = motor torque constant in the portion of the stator phase U

Kv = motor torque constant in the portion of the stator phase V

Kw = motor torque constant in the portion of the stator phase W

wherein n2 is the number of samples of the rotor angle portions, for example over 60 degrees or 90 degrees.

The frequency vector [F] can be replaced by a corresponding equivalent multiplication [FFTr] - [Kr].

The control unit 24 is configured to derive a Fourier-transform equivalent of the motor torque constant in a further step and to determine elementary and high waves at the speed of the rotor 12 by means of an order filter 26. The determination may take place preferably by means of a FFT analysis. In a further step, the control unit 24 is configured to reconstruct a temporal or local profile of the motor torque constant by means of the previously determined frequency components, particularly at least one, preferably two, more preferably a number of orders. The profile 29 of the motor torque constant can be stored in a memory 28. The memory 28 may be part of the control unit 24 or be connected thereto.

For determining the orders, the control unit 24 determines a rotational speed of the rotor 12, i.e., the rotor rotational frequency in dependence of speed signal generated by speed sensor (not shown in this figure) or the rotor rotational frequency determines induced voltages in dependence of at least one, preferably two or three of the stator coils 14, 16 and 18. The control unit 24 performs a matrix calculation for the determination of the motor torque constant, hereinafter referred as the constant Kum for the stator coil U in the spatial domain, particularly rotor angular portion. In this case, only the expected orders in time and/or spatial domain are transformed back. The matrix calculation can be performed, for example by the control unit 24:

(10)

$$[Kum]=\begin{bmatrix} Kum(0\cdot\Delta\alpha) \\ \vdots \\ Kum((nr-1)\cdot\Delta\alpha) \end{bmatrix}=\begin{bmatrix} \cos(1\cdot 0\cdot\Delta\alpha) & \cdots & \cos(m\cdot 0\cdot\Delta\alpha) & \sin(1\cdot 0\cdot\Delta\alpha) & \cdots & \sin(m\cdot 0\cdot\Delta\alpha) \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \cos(1\cdot(nr-1)\cdot\Delta\alpha) & \cdots & \cos(m\cdot(nr-1)\cdot\Delta\alpha) & \sin(1\cdot(nr-1)\cdot\Delta\alpha) & \cdots & \sin(m\cdot(nr-1)\cdot\Delta\alpha) \end{bmatrix}\bullet\begin{bmatrix} a1 \\ \vdots \\ am \\ b1 \\ \vdots \\ bm \end{bmatrix}=[R]\bullet[F]$$

with

[Kum] = vector of the motor torque constant for the phase U in the spatial domain, particularly rotor angular portion.

The detection portion or a portion of motor torque constant to be calculated can be limited electrically to 60 degrees. The control unit 24 may be configured in such a way that it can be assumed that a waveform of a motor torque constant signal is locally representing motor torque constant, and the profile of the motor torque constant has no even harmonic or even order waves. Thus the mirror symmetry of a signal, particularly the previously detected motor torque constant signal can be used. The vector of the motor torque constant can be formed as the vector (9). The control unit 24 may perform a reconstruction of the motor torque constant in the time domain or in the local area via a rotor circulation according to formula (10). The control unit 24 can perform the Fast-Fourier-Transformation in sub-matrices. This can advantageously be an equal load of the control unit 24.

Fig. 2 shows an exemplary embodiment of a waveform, which represents a portion of a rotor circulation in the area of a stator coil across location-dependent motor torque constant. The waveform is determined for a stator coil, for example, the stator coil 14 in Fig.1, by the control unit 24. Specifically, Fig. 2 shows a diagram 35, which represents an abscissa 37 and an ordinate 39. The abscissa 37 represents a rotor rotation angle of the rotor 12 in Fig. 1, and the ordinate 39 represents amplitude of the motor torque constant. The diagram 35 also shows a curve with a first part curve 40 and a second part curve 42. The first part curve 40 represents a first half cycle of the waveform of an induced voltage, where the second part curve 42 represents a second half cycle of the waveform of the induced voltage, which in each case is divided by the rotor rotational frequency of the rotor 12 generating the induced voltage. The part curves 40 and 42 have a sinusoidal fundamental curve, and in addition thereto represent odd orders.

Fig. 3 shows a spectrum 45, which has frequency components of the motor torque constant shown in Fig. 2. The spectrum 45 is shown in a diagram with a frequency axis 47 and an amplitude axis 49. The orders, for example, harmonics to a fundamental frequency of the motor torque constant, represented in Fig. 2, are carried on the frequency axis 47. The spectrum 45 shows a first order 60, the fundamental frequency with an amplitude 50 corresponding to the rotor rotational frequency, a third order 62 with an amplitude of 56, a fifth order 64 with an amplitude 54 and a seventh order 66 with an amplitude 52. The amplitude 52 is smaller than the amplitude 50, the amplitude 54 is smaller than the amplitude 52 and the amplitude 56 is smaller than the amplitude 54.

The control unit 24 shown in Fig. 1 determines the amplitudes 50, 52, 54 and 56 of the orders of the motor torque constant signal shown in Fig. 2 by order filters 26.

Fig. 4 shows an exemplary embodiment of a method for operating an electronically commutated electric motor, for example the electric motor 1 with a permanent magnetically formed rotor 12 shown in Fig. 1.

In the method, in a step 70 during operation of the electric motor, the motor torque constant representing the producible torque of the electric motor, is determined in dependence of an induced voltage during rotational movement of the rotor.

In a step 72, a Fourier transform of the motor torque constant is generated by means of an FFT analysis.

The order analysis of the Fourier-transformed motor torque constant is carried out in a further step 74 by means of an order filter, and at least one signal parameter, particularly a signal amplitude determines and stores at least an order of the motor torque constant.

In step 76, the stator is controlled in dependence of the order of the motor torque constant, for example, only odd orders of the motor torque constant.