(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 098 449 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
30.11.2016 Bulletin 2016/48

(21) Application number: **13881451.2**

(22) Date of filing: **26.12.2013**

(51) Int Cl.:
F04B 49/06 *(2006.01)*

(86) International application number:
PCT/CN2013/090551

(87) International publication number:
WO 2015/096090 (02.07.2015 Gazette 2015/26)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(54) METHOD AND DEVICE FOR AUTOMATICALLY COMPENSATING FOR MOMENT OF COMPRESSOR, COMPRESSOR, AND CONTROL METHOD FOR SAME

(57) A method for an automatic torque compensation of a compressor is provided. The method includes: obtaining a target speed and a feedback speed; generating a fluctuation speed according to the target speed and the feedback speed; generating a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner; obtaining a load torque reference value and generating a torque compensation amplitude according to the load torque reference value; and generating a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude. A method for controlling a compressor, an apparatus for an automatic torque compensation of a compressor and a compressor including the apparatus are also provided.

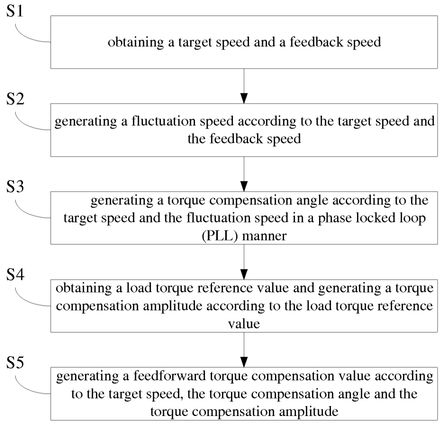

Fig. 1

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Description

FIELD

[0001] Embodiments of the present invention generally relate to a compressor control technology, and more particularly, to a method for an automatic torque compensation of a compressor, a method for controlling a compressor, an apparatus for an automatic torque compensation of a compressor and a compressor having the apparatus.

BACKGROUND

[0002] In recent years, with a rapid development of a variable-frequency control technology and a promotion of an energy-efficient concept, variable-frequency air conditioners have been promoted rapidly. By changing a power supply frequency of the compressor to adjust a rotating speed of the compressor, the variable-frequency air conditioner achieves a room temperature control, such that a room temperature fluctuation is decreased, a power consumption is reduced and a comfort degree is greatly improved.

[0003] Currently, energy-efficient variable-frequency air conditioners in the market generally adopt DC (Direct Current) inverter compressors, in an interior of which a permanent magnet synchronous motor is used as a power core. The permanent magnet synchronous motor has advantages of small volume, low loss and high efficiency. A DC inverter single cylinder compressor below 2HP is a mainstream product, however the single cylinder compressor has a characteristic of uneven load, and a speed loop bandwidth in a vector control system of the air conditioner is low, such that an electromagnetic torque cannot catch up with an actual load torque, and thus a vibration at a low frequency is big. The single cylinder compressor can operate stably at the low frequency by adding a torque compensation, however it is required for a common sine torque compensation to search for an optimum angle value and an optimum amplitude in the air conditioner system in real time according to the vibration, which costs a great deal of time and energy to debug the torque compensation, but results in a common compensation effect. Only one angle and only one amplitude are given at each operating frequency of the compressor, and the amplitude and the angle cannot be adjusted according to the load, however the load torque fundamental wave angle and load are changing in real time during the actual operation, and thus an over-compensation or an under-compensation may occur in the torque compensation, or a compensation angle difference is great, which result in the heavy vibration.

[0004] Accordingly, the torque compensation technology of the compressor in the related art is required to be improved.

SUMMARY

[0005] Embodiments of the present invention seek to solve at least one of the problems existing in the related art to at least some extent.

[0006] Accordingly, a first objective of the present invention is to provide a method for an automatic torque compensation of a compressor, which can track a load torque angle and a load torque amplitude in real time, and thus a debugging time of the torque compensation is greatly reduced and an optimal compensation effect can be implemented in all working conditions of the compressor.

[0007] A second objective of the present invention is to provide a method for controlling a compressor. A third objective of the present invention is to provide an apparatus for an automatic torque compensation of a compressor. A fourth objective of the present invention is to provide a compressor having the apparatus.

[0008] To achieve the above objectives, a method for an automatic torque compensation of a compressor according to embodiments of a first aspect of the present invention includes: obtaining a target speed and a feedback speed; generating a fluctuation speed according to the target speed and the feedback speed; generating a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner; obtaining a load torque reference value and generating a torque compensation amplitude according to the load torque reference value; and generating a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude.

[0009] With the method for the automatic torque compensation of the compressor according to embodiments of the present invention, the torque compensation angle is generated in the phase locked loop (PLL) manner and the torque compensation amplitude is generated according to the load torque reference value output from the speed loop, such that the load torque angle and load torque amplitude can be tracked in real time, and the angle and the amplitude can be adjusted on line in real time, and thus the debugging time of the torque compensation is greatly reduced and the optimal compensation effect can be implemented in all working conditions of the compressor. More particularly, the vibration of the compressor operating at the low frequency can be reduced, thus ensuring a stable operation of the compressor.

[0010] In an embodiment of the present invention, generating a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner includes: generating a mechanical angle according to the target speed; generating a first reference value according to the mechanical angle and the torque compensation angle; generating a second reference value according to the first reference value; generating a third reference value according to the fluctuation speed and the second reference value; and performing a proportional integral (PI) process on the third reference value to obtain the torque compensation angle.

[0011] Moreover, the method further includes: filtering the fluctuation speed and the second reference value with a same cut-off frequency before generating the third reference value according to the fluctuation speed and the second reference value.

[0012] Moreover, generating a second reference value according to the first reference value includes: performing a cosine function calculation on the first reference value to obtain a fourth reference value; generating a coefficient according to the fluctuation speed; and generating the second reference value according to the fourth reference value and the coefficient.

[0013] In an embodiment of the present invention, the third reference value is calculated by a formula of:

$$C = \tilde{\omega} \times BCos(\bar{\omega}t + \theta)$$

where C is the third reference value, $\tilde{\omega}$ is the fluctuation speed, $\bar{\omega}$ is the target speed, B is the coefficient, $\bar{\omega}\, t$ is the mechanical angle and θ is the torque compensation angle.

[0014] In an embodiment of the present invention, the method further includes: performing a low pass filtering process on the third reference value before performing a proportional integral (PI) process on the third reference value to obtain the torque compensation angle.

[0015] In an embodiment of the present invention, generating a torque compensation amplitude according to the load torque reference value includes: generating a fifth reference value according to the load torque reference value and a torque compensation coefficient; and generating the torque compensation amplitude according to the fifth reference value.

[0016] Generating the torque compensation amplitude according to the fifth reference value includes: when the fifth reference value is larger than a torque compensation limit, using the torque compensation limit as the torque compensation amplitude; when the fifth reference value is less than or equal to the torque compensation limit, using the fifth reference value as the torque compensation amplitude.

[0017] In an embodiment of the present invention, when the compressor is a rare earth compressor, generating a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude includes: performing a sinusoidal function calculation on the first reference value to generate a sixth reference value; and generating the feedforward torque compensation value according the sixth reference value and the torque compensation amplitude.

[0018] In another embodiment of the present invention, when the compressor is a ferrite compressor, generating a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude further includes: performing a sinusoidal function calculation on the first reference value to generate a sixth reference value; generating a seventh reference value according to the target speed and an electromechanical time constant; generating an eighth reference value according to the sixth reference value and the seventh reference value; generating the feedforward torque compensation value according to the eighth reference value and the torque compensation amplitude.

[0019] To achieve the above objectives, a method for controlling a compressor according to embodiments of a second aspect of the present invention includes: obtaining a target speed and a feedback speed and generating a fluctuation speed according to the target speed and the feedback speed; performing a speed loop control on the fluctuation speed to generate a load torque reference value; generating a feedforward torque compensation value by the above described method for the automatic torque compensation of the compressor; controlling the compressor according to the load torque reference value and the feedforward torque compensation value.

[0020] With the method for controlling the compressor, the feedforward torque compensation value is generated by the method for the automatic torque compensation of the compressor described above, and the compressor is controlled according to the load torque reference value and the feedforward torque compensation value, such that the load torque angle and load torque amplitude can be tracked in real time, and the angle and the amplitude can be adjusted on line in real time, and thus the debugging time of the torque compensation is greatly reduced and the optimal compensation effect can be implemented in all working conditions of the compressor. More particularly, the vibration of the compressor operating at the low frequency can be reduced, thus ensuring a stable operation of the compressor.

[0021] To achieve the above objectives, an apparatus for an automatic torque compensation of a compressor according to embodiments of a third aspect of the present invention includes: a speed obtaining module, configured to obtain a target speed and a feedback speed; a speed generating module, configured to generate a fluctuation speed according to the target speed and the feedback speed; a torque compensation angle generating module, configured to generate a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner; a torque compensation amplitude generating module, configured to obtain a load torque reference value and to generate a torque compensation amplitude according to the load torque reference value; and a feedforward torque compensation value generating module, configured to generate a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude.

[0022] With the apparatus for the automatic torque compensation of the compressor according to embodiments of the present invention, the torque compensation angle generating module generates the torque compensation angle in the phase locked loop (PLL) manner and the torque compensation amplitude generating module generates the torque compensation amplitude via the load torque reference value output from the speed loop, so that the load torque angle and load torque amplitude can be tracked in real time by the apparatus for the automatic torque compensation of the compressor, and the angle and the amplitude can be adjusted on line in real time, and thus the debugging time of the torque compensation is greatly reduced and the optimal compensation effect can be implemented in all working conditions of the compressor. More particularly, the vibration of the compressor operating at the low frequency can be reduced, thus ensuring a stable operation of the compressor.

[0023] In an embodiment of the present invention, the torque compensation angle generating module is configured to: generate a mechanical angle according to the target speed; generate a first reference value according to the mechanical angle and the torque compensation angle; generate a second reference value according to the first reference value; generate a third reference value according to the fluctuation speed and the second reference value; and perform a proportional integral (PI) process on the third reference value to obtain the torque compensation angle.

[0024] The torque compensation angle generating module is further configured to filter the fluctuation speed and the second reference value by a same cut-off frequency before generating the third reference value.

[0025] Moreover, the torque compensation angle generating module is further configured to: perform a cosine function calculation on the first reference value to obtain a fourth reference value; generate a coefficient according to the fluctuation speed; and generate the second reference value according to the fourth reference value and the coefficient.

[0026] In an embodiment of the present invention, the torque compensation angle generating module is configured to calculate the third reference according to a formula of:

$$C = \tilde{\omega} \times BCos(\bar{\omega} t + \theta)$$

where C is the third reference value, $\tilde{\omega}$ is the fluctuation speed, $\bar{\omega}$ is the target speed, B is the coefficient, $\bar{\omega}\, t$ is the mechanical angle and θ is the torque compensation angle.

[0027] In an embodiment of the present invention, the torque compensation angle generating module is further configured to perform a low pass filtering process on the third reference value before performing a proportional integral (PI) process on the third reference value.

[0028] In an embodiment of the present invention, the torque compensation amplitude generating module is further configured to: generate a fifth reference value according to the load torque reference value and a torque compensation coefficient; and generate the torque compensation amplitude according to the fifth reference value.

[0029] When the fifth reference value is larger than a torque compensation limit, the torque compensation amplitude generating module is configured to use the torque compensation limit as the torque compensation amplitude; when the fifth reference value is less than or equal to the torque compensation limit, the torque compensation amplitude generating module is configured to use the fifth reference value as the torque compensation amplitude.

[0030] In an embodiment of the present invention, when the compressor is a rare earth compressor, the feedforward torque compensation value generating module is configured to: perform a sinusoidal function calculation on the first reference value to generate a sixth reference value; and generate the feedforward torque compensation value according the sixth reference value and the torque compensation amplitude.

[0031] In an embodiment of the present invention, when the compressor is a ferrite compressor, the feedforward torque compensation value generating module is configured to: perform a sinusoidal function calculation on the first reference value to generate a sixth reference value; generate a seventh reference value according to the target speed and an electromechanical time constant; generate an eighth reference value according to the sixth reference value and the seventh reference value; generate the feedforward torque compensation value according to the eighth reference value and the torque compensation amplitude.

[0032] Embodiments of a fourth aspect of the present invention provide a compressor, and the compressor includes the apparatus for the automatic torque compensation of the apparatus described above.

[0033] The compressor according to embodiments of the present invention can generate the feedforward torque compensation value using the apparatus for the automatic torque compensation of the compressor, such that the load torque angle and load torque amplitude can be tracked in real time, and the angle and the amplitude can be adjusted on line in real time, and thus the debugging time of the torque compensation is greatly reduced and the optimal compensation effect can be implemented in all working conditions of the compressor. More particularly, the vibration of the compressor operating at the low frequency can be reduced, thus ensuring a stable operation of the compressor.

[0034] Additional aspects and advantages of embodiments of present invention will be given in part in the following descriptions, become apparent in part from the following descriptions, or be learned from the practice of the embodiments of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] These and other aspects and advantages of embodiments of the present invention will become apparent and more readily appreciated from the following descriptions made with reference to the accompanying drawings, in which:

Fig. 1 is a flow chart of a method for an automatic torque compensation of a compressor according to an embodiment of the present invention;

Fig. 2 is a schematic diagram showing a control principle of a compressor according to an embodiment of the present invention;

Fig. 3 is a schematic diagram showing an automatic torque compensation principle of a rare earth compressor according to an embodiment of the present invention;

Fig. 4 is a schematic diagram showing an automatic torque compensation principle of a ferrite compressor according to another embodiment of the present invention;

Fig. 5 is a schematic diagram showing a principle of a PLL angle observer according to an embodiment of the present invention;

Fig. 6 is a flow chart of a method for controlling a compressor according to an embodiment of the present invention; and

Fig. 7 is a block diagram of an apparatus for an automatic torque compensation of a compressor according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0036] Reference will be made in detail to embodiments of the present disclosure. Embodiments of the present disclosure will be shown in drawings, in which the same or similar elements and the elements having same or similar functions are denoted by like reference numerals throughout the descriptions. The embodiments described herein according to drawings are explanatory and illustrative, not construed to limit the present disclosure.

[0037] The following description provides a plurality of embodiments or examples configured to achieve different structures of the present disclosure. In order to simplify the publishment of the present disclosure, components and dispositions of the particular embodiment are described in the following, which are only explanatory and not construed to limit the present disclosure. In addition, the present disclosure may repeat the reference number and/or letter in different embodiments for the purpose of simplicity and clarity, and the repeat does not indicate the relationship of the plurality of embodiments and/or dispositions. Furthermore, examples of different processes and materials are provided in the present disclosure. However, it would be appreciated by those skilled in the art that other processes and/or materials may be also applied. Moreover, in description of the embodiments, the structure of the second characteristic "above" the first characteristic may include an embodiment formed by the first and second characteristic contacted directly, and also may include another embodiment formed between the first and the second characteristic, in which the first characteristic and the second characteristic may not contact directly.

[0038] In the description of the present disclosure, unless specified or limited otherwise, it should be noted that, terms "mounted," "connected" and "coupled" may be understood broadly, such as electronic connection or mechanical connection, inner communication between two elements, direct connection or indirect connection via intermediary. These having ordinary skills in the art should understand the specific meanings in the present disclosure according to specific situations.

[0039] A method for an automatic torque compensation of a compressor, a method for controlling a compressor, an apparatus for an automatic toque compensation of a compressor and a compressor will be described in the following with reference to drawings.

[0040] Fig. 1 is a flow chart of a method for an automatic torque compensation of a compressor according to an embodiment of the present invention. As shown in Fig. 1, the method for the automatic torque compensation of the compressor includes following steps.

[0041] At step S1, a target speed and a feedback speed are obtained.

[0042] At step S2, a fluctuation speed is generated according to the target speed and the feedback speed.

[0043] As shown in Fig. 2, a speed error, namely the fluctuation speed $\tilde{\omega}$, exists between the feedback speed w_fbk and the target speed w_ref.

[0044] At step S3, a torque compensation angle is generated according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner.

[0045] In embodiments of the present invention, due to the big fluctuation speed caused by a compressor load, a speed waveform phase is tracked in the phase locked loop (PLL) manner, and it is just required to control the torque waveform phase to catch up with the speed waveform phase. Moreover, the torque compensation is configured as a fundamental wave torque compensation, in which Fourier series of a periodic load of the compressor is shown as follows:

$$T_L = T_{L0} + \sum_{n=1}^{\infty} T_{Ln} \sin(n\bar{\omega} t + \theta_x) \quad (1)$$

[0046] In equation (1), T_{L0} is a load torque constant of the compressor, T_{Ln} is an nth order component of the load torque of the compressor, and θ_x is the torque compensation angle.

[0047] A speed in each machine cycle of the compressor is resolved into an average speed and the fluctuation speed, i.e.,

$$\omega = \bar{\omega} + \tilde{\omega} \quad (2)$$

where $\bar{\omega}$ is the average speed and $\tilde{\omega}$ is the fluctuation speed.

[0048] In addition to accommodative lag of the speed loop and the proportional integral (PI) loop, the fluctuation speed lags behind the average speed essentially, in which a lag angle therebetween is donated as $\tan^{-1}(\bar{\omega}\,\tau_m)$, and thus the fluctuation speed is denoted as:

$$\tilde{\omega} = \frac{-a_m \tau_m}{\sqrt{1 + \bar{\omega}\tau_m{}^2}} Sin(\bar{\omega}\, t + \theta_x - \tan^{-1}(\bar{\omega}\tau_m)) \quad (3)$$

where $\tau_m = \frac{JR}{p_n K_T K_e}$ is an electromechanical time constant, $a_m = \frac{T_{L1}}{J}$, is a rotational inertia, R is a phase resistance, K_T is a torque coefficient, K_e is a counter electromotive force, p_n is a number of pole-pairs, and θ_x is the torque compensation angle.

[0049] In embodiments of the present invention, the average speed $\bar{\omega}$ is the target speed w_ref, and the fluctuation speed $\tilde{\omega}$ is the speed error.

[0050] In an embodiment of the present invention, as shown in Fig. 3, step S3 includes: generating a mechanical angle $\overline{\omega t}$ according to the target speed (namely the average speed $\bar{\omega}$); generating a first reference value $\overline{\omega t} + \theta$ according to the mechanical angle $\overline{\omega t}$ and a feedback torque compensation angle θ generating a second reference value $B\cos(\overline{\omega t} + \theta)$ according to the first reference value $\overline{\omega t} + \theta$; generating a third reference value $\tilde{\omega}B\cos(\overline{\omega t} + \theta)$ according to the fluctuation speed $\tilde{\omega}$ and the second reference value $B \cos(\overline{\omega t} + \theta)$; and performing a proportional integral (PI) process on the third reference value $\tilde{\omega}B\cos(\overline{\omega t} + \theta)$ to obtain the torque compensation angle θ_x.

[0051] Furthermore, before generating the third reference value according to the fluctuation speed and the second reference value, the fluctuation speed and the second reference value are filtered with a same cut-off frequency.

[0052] Moreover, the second reference value is generated according to the first reference value by following steps: performing a cosine function calculation on the first reference value $\overline{\omega t} + \theta$ to obtain a fourth reference value $\cos(\overline{\omega t} + \theta)$; generating a coefficient B according to the fluctuation speed (namely the speed error); and generating the second reference value $B\cos(\overline{\omega t} + \theta)$ according to the fourth reference value $\cos(\overline{\omega t} + \theta)$ and the coefficient B.

[0053] Therefore, in embodiments of the present invention, the third reference value is calculated by a formula of:

$$C = \tilde{\omega} \times BCos(\bar{\omega}t + \theta) \quad (4)$$

where C is the third reference value, $\tilde{\omega}$ is the fluctuation speed, $\bar{\omega}$ is the target speed, B is the coefficient, $\bar{\omega}t$ is the mechanical angle and θ is the feedback torque compensation angle.

[0054] As shown in Fig. 3, in embodiments of the present invention, before performing a proportional integral (PI) process on the third reference value $\tilde{\omega}B\cos(\overline{\omega t} + \theta)$ to obtain the torque compensation angle, a low pass filtering process is performed on the third reference value.

[0055] At step S4, a load torque reference value is obtained and a torque compensation amplitude is generated according to the load torque reference value.

[0056] As shown in Fig. 2, the load torque reference value Trqref is obtained by performing the proportional integral (PI) process on the fluctuation speed (namely the speed error).

[0057] Moreover, at step S4, as shown in Fig. 3, the torque compensation amplitude is generated according to the load torque reference value by following steps: generating a fifth reference value Trqref × Trqcoefficient according to the load torque reference value Trqref and a torque compensation coefficient Trqcoefficient; and generating the torque compensation amplitude according to the fifth reference value Trqref × Trqcoefficient.

[0058] Specifically, in embodiments of the present invention, a torque compensation limitation process (namely an amplitude limiting process) should be performed on the fifth reference value Trqref × Trqcoefficient, and thus the torque compensation amplitude is generated according to the fifth reference value as follows: when the fifth reference value is larger than a torque compensation limit, the torque compensation limit is used as the torque compensation amplitude; when the fifth reference value is less than or equal to the torque compensation limit, the fifth reference value is used as the torque compensation amplitude.

[0059] At step S5, a feedforward torque compensation value is generated according to the target speed, the torque compensation angle and the torque compensation amplitude.

[0060] In an embodiment of the present invention, as shown in Fig. 3, when the compressor is a rare earth compressor, step S5 includes following steps: performing a sinusoidal function calculation on the first reference value $\overline{\omega t} + \theta$ to generate a sixth reference value $\sin(\overline{\omega t} + \theta)$; and generating the feedforward torque compensation value $T_{comp} = M \sin(\overline{\omega t} + \theta)$ according the sixth reference value $\sin(\overline{\omega t} + \theta)$ and the torque compensation amplitude M.

[0061] In another embodiment of the present invention, as shown in Fig. 4, when the compressor is a ferrite compressor, step S5 includes following steps: performing a sinusoidal function calculation on the first reference value $\overline{\omega t} + \theta$ to generate the sixth reference value $\sin(\overline{\omega t} + \theta)$; generating a seventh reference value according to the target speed $\overline{\omega}$ and an electromechanical time constant τ_m ; generating an eighth reference value according to the sixth reference value and the seventh reference value; and generating the feedforward torque compensation value $T_{comp} = M \sin(\overline{\omega t} + \theta)$ according to the eighth reference value and the torque compensation amplitude.

[0062] In other words, taking the fundamental wave load as an example for analysis, since a stack height of a rotor in the rare earth compressor is low, the corresponding rotational inertia J is small, and thus the electromechanical time constant τ_m is small. Moreover, the torque compensation is implemented at a low frequency, and thus an angle delay brought by $\tan^{-1}(\overline{\omega} r_m)$ can be ignored in a single-cylinder rare earth compressor, and it can be concluded that the fluctuation speed $\tilde{\omega} = ASin(\overline{\omega}t + \theta_x)$ has the same phase information as the fundamental wave torque load $T_{L1} \sin(\overline{\omega t} + \theta_x)$ of the compressor, in which $A = \frac{-a_m \tau_m}{\sqrt{1 + \overline{\omega} \tau_m^2}}$. However, in the ferrite compressor, since the rotational inertia J is large, the electromechanical time constant τ_m is great, and thus the resulting delay cannot be ignored and the angle $\tan^{-1}(\overline{\omega}\tau_m)$ should be compensated. Once the compressor has been determined, the angle $\tan^{-1}(\overline{\omega}\tau_m)$ only changes with the rotating speed.

[0063] As shown in Fig. 5, since the fluctuation speed can be observed, by tracking a rotating speed phase in the phase locked loop (PLL) manner with a PLL angle observer, a speed phase θ_x can be solved, such that the torque compensation angle θ_x is obtained.

[0064] In the embodiment of the present invention,

$$\begin{aligned} C &= \tilde{\omega} \times BCos(\overline{\omega} t + \theta) = ASin(\overline{\omega} t + \theta_x) \times BCos(\overline{\omega} t + \theta) \\ &= 0.5AB(Sin(2\overline{\omega} t + \theta + \theta_x) + Sin(\theta_x - \theta)) \end{aligned} \quad (5)$$

[0065] The low pass filtering process is performed on C with a low pass filter, so as to remove a high-frequency component $0.5ABSin(2\overline{\omega}t + \theta + \theta_x)$, and then the filtered C is fed back via a proportional integral (PI) loop, such that the torque compensation angle can be solved by taking $\theta = \theta_x$, i.e., a reference input of the proportional integral (PI) loop is considered as zero (a reference quantity can be reached only when $\theta_x = \theta$), as shown in Fig. 5.

[0066] Therefore, in embodiments of the present invention, as shown in Fig. 2, when the speed loop of the vector control system outputs the load torque reference value Trqref, a feedforward sine fundamental wave torque compensation value $T_{comp} = M \sin(\overline{\omega t} + \theta_x)$ is added, in which M and θ_x can be calculated in the above descriptions, ωt (i.e., a rotor angle) and Trqref can be extracted directly from the vector control system without other computing process.

[0067] Since many high order harmonics exist in a speed sampling signal, it is required to perform a first order low pass filtering process on the fluctuation speed $\tilde{\omega}$, however a certain delay may exist in the filtering, and thus a first order low pass filtering process with a same delay is performed on $BCos(\overline{\omega}t + \theta)$, i.e., two first order low pass filters have the same cut-off frequency. In other words, the fluctuation speed and the second reference value are filtered with the same cut-off frequency.

[0068] After the speed loop outputs the load torque reference Trqref, a sine wave amplitude is required to be superimposed onto the load torque reference Trqref to obtain the torque compensation amplitude M=Trqref*Trqcofficient. In order to avoid an instability of the system or a demagnetization of the compressor due to a too large torque compensation amplitude, an amplitude limitation is applied to the torque compensation coefficient Trqcofficient.

[0069] Since a difference between the speed signal without the torque compensation and the speed signal with the correct torque compensation is obvious and the phase locked loop (PLL) may be disabled due to a too great difference between A and B, it is required to select a value of B with reference to B=lowpass ($|\tilde{\omega}|$), in which the filtering is deep, i.e., a taking positive calculation is performed on the amplitude of the speed error signal obtained in real time, and then the low pass filtering is performed on the processed speed error signal to obtain B.

[0070] In conclusion, in the method for the automatic toque compensation of the compressor according to embodiments of the present invention, the phase locked loop (PLL) torque compensation is a feedforward control and is implemented based on a sine wave and fundamental wave compensation, in which an angle of the automatic torque compensation is obtained in the phase locked loop (PLL) manner and a sine amplitude of the compressor is controlled automatically according to the load torque reference value output from the speed loop. Thus, the angle and the amplitude can be adjusted on line in real time, a debugging time of the torque compensation is greatly reduced, and the optimal compensation effect can be implemented in all working conditions of the compressor.

[0071] With the method for the automatic torque compensation of the compressor according to embodiments of the present invention, the torque compensation angle is generated in the phase locked loop (PLL) manner and the torque compensation amplitude is generated according to the load torque reference value output from the speed loop, such that the load torque angle and load torque amplitude can be tracked in real time, and the angle and the amplitude can be adjusted on line in real time, and thus the debugging time of the torque compensation is greatly reduced and the optimal compensation effect can be implemented in all working conditions of the compressor. More particularly, the vibration of the compressor operating at the low frequency can be reduced, thus ensuring a stable operation of the compressor.

[0072] Fig. 6 is a flow chart of a method for controlling a compressor according to an embodiment of the present invention. As shown in Fig. 6, the method for controlling the compressor includes following steps.

[0073] At step S601, a target speed and a feedback speed are obtained and a fluctuation speed is generated according to the target speed and the feedback speed.

[0074] At step S602, a speed loop control is performed on the fluctuation speed to generate a load torque reference value.

[0075] At step S603, a feedforward torque compensation value is generated by the method for the automatic torque compensation of the compressor described above.

[0076] At step S604, the compressor is controlled according to the load torque reference value and the feedforward torque compensation value.

[0077] Specifically, as shown in Fig. 2, a proportional integral (PI) control is performed on a speed error (i.e., the fluctuation speed $\tilde{\omega}$) between the feedback speed w_fbk and the target speed w_ref to obtain the load torque reference value Trqref. According to the load torque reference value Trqref, the feedback speed w_fbk, the target speed w-fbk and an electromechanical time constant τ_m, the feedforward torque compensation value Tcomp is obtained by the method for the automatic torque compensation of the compressor described above. The feedforward torque compensation value Tcomp can be superimposed onto the load torque reference value Trqref output by the speed loop in a feedforward manner to take part in an input process of a current loop. Thus, a space vector pulse width modulation (SVPWM) can be performed on the three-phase output voltage (VA, VB and VC) of the compressor, and a control to the compressor is achieved.

[0078] With the method for controlling the compressor according to embodiments of the present invention, the feedforward torque compensation value is generated by the method for the automatic torque compensation of the compressor described above, and the compressor is controlled according to the load torque reference value and the feedforward torque compensation value, such that the load torque angle and load torque amplitude can be tracked in real time, and the angle and the amplitude can be adjusted on line in real time, and thus the debugging time of the torque compensation is greatly reduced and the optimal compensation effect can be implemented in all working conditions of the compressor. More particularly, the vibration of the compressor operating at the low frequency can be reduced, thus ensuring a stable operation of the compressor.

[0079] Fig. 7 is a block diagram of an apparatus for an automatic torque compensation of a compressor according to an embodiment of the present invention. As shown in Fig. 7, the apparatus for the automatic torque compensation of the compressor includes a speed obtaining module 10, a speed generating module 20, a torque compensation angle generating module 30, a torque compensation amplitude generating module 40 and a feedforward torque compensation value generating module 50.

[0080] Specifically, the speed obtaining module 10 is configured to obtain a target speed and a feedback speed, the speed generating module 20 is configured to generate a fluctuation speed according to the target speed and the feedback speed, the torque compensation angle generating module 30 is configured to generate a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner, the torque compensation amplitude generating module 40 is configured to obtain a load torque reference value and to generate a torque compensation amplitude according to the load torque reference value, and the feedforward torque compensation value generating module 50 is configured to generate a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude.

[0081] In an embodiment of the present invention, as shown in Fig. 3 or 4, the torque compensation angle generating module 30 is configured to generate a mechanical angle according to the target speed, to generate a first reference value according to the mechanical angle and the torque compensation angle, to generate a second reference value according to the first reference value, to generate a third reference value according to the fluctuation speed and the second reference value, and to perform a proportional integral (PI) process on the third reference value to obtain the torque compensation angle.

[0082] Moreover, the torque compensation angle generating module 30 is further configured to filter the fluctuation speed and the second reference value with a same cut-off frequency before generating the third reference value.

[0083] The torque compensation angle generating module 30 is further configured to: perform a cosine function calculation on the first reference value to obtain a fourth reference value, to generate a coefficient B according to the fluctuation speed, and to generate the second reference value according to the fourth reference value and the coefficient B.

[0084] In an embodiment of the present invention, the torque compensation angle generating module 30 is configured to calculate the third reference according to a formula of:

$$C = \tilde{\omega} \times B Cos(\bar{\omega} t + \theta)$$

where C is the third reference value, $\tilde{\omega}$ is the fluctuation speed, $\bar{\omega}$ is the target speed, B is the coefficient, $\bar{\omega} t$ is the mechanical angle and θ is the torque compensation angle.

[0085] Moreover, the torque compensation angle generating module 30 is further configured to perform a low pass filtering process on the third reference value before performing a proportional integral (PI) process on the third reference value.

[0086] As shown in Fig. 3 or 4, the torque compensation amplitude generating module 40 is further configured to generate a fifth reference value according to the load torque reference value and a torque compensation coefficient and to generate the torque compensation amplitude according to the fifth reference value.

[0087] When the fifth reference value is larger than a torque compensation limit, the torque compensation amplitude generating module 40 is configured to use the torque compensation limit as the torque compensation amplitude; when the fifth reference value is less than or equal to the torque compensation limit, the torque compensation amplitude generating module 40 is configured to use the fifth reference value as the torque compensation amplitude.

[0088] As shown in Fig. 3, when the compressor is a rare earth compressor, the feedforward torque compensation value generating module 50 is configured to perform a sinusoidal function calculation on the first reference value to generate a sixth reference value and to generate the feedforward torque compensation value according the sixth reference value and the torque compensation amplitude.

[0089] As shown in Fig. 4, when the compressor is a ferrite compressor, the feedforward torque compensation value generating module 50 is configured to perform a sinusoidal function calculation on the first reference value to generate a sixth reference value, to generate a seventh reference value according to the target speed and an electromechanical time constant, to generate an eighth reference value according to the sixth reference value and the seventh reference value, and to generate the feedforward torque compensation value according to the eighth reference value and the torque compensation amplitude.

[0090] With the apparatus for the automatic torque compensation of the compressor according to embodiments of the present invention, the torque compensation angle generating module generates the torque compensation angle in the phase locked loop (PLL) manner and the torque compensation amplitude generating module generates the torque compensation amplitude according to the load torque reference value output from the speed loop, so that the load torque angle and load torque amplitude can be tracked in real time by the apparatus for the automatic torque compensation of the compressor, and the angle and the amplitude can be adjusted on line in real time, and thus the debugging time of the torque compensation is greatly reduced and the optimal compensation effect can be implemented in all working conditions of the compressor. More particularly, the vibration of the compressor operating at the low frequency can be reduced, thus ensuring a stable operation of the compressor.

[0091] In addition, a compressor is further provided in embodiments of the present invention, and the compressor includes the apparatus for the automatic torque compensation of the compressor described above.

[0092] The compressor according to embodiments of the present invention can generate the feedforward torque compensation value using the above described apparatus for the automatic torque compensation of the compressor, such that the load torque angle and load torque amplitude can be tracked in real time, and the angle and the amplitude can be adjusted on line in real time, and thus the debugging time of the torque compensation is greatly reduced and the optimal compensation effect can be implemented in all working conditions of the compressor. More particularly, the vibration of the compressor operating at the low frequency can be reduced, thus ensuring a stable operation of the compressor.

[0093] Any process or method described in a flow chart or described herein in other ways may be understood to include one or more modules, segments or portions of codes of executable instructions for achieving specific logical functions or steps in the process, and the scope of a preferred embodiment of the present disclosure includes other implementations, which should be understood by those skilled in the art.

[0094] The logic and/or step described in other manners herein or shown in the flow chart, for example, a particular sequence table of executable instructions for realizing the logical function, may be specifically achieved in any computer readable medium to be used by the instruction execution system, device or equipment (such as the system based on computers, the system comprising processors or other systems capable of obtaining the instruction from the instruction execution system, device and equipment and executing the instruction), or to be used in combination with the instruction execution system, device and equipment. As to the specification, "the computer readable medium" may be any device adaptive for including, storing, communicating, propagating or transferring programs to be used by or in combination with the instruction execution system, device or equipment. More specific examples of the computer readable medium comprise but are not limited to: an electronic connection (an electronic device) with one or more wires, a portable computer enclosure (a magnetic device), a random access memory (RAM), a read only memory (ROM), an erasable programmable read-only memory (EPROM or a flash memory), an optical fiber device and a portable compact disk read-only memory (CDROM). In addition, the computer readable medium may even be a paper or other appropriate medium capable of printing programs thereon, this is because, for example, the paper or other appropriate medium may be optically scanned and then edited, decrypted or processed with other appropriate methods when necessary to obtain the programs in an electric manner, and then the programs may be stored in the computer memories.

[0095] It should be understood that each part of the present disclosure may be realized by the hardware, software, firmware or their combination. In the above embodiments, a plurality of steps or methods may be realized by the software or firmware stored in the memory and executed by the appropriate instruction execution system. For example, if it is realized by the hardware, likewise in another embodiment, the steps or methods may be realized by one or a combination of the following techniques known in the art: a discrete logic circuit having a logic gate circuit for realizing a logic function of a data signal, an application-specific integrated circuit having an appropriate combination logic gate circuit, a programmable gate array (PGA), a field programmable gate array (FPGA), etc.

[0096] Those skilled in the art shall understand that all or parts of the steps in the above exemplifying method of the present disclosure may be achieved by commanding the related hardware with programs. The programs may be stored in a computer readable storage medium, and the programs comprise one or a combination of the steps in the method embodiments of the present disclosure when run on a computer.

[0097] In addition, each function cell of the embodiments of the present disclosure may be integrated in a processing module, or these cells may be separate physical existence, or two or more cells are integrated in a processing module. The integrated module may be realized in a form of hardware or in a form of software function modules. When the integrated module is realized in a form of software function module and is sold or used as a standalone product, the integrated module may be stored in a computer readable storage medium.

[0098] The storage medium mentioned above may be read-only memories, magnetic disks or CD, etc.

[0099] Reference throughout this specification to "an embodiment," "some embodiments," "one embodiment", "another example," "an example," "a specific example," or "some examples," means that a particular feature, structure, material, or characteristic described in connection with the embodiment or example is included in at least one embodiment or example of the present invention. Thus, the appearances of the phrases such as "in some embodiments," "in one embodiment", "in an embodiment", "in another example," "in an example," "in a specific example," or "in some examples," in various places throughout this specification are not necessarily referring to the same embodiment or example of the present invention. Furthermore, the particular features, structures, materials, or characteristics may be combined in any suitable manner in one or more embodiments or examples.

[0100] Although explanatory embodiments have been shown and described, it would be appreciated by those skilled in the art that the above embodiments cannot be construed to limit the present invention, and changes, alternatives, and modifications can be made in the embodiments without departing from spirit, principles and scope of the present invention.

Claims

1. A method for an automatic torque compensation of a compressor, comprising:

obtaining a target speed and a feedback speed;
generating a fluctuation speed according to the target speed and the feedback speed;
generating a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner;
obtaining a load torque reference value and generating a torque compensation amplitude according to the load torque reference value; and
generating a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude.

2. The method according to claim 1, wherein generating a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner comprises:

generating a mechanical angle according to the target speed;
generating a first reference value according to the mechanical angle and a feedback torque compensation angle;
generating a second reference value according to the first reference value;
generating a third reference value according to the fluctuation speed and the second reference value; and
performing a proportional integral (PI) process on the third reference value to obtain the torque compensation angle.

3. The method according to claim 2, further comprising:

filtering the fluctuation speed and the second reference value with a same cut-off frequency before generating the third reference value according to the fluctuation speed and the second reference value.

4. The method according to claim 2, wherein generating a second reference value according to the first reference value comprises:

performing a cosine function calculation on the first reference value to obtain a fourth reference value;
generating a coefficient according to the fluctuation speed; and
generating the second reference value according to the fourth reference value and the coefficient.

5. The method according to claim 4, wherein the third reference value is calculated by a formula of:

$$C = \tilde{\omega} \times BCos(\bar{\omega}t + \theta)$$

where C is the third reference value, $\tilde{\omega}$ is the fluctuation speed, $\bar{\omega}$ is the target speed, B is the coefficient, $\bar{\omega}t$ is the mechanical angle and θ is the feedback torque compensation angle.

6. The method according to claim 2, further comprising:

performing a low pass filtering process on the third reference value before performing a proportional integral (PI) process on the third reference value to obtain the torque compensation angle.

7. The method according to claim 1, wherein generating a torque compensation amplitude according to the load torque reference value comprises:

generating a fifth reference value according to the load torque reference value and a torque compensation coefficient; and
generating the torque compensation amplitude according to the fifth reference value.

8. The method according to claim 7, wherein generating the torque compensation amplitude according to the fifth reference value comprises:

when the fifth reference value is larger than a torque compensation limit, using the torque compensation limit as the torque compensation amplitude;
when the fifth reference value is less than or equal to the torque compensation limit, using the fifth reference value as the torque compensation amplitude.

9. The method according to claim 2, wherein when the compressor is a rare earth compressor, generating a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude comprises:

performing a sinusoidal function calculation on the first reference value to generate a sixth reference value; and
generating the feedforward torque compensation value according the sixth reference value and the torque compensation amplitude.

10. The method according to claim 2, wherein when the compressor is a ferrite compressor, generating a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude further comprises:

performing a sinusoidal function calculation on the first reference value to generate a sixth reference value;
generating a seventh reference value according to the target speed and an electromechanical time constant;
generating an eighth reference value according to the sixth reference value and the seventh reference value;
generating the feedforward torque compensation value according to the eighth reference value and the torque compensation amplitude.

11. A method for controlling a compressor, comprising:

obtaining a target speed and a feedback speed and generating a fluctuation speed according to the target speed and the feedback speed;
performing a speed loop control on the fluctuation speed to generate a load torque reference value;
generating a feedforward torque compensation value by a method for an automatic torque compensation of a compressor according to any one of claims 1-10;
controlling the compressor according to the load torque reference value and the feedforward torque compensation value.

12. An apparatus for an automatic torque compensation of a compressor, comprising:

a speed obtaining module, configured to obtain a target speed and a feedback speed;
a speed generating module, configured to generate a fluctuation speed according to the target speed and the feedback speed;
a torque compensation angle generating module, configured to generate a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner;
a torque compensation amplitude generating module, configured to obtain a load torque reference value and to generate a torque compensation amplitude according to the load torque reference value; and
a feedforward torque compensation value generating module, configured to generate a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude.

13. The apparatus according to claim 12, wherein the torque compensation angle generating module is configured to:

generate a mechanical angle according to the target speed;

generate a first reference value according to the mechanical angle and a feedback torque compensation angle;
generate a second reference value according to the first reference value;
generate a third reference value according to the fluctuation speed and the second reference value; and
perform a proportional integral (PI) process on the third reference value to obtain the torque compensation angle.

14. The apparatus according claim 13, wherein the torque compensation angle generating module is further configured to filter the fluctuation speed and the second reference value by a same cut-off frequency before generating the third reference value.

15. The apparatus according to claim 13, wherein the torque compensation angle generating module is further configured to:

perform a cosine function calculation on the first reference value to obtain a fourth reference value;
generate a coefficient according to the fluctuation speed; and
generate the second reference value according to the fourth reference value and the coefficient.

16. The apparatus according to claim 15, wherein the torque compensation angle generating module is configured to calculate the third reference according to a formula of:

$$C = \tilde{\omega} \times BCos(\bar{\omega}t + \theta)$$

where C is the third reference value, $\tilde{\omega}$ is the fluctuation speed, $\bar{\omega}$ is the target speed, B is the coefficient, $\bar{\omega}t$ is the mechanical angle and θ is the feedback torque compensation angle.

17. The apparatus according to claim 13, wherein the torque compensation angle generating module is further configured to perform a low pass filtering process on the third reference value before performing a proportional integral (PI) process on the third reference value.

18. The apparatus according to claim 12, wherein the torque compensation amplitude generating module is further configured to:

generate a fifth reference value according to the load torque reference value and a torque compensation coefficient; and
generate the torque compensation amplitude according to the fifth reference value.

19. The apparatus according to claim 18, wherein
when the fifth reference value is larger than a torque compensation limit, the torque compensation amplitude generating module is configured to use the torque compensation limit as the torque compensation amplitude;
when the fifth reference value is less than or equal to the torque compensation limit, the torque compensation amplitude generating module is configured to use the fifth reference value as the torque compensation amplitude.

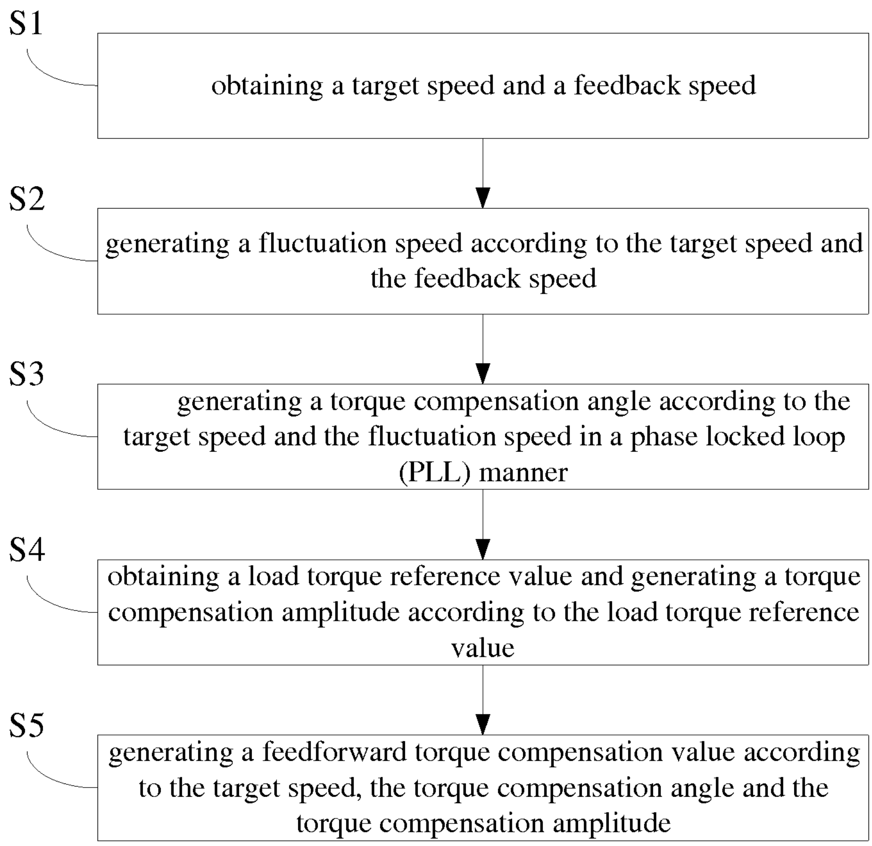
20. The apparatus according to claim 13, wherein when the compressor is a rare earth compressor, the feedforward torque compensation value generating module is configured to:

perform a sinusoidal function calculation on the first reference value to generate a sixth reference value; and
generate the feedforward torque compensation value according the sixth reference value and the torque compensation amplitude.

21. The apparatus according to claim 13, wherein when the compressor is a ferrite compressor, the feedforward torque compensation value generating module is configured to:

perform a sinusoidal function calculation on the first reference value to generate a sixth reference value;
generate a seventh reference value according to the target speed and an electromechanical time constant;
generate an eighth reference value according to the sixth reference value and the seventh reference value;
generate the feedforward torque compensation value according to the eighth reference value and the torque compensation amplitude.

22. A compressor, comprising an apparatus for an automatic torque compensation of a compressor according to any one of claims 12-21.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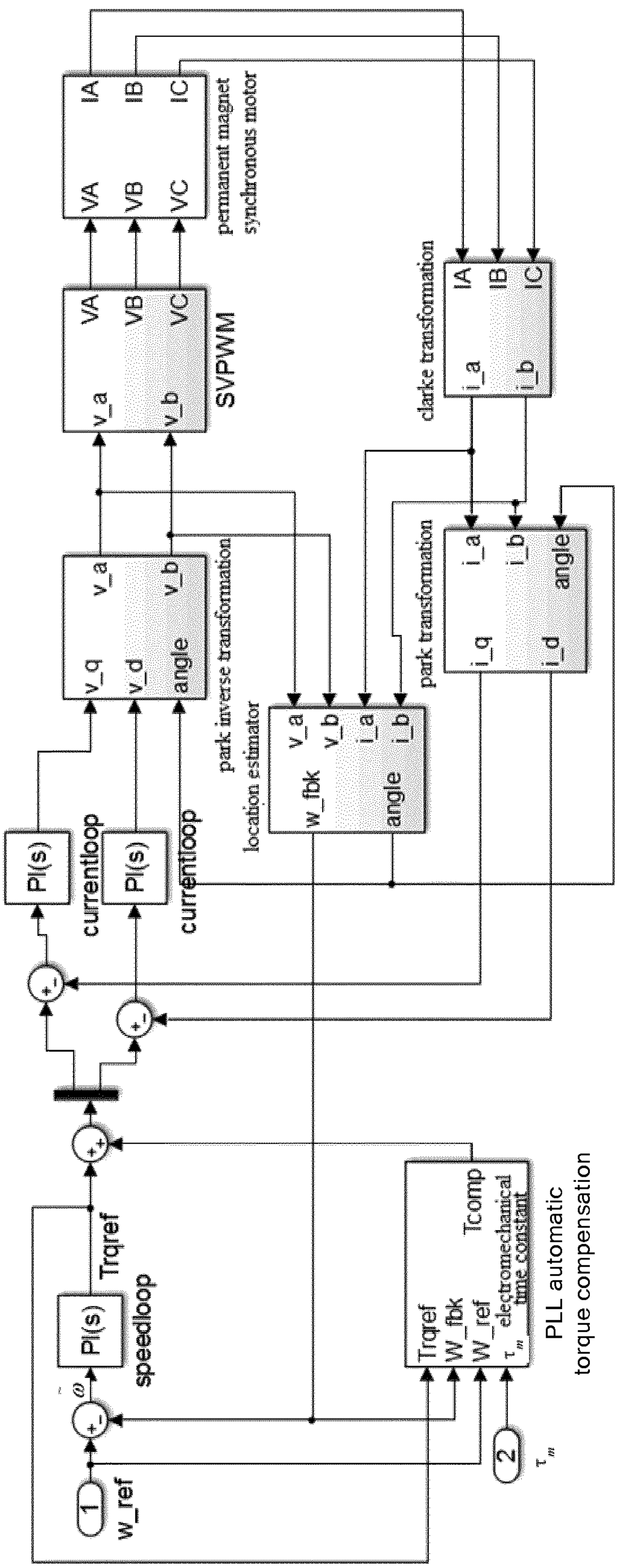
S2
generating a fluctuation speed according to the target speed and the feedback speed
S3
generating a torque compensation angle according to the target speed and the fluctuation speed in a phase locked loop (PLL) manner
S4
obtaining a load torque reference value and generating a torque compensation amplitude according to the load torque reference value
S5
generating a feedforward torque compensation value according to the target speed, the torque compensation angle and the torque compensation amplitude

Fig. 1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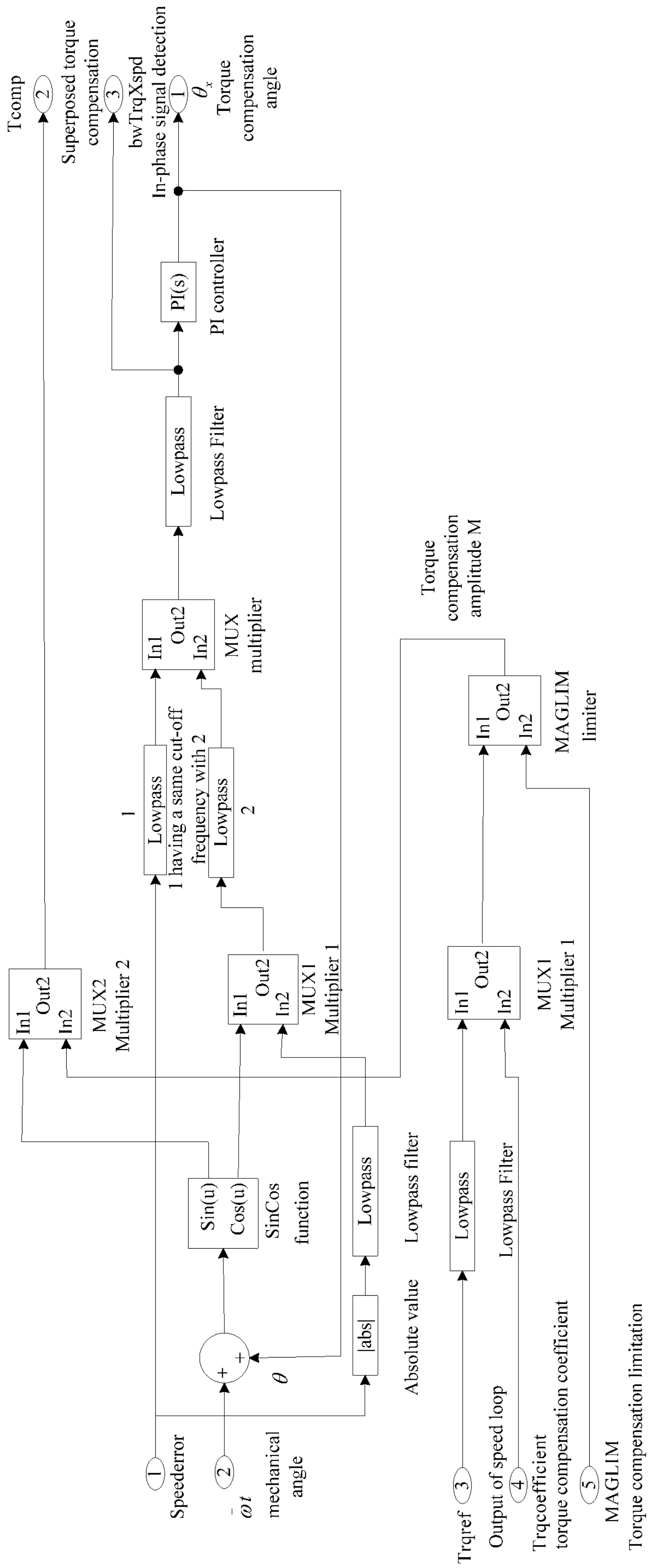
synchronous motor
VA
VB
VC
IA
IB
IC
SVPWM
v_a
v_b
VA
VB
VC
clarke transformation
IA
IB
IC
i_a
i_b
park inverse transformation
v_q
v_d
angle
v_a
v_b
park transformation
i_a
i_b
angle
i_q
i_d
location estimator
v_a
v_b
i_a
i_b
w_fbk
angle
PI(s)
currentloop
PI(s)
currentloop
PI(s)
speedloop
Trqref
w_ref
1
2
Trqref
W_fbk
W_ref
Tcomp
electromechanical
time constant
PLL automatic
torque compensation

Fig.2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Superposed torque compensation
3
bwTrqXspd
In-phase signal detection
1
θ_x
Torque compensation angle
PI(s)
PI controller
Lowpass
Lowpass Filter
In1 Out2 In2
MUX multiplier
Torque compensation amplitude M
In1 Out2 In2
MAGLIM limiter
1
Lowpass
1 having a same cut-off frequency with 2
Lowpass
2
In1 Out2 In2
MUX2 Multiplier 2
In1 Out2 In2
MUX1 Multiplier 1
In1 Out2 In2
MUX1 Multiplier 1
Sin(u) Cos(u)
SinCos function
Lowpass
Lowpass filter
Lowpass
Lowpass Filter
|abs|
Absolute value
+ +
θ
1
Speederror
2
ωt
mechanical angle
Trqref 3
Output of speed loop
4
Trqcoefficient
torque compensation coefficient
5
MAGLIM
Torque compensation limitation

Fig. 3

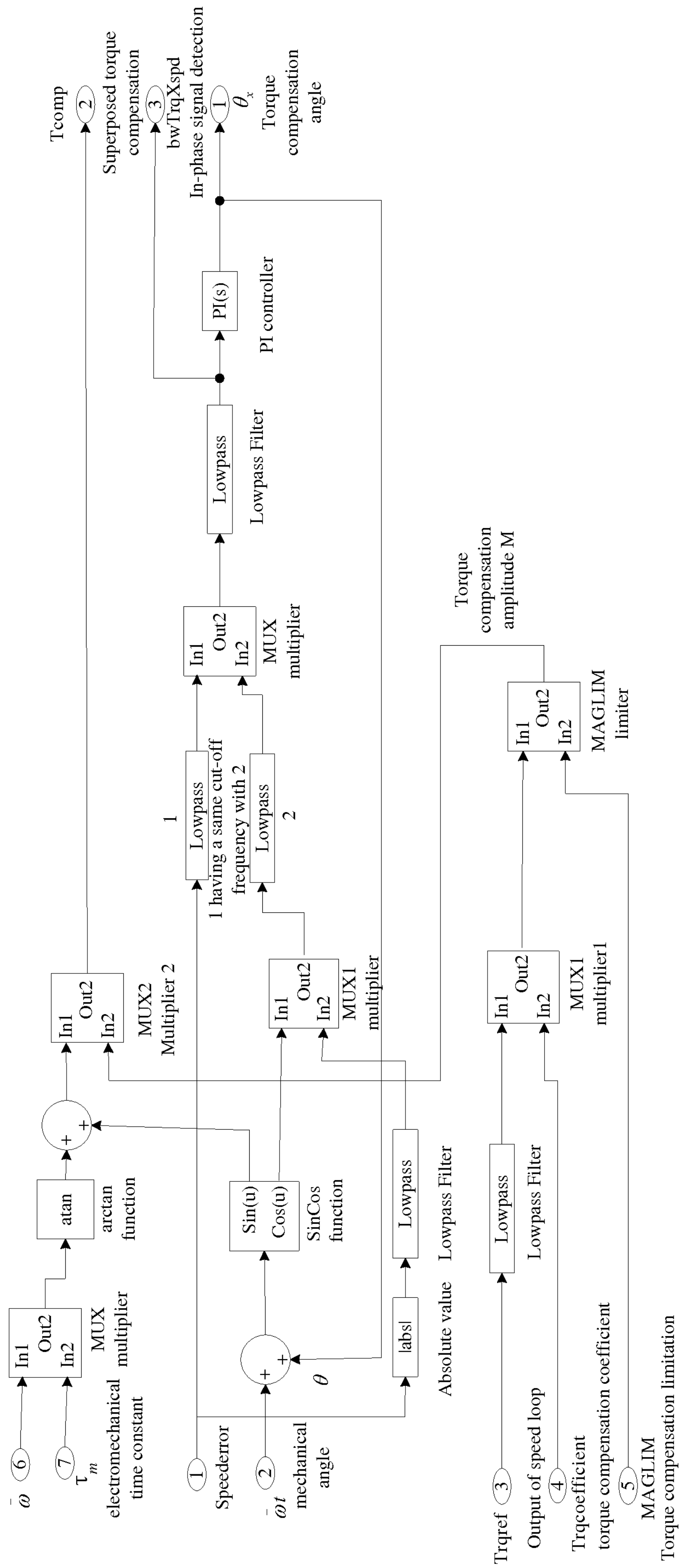
Tcomp
Superposed torque compensation
bwTrqXspd
In-phase signal detection
Torque compensation angle
PI(s)
PI controller
Lowpass
Lowpass Filter
Torque compensation amplitude M
In1
Out2
In2
MUX
multiplier
MAGLIM
limiter
Lowpass
1
1 having a same cut-off frequency with 2
Lowpass
2
MUX2
Multiplier 2
MUX1
multiplier
MUX1
multiplier1
atan
arctan function
Sin(u)
Cos(u)
SinCos function
Lowpass
Lowpass Filter
|abs|
Absolute value
Lowpass
Lowpass Filter
electromechanical time constant
Speederror
mechanical angle
Trqref
Output of speed loop
Trqcoefficient
torque compensation coefficient
MAGLIM
Torque compensation limitation

Fig. 4

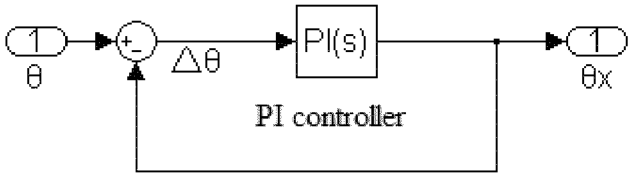

Fig. 5

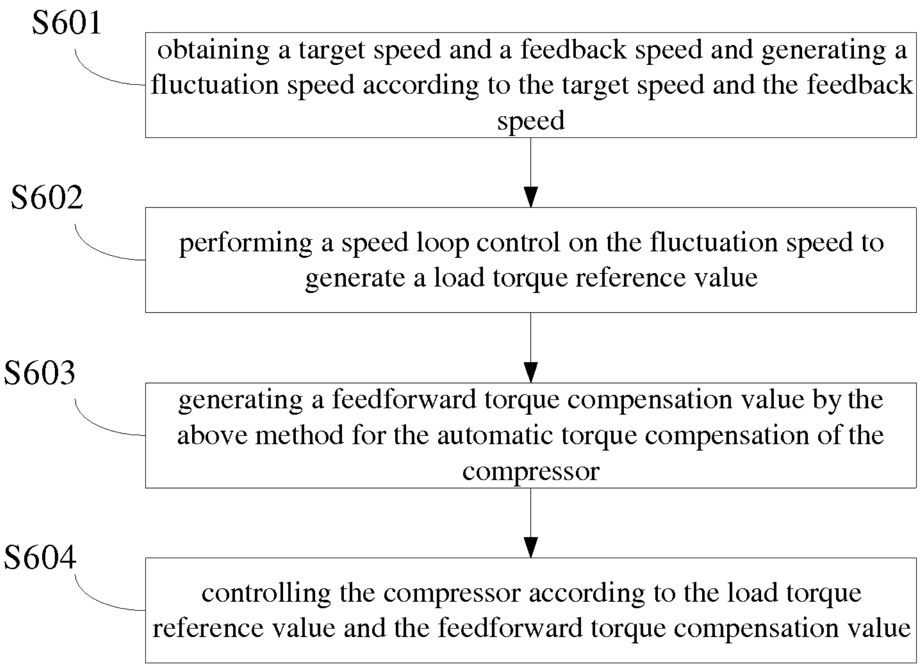

Fig. 6

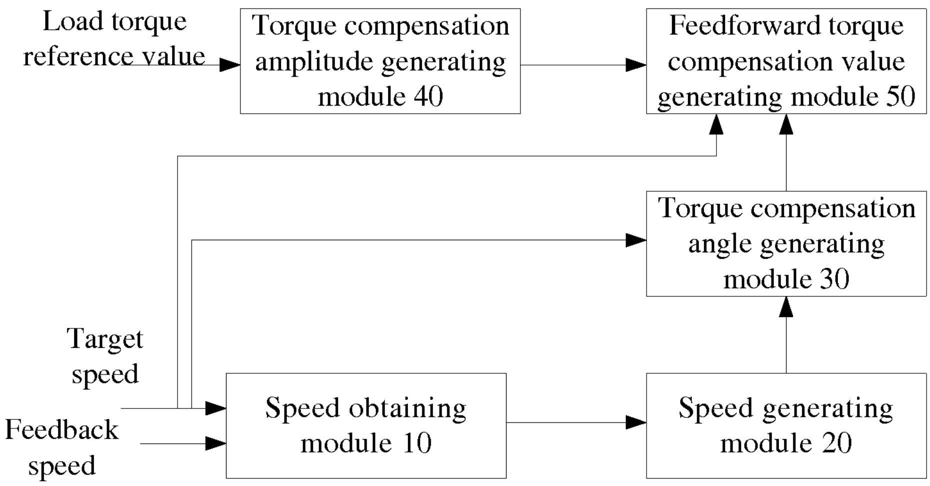

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/090551

A. CLASSIFICATION OF SUBJECT MATTER

F04B 49/06 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F04B 49/06; F04B 49/00; F04C 28/00; F24F 11/02; F24F 11/00; H02P 21/05

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, VEN, CNKI: rotating speed, compressor?, moment, torque, compensat+, speed

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	CN 103742396 A (GUANGDONG MEIZHI COMPRESSOR CO., LTD.), 23 April 2014 (23.04.2014), claims 1-22	1-22
A	CN 103470483 A (GUANGDONG MEIZHI COMPRESSOR CO., LTD.), 25 December 2013 (25.12.2013), claims 1-12	1-22
A	US 2011138816 A1 (TAKEDA, K. et al.), 16 June 2011 (16.06.2011), the whole document	1-22
A	JP 2009296722 A (TOSHIBA CORP.), 17 December 2009 (17.12.2009), the whole document	1-22
A	JP 2008295204 A (TOSHIBA CORP.), 04 December 2008 (04.12.2008), the whole document	1-22
A	CN 102522941 A (HAIER ELECTRONICS GROUP CO., LTD. et al.), 27 June 2012 (27.06.2012), the whole document	1-22

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 July 2014 (08.07.2014)	**06 August 2014 (06.08.2014)**

Name and mailing address of the ISA/CN:
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Facsimile No.: (86-10) 62019451

Authorized officer
QIN, Baojun
Telephone No.: (86-10) **62084087**

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2013/090551

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 103742396 A	23 April 2014	None	
CN 103470483 A	25 December 2013	None	
US 2011138816 A1	16 June 2011	AU 2009315131 B2	08 December 2011
		JP 2010116831 A	27 May 2010
		EP 2325491 A1	25 May 2011
		JP 5167078 B2	21 March 2013
		AU 2009315131 A1	20 May 2010
		WO 2010055723 A1	20 May 2010
JP 2009296722 A	17 December 2009	None	
JP 2008295204 A	04 December 2008	None	
CN 102522941 A	27 June 2012	None	

Form PCT/ISA/210 (patent family annex) (July 2009)