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

(11) EP 2 692 683 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
05.02.2014 Bulletin 2014/06

(51) Int Cl.:
B66C 23/84 *(2006.01)*

(21) Application number: **13178832.5**

(22) Date of filing: **31.07.2013**

(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

(30) Priority: **31.07.2012 DE 102012015306**

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(54) **Method of controlling the slewing gear of a slewing crane**

(57) A method of controlling the slewing gear (4) of a slewing crane (1) comprising at least one three-phase motor (10) which is mechanically coupled to a slewable part of the crane (1) and by which the slewable part of the crane (1) is turned about a slewing axis (5), wherein when a change of loading of the three-phase motor (10) occurs the speed of the three-phase motor (10) is changed and the torque of the three-phase motor (10) is kept constant or substantially constant.

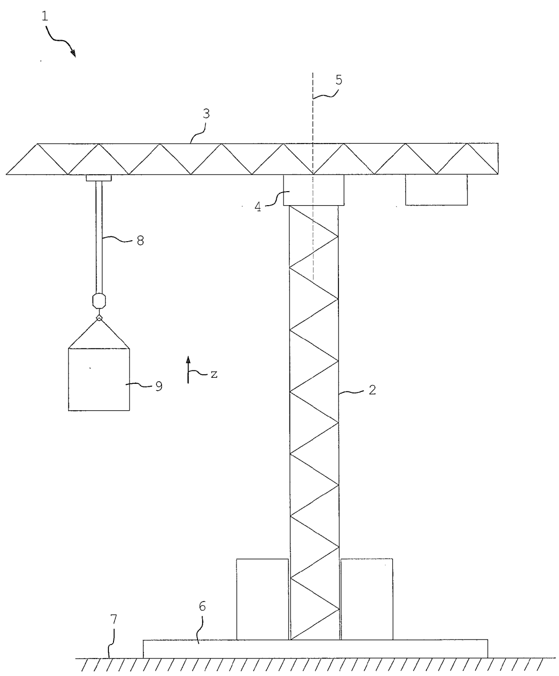

Fig. 1

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Description

[0001] This disclosure relates to a method of controlling the slewing gear of a slewing crane comprising at least one three-phase motor which is mechanically coupled to a slewable part of the crane and by which the slewable part of the crane is turned about a slewing axis. This disclosure further relates to a drive for such a slewing gear.

[0002] A problem which occurs in the case of slewing cranes is that swinging loads have a strong influence on the slewing movement of the crane, so that the control of the slewing movement requires the crane operator to have a high level of skill and good concentration. However, this can lead to premature fatigue of the crane operator.

[0003] EP 0 691 301 A1 discloses a slewing gear for a crane, with an electric motor which drives the pinion which meshes with a slewing ring of the crane mass to be turned and with means for controlling the motor according to the control movements applied to an actuating means. Means are provided for measurement of the motor speed and the motor torque, wherein as the motor speed increases due to the load swinging forward during the start-up and slewing operation the driving torque is lowered towards zero and as the load swings back the driving torque is substantially maintained.

[0004] Although according to EP 0 691 301 A1 the controllability of the slewing movement of the crane is improved, it has been appreciated by the present inventors that it is difficult to control the slewing movement of the crane in the event of a change of loading of the motor, caused in particular by swinging of the load.

[0005] The present disclosure provides a way of improving the controllability of the slewing movement of a slewing crane in the event of a change of loading.

[0006] An invention is set out in the independent claims. Optional features are set out in the dependent claims.

[0007] According to an aspect, there is provided a method for controlling the slewing gear of a slewing crane comprising at least one three-phase motor which is mechanically coupled to a slewable part of the crane and by means of which the slewable part of the crane is turnable about a slewing axis, wherein when a change of loading of the three-phase motor occurs the speed of the three-phase motor is changed and the torque of the three-phase motor is kept constant or substantially constant.

[0008] A reduction and/or attenuation of the loading and/or of the change of loading of the three-phase motor is effected by the change of speed, the torque of the three-phase motor being kept constant or substantially constant, so that in particular abrupt changes of the torque transmitted by the three-phase motor can be avoided. Such abrupt changes of the torque may, for example in the case of high tower cranes, lead to the generation of additional vibrations of the tower and thus make it more difficult to control the slewing movement of the slewing part of the crane. This disadvantage is avoided or at least perceptibly reduced in the present disclosure.

[0009] The change in the speed may be a reduction or an increase in the speed. This is a function in particular of the loading and/or of the change of loading of the three-phase motor. The speed is optionally reduced or increased as a function of the loading and/or of the change of loading of the three-phase motor, so that in particular a reduction and/or attenuation of the loading and/or of the change of loading of the three-phase motor takes place.

[0010] The three-phase motor is connected in particular to a controllable converter and is supplied thereby with electrical power. When a change of loading occurs the speed of the three-phase motor is changed optionally by control of the converter and the torque of the three-phase motor is kept constant or substantially constant. The use of the converter offers an excellent possibility for control of the three-phase motor, since by means of the converter the frequency and the level of the operating voltage supplied to the three-phase motor and/or the strength and the frequency of the operating current supplied to the three-phase motor can be changed. Furthermore, the phase angle or angles between the operating voltage and the operating current can optionally be changed by means of the converter.

[0011] The operating voltage is in particular a monophase or polyphase electrical voltage, optionally a three-phase electrical voltage. Furthermore, the operating current is in particular a monophase or polyphase electrical current, optionally a three-phase electrical current. In particular there are an equal number of phases in the operating current and the operating voltage.

[0012] One or more operating parameters of the three-phase motor are optionally detected and optionally evaluated. Thus the occurrence of the change of loading can be detected and/or recognised. The detection of the operating parameter or parameters optionally takes place by measurement. The operating parameter or parameters advantageously include the speed of the three-phase motor. Additionally or alternatively the operating parameter or parameters optionally include the operating current consumed by the three-phase motor. Additionally or alternatively the operating parameter or parameters may also include the operating voltage at the three-phase motor and/or the phase angle. The operating parameter or parameters may be changed optionally by control of the converter.

[0013] In some embodiments, in particular if a change of loading occurs, the speed of the three-phase motor is changed as a function of the loading. This change in the speed may be an increase or a reduction in the speed. The loading and/or the change of loading of the three-phase motor can in particular be reduced and/or attenuated by the change and/or reduction of the speed as a function of the loading. It has been shown that a change and/or reduction of the speed as a function of the loading simulates the action of an eddy current brake coupled to the three-phase motor, so that in particular a reduction and/or attenuation of the loading and/or of the change of loading of the three-phase motor takes place. In this case it is optionally assumed that the (imaginary) eddy current brake is mechanically coupled to the three-phase motor, in particular mechanically coupled to the rotor shaft of the three-phase motor. Costs can be saved by the simulation of the action of an eddy current brake, since the integration of an eddy current brake into the slewing gear of the crane can be omitted. However, this should not be understood as a limitation, so that it is entirely possible for an eddy current brake coupled to the three-phase motor to be integrated into the slewing gear.

[0014] Since the loading of the three-phase motor can be deduced from one or more of the operating parameters, when the change of loading occurs the speed of the three-phase motor optionally changes as a function of one or more of the operating parameters. In particular when the change of loading occurs the frequency and/or the level of the operating voltage at the three-phase motor changes. The change in the frequency and/or the level of the operating voltage at the three-phase motor optionally takes place as a function of one or more of the operating parameters. Since the frequency of the rotating field in the three-phase motor is determined by the frequency of the operating voltage, the frequency of the rotating field which is also designated as the synchronous speed can change due to the change in the frequency of the operating voltage. The frequency of the rotating field is optionally equal to the quotient of the frequency of the operating voltage and the number of pole pairs of the three-phase motor. In the case of a polyphase operating voltage the change in the level and/or the frequency of the operating voltage optionally takes place in each phase and/or for each line voltage. In particular in the case of a polyphase operating voltage the level and/or the frequency of the phase voltages in all phases and/or all line voltages are equal, but it should be taken into consideration that the voltages are phase-shifted with respect to one another and in particular exhibit a fixed phase shift. This phase shift is optionally equal to the quotient of 360° and the number of phases. Thus in the case of three phases the phase shift is optionally 120°.

[0015] The three-phase motor is optionally an asynchronous motor. In the case of an asynchronous motor the torque of the three-phase motor can be kept constant by simultaneous changing of the frequency and the level of the operating voltage. For example, according to one model for describing the asynchronous motor the torque can be kept constant over a frequency range of the operating voltage if the quotient of the level and the frequency of the operating voltage is kept constant.

[0016] In some embodiments, the speed is controlled as a function of a desired speed value. The desired speed value is optionally determined on the basis of a speed reference value which is optionally predetermined. The desired speed value is advantageously changed when the change of loading occurs. In particular when the change of loading occurs the desired speed value is changed as a function of the loading, so that when the change of loading occurs the desired speed value is optionally changed as a function of one or more of the operating parameters. Without a change of the loading the desired speed value optionally corresponds to the speed reference value.

[0017] In some embodiments, a plurality of preset speed values are predetermined, one of which is selected as speed reference value. The preset speed values are optionally constant. Furthermore the preset speed values are optionally different. Therefore the crane operator can select one value from the preset speed values as the speed reference value. Since the desired speed value is determined on the basis of the speed reference value the crane operator can control the speed by way of the selection of the speed reference value from the preset speed values. In particular the preset speed values are each associated with a speed stage. The speed stages are optionally predetermined. Four preset speed values and/or speed stages are optionally provided. Thus the crane operator can change the speed discretely as a function of the preset speed values and/or the speed stages. The controllability of the slewing movement of the crane is also simplified in this way.

[0018] When the change of loading occurs the desired speed value is optionally changed as a function of a slip reference value. The slip reference value is optionally predetermined. The slip reference value is optionally combined with one or more of the operating parameters to give a speed change value, as a function of which the speed is changed when the change of loading occurs. The slip reference value is optionally combined with the load-dependent part of the operating current to give the speed change value.

[0019] A plurality of preset slip values is optionally predetermined, and one or at least one of the preset slip values is assigned to each of the preset speed values. The preset slip values are optionally constant. Furthermore the preset slip values are optionally different. Each of the speed stages is assigned to one or at least one of the preset slip values. In particular the or one of the preset slip values assigned to the selected preset speed value is selected as slip reference value. Thus the speed change value is a function of the preset speed value selected as speed reference value, so that the speed change takes place in particular as a function of the selected speed stage. Two of the preset slip values are optionally assigned to each of the preset speed values, a first preset slip value being associated in particular with a reduction in speed and a second being associated in particular with an increase in speed. When the change of loading occurs a decision is advantageously made on the basis of the operating parameter or parameters as to whether the speed must be reduced or increased for the reduction and/or attenuation of the change of loading. If the speed is reduced when the change of load occurs then the first preset slip value assigned to the selected preset speed value is selected as slip reference value. If the speed is increased when the change of load occurs then the second preset slip value assigned to the selected preset speed value is selected as slip reference value. Thus different speed change values can be formed within the same speed stage for the braking and the acceleration of the three-phase motor.

[0020] In some embodiments, a pivotable jib is provided, the tip of which can be varied in height. As a result the inertia of the mechanical slewing system changes. In order to adapt the attenuation, various slip reference values are switched over as a function of the angle, for example between the jib being horizontal, inclined and vertical.

[0021] A load is optionally suspended on the slewable part of the crane, optionally by means of at least one wire rope. The change of load is brought about for example by swinging of the load. Such swinging may be caused for example by initiation of the slewing, by changing of the speed stage during slewing, by ending of the slewing and/or by wind. Additionally or alternatively the change of load can also be caused by wind acting on the slewing part of the crane.

[0022] According to an aspect, there is provided a drive for the slewing gear of a slewing crane, with at least one three-phase motor mechanically coupled to a part of the crane which is slewable about a slewing axis, a controllable converter which is electrically connected to the three-phase motor and supplies it with electrical power, and a controller electrically connected to the converter and by means of which the converter is controlled, so that the slewable part of the crane slews about the slewing axis by means of the three-phase motor, wherein when a change of loading of the three-phase motor occurs, by means of the controller the speed of the three-phase motor is changed and the torque of the three-phase motor is kept constant or substantially constant.

[0023] The drive may be configured according to any of the embodiments described in connection with the method. Furthermore, the method may be configured according to any embodiments described in connection with the drive. The method according to described embodiments is optionally carried out with the drive according to described embodiments.

[0024] In particular, in some embodiments, the drive comprises one or more measurement means which are coupled to the controller and each measure one or more operating parameters of the three-phase motor. Thus the occurrence of the change of loading can be detected and/or recognised by the controller, optionally with evaluation of the operating parameter or parameters. The one or more measurement means optionally comprise a speed measurement means which measures the speed and/or a current measurement means which measures the operating current consumed by the three-phase motor. Additionally or alternatively the one or more measurement means can also comprise a voltage measurement means for measuring the operating voltage at the three-phase motor and/or a voltage measurement means for measuring the intermediate circuit voltage applied to the intermediate circuit of the converter and/or a phase angle measurement means for measuring the phase angle or angles between the operating current and operating voltage.

[0025] In some embodiments, in particular when the change of loading occurs the speed of the three-phase motor is changed as a function of the loading by means of the controller. This change of speed may be an increase or a reduction in the speed. The converter is optionally controlled by means of the controller in such a way that by the loading-dependent change and/or reduction of the speed the action of an eddy current brake coupled to the three-phase motor is simulated so that in particular a reduction and/or attenuation of the loading and/or of the change of loading of the three-phase motor takes place. In this case it is optionally assumed that the (imaginary) eddy current brake is mechanically coupled to the three-phase motor, in particular mechanically coupled to the rotor shaft of the three-phase motor.

[0026] By means of the controller, when the change of loading occurs the level and/or the frequency of the operating voltage at the three-phase motor and supplied by the converter is changed in particular as a function of one or more of the operating parameters. The three-phase motor is optionally an asynchronous motor.

[0027] In some embodiments, the speed is controlled by means of the controller as a function of a desired speed value which is optionally changed when the change of loading occurs. When the change of loading occurs, the change in the desired speed optionally takes place as a function of the loading, in particular as a function of one or more of the operating parameters. The desired speed value is optionally determined on the basis of a speed reference value. The speed reference value is optionally predetermined.

[0028] In some embodiments, a memory is provided which is coupled to the controller or integrated therein and in which are stored a plurality of predetermined preset speed values from which one is selected as speed reference value. The preset speed values are optionally constant. Furthermore the preset speed values are optionally different. In particular an actuating means, such as for example a master switch, by means of which this selection takes place or can take place is coupled to the controller.

[0029] When the change of loading occurs, the desired speed value is advantageously changed by means of the controller as a function of a slip reference value. The slip reference value is optionally predetermined. In particular a plurality of predetermined preset slip values are stored in the memory, wherein one or at least one of the preset slip values is assigned to each of the preset speed values, and wherein the or one of the preset slip values assigned to the selected preset speed value is selected by means of the controller. The preset slip values are optionally constant. Furthermore the preset slip values are optionally different.

[0030] In some embodiments, the slewable part of the crane comprises a jib on which a load is or can be suspended, optionally by means of at least one wire rope. The load can in particular be raised and/or lowered by means of the crane. The change of load is brought about for example by swinging of the load. The slewable part of the crane may comprise a tower. The slewing crane is optionally a slewing tower crane. In particular the slewing crane may be constructed as a top-slewing crane or as a bottom-slewing crane. The slewable part of the crane is optionally connected mechanically to a stationary part of the crane by means of the slewing gear. In particular the slewable part of the crane can turn about the slewing axis relative to the stationary part of the crane by means of the three-phase motor. The stationary part of the crane comprises for example a tower foundation or an undercarriage. Furthermore if the crane is a top-slewing crane the stationary part of the crane optionally comprises the tower which is for example non-rotatably connected to the tower foundation.

[0031] In an aspect, there is provided a slewing crane with a slewing gear and a drive according to the present disclosure, the slewable part of the crane being mechanically connected to a stationary part of the crane by means of the slewing gear. In particular the slewing gear can be driven by means of the drive or is driven by means of the drive. The slewing crane according to the present disclosure can be configured according to all embodiments explained in connection with the method according to the present disclosure and the drive according to the present disclosure.

[0032] The following items are disclosed:

1. Method of controlling the slewing gear of a slewing crane comprising at least one three-phase motor which is mechanically coupled to a slewable part of the crane and by which the slewable part of the crane is turned about a slewing axis, characterised in that when a change of loading of the three-phase motor occurs the speed of the three-phase motor is changed and the torque of the three-phase motor is kept constant or substantially constant.

2. Method according to Item 1, characterised in that one or more operating parameters of the three-phase motor are measured so that the occurrence of the change of loading is detected.

3. Method according to item 2, characterised in that the operating parameter or parameters includes at least the speed (n) and/or the operating current (Ib) consumed by the three-phase motor.

4. Method according to item 2 or item 3, characterised in that when the change of loading occurs the speed of the three-phase motor is changed as a function of one or more of the operating parameters.

5. Method according to any one of the preceding items, characterised in that the change of loading is attenuated by the change in speed.

6. Method according to any one of the preceding items, characterised in that the speed is changed as a function of the loading.

7. Method according to item 6, characterised in that the action of an eddy current brake coupled to the three-phase motor is simulated by the change in speed as a function of the loading.

8. Method according to any one of the preceding items, characterised in that when the change of loading occurs the frequency and/or the level of the operating voltage at the three-phase motor are changed.

9. Method according to any one of the preceding items, characterised in that the speed is controlled as a function of a desired speed value which is determined on the basis of a speed reference value and is changed when the change of loading occurs.

10. Method according to item 9, characterised by several predetermined and constant preset speed values, one of which is selected as speed reference value.

11. Method according to item 9 or item 10, characterised in that when the change of loading occurs the desired speed value is changed as a function of a slip reference value.

12. Method according to item 10 and item 11, characterised by several predetermined and constant preset slip values, wherein one or at least one of the preset slip values is assigned to each of the preset speed values, and wherein the or one of the preset slip values assigned to the selected preset speed value is chosen as slip reference value.

13. Method according to any one of the preceding items, characterised in that a load (9) is suspended on the slewable part of the crane by means of at least one wire rope and the change of loading is brought about by swinging of the load.

14. Drive for the slewing gear of a slewing crane, with at least one three-phase motor mechanically coupled to a part of the crane which is slewable about a slewing axis, a controllable converter which is electrically connected to the three-phase motor and supplies it with electrical power, and a controller electrically connected to the converter and by means of which the converter is controlled, so that the slewable part of the crane slews about the slewing axis by

means of the three-phase motor, characterised in that when a change of loading of the three-phase motor occurs, by means of the controller the speed of the three-phase motor is changed and the torque of the three-phase motor is kept constant or substantially constant.

15. Drive according to item 14, characterised by one or several measurement means which are coupled to the controller and each measure one or more operating parameters of the three-phase motor, so that the occurrence of the change of loading is detected by the controller.

16. Drive according to item 15, characterised in that the one or the several measurement means preferably comprise a speed measurement means which measures the speed and/or a current measurement means which measures the operating current consumed by the three-phase motor.

17. Drive according to any one of items 14 to 16, characterised in that when the change of loading occurs, the frequency and/or the level of the operating voltage at the three-phase motor and supplied by the converter are changed

18. Drive according to any one of items 14 to 17, characterised in that the slewable part of the crane comprises a jib on which a load is or can be suspended so that it can be raised and lowered by means of at least one wire rope.

19. Drive according to any one of items 14 to 18, characterised in that the change of load is attenuated by the change in speed.

20. Drive according to any one of items 14 to 19, characterised in that the speed is changed as a function of the loading by means of the controller.

21. Drive according to item 20, characterised in that the converter is controlled by means of the controller in such a way that the action of an eddy current brake coupled to the three-phase motor is simulated by the change of speed as a function of the loading.

[0033] Specific embodiments are described below with reference to the drawings, in which:

Figure 1 shows a schematic representation of a slewing tower crane constructed as a top-slewing crane,

Figure 2 shows a schematic top view of the slewing gear of the crane,

Figure 3 shows a schematic side view of the slewing gear,

Figure 4 shows a schematic representation of a drive according to one embodiment of the present disclosure by means of which the slewing gear is driven,

Figure 5 shows a schematic representation of a torque/speed characteristic curve of a three-phase motor of the drive, and

Figure 6 shows one or more tables for controlling the speed of the three-phase motor.

[0034] A schematic representation of a slewing crane 1 can be seen from Figure 1 and comprises a crane tower 2 and a jib 3 which is connected to the tower 2 so as to be slewable about a slewing axis 5 by means of a slewing gear 4. The slewing gear 4 is disposed on the upper end of the tower 2, the lower end of which is rigidly connected to a tower foundation 6 set up on the ground 7. The slewing axis 5 coincides with the longitudinal central axis of the tower 2. The jib 3 forms slewing part of the crane 1, whereas the tower 2 and the tower foundation 6 form a stationary part of the crane 1. A load 9 is suspended on the jib 3 by way of a wire rope 8 so that it can be raised and lowered in the vertical direction z.

[0035] The slewing gear 4 comprises a three-phase motor 10 constructed as an asynchronous motor (see Figure 3) by means of which the jib 3 is slewable relative to the tower 2 about the slewing axis 5 extending in the direction z. During such a slewing movement swinging of the load may occur, which leads to a change of loading of the three-phase motor 10.

[0036] Different schematic views of the slewing gear 4 can be seen from Figures 2 and 3, wherein a ring gear 11 rigidly connected to the jib 3 meshes with a pinion 12 which is non-rotatably connected to the rotor shaft 13 of the three-phase motor 10. Since the stator 28 of the three-phase motor 10 is rigidly connected to the tower 2, a rotation of the rotor shaft 13 about its slewing axis 14 leads to a slewing movement of the ring gear 11 about the slewing axis 5, so that the jib 3 also turns relative to the tower 2 about the slewing axis 5. The ring gear 11 is connected to the tower 2 by way of a rotary bearing 15.

[0037] With regard to Figures 2 and 3 it is pointed out that a contrary arrangement is also possible according to which the ring gear 11 is rigidly connected to the tower 2 and the stator 28 of the three-phase motor 10 is rigidly connected to the jib 3. In this case the jib 3 is optionally connected to the ring gear 11 by way of rotary bearing.

[0038] Figure 4 shows a schematic circuit diagram of a drive 16 comprising the three-phase motor 10 according to an embodiment by means of which the slewing gear 4 is driven. The three-phase motor 10 is electrically connected to a converter 17 which supplies the three-phase motor 10 with electrical power. The converter 17 is supplied by a three-phase power supply 18 which for example supplies three line voltages each of 400V and with a frequency of 50Hz. The converter 17 comprises a rectifier 19 which rectifies these voltages and delivers them to a DC intermediate circuit. The output of the rectifier 19 is connected via the intermediate circuit 20 to an inverter 21 which converts the intermediate circuit voltage U_z at the intermediate circuit 20 into a plurality of (optionally three) AC voltages which are applied as operating voltage to the three-phase motor 10. Thus the three-phase motor 10 is supplied with electrical power by the inverter 21, wherein the level of the operating voltage and the frequency of the operating voltage can be set by means of a controller 22 electrically connected to the converter 17.

[0039] The controller 22 is electrically connected to a speed measuring means 23 constructed as an incremental encoder by means of which the speed n of the rotor shaft 13 is measured. The controller 22 is also electrically connected to a current measuring means 24 by means of which the operating current Ib delivered to the three-phase motor 10 is measured. Two phase currents of the operating current Ib are measured by means of current measuring means 24, since the third phase current can be determined from the two measured phase currents. However, as an alternative all phase currents can also be measured.

[0040] The speed n of the rotor shaft 13 measured by means of the speed measuring means as well as the operating current Ib measured by means of the current measuring means 24 form operating parameters of the three-phase motor 10. The controller 22 can also be electrically connected to additional measurement means or may comprise these measurement means, by means of which additional operating parameters of the three-phase motor 10 are measured. Furthermore an actuating means 25, for example in the form of a master switch, is electrically connected to the controller 22.

[0041] The controller 22 comprises a memory 26 as well as a computer 27 which is optionally constructed as a digital computer. A table which can be seen in Figure 6 is stored in the memory 26, and in this table a plurality of preset speed values n_{vi} are included in the "speed" column. A preset slip value s_{vvi} for a deceleration in the "deceleration" column is assigned to each of these preset speed values and a preset slip value s_{vbi} for an acceleration is assigned to each of the preset speed values, wherein the index "i" is a natural number and characterises a speed stage "i" which is shown in the "stage" column. Depending upon the embodiment the index "i" has values from 1 to 4.

[0042] By means of the actuating device 25 one of the speed stages i is selected, a speed reference value being formed from the preset speed value n_{vi} assigned to the selected stage i. On the basis of the selected speed reference value a desired speed value is formed, as a function of which the controller 22 controls the speed n of the three-phase motor 10. In this case the desired speed value corresponds to the speed reference value in an undisrupted operating state of the three-phase motor 10.

[0043] If a change of the loading of the three-phase motor 10 occurs due to swinging of the load 9 or due to wind, then this change of loading is recognised by evaluation of the operating parameters by means of the controller 22. Furthermore by evaluation of the operating parameters the controller 22 can recognise whether an increase or a reduction in the speed is necessary for the reduction and/or attenuation of the change of loading. If a reduction of the speed n is necessary for reduction and/or attenuation of the change of loading, then the preset slip value s_{vvi} for a deceleration assigned to the selected preset speed value n_{vi} is selected as slip reference value. If an increase of the speed n is necessary for reduction and/or attenuation of the change of loading, then the preset slip value s_{vbi} for an acceleration assigned to the selected preset speed value n_{vi} is selected as slip reference value. The slip reference value is combined with one or more of the measured operating parameters, in particular the operating current Ib, to give a speed change value, as a function of which the desired speed value is changed. Thus the desired speed value is a function of the speed reference value and of the speed change value. Since the controller 22 controls the speed n of the three-phase motor 10 as a function of the desired speed value, the speed n is changed as a function of the slip reference value and the loading of the three-phase motor 10, this loading being characterised by one or more of the operating parameters. Thus the speed n is changed as a function of the loading. This results in an operating state of the three-phase motor 10 which may be designated as a disrupted operating state relative to the undisrupted operating state. Thus the change of loading can also be designated as a disruption of loading.

[0044] If a pivotable jib is provided, then as a function of the jib position the preset slip value assigned to the selected preset speed value n_{vi} is chosen from an associated table as slip reference value.

[0045] In order to change the speed n the controller 22 controls the converter 17 in such a way that the level and the frequency of the operating voltage at the three-phase motor 10 are changed. In this case this change of the operating voltage level and the operating voltage frequency takes place in such a way that the torque of the three-phase motor 10 remains constant or substantially constant.

[0046] Figure 5 shows two torque/speed characteristic curves according to a model of the three-phase motor 10 which are produced for different frequencies and levels of the operating voltage. The torque "M" of the three-phase motor 10 relative to the rated tilting torque "$M_{Kipp,N}$" is shown on the y axis, and the speed "n" relative to the rated speed "n_N" is shown on the x axis. In this case the curve A represents the characteristic at the rated frequency of the three-phase motor 10 and the curve B represents the characteristic at a frequency below the rated frequency. Thus the characteristic curve can be adjusted by changing the frequency of the operating voltage. With a suitable choice of operating voltage level and operating voltage frequency the torque of the three-phase motor can be kept constant or substantially constant. According to the model, if the frequency of the operating voltage is changed the torque remains constant or substantially constant within a specific range if the quotient of operating voltage level and operating voltage frequency remains constant. In this case the characteristic curve is shifted along the x axis.

[0047] It will be understood that the above description of specific embodiments is by way of example only and it is not intended to limit the scope of the present disclosure. Many modifications of the described embodiments are envisaged and intended to be within the scope of the present disclosure.

List of reference numerals

[0048]

1	slewing crane
2	crane tower
3	jib
4	slewing gear
5	slewing axis
6	tower foundation
7	ground
8	wire rope
9	load
10	three-phase motor
11	ring gear
12	pinion
13	rotor shaft of the three-phase motor
14	slewing axis of the rotor shaft
15	rotary bearing
16	drive
17	converter
18	three-phase power supply
19	rectifier of the converter
20	intermediate circuit of the converter
21	inverter of the converter
22	controller
23	speed measurement means
24	current measurement means
25	actuating means
26	memory
27	computer
28	stator of the three-phase motor
n	speed of the rotor shaft
lb	operating current of the three-phase motor
U_z	intermediate circuit voltage

Claims

1. A method of controlling the slewing gear (4) of a slewing crane (1) comprising at least one three-phase motor (10) which is mechanically coupled to a slewable part of the crane (1) and by which the slewable part of the crane (1) is turned about a slewing axis (5), wherein when a change of loading of the three-phase motor (10) occurs the speed of the three-phase motor (10) is changed and the torque of the three-phase motor (10) is kept constant or substantially constant.

2. A method as claimed in Claim 1, wherein one or more operating parameters of the three-phase motor (10) are measured so that the occurrence of the change of loading is detected.

3. A method as claimed in Claim 2, wherein the one or more operating parameters includes at least the speed (n) and/or the operating current (lb) consumed by the three-phase motor (10).

4. A method as claimed in Claim 2 or Claim 3, wherein when the change of loading occurs the speed of the three-phase motor (10) is changed as a function of one or more of the operating parameters.

5. A method as claimed in any one of the preceding claims, wherein the change of loading is attenuated by the change in speed.

6. A method as claimed in any one of the preceding claims, wherein the speed is changed as a function of the loading.

7. A method as claimed in Claim 6, wherein the action of an eddy current brake coupled to the three-phase motor is simulated by the change in speed as a function of the loading.

8. A method as claimed in any one of the preceding claims, wherein when the change of loading occurs the frequency and/or the level of the operating voltage at the three-phase motor (10) are changed.

9. A method as claimed in any one of the preceding claims, wherein the speed is controlled as a function of a desired speed value which is determined on the basis of a speed reference value and is changed when the change of loading occurs.

10. A method as claimed in any one of the preceding claims, wherein a load (9) is suspended on the slewable part of the crane (1) by means of at least one wire rope and the change of loading is brought about by swinging of the load (9).

11. A drive for the slewing gear (4) of a slewing crane (1), comprising:

    a three-phase motor (10) mechanically coupled to a part of the crane (1) which is slewable about a slewing axis (5);
    a controllable converter (17) which is electrically connected to the three-phase motor (10) to sup-

ply it with electrical power; and
a controller (22) electrically connected to the converter (17) and by means of which the converter (17) is controllable so that the slewable part of the crane (1) slews about the slewing axis (5) by means of the three-phase motor (10), wherein the controller is configured such that when a change of loading of the three-phase motor (10) occurs, by means of the controller (22) the speed of the three-phase motor is changed and the torque of the three-phase motor (10) is kept constant or substantially constant.

12. A drive as claimed in Claim 11, the drive comprising one or more measurement means which are coupled to the controller (22) and each is configured to measure one or more operating parameters of the three-phase motor (10) so that the occurrence of the change of loading is detected by the controller (22).

13. A drive as claimed in Claim 12, wherein the one or more measurement means optionally comprise a speed measurement means (23) for measuring the speed, and/or a current measurement means (24) for measuring the operating current consumed by the three-phase motor (10).

14. A drive as claimed in any one of Claims 11 to 13, wherein the drive is configured such that when the change of loading occurs, the frequency and/or the level of the operating voltage at the three-phase motor (10) and supplied by the converter (17) are changed.

15. A drive as claimed in any one of Claims 11 to 14, wherein the slewable part of the crane comprises a jib on which a load is suspended or suspendable so that the load can be raised and lowered by means of at least one wire rope.

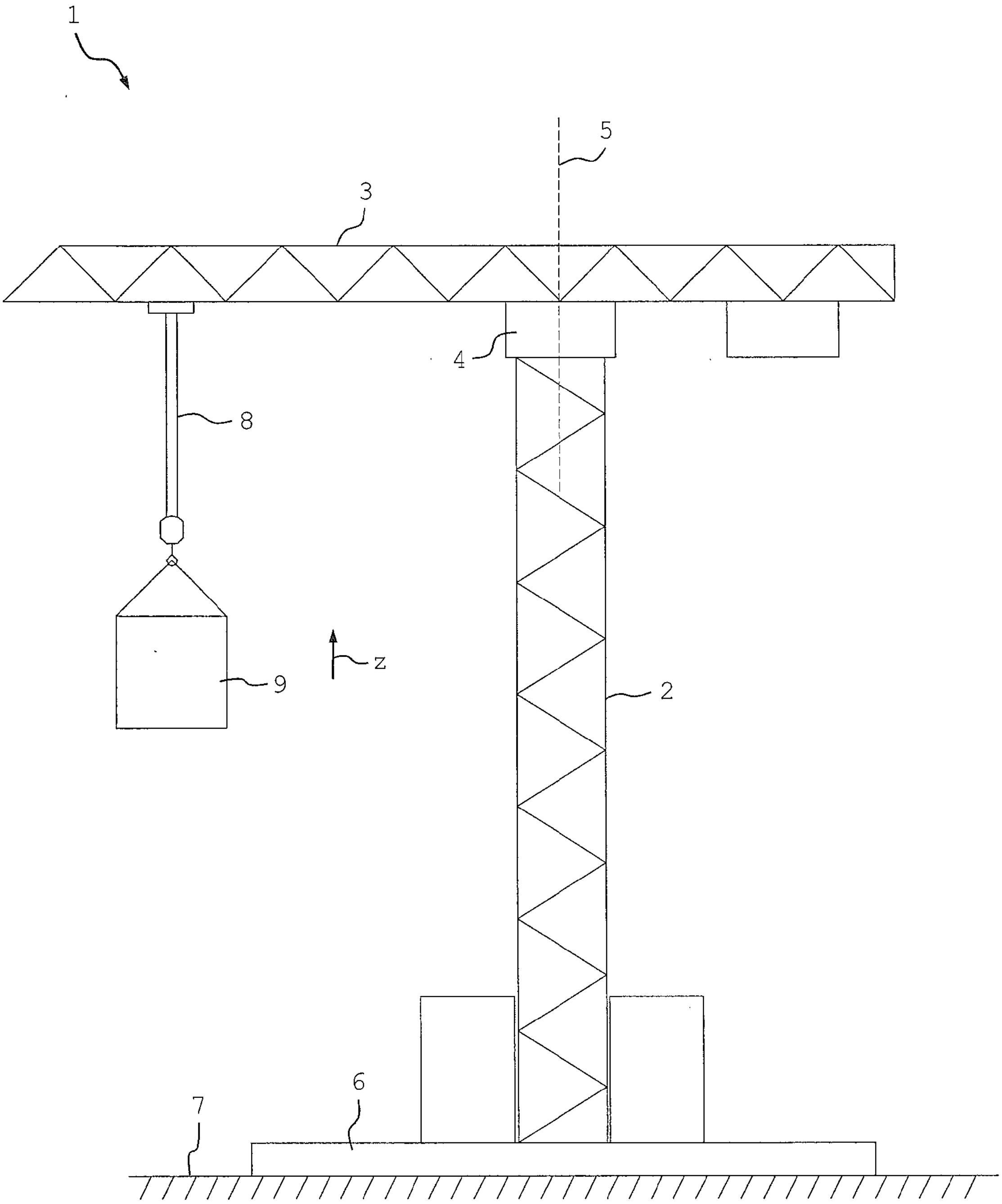

Fig. 1

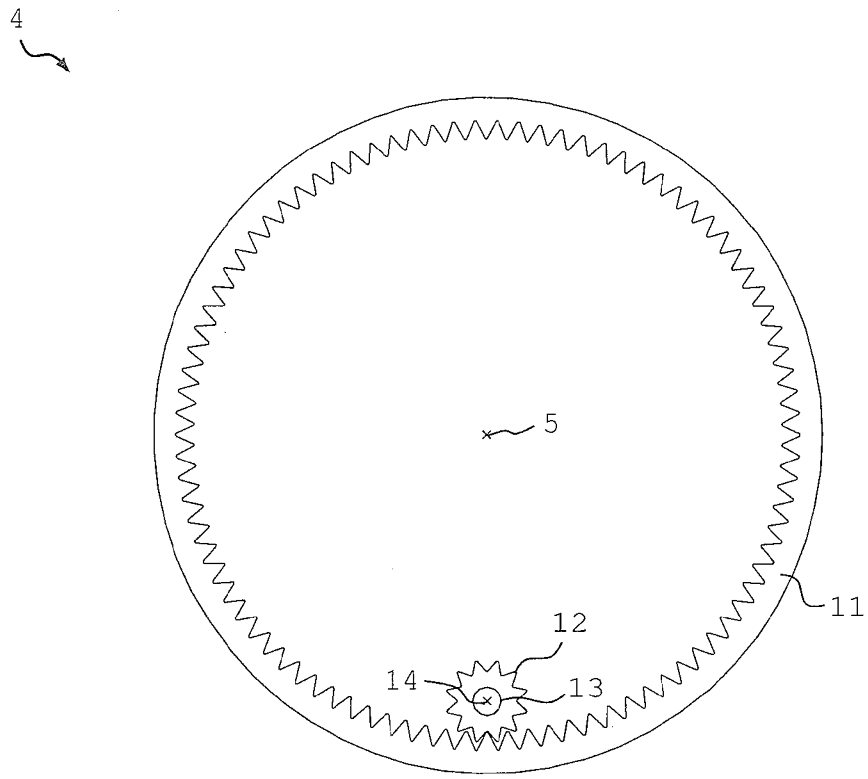

Fig. 2

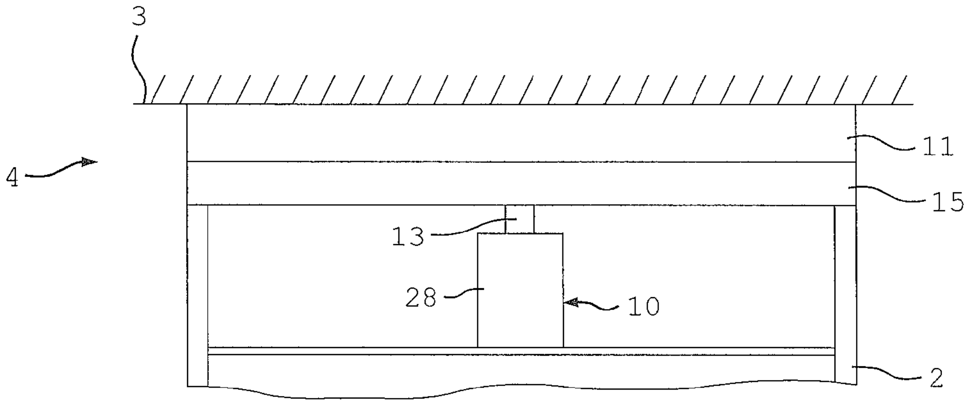

Fig. 3

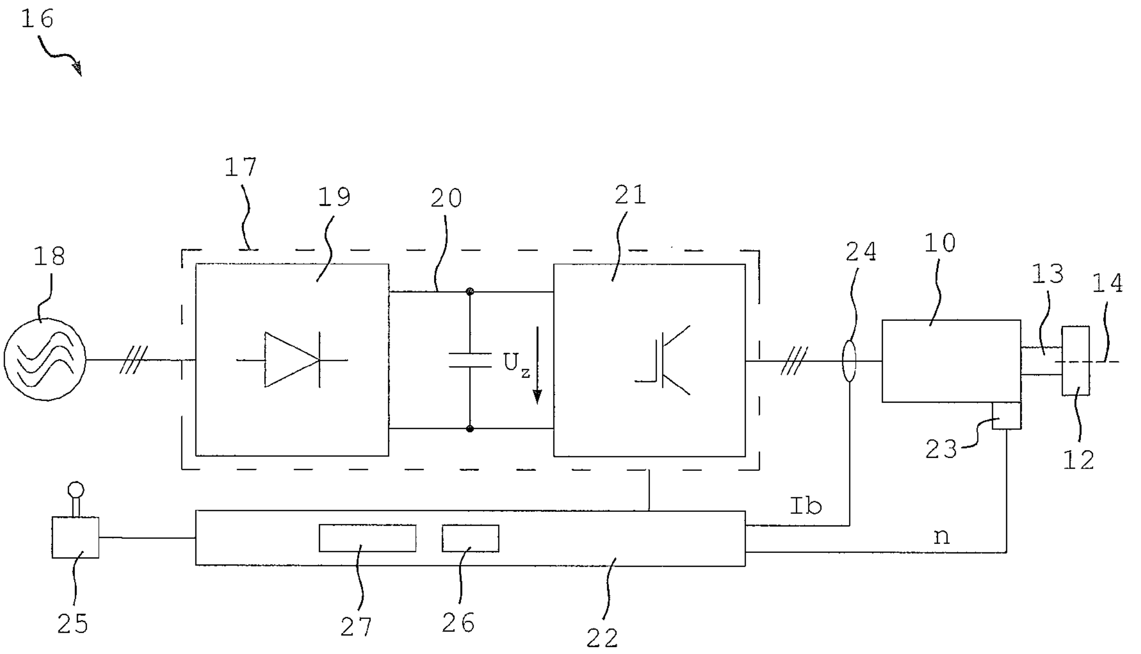

Fig. 4

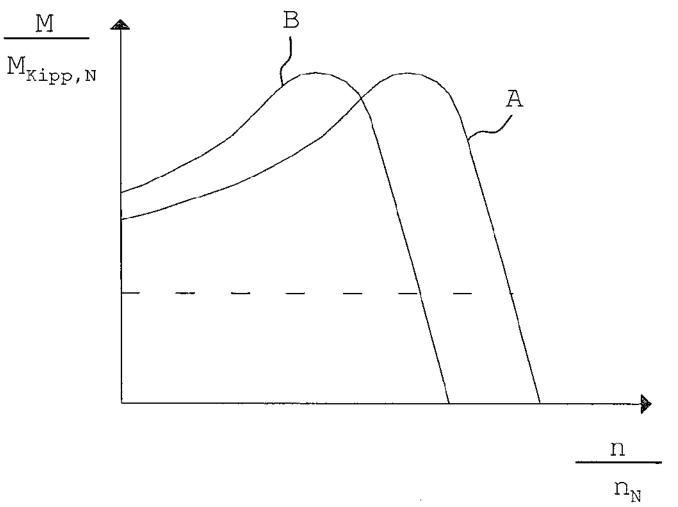

Fig. 5

Stage	Speed	Deceleration	Acceleration
1	n_{V1}	s_{VV1}	s_{Vb1}
2	n_{V2}	s_{VV2}	s_{Vb2}
3	n_{V3}	s_{VV3}	s_{Vb3}
4	n_{V4}	s_{VV4}	s_{Vb4}

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 13 17 8832

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B66C
H02P

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	18 October 2013	Faymann, L

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