(19) DANMARK

(10) **DK/EP 3427367 T3**

Patent- og
Varemærkestyrelsen

(12) Oversættelse af
europæisk patentskrift

(51) Int.Cl.: ***H 02 K 11/00 (2016.01)*** ***H 02 K 1/16 (2006.01)*** ***H 02 K 17/30 (2006.01)*** ***H 02 K 41/025 (2006.01)*** ***H 02 K 41/03 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2022-01-03**

(80) Dato for Den Europæiske Patentmyndigheds
bekendtgørelse om meddelelse af patentet: **2021-09-29**

(86) Europæisk ansøgning nr.: **17763733.7**

(86) Europæisk indleveringsdag: **2017-02-22**

(87) Den europæiske ansøgnings publiceringsdag: **2019-01-16**

(86) International ansøgning nr.: **US2017018835**

(87) Internationalt publikationsnr.: **WO2017155690**

(30) Prioritet: **2016-03-10 US 201615066064**

(84) Designerede stater: **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**

(73) Patenthaver: **Laitram, L.L.C., 200 Laitram Lane, Harahan, LA 70123, USA**

(72) Opfinder: **RAGAN, Bryant G., 4812 Church Street, Metairie, Louisiana 70001, USA**

(74) Fuldmægtig i Danmark: **CHAS. HUDE A/S, Langebrogade 1, 2. B2, 1411 København K, Danmark**

(54) Benævnelse: **Linearmotor-stator med integreret ledningsreaktor**

(56) Fremdragne publikationer:
WO-A1-2013/059934
DE-A1- 4 423 783
JP-A- 2005 245 108
JP-A- 2012 157 183
KR-A- 20040 003 930
US-A- 4 781 286
US-A1- 2004 004 410
US-A1- 2005 062 356
US-A1- 2015 129 393
US-B1- 7 820 923

DESCRIPTION

BACKGROUND

[0001] The invention relates generally to polyphase linear motors and more particularly to line reactors unitarily housed with linear-motor stators.

[0002] Linear induction motors and other linear motors are often configured as polyphase motors, usually with three phases. Because of magnetic end effects and winding layouts, the inductances of the stator windings typically differ from phase to phase. The stator phases should be excited by currents nearly equal in magnitude so that an optimal traveling magnetic flux wave is generated. The current imbalance in stators resulting from unequal phase inductances is solved in two main ways. One solution is to drive the stator coils with a current-regulated amplifier, but current-regulated drives are expensive. Another way stator inductances are balanced is with inductive reactors. Inductor coils in the reactors are connected in series with the stator windings to balance the net inductances of the phases so that the stator can be driven by a more common variable-frequency drive (VFD). Because the reactors are separate units external to the stators, they must be packaged with and electrically connected to the stator. The packaging and the cabling can be difficult in harsh environments, such as those requiring NEMA 4X or IP67 washdown ratings.

[0003] US 2005/062356 A1 discloses an electric AC machine with a primary section and a secondary section.

[0004] DE 44 23 783 A1 discloses a travelling-field inductor connected to a supply grid via a frequency converter comprising (a) capacitors connected to the inductor coils in such a way that they form respectively the capacitance and inductance of a parallel resonance circuit; (b) further inductors connected in series to this parallel resonance circuit form jointly with the capacitors a series resonance circuit.

SUMMARY

[0005] One version of a linear-motor stator assembly embodying features of the invention comprises a stator and a reactor according to claim 1. The stator includes a stator core portion having a first end and an opposite second end defining the length of the stator core portion and an outer face having a plurality of pole faces separated by a plurality of stator coil slots opening onto the outer face between the first and second ends. A plurality of sets of stator coils reside in the stator coil slots and are connected to form polyphase stator windings propagating a magnetic flux wave along the length of the stator portion through the pole faces. The reactor includes a reactor core portion abutting the stator core portion and having an outer face with a plurality of inductor coil slots opening onto the outer face. A plurality of inductor coils reside in the inductor coil slots. Each of the inductor coils is connected electrically in series with one or another of the sets of stator coils.

[0006] In another aspect, a linear-motor system according to claim 11 comprises a housing, a stator having three stator windings housed in the housing, a reactor having inductors housed in the housing adjacent to the stator, and a three-phase variable-frequency drive. The inductors are electrically connected between the three-phase variable-frequency drive and one or more of the three stator windings to balance the currents in the three stator windings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 is an isometric view of a linear-motor stator assembly embodying features of the invention;

FIG. 2 is a side elevation view of the stator assembly of FIG. 1;

FIG. 3 is an electrical schematic diagram of the stator assembly of FIG. 1;

FIG. 4 is a side elevation view of another version of a linear-motor stator assembly as in FIG. 1, but with isolated stator and reactor cores;

FIG. 5 is an isometric view of a third version of a linear-motor stator assembly with an integral reactor side-by-side with a stator;

FIG. 6 is a side elevation view of the linear-motor stator assembly of FIG. 5; and

FIG. 7 is an isometric view of a roller transfer plate using a linear-motor stator assembly as in FIG. 1, FIG. 4, or FIG. 5 to rotate the rollers.

DETAILED DESCRIPTION

[0008] A stator assembly embodying features of the invention is shown in FIGS. 1 and 2 for a linear motor, such as a linear induction motor or a linear synchronous motor. The stator assembly 10 comprises a core 12 that extends in length from a first end 14 to a second end 15. The core extends in thickness from an upper obverse outer face 16 to a lower reverse outer face 17. Slots 18 open onto the upper outer face 16 between the first and second ends 14, 15 and divide the upper outer face into pole faces 20 between consecutive slots. Stator coils 22 reside in the stator slots 18. In this example the stator coils 22 are arranged in three layers: a bottom layer 24A, a middle layer 24B, and a top layer 24C. Some of the slots have coils in each layer; others have coils in only two of the layers. The stator coils 22 are arranged in three sets. The coils in each set are connected electrically in series to form one winding of a three-phase stator. For example, all the stator coils 22 in the bottom layer 24A could be wired in series to form the U-phase winding. The coils 22 in the middle layer 24B could be wired in series to form the V-phase winding. And the coils 22 in the top layer 24C could be wired in series to form the W-phase winding. When the three stator windings are connected to three-phase power, the stator propagates a magnetic flux wave through the pole faces 20 in its upper outer face 18 in a propagation direction 26 along the length of the stator.

[0009] Pairs of slots 28, 28' open onto the bottom outer face 17 of the core 12 to receive inductor coils 30A-C-three, in this example. There are more stator coil slots 18 than inductor coil slots 28, 28'. A core piece 32 between each pair of inductor coil slots 28, 28' extends through the center of each inductor coil and forms a high permeability core for the coil. A steel plate 34 separated from the inductors' core pieces 32 and the bottom outer face 17 of the core 12 by a gap 36 serves as a magnetic shunt completing the inductors' magnetic circuits. The plate 34 can also serve as a mounting plate for the stator assembly 10. When electrically connected to the stator coils 22, the inductor coils 30A-C can compensate for differences in the reactances of the stator coils. Thus, the induction coils are equivalent to line reactors.

[0010] In FIGS. 1 and 2 the inductor coils 30A-C and the stator coils 22 share the same core 12. But the core 12 is thicker between the top and bottom faces 16, 17 than if the stator did not include the integral inductor coils 30A-C. The thicker core 12 helps decouple the stator flux from the inductor flux. So the core 12 is separated into a stator core portion 38 and a reactor core portion 39 by an imaginary plane 40 between the top and bottom faces 16, 17. The core 12 is constructed of transformer-steel laminations to reduce eddy currents, but could be a solid piece of metal. Appropriate sizing of the pole faces 20 and the depths of the slots 18, 28, 28' can result in the use of the same coil forms for both the stator coils 22 and the inductor coils 30A-C of the reactor.

[0011] The electrical wiring of the stator portion of a linear-motor system with the reactor inductors connected between the stator windings and a VFD is shown schematically in FIG. 3. The three-phase output lines U, V, W of the VFD 42 are connected to the three stator windings, whose inductances are L_u, L_V, and L_W. In general the three inductances will not be equal. To compensate for imbalanced currents in the stator windings due to the effect of unequal winding inductances L_U, L_V, L_W on the VFD 42, a line reactor 44 composed of the inductor coils 30A-C is used. In this example, $L_U < L_V < L_W$. Without compensation the currents I_U, I_V, I_W in the stator windings are unbalanced because of the effect of the different inductances L_U, L_V, L_W in each phase on the voltage-source VFD. Because L_U is the lowest inductance, two inductor coils 30A and 30C are connected electrically in series between the VFD 42 and the U-phase winding. So the inductance seen by the VFD in phase U is $L_U + L_1 + L_3$. The remaining inductor coil 30B is connected in series with the stator's V-phase winding to increase the inductance seen by the VFD 42 to $L_V + L_2$. No inductance is added to the highest-inductance W-phase winding. In that way the total inductances in the phases are more nearly equal and the resulting phase currents I_U, I_V, I_W better balanced for a more effective magnetic flux wave.

[0012] FIG. 4 shows another version of the core. In this version the core 46 comprises, rather than a monolithic core as in FIGS. 1 and 2, two separate core pieces: a stator core portion 48 and a reactor core portion 49. The two portions 48, 49 are shown to have the same length and are encapsulated together to form an integral structure. The two separate pieces 48, 49 are separated back to back by a small gap 50 that helps magnetically isolate the flux return paths 52 of the stator coils 22 from the flux return paths 53 of the inductor coils 30.

[0013] Instead of the back-to-back configuration of the stator assemblies of FIGS. 1 and 4, the stator-assembly 54 in FIGS. 5 and 6 is configured with a stator core portion 56 abutting a reactor core portion 58 at an end 60 of the stator core portion. A single solid core or laminated core profile could be used to form a stator 62 integral with a reactor 64. The reactor 64 in FIG. 6 has three inductor coils 66A-C and three pole faces 68 facing upward in the same direction as stator pole faces 70. A magnetic-shunt plate 74 facing the reactor pole faces 68 completes the inductors' magnetic circuits.

[0014] FIG. 7 shows an exemplary application for a linear-motor stator assembly as in any of FIGS. 1-6. A stator assembly with integral reactors resides in a housing 78 beneath an array of electrically conductive or magnetic rollers 80 arranged in parallel across a small gap from the stator pole faces. For electrically conductive rollers, the stator's magnetic flux wave induces currents in the rollers 80 that create magnetic fields that interact with the stator's magnetic flux wave and cause the rollers to rotate. Thus, the electrically conductive rollers 80 serve as rotors that form linear induction motors with the stator. For magnetic rollers, the stator's magnetic flux wave interacts with the magnetic fields of the permanent magnets and causes the rollers to rotate. Thus, the magnetic rollers 80 serve as rotors that form linear synchronous motors with the stator. Boxes 82 transfer across the rotating rollers 80 from an infeed conveyor belt 84 to a discharge conveyor belt 86.

[0015] The invention has been described in detail by reference to a few example versions. But other versions are possible. For example, the system could be a polyphase system of more than three phases. The use of the terms "integral" or "unitary" with respect to the stator and the reactor means that they are joined and enclosed together in a single housing. The unitary stator and reactor can share a common monolithic (solid or laminated) core or can have separate cores. One is not external to the other's housing.

REFERENCES CITED IN THE DESCRIPTION

Cited references

form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US2005062356A1 **[0003]**
- DE4423783A1 **[0004]**

PATENTKRAV

1. Linearmotor-statoranordning (10), omfattende: en stator (62), som inkluderer

et statorkerneafsnit (48; 56) med:

en første ende og en modstående anden ende, der definerer længden af statorkerneafsnittet (38, 48, 56);

en yderside med en flerhed af polflader (20, 70), som er adskilt af

en flerhed af statorspoleslidser (18), der åbner ind i ydersiden mellem den første og den anden ende;

en flerhed af sæt af statorspoler (22), som ligger i statorspoleslidserne (18) og er forbundet, så der dannes mange-fase-statorviklinger, der udbreder en magnetisk fluxbølge langs længden af statorafsnittet via polfladerne;

hvorved hvert sæt statorspoler (22) har en induktans (L_u, L_v, L_w) og definerer en fase for mange-fase-statoren;

en drosselspole (64), inkluderende:

et drosselspolekerneafsnit (39, 49, 58), som grænser op til statorkerneafsnittet (34, 48, 56), og med:

en yderside, med en flerhed af induktorspoleslidser (28, 28'), som åbner mod ydersiden; **kendetegnet ved, at** drosselspolen ydermere omfatter:

en flerhed af induktorspoler (30; 30A, 30B, 30C, 66A, 66B, 66C), som ligger i induktorspoleslidserne, hvorved hver af induktorspolerne har en induktans (L_1, L_2, L_3) og elektrisk er forbundet i serie med et eller andet af sættene af statorspoler, således at den samlede induktans i hver fase er summen af statorspolens induktans og induktansen af hvilken som helst induktorspole, der elektrisk er forbundet i serie med statorspolen; hvorved de samlede induktanser af faserne er næste mere lig med induktanserne (L_u, L_v, L_w) af sættene af statorspoler.

2. Linearmotor-statoranordning ifølge krav 1, hvorved statoren (62) inkluderer tre sæt statorspoler (22), som er forbundet med henblik på dannelse af trefase-statorviklinger, og hvorved drosselspolen (64) inkluderer tre induktorspoler (30; 30A, 30B, 30C, 66A, 66C), og
hvorved en af induktionsspolerne elektrisk er forbundet i serie med et af de tre sæt statorspoler, og de andre to induktorspoler elektrisk er forbundet i serie med hinanden og med et andet af sættene af statorspoler.

3. Linearmotor-statoranordning ifølge krav 2, hvorved de tre induktorspoler (30A, 30B, 30C) elektrisk er forbundet med de tre sæt af statorspoler for at kompensere for uens reaktanser i de tre sæt af reaktorspoler.

4. Linearmotor-statoranordning ifølge krav 1 eller krav 2, ydermere omfattende en stålplade (34), der vender mod ydersiden af reaktorkerneafsnittet for at tilvejebringe en magnetisk shunt for reaktoren samt tjene som en monteringsplade for linearmotor-statoranordningen.

5. krav 1 eller krav 2, hvorved statorkerneafsnittet (38) og drosselspolekerneafsnittet (39) er komplementære afsnit af en monolitisk kerne, hvis forside er ydersiden af statorkerneafsnittet, og hvis bagside er ydersiden af drosselspolekerneafsnittet.

6. Linearmotor-statoranordning ifølge krav 1, hvorved statorkerneafsnittet (48) og drosselspolekerneafsnittet (49) er separate kerner, magnetisk isolerede fra hinanden og sammen kapslet i en enhedsstruktur.

7. Linearmotor-statoranordning ifølge krav 1 eller krav 2, hvorved drosselspolekerneafsnittet (58) grænser op til den første ende af statorkerneafsnittet (56), og

ydersiden af statorkerneafsnittet og ydersiden af drosselspolekerneafsnittet vender i samme retning.

8. Linearmotor-statoranordning ifølge krav 1, hvorved der findes flere statorspoleslidser (18) end induktorspoleslidser (28, 28').

9. Linearmotor-statoranordning ifølge krav 1, ydermere omfattende et array af elektrisk ledende ruller (80), arrangeret parallelt langs længden af statorkerneafsnittet, hen over en lille spalte med henblik på at tjene som rotorer, der roteres af den magnetiske fluxbølge og danner lineære induktionsmotorer sammen med statoren.

10. Linearmotor-statoranordning ifølge krav 1, ydermere omfattende et array af ruller (80), der er arrangeret parallelt langs længden af statorkerneafsnittet hen over en lille spalte og inkluderer permanentmagneter, hvorved rullerne tjener som rotorer af den magnetiske fluxbølge og danner lineære synkronmotorer sammen med statoren.

11. Linearmotorsystem, omfattende:

et hus (78)
en stator ifølge krav 1 med tre statorviklinger, som er placeret i huset (78), hvorved hver statorvikling har en induktans;
en reaktor ifølge krav 1, med induktorer, som er placeret i huset (78), grænsende op til statoren, hvorved hver induktor har en induktans;
et trefaset variabel-frekvens-drev;
hvorved induktorerne elektrisk er forbundet mellem det trefasede variabel-frekvens-drev og en eller flere af de tre statorviklinger med henblik på at balancere strømmene i de tre statorviklinger ved at gøre de samlede induktanser i statorviklingen og hvilke som helst induktorer i hver fase i højere grad lig med induktanserne i de tre statorviklinger.

12. Linearmotorsystem ifølge krav 11, ydermere omfattende et array af elektrisk ledende ruller (80), arrangeret i parallel hen over en lille spalte fra statoren for at tjene som rotorer, der roteres af en magnetisk fluxbølge og danner lineære induktionsmotorer sammen med statoren;
et array af ruller, arrangeret i parallel hen over en lille spalte fra statoren og inkluderende permanentmagneter, hvorved rullerne tjener som rotorer, der roteres af en magnetisk fluxbølge, som frembringes af statoren og danner lineære synkronmotorer sammen med statoren.

DRAWINGS

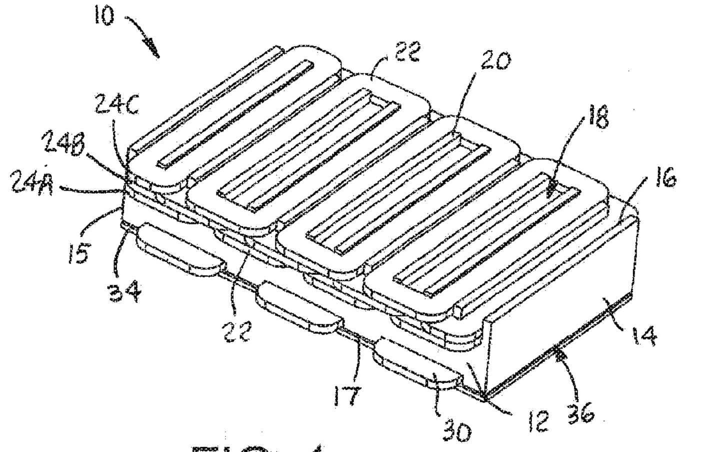

FIG. 1

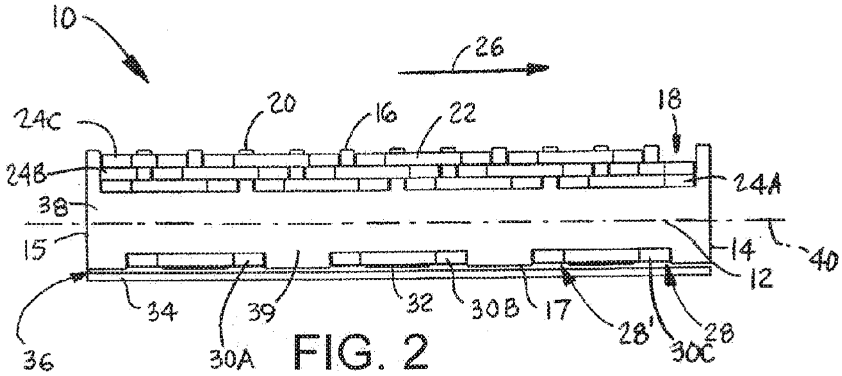

FIG. 2

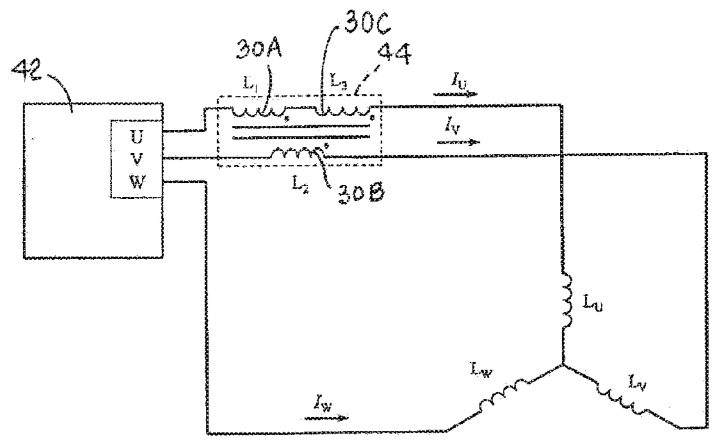

FIG. 3

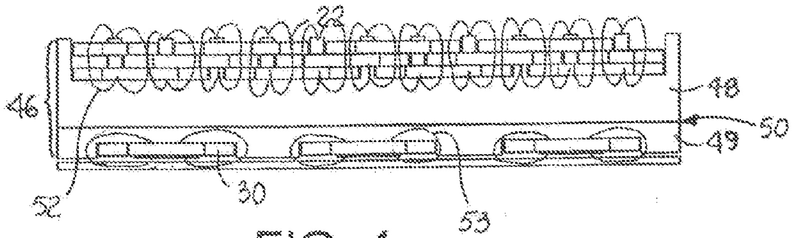

FIG. 4

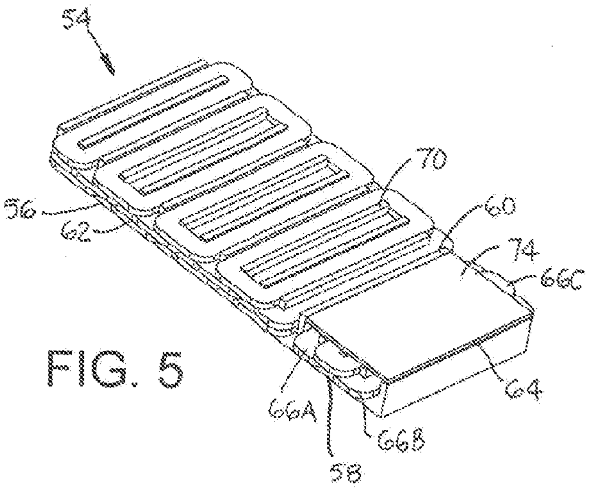

FIG. 5

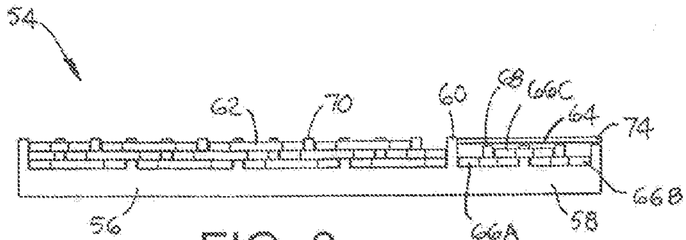

FIG. 6

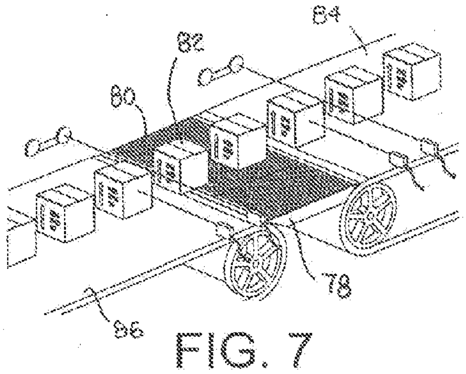

FIG. 7