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(54) Title: INTELLIGENT CONTROLS FOR INDEPENDENTLY OPERABLE INVERTERS

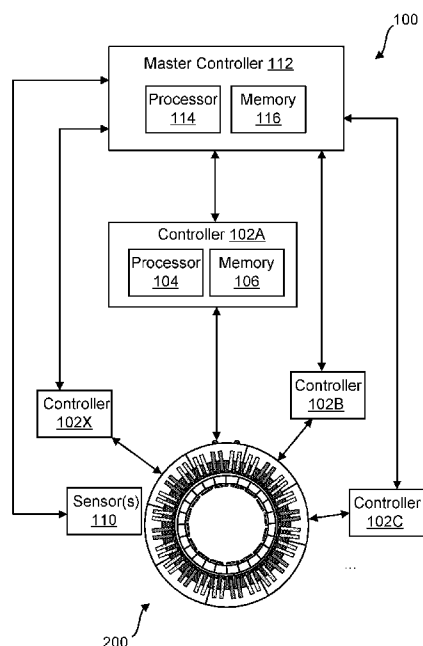


FIG. 1

(57) Abstract: Methods of operating an electric machine having a plurality of independently operable inverters, and systems implementing the same, include: receiving a torque demand for the electric machine; receiving a torque demand for the electric machine; determining available inverters based on the plurality of independently operable inverters; selecting a subset number of inverters from the available inverters to operate based on an efficiency map of the electric machine and the torque command for the electric machine; and switching operation of at least one of the subset number of inverters with at least one of the available inverters that is not in the selected subset number of inverters based on one or more conditions.

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

- *with international search report (Art. 21(3))*

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26 December 2024 (26.12.2024)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/023674

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. H02H 3/20; B60L 3/00 (2024.01)

ADD.

CPC - INV. H02H 3/202; B60L 3/003; B60L 3/0092

ADD. B60L 2240/525

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)

See Search History document

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

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,414,339 A (MASAKI, R. ET AL.) 09 May 1995; see entire document, especially col 3	1-15
A	US 2009/0118882 A1 (HEAP, A. ET AL.) 07 May 2009; see entire document	1-15
A	US 2013/0343105 A1 (KOSUGI, H.) 26 December 2013; see entire document	1-15
☐ 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

"D" document cited by the applicant in the international application

"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

31 July 2024 (31.07.2024)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/023674

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-Please See Supplemental Page-

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

-***-Continued From Box No. III: Observations where unity of invention is lacking-***-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claims 1-10, and 14-15 are directed toward method of operating an electric machine using a controller comprising an efficiency map.

Group II: Claims 11-15 are directed toward method of operating an electric machine using a controller comprising winding separation.

The special technical features of Group I include at least selecting, from the available inverters, a subset number of inverters to operate based on an efficiency map of the electric machine and the torque demand for the electric machine; and based on one or more conditions, switching operation of at least one of the subset number of inverters with at least one of the available inverters that is not in the subset number of inverters.

The special technical features of Group II include at least selecting one or more inverter pairs of the available inverters to operate, wherein each inverter pair includes two of the available inverters coupled to machine winding sets positioned in 180 degrees of separation from each other in the electric machine; and switching operation of at least one of the selected inverter pairs with at least one other inverter pair of the available inverters, wherein the at least one other inverter pair is not among the selected inverter pairs of the available inverters.

The common technical features shared by Groups I & II are a method of operating an electric machine using a controller, the method comprising: receiving a torque demand for the electric machine, the electric machine comprising a plurality of independently operable inverters; determining available inverters based on the plurality of independently operable inverters. However, these common features are previously disclosed by US 2009/0118882 A1 to Heap, A. et al. (hereinafter "HEAP"). HEAP discloses a method of operating an electric machine using a controller (electric machine with controller; [0017]), the method comprising: receiving a torque demand for the electric machine (torque command and request for electric machine; [0020]), the electric machine comprising a plurality of independently operable inverters (inverters with independent motor torques; [0017]); determining available inverters based on the plurality of independently operable inverters (inverters with operation states; [0016-0017]).

Since the common technical features are previously disclosed by the HEAP reference, these common features are not special and so Groups I-II lack unity.