



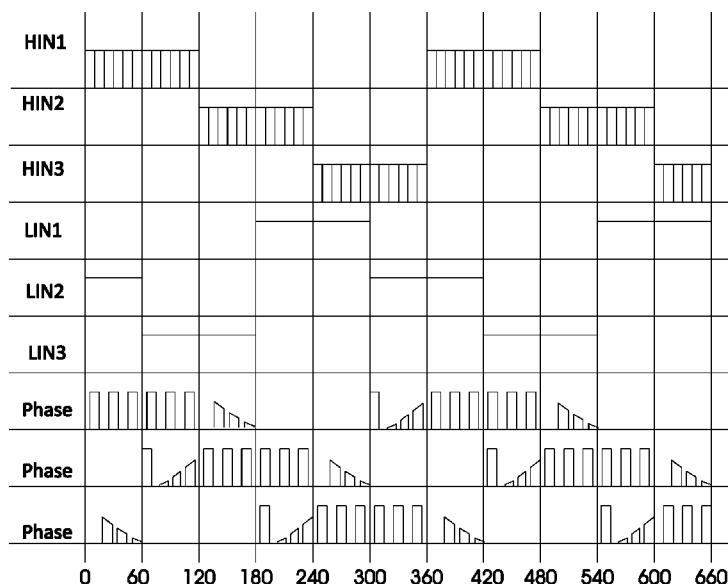
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(54) Title: HOUSEHOLD APPLIANCE WITH A POWER MODULE HAVING DECREASED FREEWHEELING TIME DURATION

Fig. 1



(57) Abstract: The present invention relates to an electrical household appliance with a power module having decreased freewheeling time duration. The present invention relates to an electrical household appliance comprising more particularly at least one electric motor, a driver circuit capable of driving said at least one electric motor, said driver circuit comprising a converter that converts AC mains voltage to DC voltage, a driver circuit inverter stage that inverts the direct current, said driver circuit inverter stage comprising an inverter power module (1).



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Description**HOUSEHOLD APPLIANCE WITH A POWER MODULE HAVING DECREASED
FREEWHEELING TIME DURATION**

- [0001] The present invention relates to an electrical household appliance with a power module having decreased freewheeling time duration.
- [0002] It is well-known that a synchronous machine is an electrical machine with a rotating stator magnetic flux and a rotor flux locked therewith to rotate in the synchronous frequency. A brushless DC (BLDC) motor is a kind of synchronous motor that has trapezoidal back-EMF voltage shape.
- [0003] It is also well-known that synchronous motors are widely used in rotary household appliances and especially in dishwashers and laundry treatment appliances. For instance, washing machines may have a jet pump for spraying water jets into the rotary drum targeting at specific regions inside it, at which the laundry may tend to adhere within the same, as well as a discharge pump for discharging the water contained in the drum. Likewise, a washing and/or drying machine may have a discharge pump as well as a circulation pump for circulating a refrigerant fluid.
- [0004] A three-phase inverter driver circuit can typically be used to drive the BLDC motor. An inverter has six semiconductor switches with the inverter drivers collected in a single package in the form of an integrated power module (IPM). The semiconductors in the power module or inverter can be of different types such as; MOSFET, IGBT, etc.
- [0005] One of the well-known six step trapezoidal BLDC control method involves positioning of the rotor by a microcontroller. The BLDC motor is used in various applications due to its compact size and easy controllability. It is usually operated with one or more rotor-position sensors. However, the motor control can be performed without making use of Hall sensors in the manner that timing to commutate the motor-drive voltages are determined by way of sensing the BEMF voltage on a not driven motor terminal. For each step of 60 electrical degrees, two windings are energized and one winding is not energized as shown in Fig. 1.
- [0006] Among others, one of the prior art disclosures in the technical field of the present invention can be referred to as WO2012053027, which discloses a

boost DC-to-DC converter capable of changing a voltage ratio between an input voltage and an output voltage smoothly in a wide range. Two pairs of one reactor and one battery is connected by a parallel switch. The parallel switch and one pair of the reactor and the battery are short-circuited by the first parallel switch. The parallel switch and the other pair of the reactor and the battery are short-circuited by the second parallel switch. The switched reluctance motor has a transient period while a freewheeling current is flowing from a phase winding of the switched reluctance motor. In a first half of transient period, the boost DC-to-DC converter applies a boost voltage to the bridge converter.

- [0007] The present invention, on the other hand, provides a control scheme capable of transferring accumulated energy more rapidly to the bus so that the DC bus is more rapidly charged and the freewheeling duration is shortened.
- [0008] Primary object of the present invention is therefore to provide an electrical household appliance with a BLDC motor control scheme by which energy stored in the motor phases is more rapidly transferred to the bus.
- [0009] The present invention proposes an electrical household appliance comprising an inverter power module in the form of a six-switch three-phase inverter connected to a DC link, said inverter driving a brushless DC motor in the manner that all high side and low side power switches are switched off during commutation of said brushless DC motor.
- [0010] More particularly, if a first power switch is already in conduction prior to programmed commutation time, said first power switch is temporarily switched off during commutation and if a second power switch is biased to non-conduction mode just prior to programmed commutation time, said second power switch maintains its non-operational state during commutation and if a third power switch is programmed to be switched on just with the start of the commutation, said third power switch is not switched on until the end of the commutation period.
- [0011] Accompanying drawings are given solely for the purpose of exemplifying a household appliance having a BLDC motor and a control module whose advantages over prior art were outlined above and will be explained in

brief hereinafter.

- [0012] The drawings are not meant to delimit the scope of protection as identified in the claims nor should they be referred to alone in an effort to interpret the scope identified in said claims without recourse to the technical disclosure in the description of the present invention.
- [0013] Fig. 1 demonstrates conventional trapezoidal control graph of a BLDC motor with the switching order and phase voltages being shown.
- [0014] Fig. 2 demonstrates an inverter module circuit during which HIN1 and LIN2 power switches are in conduction mode and other power switches are in non-conduction mode just before programmed commutation according to the present invention.
- [0015] Fig. 3 demonstrates the inverter module circuit in which freewheeling diodes charge the DC bus during commutation where HIN1 is switched off, LIN2 is biased to non-conduction mode and LIN3 is not switched on until the end of the commutation according to the present invention.
- [0016] Fig. 4 demonstrates the voltage-time graph of the power switches during commutation at each step of the trapezoidal control according to the present invention.
- [0017] The following numerals being referred to are used in the detailed description of the invention:
1. Power module
 2. Phase A
 3. Phase B
 4. Phase C
 5. Freewheeling diode
 6. High side power switch
 7. Low side power switch
- [0018] The present invention proposes an electrical household appliance and particularly a washing machine, a dishwasher, a drying machine or a combo drying and washing machine, which might contain an electric motor in the form of a brushless DC (BLDC) motor to fulfill various functions for instance in a washing machine, such as for instance driving a jet pump for spraying water jets into the rotary drum targeting at specific regions inside

the same, at which the laundry may tend to adhere within the same, driving a discharge pump for discharging the water contained in the drum or driving a discharge pump as well as a circulation pump for circulating a refrigerant fluid.

- [0019] The electrical household appliance comprises a power module (1) driving a BLDC motor having three phases (phase A, phase B and phase C, respectively 2, 3 and 4). High side power switches (6) and low side power switches (7) of the power module are typically provided with freewheeling diodes (5) allowing reverse current to flow therethrough to be dissipated. Phase windings are thereby deenergized through respective freewheeling diodes (5) and the stored magnetic energy in the respective phases is dissipated.
- [0020] The BLDC motor control can be conventionally performed without making use of Hall sensors such that timing to commutate the drive voltages are determined by way of sensing the BEMF voltage on a not driven motor terminal. For each step (60 electrical degrees), two windings are energized and one winding is not energized. In a sensorless configuration, thanks to the
- [0021] back-EMF sensing principle, the commutation moments can be derived from the zero-crossings of the back-EMF. A microcontroller may conventionally detect phase voltage and bus voltage when they are equal to each other. The phase zero crossing can be detected at the moment when the phase voltage crosses the half DC-bus voltage. The respective commutation moment can be configured as being shifted 30 degrees in accordance with the speed of the motor.
- [0022] It is to be noted that as the current in the motor phases increases at higher speeds and torques, energy stored in the motor phases also increases. To this end, freewheeling period at higher speeds being longer, if freewheeling state is extended to a later time after BEMF zero-crossing point or a freewheeling state longer than 30 degrees occurs, BEMF zero-crossing point may not be determined. In this case, as the accurate moment for commutation cannot be calculated, torque ripples will occur.
- [0023] According to the present invention, all high side power switches (6, HIN1,

HIN2 and HIN3) as well as low side power switches (7, LIN1, LIN2 and LIN3) are switched off during commutation. In reference to Fig. 1, at 60 degrees, normally HIN1 is in conduction, LIN2 is biased to non-conduction mode and LIN3 is about to be switched on. During commutation, however, in order for allowing freewheeling diodes (5) transfer the stored energy to the DC bus, HIN1 is temporarily switched off, LIN2 is biased to non-conduction mode and LIN3 is not switched on until the end of the commutation period.

- [0024] In other words, as shown in Fig. 4, all power switches during commutation at each step of the trapezoidal control are switched off according to the present invention. This is particularly advantageous in that freewheeling period at higher speeds is shortened and drawbacks associated with the back-EMF sensing principle in the sensorless configuration will be avoided.
- [0025] In a nutshell, the present invention proposes an electrical household appliance comprising at least one electric motor, a driver circuit capable of driving said at least one electric motor, said driver circuit comprising a converter that converts AC mains voltage to DC voltage, a driver circuit inverter stage that inverts the direct current, said driver circuit inverter stage comprising a inverter power module (1).
- [0026] In one embodiment of the present invention, said electric motors is a brushless DC motor and said power module (1) comprises high side and low side power switches (6, 7) with freewheeling diodes (5).
- [0027] In a further embodiment of the present invention, all high side and low side power switches (6, 7) are programmed to be switched off during commutation of said brushless DC motor.
- [0028] In a further embodiment of the present invention, if a first power switch is in conduction prior to commutation, said first power switch is temporarily switched off during commutation.
- [0029] In a further embodiment of the present invention, if a second power switch is biased to non-conduction mode prior to commutation, said second power switch maintains its non-operational state.
- [0030] In a further embodiment of the present invention, if a third power switch is

programmed to be switched on with the start of the commutation, said third power switch is not switched on until the end of the commutation period.

- [0031] In a further embodiment of the present invention, said inverter power module (1) is a six-switch three-phase inverter connected to a DC link.
- [0032] In a further embodiment of the present invention, said electrical household appliance is a washing machine, a dishwasher, a drying machine or a combo drying and washing machine.
- [0033] Accordingly, the present invention ensures a control scheme capable of effectuating transfer of accumulated energy to the bus more rapidly by means of said freewheeling diodes (5) in a simultaneous manner by way of switching off all power switches during commutation so that the DC bus is more rapidly charged and the freewheeling duration is shortened so as to avoid situations where the freewheeling state is extended to a later time after BEMF zero-crossing point or a freewheeling state longer than 30 degrees occurs.

Claims

1. An electrical household appliance comprising at least one electric motor, a driver circuit capable of driving said at least one electric motor, said driver circuit comprising a converter that converts AC mains voltage to DC voltage, a driver circuit inverter stage that inverts the direct current, said driver circuit inverter stage comprising a inverter power module (1) **characterized in that;** said electric motors is a brushless DC motor and said power module (1) comprises high side and low side power switches (6, 7) with freewheeling diodes (5) and,
all high side and low side power switches (6, 7) are programmed to be switched off during commutation of said brushless DC motor.
2. An electrical household appliance as in Claim 1, **characterized in that** if a first power switch is in conduction prior to commutation, said first power switch is temporarily switched off during commutation.
3. An electrical household appliance as in Claim 1, **characterized in that** if a second power switch is biased to non-conduction mode prior to commutation, said second power switch maintains its non-operational state during commutation.
4. An electrical household appliance as in Claim 1, **characterized in that** if a third power switch is programmed to be switched on with the start of the commutation, said third power switch is not switched on until the end of the commutation period.
5. An electrical household appliance as in any preceding Claims, **characterized in that** said inverter power module (1) is a six-switch three-phase inverter connected to a DC link.
6. An electrical household appliance as in any preceding Claims, **characterized in that** said electrical household appliance is a washing machine, a dishwasher, a drying machine or a combo drying and washing machine.

Fig. 1

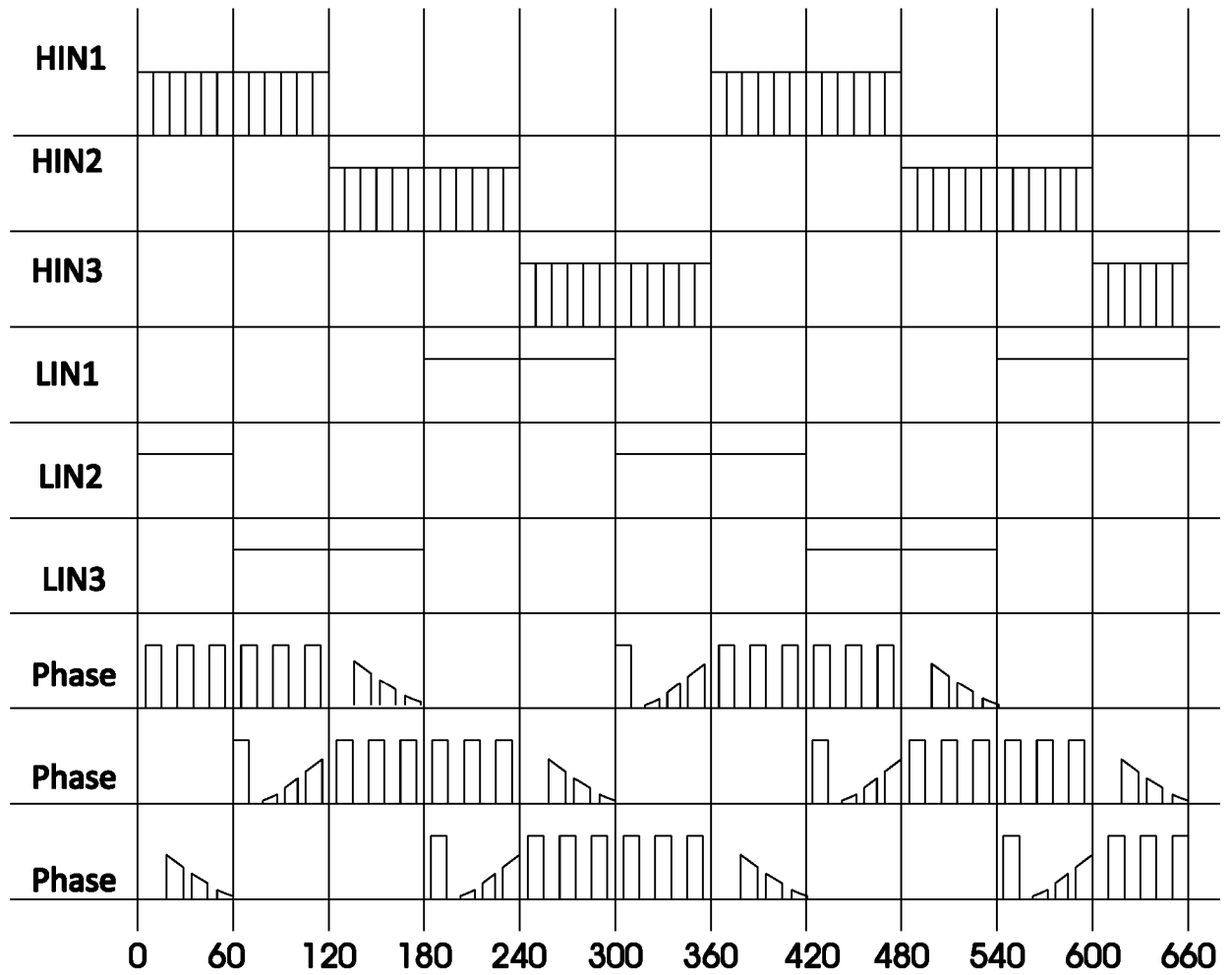


Fig. 2

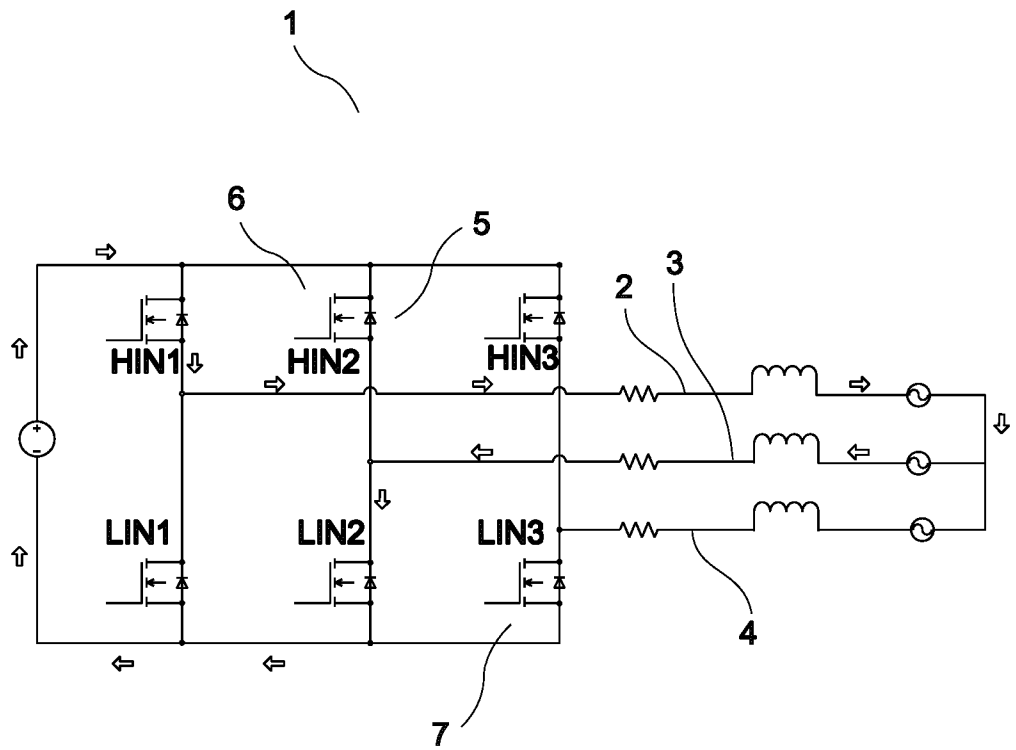


Fig. 3

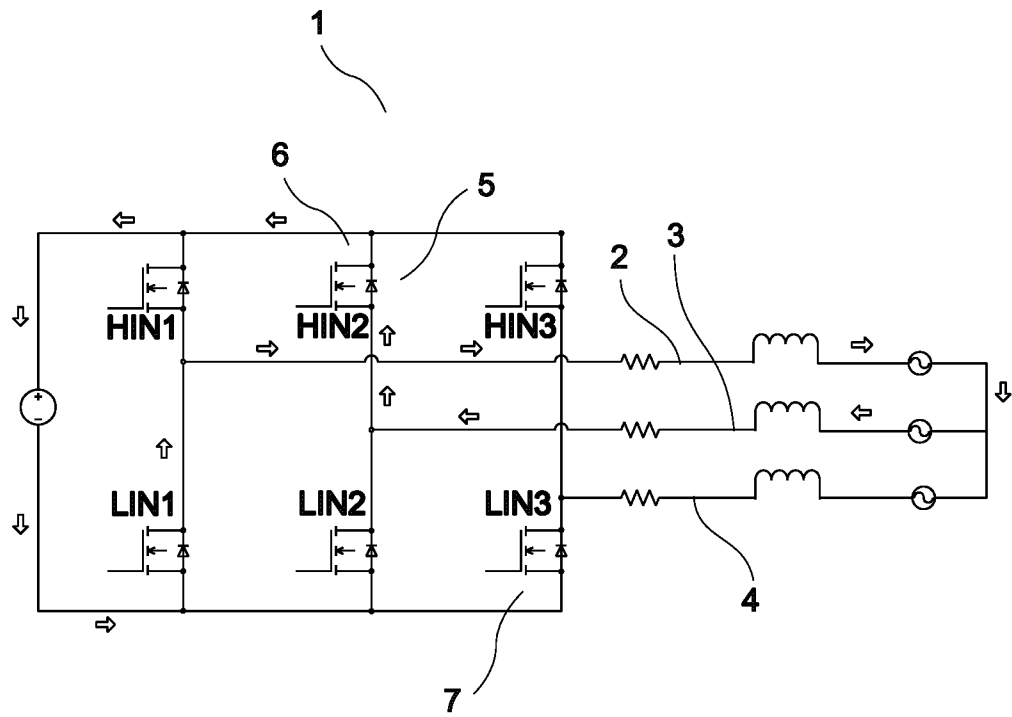
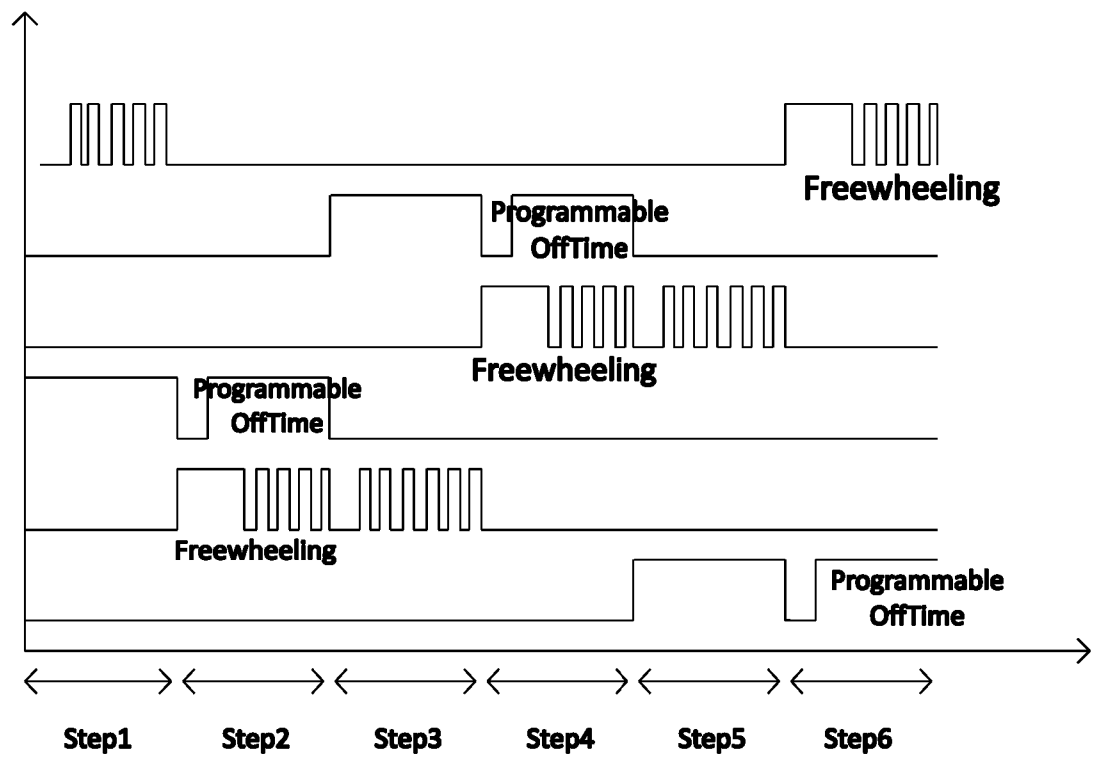


Fig. 4



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065515

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02P6/08
ADD.
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)
H02P
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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 256 949 A (REICHARD JOHN G [US] ET AL) 26 October 1993 (1993-10-26)	1-5
Y	column 5, line 67 - column 7, line 52; figures 1-6,12-16 column 18, line 66 - column 21, line 17	6
Y	----- WO 2015/078524 A1 (ARCELIK AS [TR]) 4 June 2015 (2015-06-04) paragraph [0001] - paragraph [0003]; figure 3	6
A	----- US 2006/197482 A1 (HARWOOD JONATHAN D [NZ]) 7 September 2006 (2006-09-07) abstract; figure 1 ----- -/--	1-6

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
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Date of the actual completion of the international search 9 March 2017	Date of mailing of the international search report 16/03/2017
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Hascher, Thierry

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065515

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>KIM HYUNG-KYU ET AL: "Comparison Analysis of Demagnetization and Torque Ripple in Accordance With Freewheeling Current in PM BLDC Motor", IEEE TRANSACTIONS ON MAGNETICS, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 51, no. 11, 1 November 2015 (2015-11-01), pages 1-4, XP011587307, ISSN: 0018-9464, DOI: 10.1109/TMAG.2015.2433933 [retrieved on 2015-10-23] abstract; figure 1 -----</p>	1-6

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/EP2016/065515

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WO 2015078524	A1	04-06-2015	CN 106063116 A 26-10-2016
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