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(54) **MOTOR DRIVING APPARATUS AND AIR CONDITIONER INCLUDING THE SAME**

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(57) **ABSTRACT**

A motor driving apparatus for driving a compressor of an air conditioner can include a rectifier configured to rectify an alternating current voltage, a first capacitor configured to store a voltage based on the alternating current voltage, a harmonic reducer connected between the rectifier and the first capacitor, the harmonic reducer including a second capacitor, at least one switching element and an inductor, an inverter including a plurality of switching elements, and configured to output a converted alternating current voltage based on a voltage of the first capacitor, and a controller configured to turn on and turn off the at least one switching element in the harmonic reducer based on an output power of the inverter.

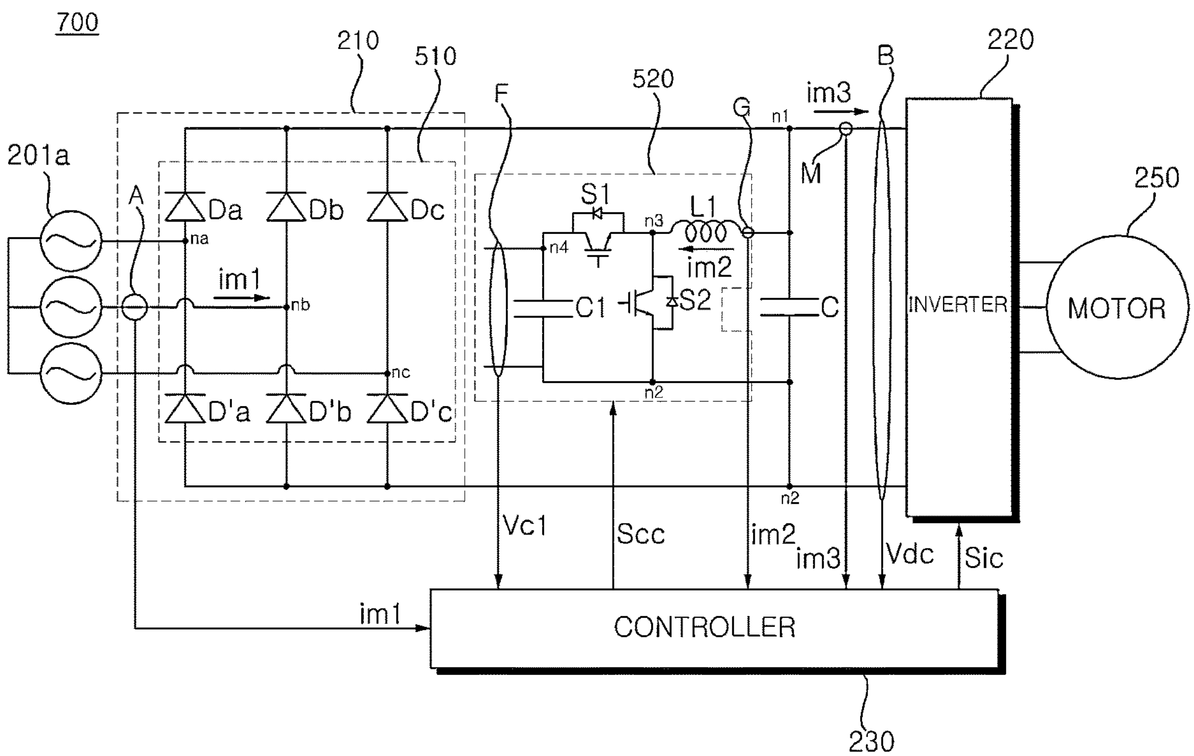


FIG. 1

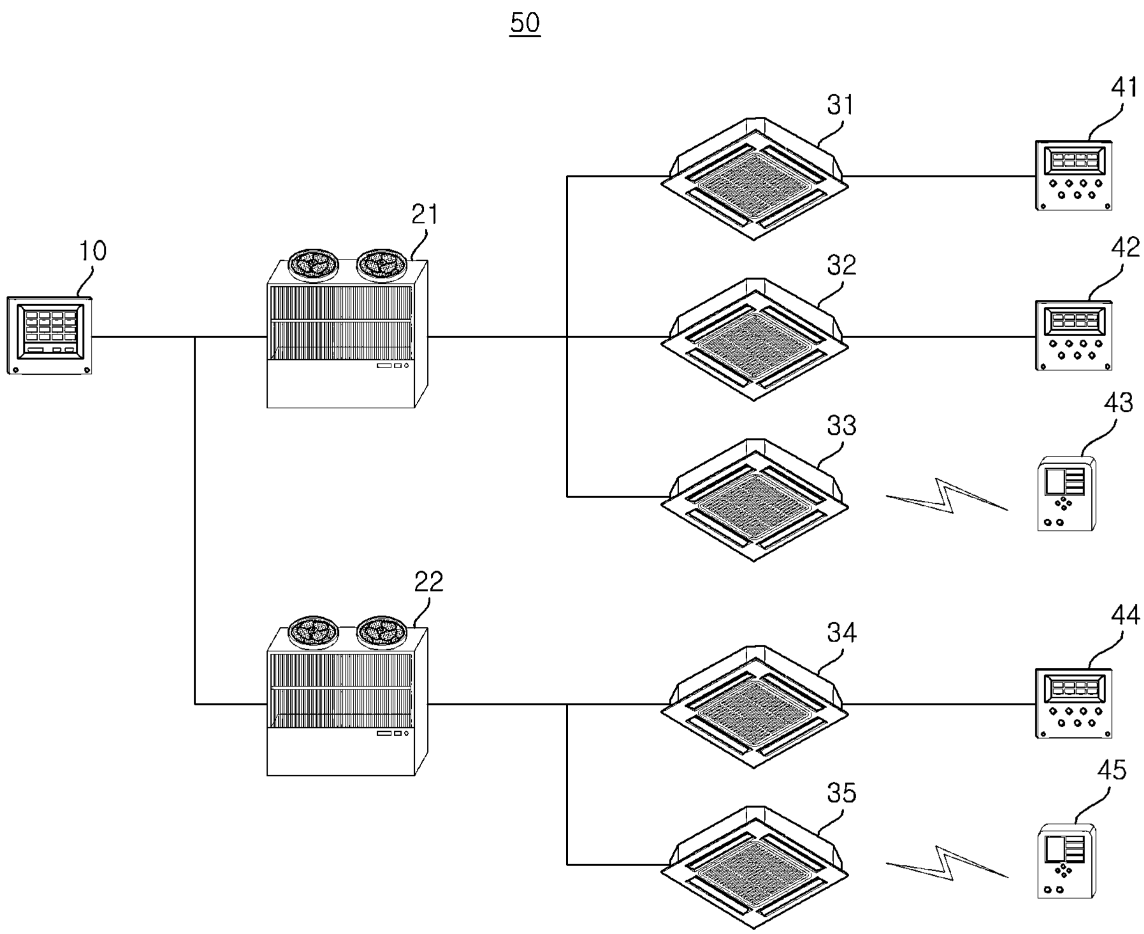


FIG. 2

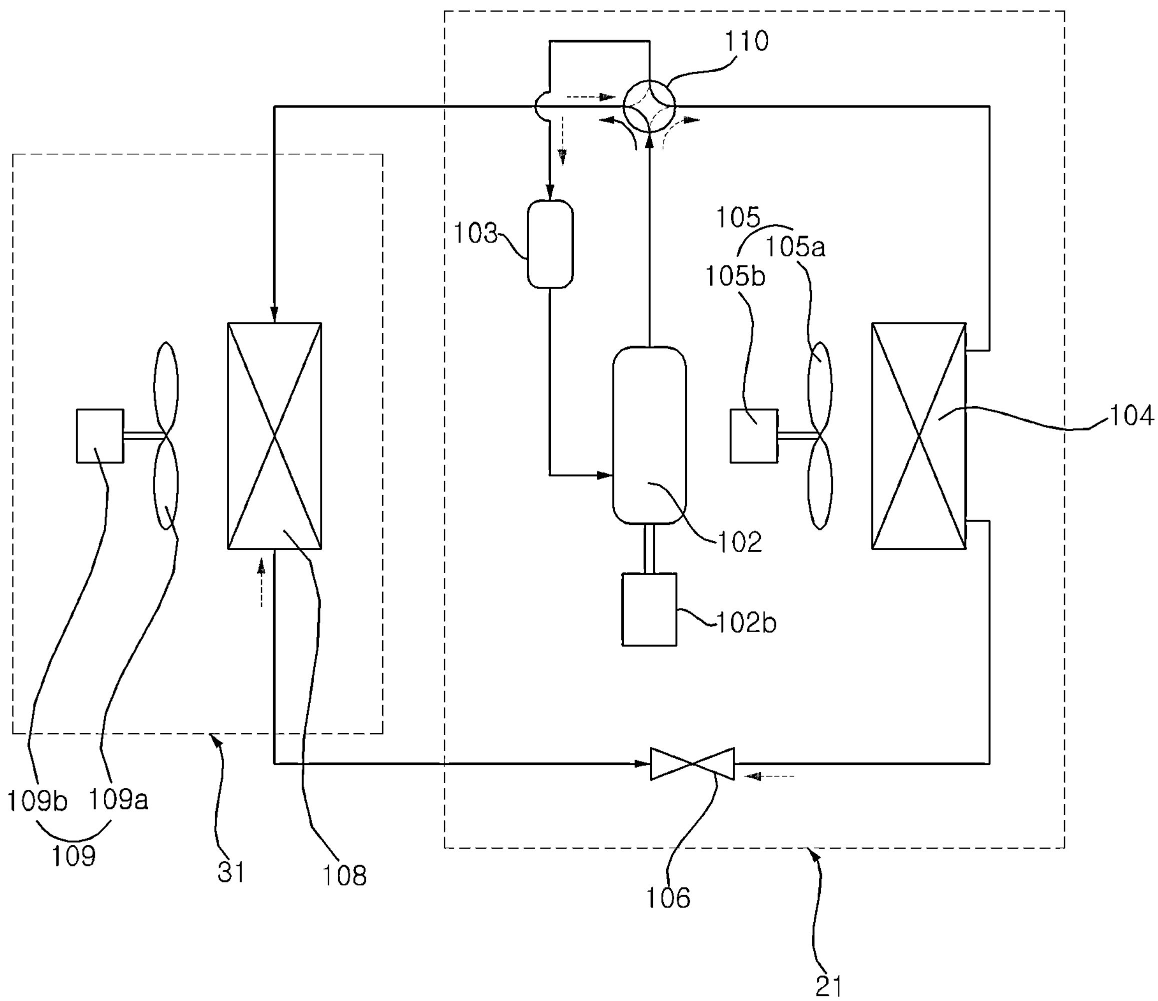


FIG. 3

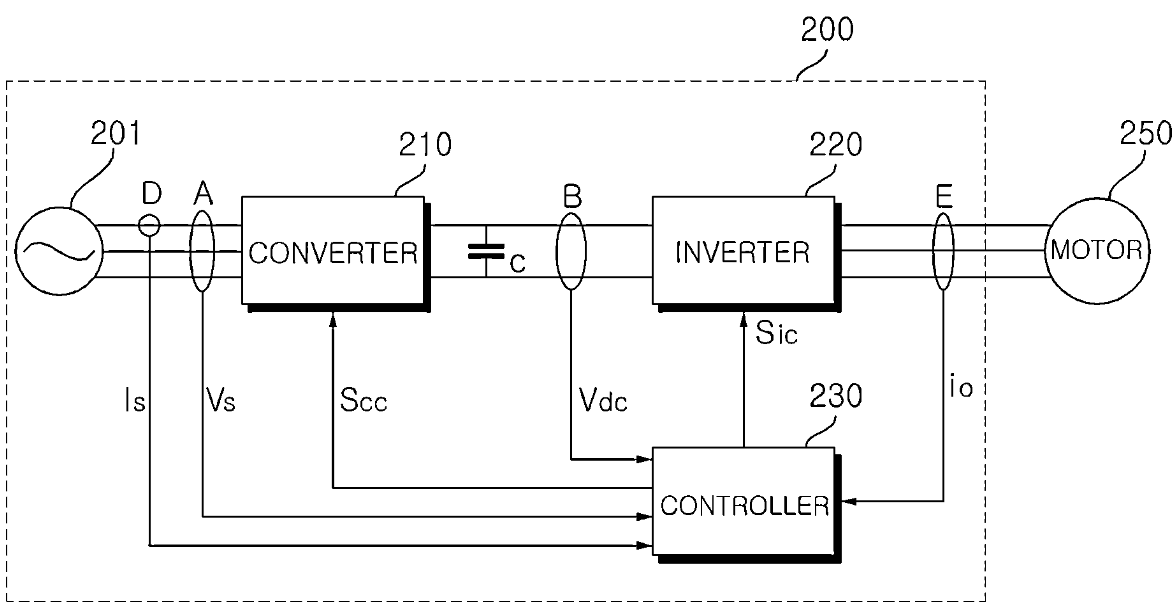

200
201
D
A
210
CONVERTER
C
B
220
INVERTER
E
250
MOTOR
Sic
Is
Vs
Scc
Vdc
230
io
CONTROLLER

FIG.4

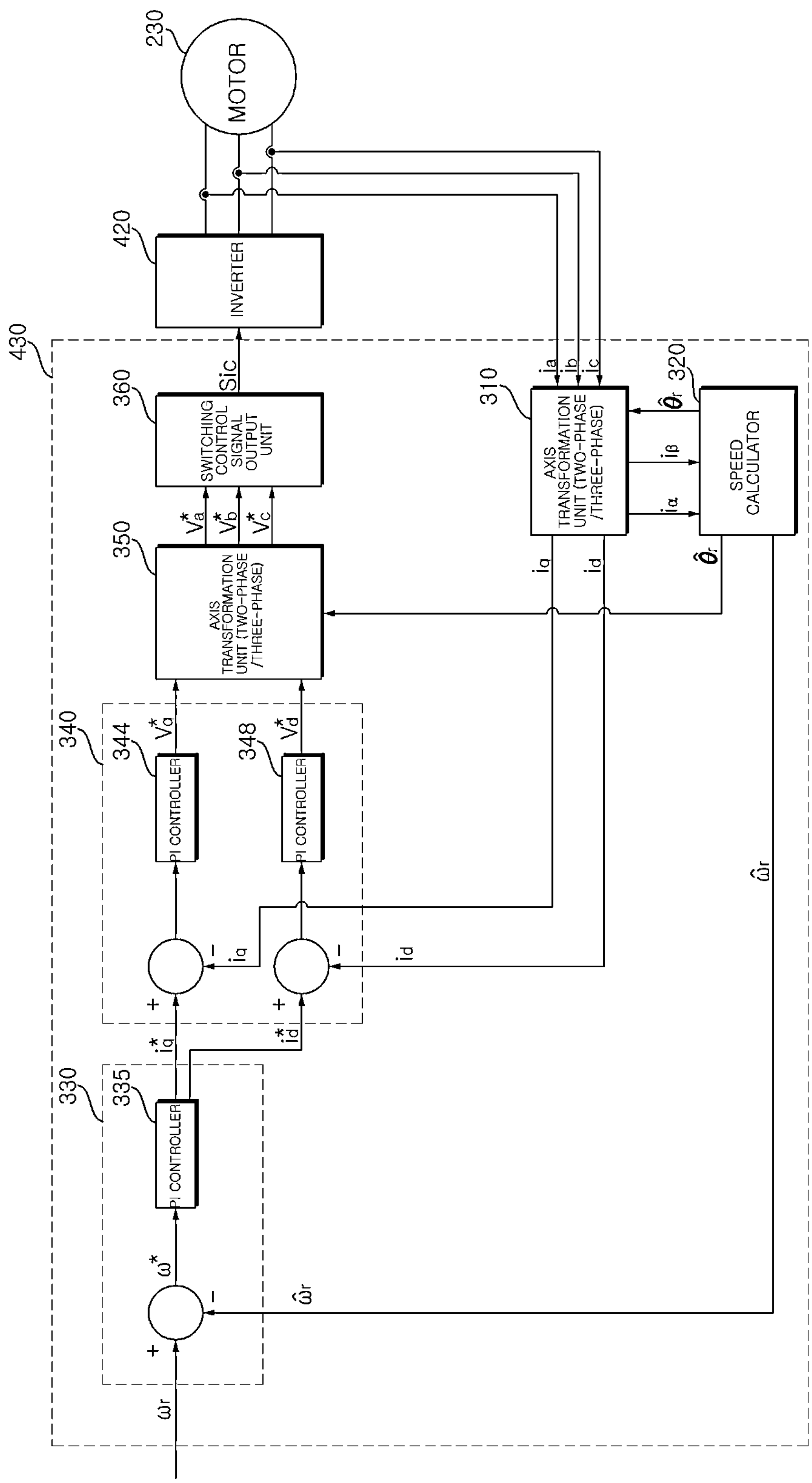

230
MOTOR
420
INVERTER
430
360
SWITCHING CONTROL SIGNAL OUTPUT UNIT
Sic
350
AXIS TRANSFORMATION UNIT (TWO-PHASE /THREE-PHASE)
V_a^*
V_b^*
V_c^*
310
AXIS TRANSFORMATION UNIT (TWO-PHASE /THREE-PHASE)
i_a
i_b
i_c
320
SPEED CALCULATOR
$\hat{\theta}_r$
i_β
i_α
i_q
i_d
340
344
PI CONTROLLER
V_q^*
348
PI CONTROLLER
V_d^*
330
335
PI CONTROLLER
i_q^*
i_d^*
ω^*
ω_r
$\hat{\omega}_r$
+
−

FIG. 5

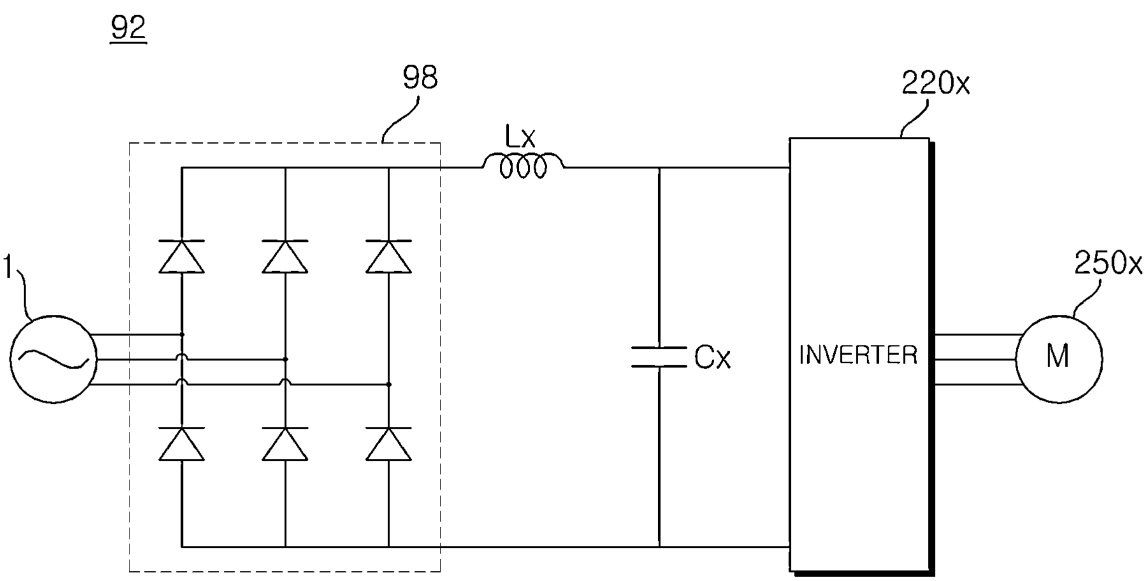


FIG. 6A

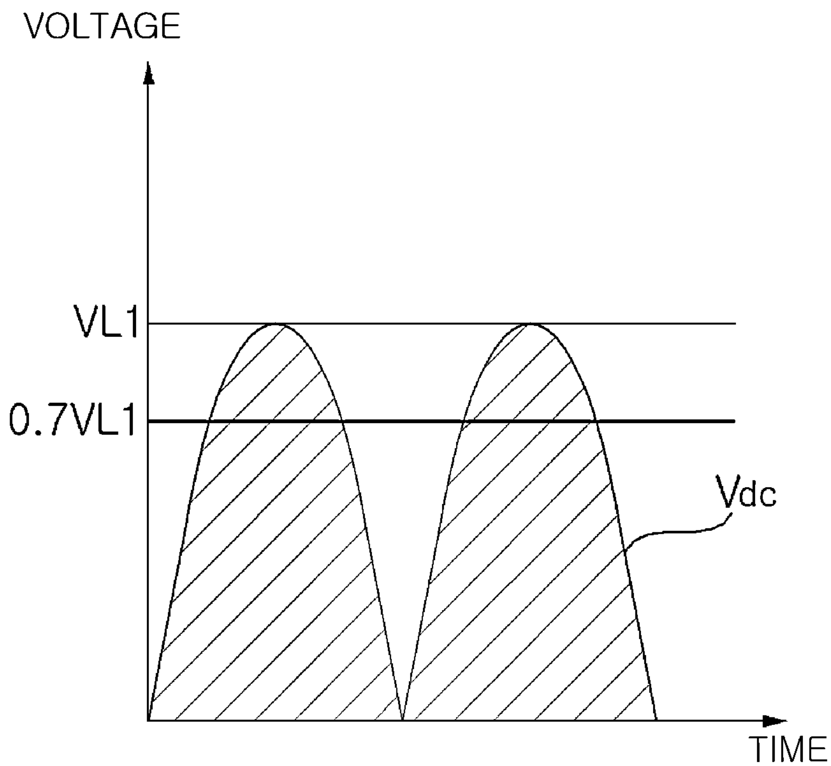


FIG. 6B

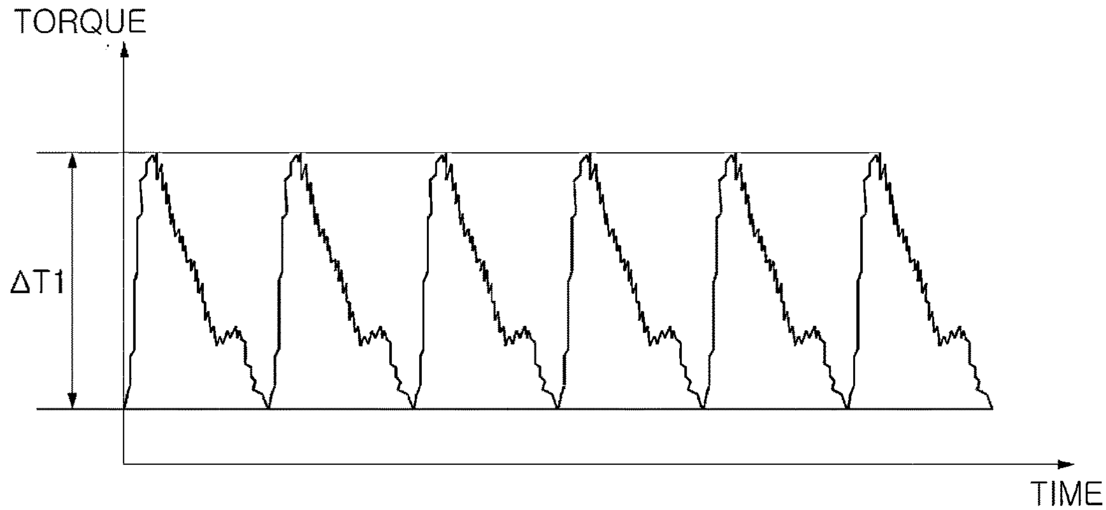

TORQUE
ΔT1
TIME

FIG. 6C

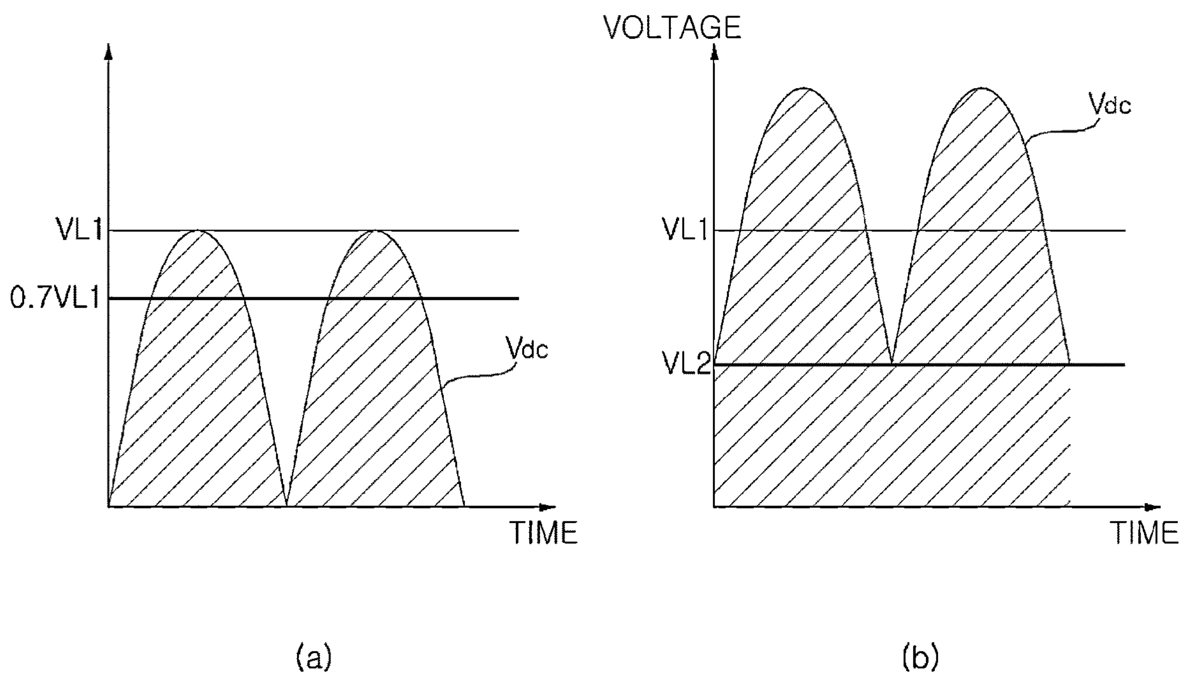

VL1
0.7VL1
Vdc
TIME
(a)
VOLTAGE
Vdc
VL1
VL2
TIME
(b)

FIG. 6D

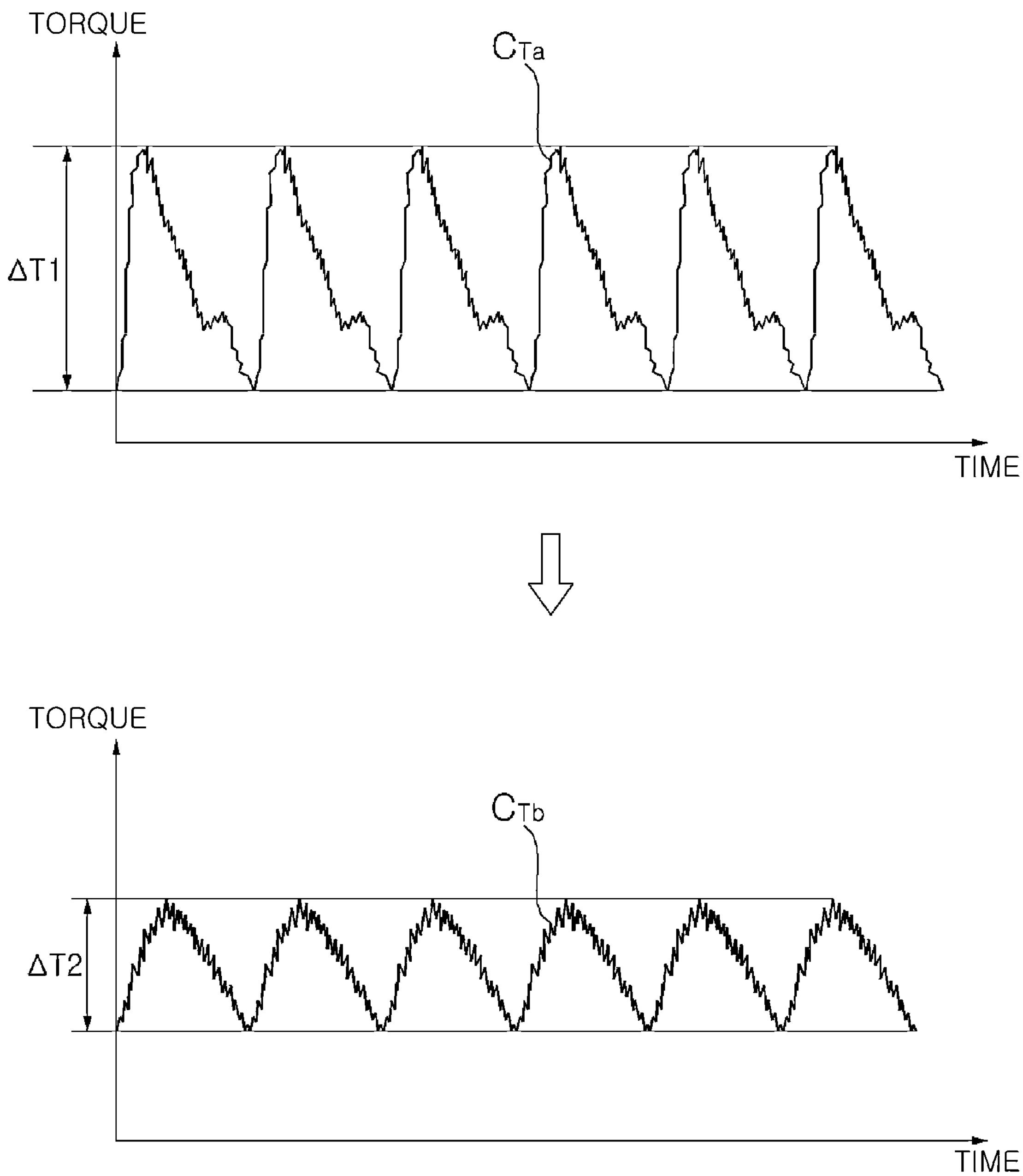


FIG. 7

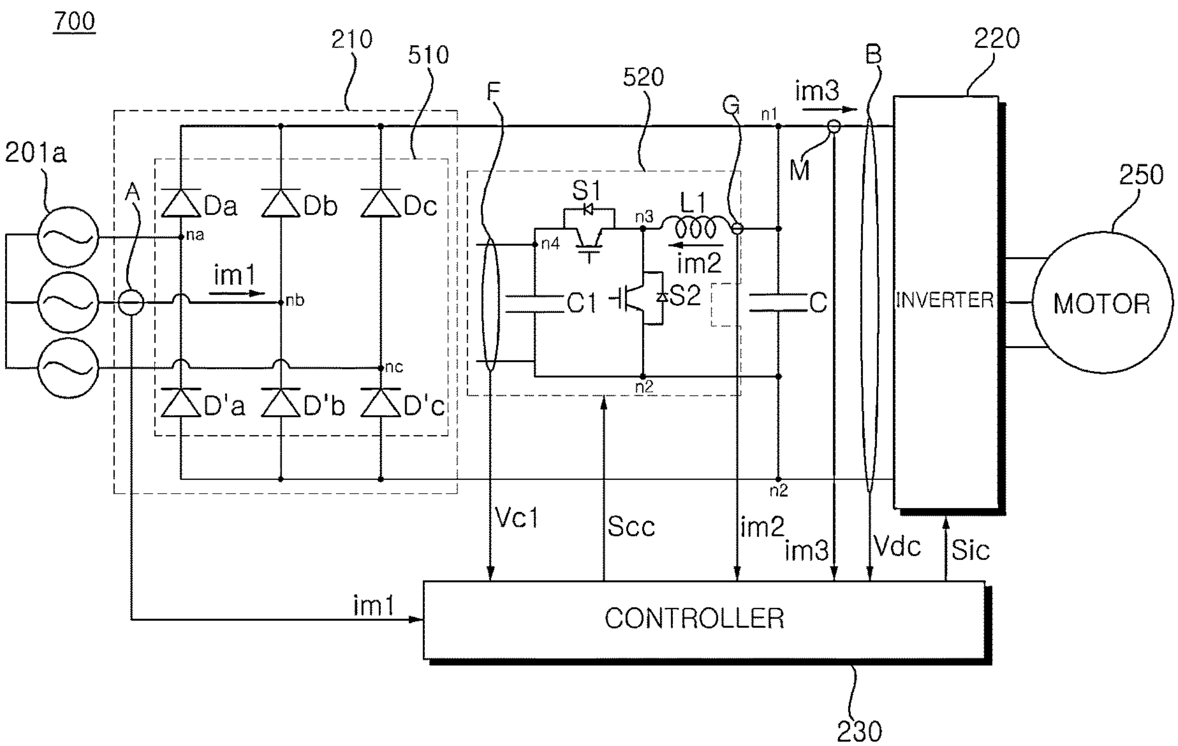

700
210
510
520
220
250
201a
A
F
G
B
M
Da
Db
Dc
D'a
D'b
D'c
na
nb
nc
n1
n2
n3
n4
S1
S2
L1
C1
C
im1
im2
im3
INVERTER
MOTOR
Vc1
Scc
Vdc
Sic
CONTROLLER
230

FIG.8

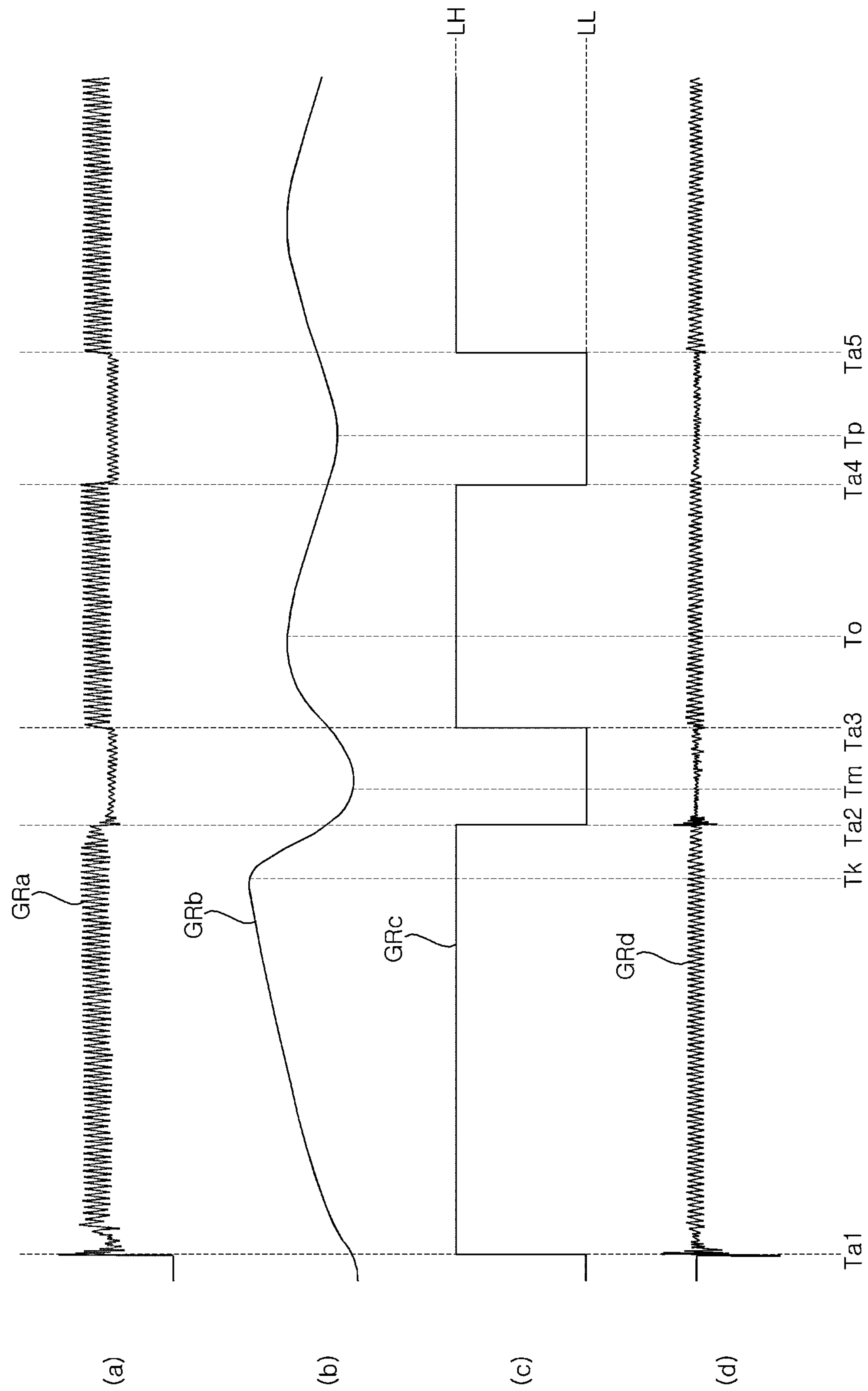


FIG. 9A

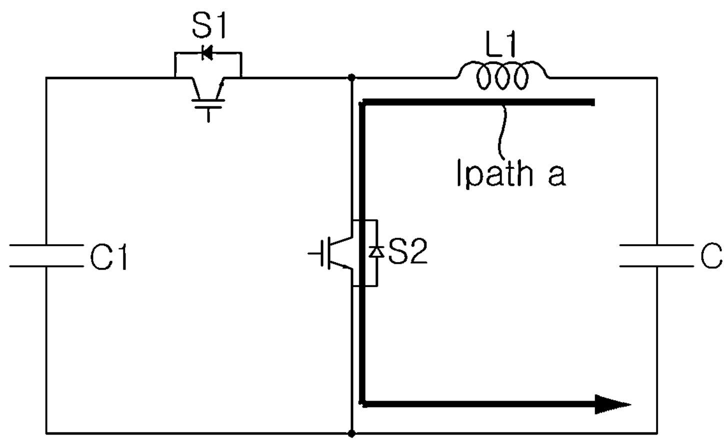


FIG. 9B

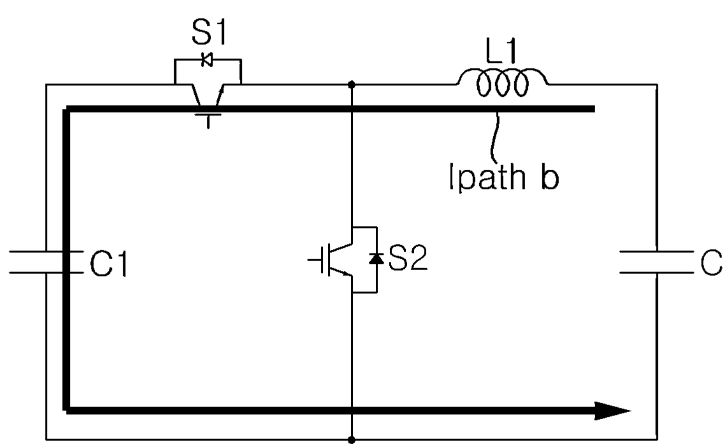


FIG. 9C

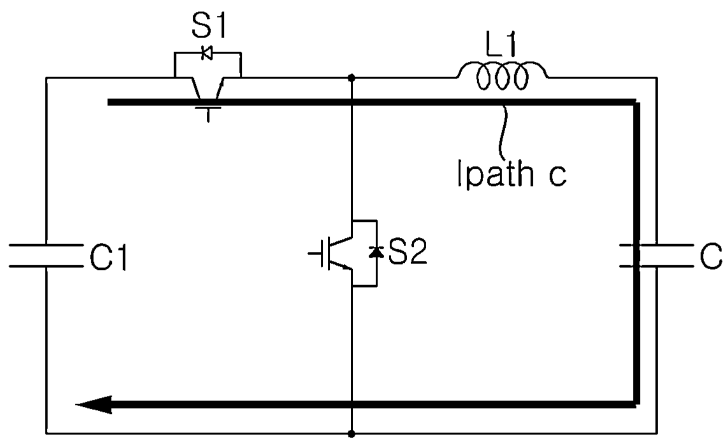


FIG. 9D

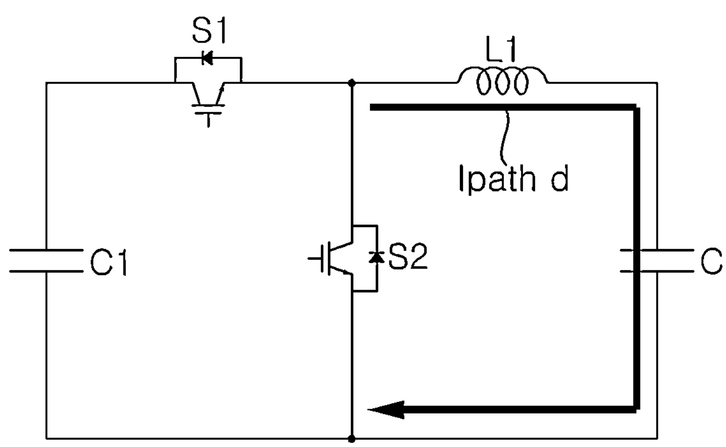


FIG. 10A

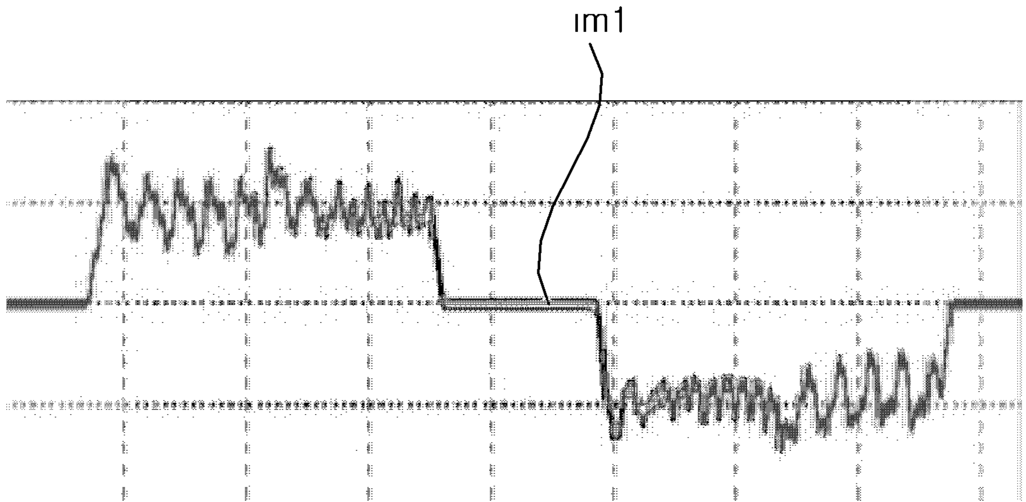


FIG. 10B

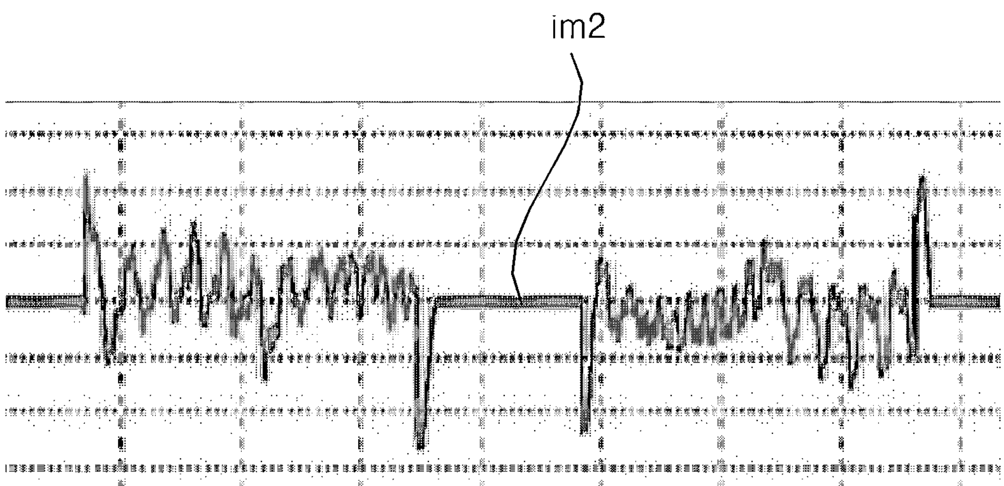


FIG. 10C

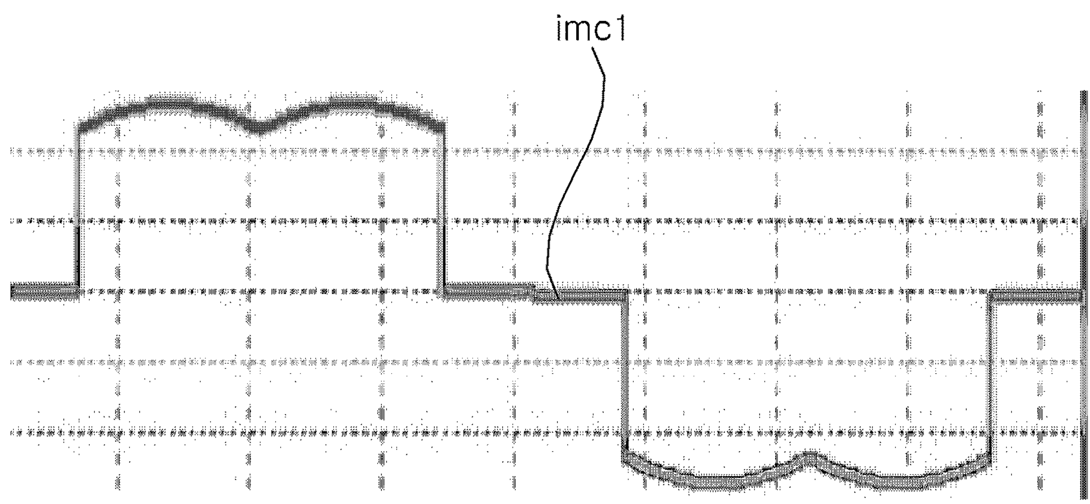


FIG. 11

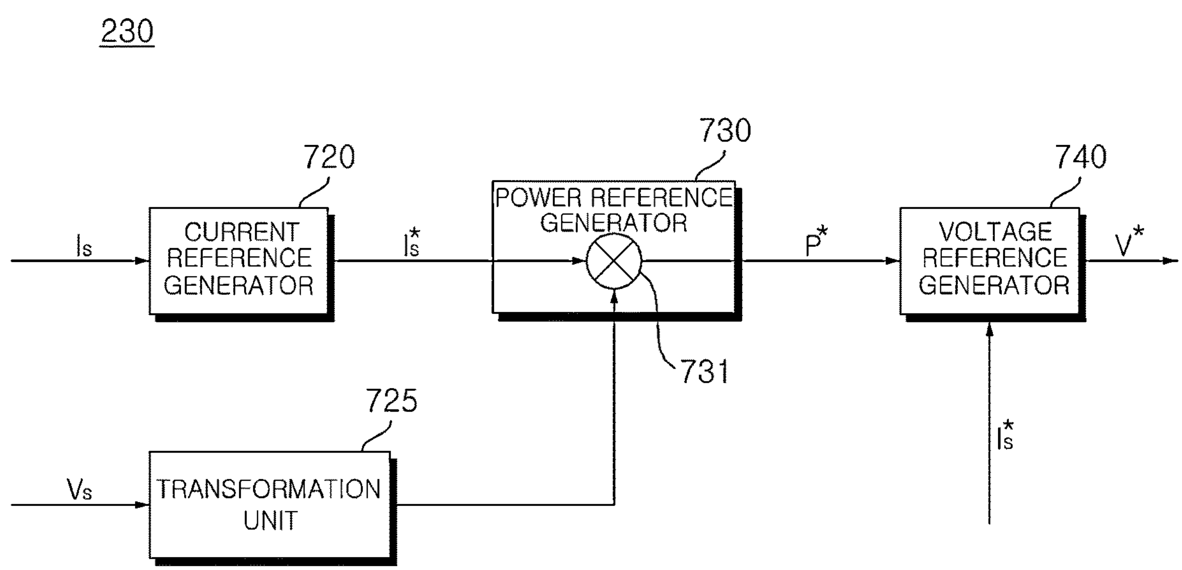


FIG. 12A

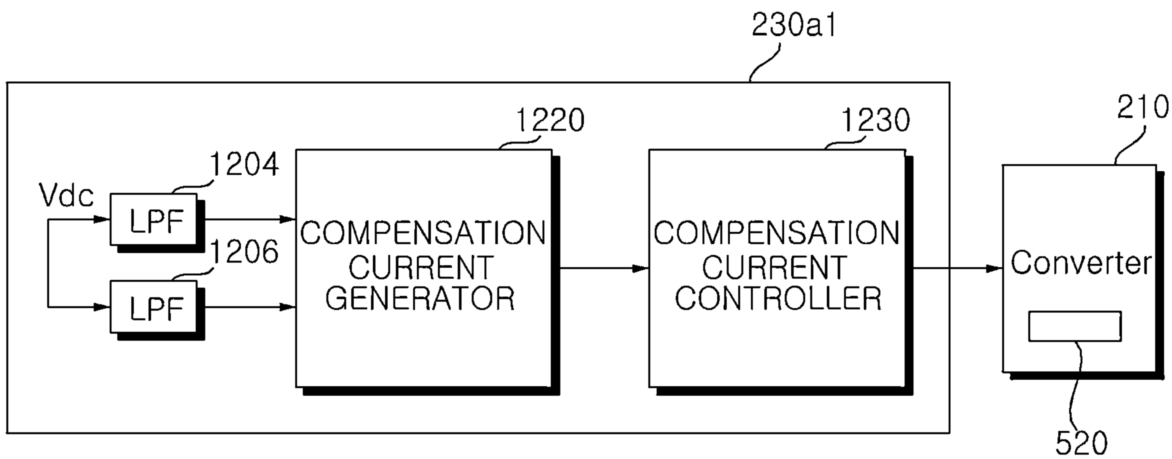


FIG. 12B

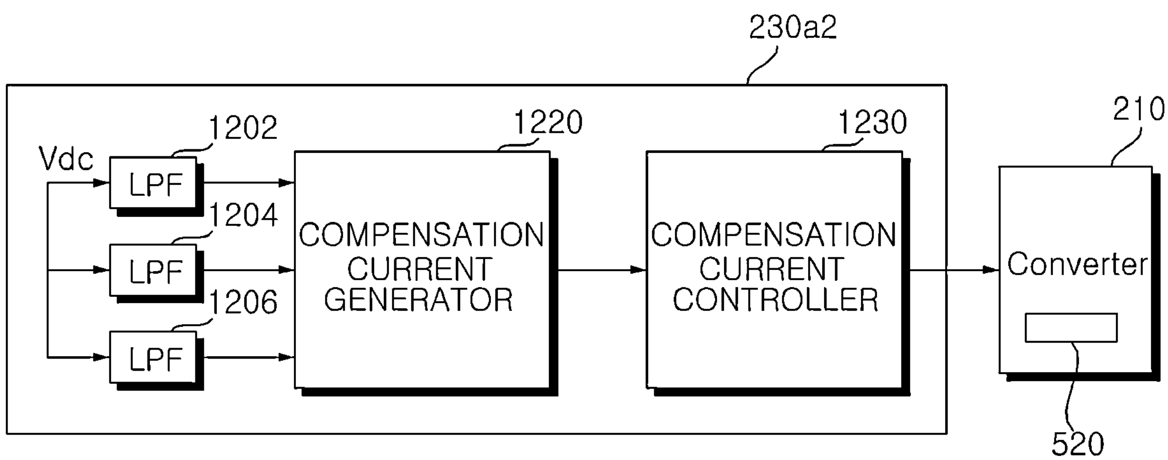


FIG. 13A

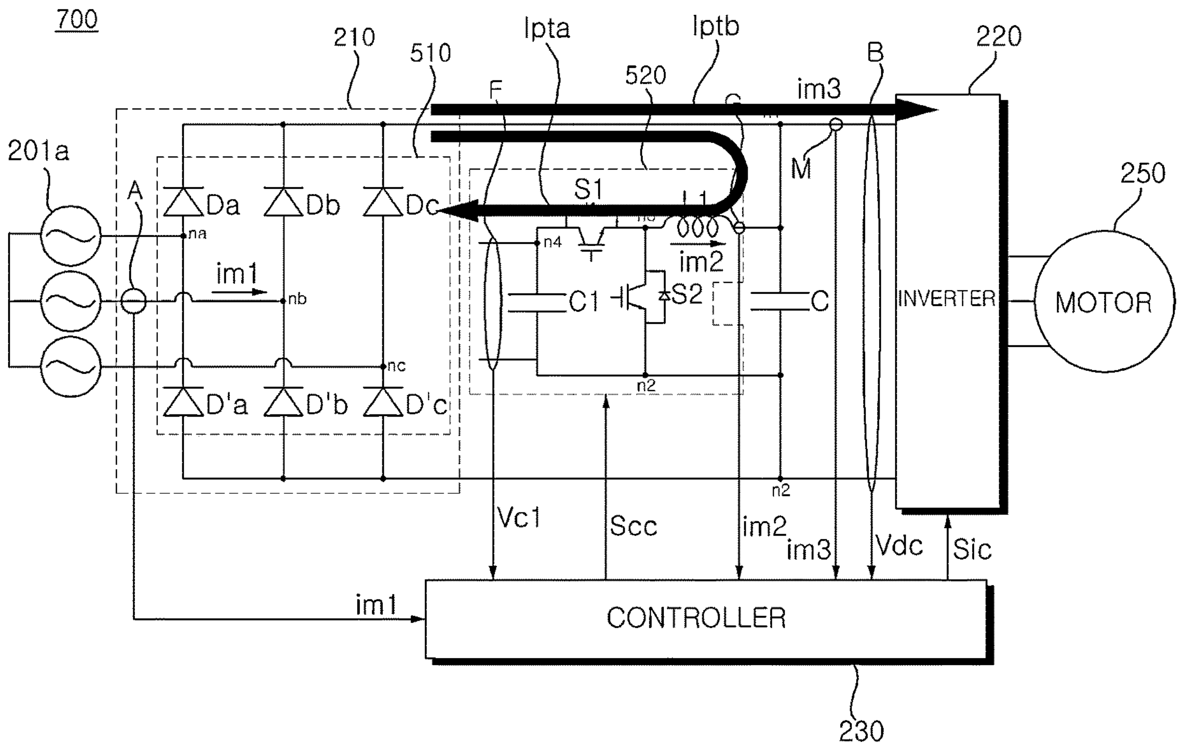


FIG. 13B

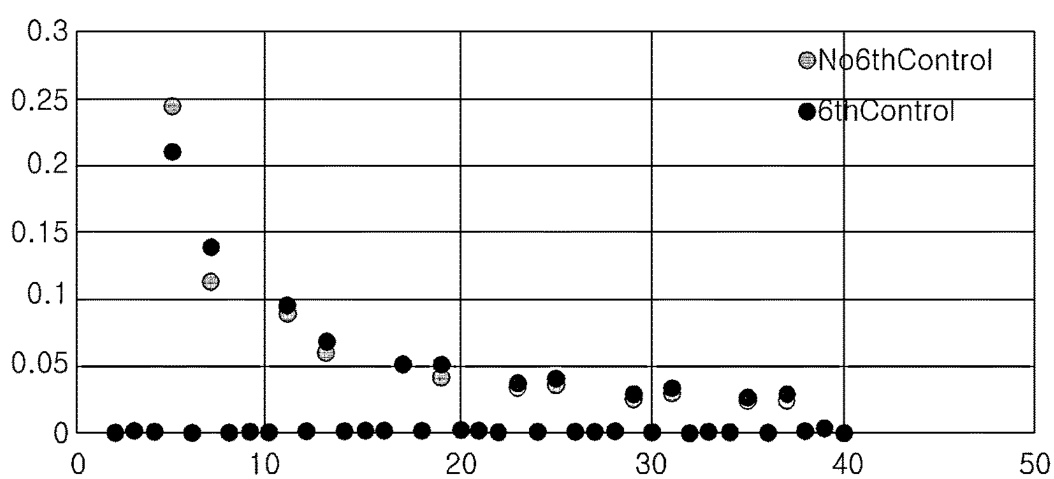


FIG. 14

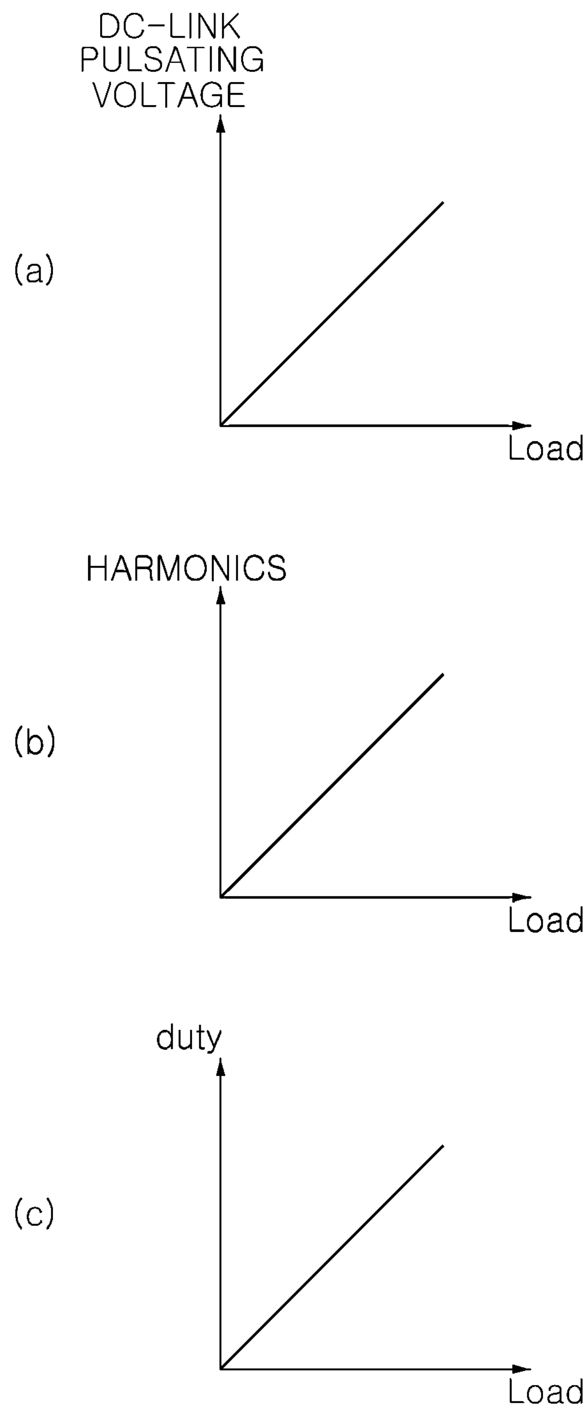
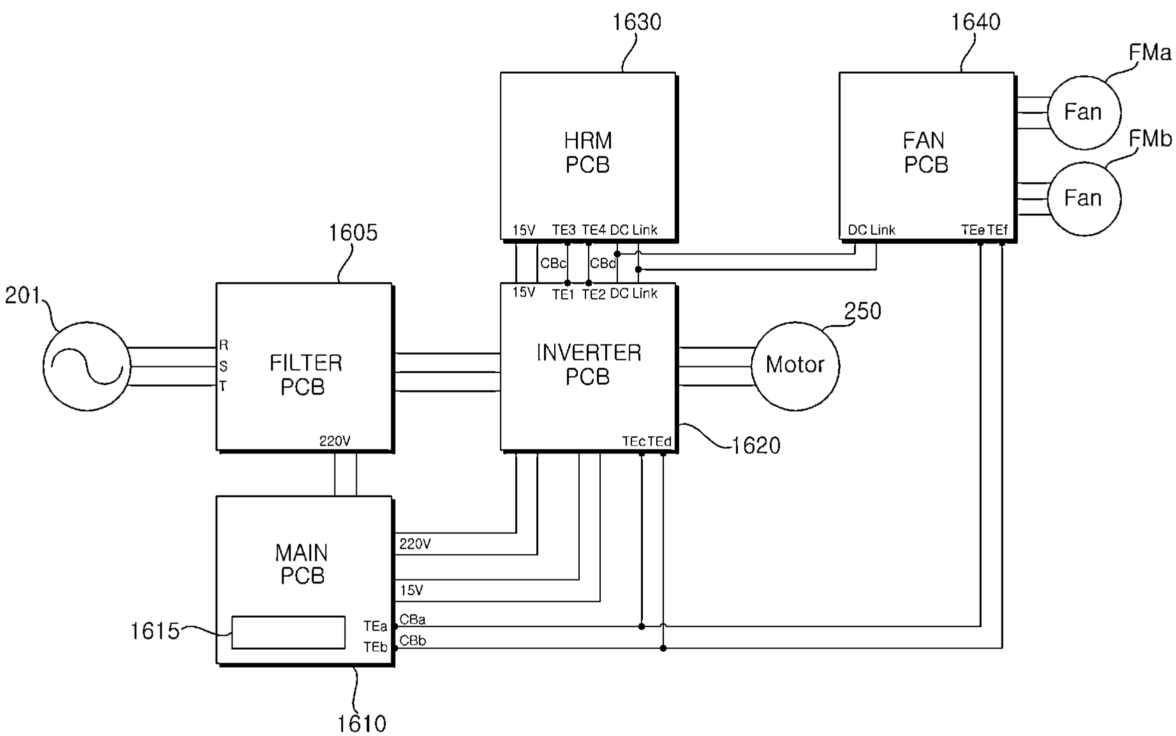

DC-LINK
PULSATING
VOLTAGE
(a)
Load
HARMONICS
(b)
Load
duty
(c)
Load

FIG. 15



1630
1640
FMa
HRM
PCB
FAN
PCB
Fan
FMb
Fan
15V
TE3
TE4
DC Link
DC Link
TEe
TEf
1605
CBc
CBd
201
15V
TE1
TE2
DC Link
250
R
S
T
FILTER
PCB
INVERTER
PCB
Motor
220V
TEc
TEd
1620
MAIN
PCB
220V
15V
CBa
CBb
1615
TEa
TEb
1610

FIG. 16

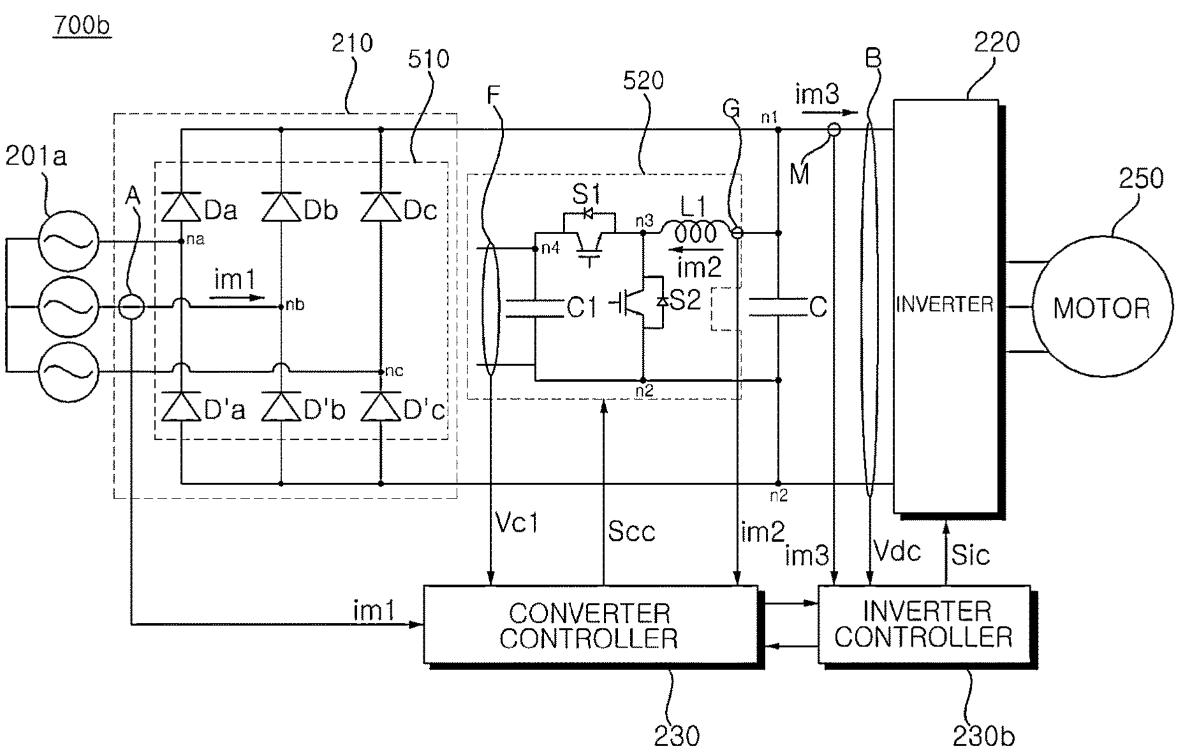
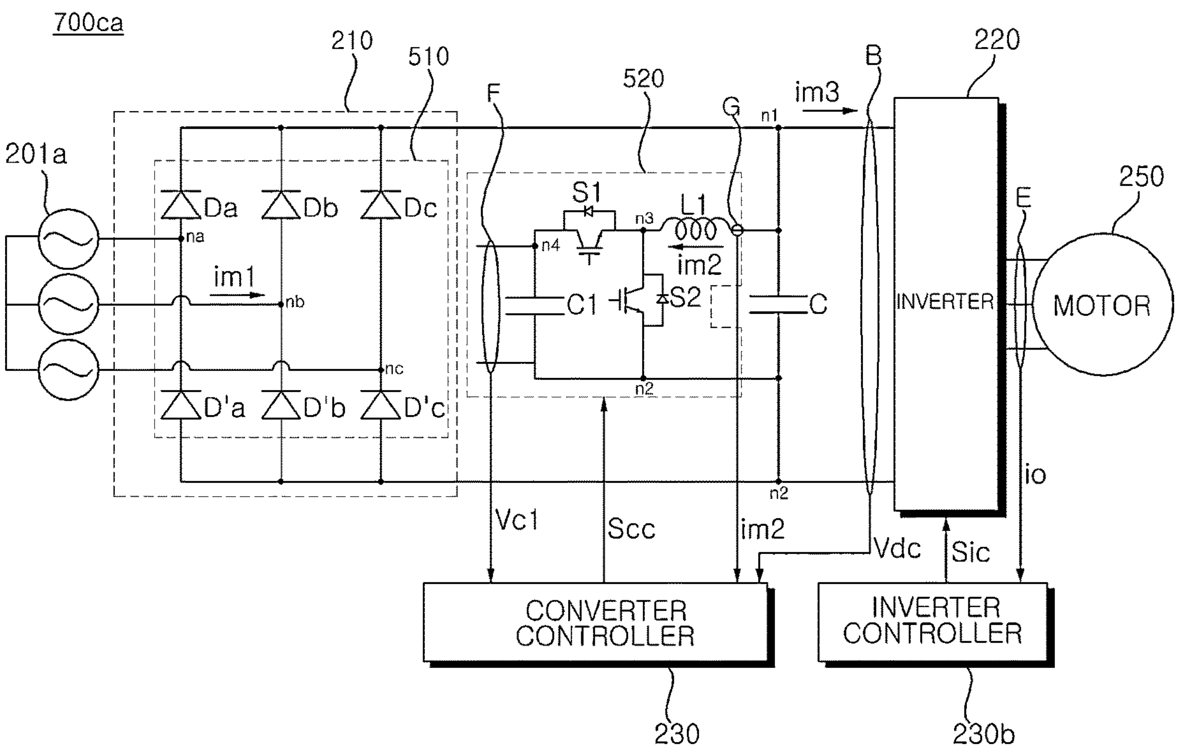

700b
210
510
520
F
G
n1
im3
B
220
201a
A
Da
Db
Dc
S1
n3
L1
M
250
na
n4
im1
nb
im2
C1
S2
C
INVERTER
MOTOR
nc
D'a
D'b
D'c
n2
n2
Vc1
Scc
im2
im3
Vdc
Sic
im1
CONVERTER CONTROLLER
INVERTER CONTROLLER
230
230b

FIG. 17



700ca
210
510
520
201a
Da
Db
Dc
na
nb
nc
im1
D'a
D'b
D'c
F
S1
n4
n3
L1
im2
C1
S2
n2
G
n1
im3
C
n2
B
220
INVERTER
E
250
MOTOR
io
Vc1
Scc
im2
Vdc
Sic
CONVERTER CONTROLLER
INVERTER CONTROLLER
230
230b

FIG. 18

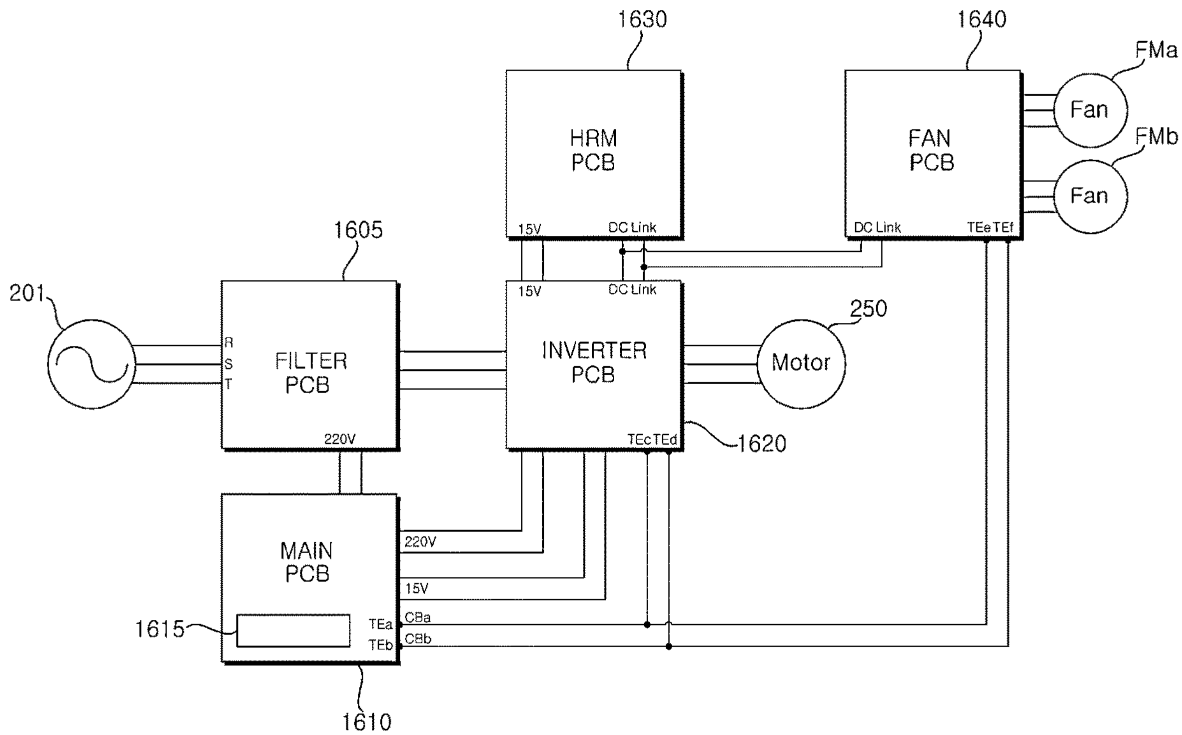
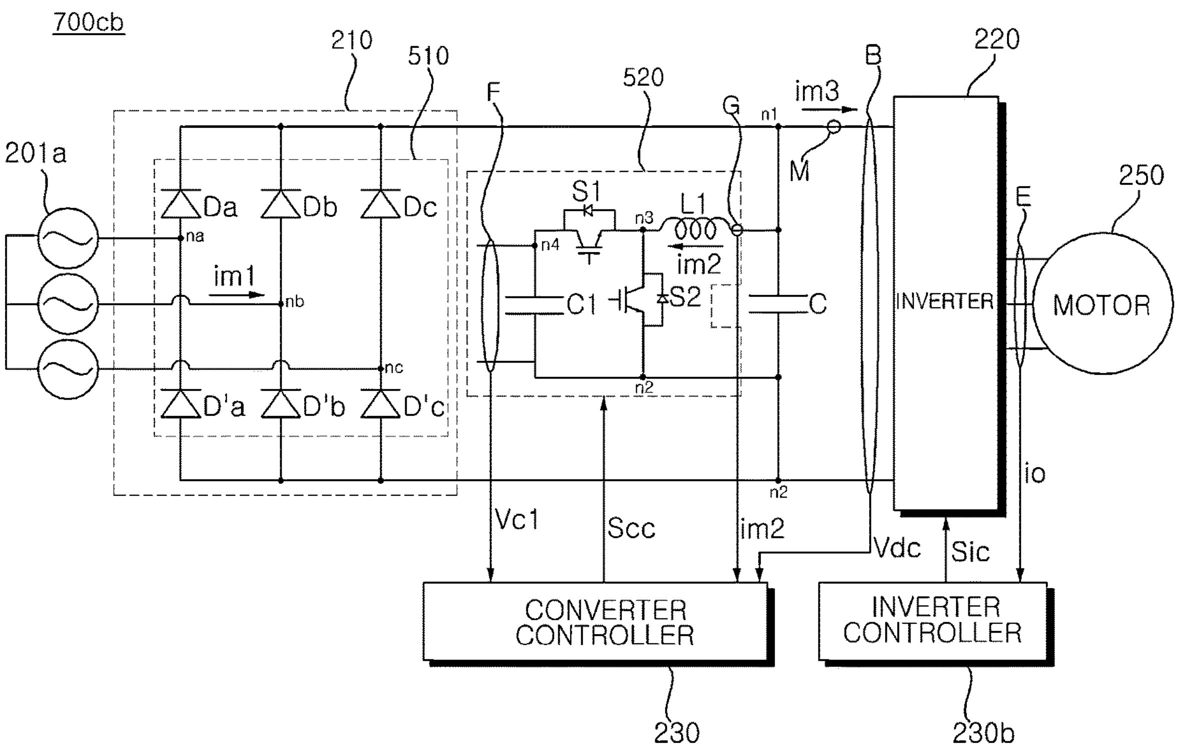
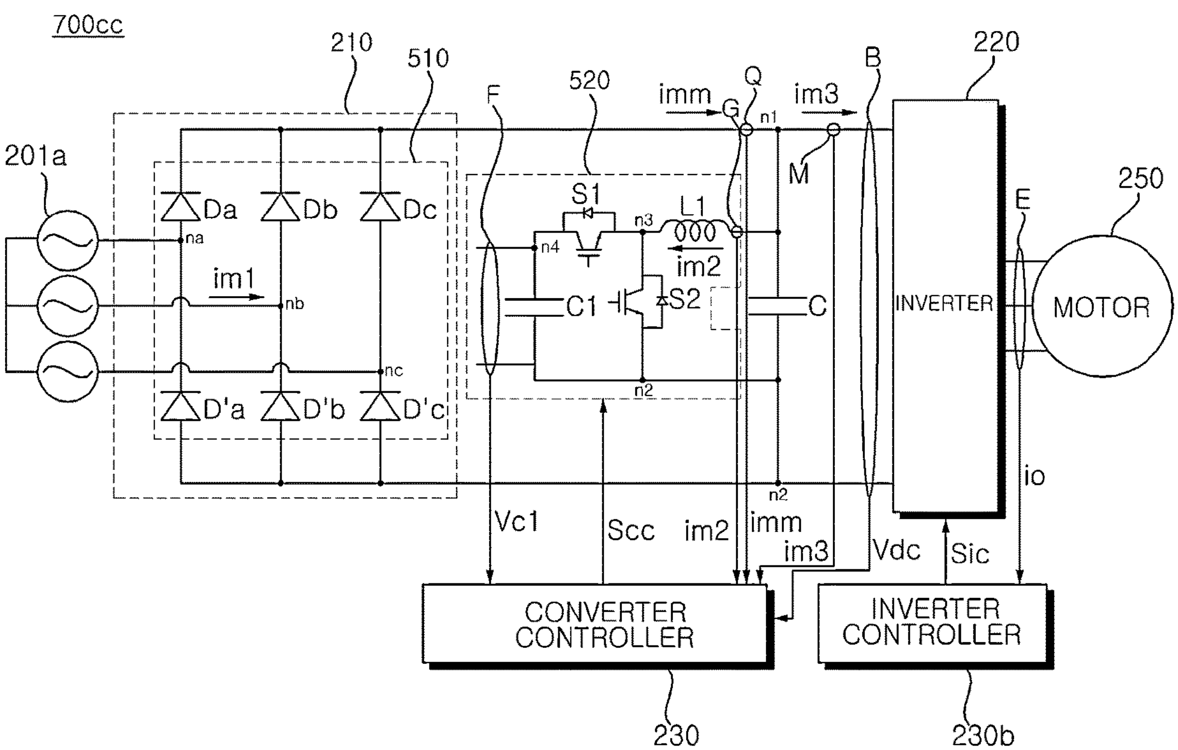

1630
HRM PCB
15V
DC Link
1640
FAN PCB
DC Link
TEe TEf
Fan
FMa
Fan
FMb
1605
201
R
S
T
FILTER PCB
220V
15V
DC Link
INVERTER PCB
TEc TEd
1620
Motor
250
MAIN PCB
220V
15V
CBa
CBb
TEa
TEb
1615
1610

FIG. 19



700cb
210
510
520
201a
Da
Db
Dc
na
im1
nb
nc
D'a
D'b
D'c
F
S1
n4
n3
L1
im2
C1
S2
n2
G
n1
im3
M
C
B
220
INVERTER
E
250
MOTOR
n2
io
Vc1
Scc
im2
Vdc
Sic
CONVERTER CONTROLLER
INVERTER CONTROLLER
230
230b

FIG. 20


700cc
210
510
520
F
imm
Q
G
n1
im3
B
220
201a
M
250
S1
n3
L1
Da
Db
Dc
n4
E
na
im2
im1
nb
C1
S2
C
INVERTER
MOTOR
nc
D'a
D'b
D'c
n2
n2
io
Vc1
Scc
im2
imm
im3
Vdc
Sic
CONVERTER CONTROLLER
INVERTER CONTROLLER
230
230b

MOTOR DRIVING APPARATUS AND AIR CONDITIONER INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Korean Patent Application No. 10-2024-0019550 filed in the Republic of Korea, on Feb. 8, 2024, the entirety of which is hereby incorporated by reference into the present application for all purposes as if fully set forth herein.

BACKGROUND

1. Field

[0002] The present disclosure relates to a motor driving apparatus and an air conditioner including the same, and more particularly to a motor driving apparatus capable of reducing a harmonic of an input current based on a three-phase AC voltage, and an air conditioner including the same.

2. Description of the Related Art

[0003] An air conditioner is an apparatus for discharging cool or hot air into a room to adjust room temperature and to purify air in the room, thereby providing a comfortable room environment to users. Generally, the air conditioner includes an indoor device installed in a room and including a heat exchanger, and an outdoor device including a compressor, a heat exchanger, etc., and configured to supply refrigerant to the indoor device.

[0004] Meanwhile, a compressor motor driving device is used to drive a compressor of an air conditioner.

[0005] The compressor motor driving device converts an input AC voltage into a DC voltage, stores the converted AC voltage based on a capacitor, and operates an inverter based on the DC voltage stored in the capacitor to drive the compressor motor.

[0006] Recently, a film capacitor is widely used, rather than an electrolytic capacitor, such that the capacitor provided in the compressor motor driving device can be manufactured in a compact size.

[0007] However, compared to the electrolytic capacitor, the film capacitor has a low capacitance, such that the ripple of the voltage stored in the capacitor becomes larger, and harmonic components of the input AC voltage increase.

[0008] According to the International Standard for surge protection IEC 61000 Mar. 12 that specifies limits for harmonics, it is required to meet requirements for Total Harmonic Distortion (THD) and Partial Weighted Harmonic Distortion (PWHD).

[0009] Korean Patent No. 10-1905480, which is a related art, discloses a motor driving apparatus and an air conditioner including the same, in which a harmonic reducer for reducing harmonics is included.

[0010] However, the related art has a problem in that only the 14th and higher harmonics are compensated such that harmonic components of orders 5, 7, 11, 13, and the like are not compensated, thereby causing distortion of harmonics in a current flowing through the inverter.

[0011] Thus, a need exist for a motor driving apparatus and an air conditioner including the same that is capable of reducing harmonic components of an input current. Also, there is a need for a motor driving apparatus having a configuration including a film capacitor, which can dynamically respond to changing harmonic components.

SUMMARY OF THE DISCLOSURE

[0012] It is an objective of the present disclosure to provide a motor driving apparatus capable of reducing a harmonic of an input current based on a three-phase AC voltage, and an air conditioner including the same.

[0013] It is another objective of the present disclosure to provide a motor driving apparatus capable of efficiently reducing a specific order harmonic of an input current based on a three-phase AC voltage, and an air conditioner including the same.

[0014] It is yet another objective of the present disclosure to provide a motor driving apparatus capable of reducing harmonic distortion in a current flowing through an inverter, and an air conditioner including the same.

[0015] It is further another objective of the present disclosure to provide a motor driving apparatus capable of reducing a harmonic without detecting an input current when a three-phase AC voltage is input.

[0016] In accordance with an aspect of the present disclosure, the above and other objectives can be accomplished by providing a motor driving apparatus and an air conditioner including the same, which include a rectifier configured to rectify a three-phase alternating current (AC) voltage, a capacitor configured to store a pulsating voltage from the rectifier, a harmonic reducer disposed between the rectifier and the capacitor and including at least one switching element, and configured to reduce a harmonic of the three-phase AC voltage, and an inverter including a plurality of switching elements, and configured to output a converted AC voltage to a motor based on a voltage of both ends of the capacitor, in which the harmonic reducer is turned on or turned off based on output power of the inverter.

[0017] Meanwhile, the harmonic reducer can be turned off based on increase and then decrease of the output power of the inverter, and can be turned on based on decrease and then increase of the output power of the inverter.

[0018] Meanwhile, the harmonic reducer can be turned on based on increase of the output power of the inverter.

[0019] Meanwhile, the harmonic reducer can be turned on during a first period of time based on increase of the output power of the inverter, the harmonic reducer can be turned off during a second period of time based on increase and then decrease of the output power of the inverter, and the harmonic reducer can be turned on during a third period of time based on decrease and then increase of the output power of the inverter.

[0020] Meanwhile, the pulsating voltage stored in the capacitor can be lower when the harmonic reducer is turned off than turned on.

[0021] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a voltage detector configured to detect the pulsating voltage stored in the capacitor, and a controller configured to control operation of the harmonic reducer, in which based on a 6th or 12th harmonic component of the pulsating voltage, the controller can be configured to control a switching operation of the switching element in the harmonic reducer.

[0022] Meanwhile, the controller can be configured to generate a current reference based on the 6th or 12th harmonic component of the pulsating voltage, and to control operation of the harmonic reducer based on the generated current reference.

[0023] Meanwhile, the controller can be configured to increase a turn-on duty of the switching element in the harmonic reducer as the 6th or 12th harmonic component of the pulsating voltage increases.

[0024] Meanwhile, the controller can include a first filter configured to filter a DC component of the pulsating voltage, and a second filter configured to filter the 6th or 12th harmonic component of the pulsating voltage.

[0025] Meanwhile, the controller can include a first filter configured to filter a DC component of the pulsating voltage, a second filter configured to filter the 6th or 12th harmonic component of the pulsating voltage, and a third filter configured to filter a 40th or lower harmonic component of the pulsating voltage.

[0026] Meanwhile, the harmonic reducer can include an inductor, a first switching element, and a second capacitor which are connected between both ends of the capacitor, and a second switching element connected to a first node between the inductor and the first switching element and a second node between the second capacitor and the capacitor.

[0027] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a voltage detector configured to detect the pulsating voltage stored in the capacitor, and a controller configured to control operation of the harmonic reducer, in which the controller can be configured to extract a 40th or lower harmonic component of the pulsating voltage, and to control the harmonic reducer based on the extracted harmonic voltage.

[0028] Meanwhile, the controller can include a current reference generator configured to extract a 40th or lower harmonic component of the pulsating voltage, a power reference generator configured to generate a power reference value based on the 40th or lower harmonic component, and a voltage reference generator configured to generate a compensation voltage reference value based on the generated power reference value, in which an operation of the first switching element or the second switching element in the harmonic reducer can be controlled based on the compensation voltage reference value.

[0029] Meanwhile, the capacitor can include a film capacitor.

[0030] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a voltage detector configured to detect the pulsating voltage stored in the capacitor, a controller configured to control operation of the harmonic reducer, and an inverter controller configured to control the inverter.

[0031] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a first voltage detector configured to detect the pulsating voltage stored in the capacitor, a current detector configured to detect a current flowing in the harmonic reducer, a second voltage detector configured to detect a voltage of both ends of the second capacitor in the harmonic reducer, and a controller configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, and the voltage detected by the second voltage detector.

[0032] Meanwhile, the harmonic reducer, the current detector, the first voltage detector, the second voltage detector, and the controller can be placed on a first circuit board, and the inverter can be placed on a second circuit board spaced apart from the first circuit board.

[0033] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a second current detector configured to detect a second current flowing between the capacitor and the inverter, in which the controller can be configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, the voltage detected by the second voltage detector, and the second current detected by the second current detector.

[0034] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a third current detector configured to detect a third current flowing between the rectifier and the capacitor, in which the controller can be configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, the voltage detected by the second voltage detector, and the third current detected by the third current detector.

[0035] A motor driving apparatus and an air conditioner including the same according to another embodiment of the present disclosure includes a rectifier configured to rectify a three-phase alternating current (AC) voltage, a capacitor configured to store a pulsating voltage from the rectifier, a harmonic reducer disposed between the rectifier and the capacitor and including at least one switching element, and configured to reduce a harmonic of the three-phase AC voltage, an inverter including a plurality of switching elements, and configured to output a converted AC voltage to a motor based on a voltage of both ends of the capacitor, a voltage detector configured to detect the pulsating voltage stored in the capacitor, and a controller configured to control operation of the harmonic reducer, in which based on a 6th or 12th harmonic component of the pulsating voltage, the controller is configured to control a switching operation of the switching element in the harmonic reducer.

[0036] Meanwhile, the controller can be configured to increase a turn-on duty of the switching element in the harmonic reducer as the 6th or 12th harmonic component of the pulsating voltage increases.

[0037] Meanwhile, the controller can include a first filter configured to filter a DC component of the pulsating voltage, and a second filter configured to filter the 6th or 12th harmonic component of the pulsating voltage.

[0038] Meanwhile, the harmonic reducer can include an inductor, a first switching element, and a second capacitor which are connected between both ends of the capacitor, and a second switching element connected to a first node between the inductor and the first switching element and a second node between the second capacitor and the capacitor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] The above and other objects, features and other advantages of the present disclosure will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0040] FIG. **1** is a view showing the construction of an air conditioner according to an embodiment of the present disclosure;

[0041] FIG. **2** is a schematic view showing an outdoor device and an indoor device of FIG. **1** according to an embodiment of the present disclosure;

[0042] FIG. **3** is an example block diagram illustrating a motor driving apparatus for driving a compressor in an outdoor device of FIG. **1** according to an embodiment of the present disclosure;

[0043] FIG. **4** is an example internal block diagram illustrating the controller of FIG. **3** according to an embodiment of the present disclosure;

[0044] FIG. **5** is a diagram illustrating an example of a motor driving apparatus according to an embodiment of the present disclosure;

[0045] FIGS. **6**A to **6**D are diagrams referred to in the description of the motor driving apparatus of FIG. **3** according to an embodiment of the present disclosure;

[0046] FIG. **7** is an example circuit diagram illustrating a motor driving apparatus according to an embodiment of the present disclosure;

[0047] FIGS. **8** to **15** are diagrams referred to in the description of FIG. **7** according to embodiments of the present disclosure;

[0048] FIG. **16** is an example circuit diagram illustrating a motor driving apparatus according to another embodiment of the present disclosure;

[0049] FIG. **17** is an example circuit diagram illustrating a motor driving apparatus according to yet another embodiment of the present disclosure;

[0050] FIG. **18** is a diagram referred to in the description of FIG. **17** according to an embodiment of the present disclosure;

[0051] FIG. **19** is an example circuit diagram illustrating a motor driving apparatus according to yet another embodiment of the present disclosure; and

[0052] FIG. **20** is an example circuit diagram illustrating a motor driving apparatus according to yet another embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0053] Example embodiments of the present invention will be described with reference to the accompanying drawings.

[0054] The terms "module" and "unit," when attached to the names of components are used herein to help the understanding of the components and thus they should not be considered as having specific meanings or roles. Accordingly, the terms "module" and "unit" can be used interchangeably.

[0055] The features of various embodiments of the present disclosure can be partially or entirely coupled to or combined with each other and can be interlocked and operated in technically various ways, and the embodiments can be carried out independently of or in association with each other. Also, the term "can" used herein includes all meanings and definitions of the term "may."

[0056] FIG. **1** is a view showing the construction of an air conditioner according to an embodiment of the present disclosure.

[0057] As illustrated in FIG. **1**, the air conditioner according to the embodiment of the present disclosure is a large-sized air conditioner **50**, and can include a plurality of indoor devices **31** to **35**, a plurality of outdoor devices **21** and **22** connected to the plurality of indoor devices **31** to **35**, a plurality of remote controls **41** to **45** connected to the respective indoor devices, and a remote controller **10** for controlling the plurality of indoor devices and outdoor devices.

[0058] The remote controller **10** can be connected to the plurality of indoor devices **31** to **36** and the plurality of outdoor devices **21** and **22** to monitor and control operations thereof. In this situation, the remote controller **10** can be connected to the plurality of indoor devices to perform operation setting, locking setting, schedule control, group control, and the like.

[0059] Any one of a stand type air conditioner, a wall mount type air conditioner, and a ceiling type air conditioner can be used as the air conditioner, but a ceiling type air conditioner will be described below by way of example, for the convenience of description. In addition, the air conditioner can further include at least one of a ventilator, an air purifier, a humidifier, and a heater, which can be operated in response to the operations of the indoor devices and the outdoor devices.

[0060] The outdoor devices **21** and **22** can include a compressor for receiving and compressing a refrigerant, an outdoor heat exchanger for heat exchange between the refrigerant and outside air, an accumulator for extracting a gaseous refrigerant from the received refrigerant and supplying the refrigerant to the compressor, and a four-way valve for selecting a refrigerant passage for a heating operation. In addition, the outdoor devices **21** and **22** can further include a plurality of sensors, valves, an oil recovery device, etc., but a description thereof will be omitted below.

[0061] The outdoor devices **21** and **22** operate the compressor and the outdoor heat exchanger included therein, to compress or heat exchange the refrigerant according to a setting, and supply the refrigerant to the indoor devices **31** to **35**. The outdoor devices **21** and **22** are driven by a request from the remote controller **10** or the indoor devices **31** to **35**, and a cooling/heating capacity changes according to the driven outdoor devices, such that a number of operating outdoor devices and a number of operating compressors installed in the outdoor devices can change.

[0062] In this situation, the following description will be made based on an example in which the plurality of outdoor devices **21** and **22** respectively supply the refrigerant to each of the indoor devices connected thereto, but depending on a connection structure of the outdoor devices and the indoor devices, the plurality of outdoor devices can be connected to each other to supply the refrigerant to the plurality of indoor devices.

[0063] The indoor devices **31** to **35** can be connected to any one of the plurality of outdoor devices **21** and **22**, to be supplied with the refrigerant and to discharge cool or hot air into a room. The indoor devices **31** to **35** include an indoor heat exchanger, an indoor fan, an expansion valve in which the supplied refrigerant is expanded, and a plurality of sensors.

[0064] In this situation, the outdoor devices **21** and **22** and the indoor devices **31** to **35** can be connected to each other via a communication line to transmit and receive data therebetween, and the outdoor devices **21** and **22** and the indoor devices **31** to **35** can be connected to the remote controller **10** via another communication line to operate under the control of the remote controller **10**.

[0065] The remote controls **41** to **45**, which are connected to the respective indoor devices, can transmit a user's control command to the indoor devices, and can receive and display information about the state of the indoor devices. In this situation, the remote controls communicate by wire or wirelessly with the indoor devices depending on the manner in which the input devices are connected to the indoor devices, and in some situations a single remote control can be connected to the plurality of indoor devices such that settings of the plurality of indoor devices can be changed by the input of the single remote control.

[0066] In addition, each of the remote controls **41** to **45** can include a temperature sensor provided therein.

[0067] FIG. **2** is a schematic view showing an outdoor device and an indoor device of FIG. **1** according to an embodiment of the present disclosure.

[0068] Referring to the drawing, the air conditioner is basically divided into an indoor device **31** and an outdoor device **21**.

[0069] The outdoor device **21** includes a compressor **102** for compressing refrigerant, a compressor motor **102***b* for driving the compressor, an outdoor heat exchanger **104** for cooling the compressed refrigerant, an outdoor blower **105** including an outdoor fan **105***a* disposed at one side of the outdoor heat exchanger **104** for accelerating the cooling of the refrigerant and a motor **105***b* for rotating the outdoor fan **105***a*, an expansion device **106** for expanding the condensed refrigerant, a cooling/heating switch valve **110** for changing the path of the compressed refrigerant, and an accumulator **103** for temporarily storing the gaseous refrigerant, removing moisture and foreign matter from the refrigerant, and supplying the refrigerant to the compressor under a predetermined pressure.

[0070] An indoor device **31** includes an indoor heat exchanger **109** disposed in a room for performing cooling/heating and an indoor blower **109** including an indoor fan **109***a* disposed at one side of the indoor heat exchanger **109** for accelerating the cooling of the refrigerant and a motor **109***b* for rotating the indoor fan **109***a*.

[0071] At least one indoor heat exchanger **109** can be installed. An inverter compressor or a fixed speed compressor can be used as the compressor **102**.

[0072] In addition, the air conditioner can be configured as a cooler for cooling a room or as a heat pump for cooling or heating a room.

[0073] A single indoor device **31** and a single outdoor device **21** are shown in FIG. **2**. However, the present disclosure is not limited thereto. The present disclosure can also be applied to a multi-type air conditioner including a plurality of indoor devices and a plurality of outdoor devices or an air conditioner including a single indoor device and a plurality of outdoor devices.

[0074] The compressor **102** in the outdoor device **21** can be driven by a motor driving apparatus **200** for compressor driving, which drives a compressor motor **250** (e.g., see FIG. **3**).

[0075] FIG. **3** is an example block diagram illustrating a motor driving apparatus for driving a compressor in the outdoor device of FIG. **1** according to an embodiment of the present disclosure.

[0076] First, a motor driving apparatus **200** of FIG. **3** includes an inverter **220** configured to output a three-phase alternating current (AC) voltage to a compressor motor **250**, a converter **210** configured to supply a direct current (DC) voltage to the inverter **220**, and a controller **230** configured to control the converter **210** or the inverter **220**.

[0077] The motor driving apparatus **200** receives AC power from a power supply system and converts the received power and supplies the converted power to the compressor motor **250**. In this regard, the motor driving apparatus **200** can be referred to as a power conversion device or a compressor driving device.

[0078] Meanwhile, the motor driving apparatus according to an embodiment of the present disclosure employs a DC-DC capacitor C having a low capacitance of several tens of μF or less. For example, the low-capacitance DC-DC capacitor C can include a film capacitor, rather than an electrolytic capacitor.

[0079] When the low-capacitance capacitor C is used, the DC link voltage pulsates due to an increased variation thereof and, as such, little or no smoothing operation of the DC link capacitor is achieved.

[0080] The motor driving device, which includes a DC link capacitor having a low capacitance of several tens of μF or less, as described above, can be referred to as a "capacitorless motor driving device."

[0081] The following description will be given of the motor driving apparatus **200**, which includes the low-capacitance DC-DC capacitor C.

[0082] In this embodiment, the converter **210** that supplies DC power to the inverter **220** receives a three-phase AC voltage and converts the three-phase AC voltage into a DC voltage. To this end, the converter **210** can include a rectifier **510** (see FIG. **7**).

[0083] The rectifier **510** (see FIG. **7**) rectifies a three-phase AC voltage **201** input thereto, and outputs rectified power. If the three-phase AC voltage **201** is a three-phase AC voltage, the rectifier **510** can rectify and output the three-phase AC voltage.

[0084] Meanwhile, the converter **210** can also include a boost converter for boosting voltage, in consideration of a pulsating voltage of both ends of the DC link capacitor C.

[0085] The DC link capacitor C is connected to an output terminal of the converter **210**. The DC link capacitor C can store a pulsating voltage output from the converter **210**. The voltage output from the converter **210** is a DC voltage, such that the capacitor C can be referred to as a DC link capacitor.

[0086] An input voltage detector A can detect an input voltage Vs from the three-phase AC voltage **201**. For example, the input voltage detector A can be located upstream of the converter **210**.

[0087] For detection of voltage, the input voltage detector A can include a resistor, an operational amplifier (OP AMP), and the like. The detected input voltage Vs can be a pulse type discrete signal and can be applied to the controller **230**.

[0088] Meanwhile, a zero crossing point of the input voltage can also be detected by the input voltage detector A.

[0089] Next, the input current detector D can detect an input current Is from the input AC voltage **201**. Specifically, the input current detector D can be located upstream of the converter **210**.

[0090] For detection of current, the input current detector D can include a current sensor, a current transformer (CT), a shunt resistor, and the like. The detected input current Is can be a pulse type discrete signal and can be applied to the controller **230**.

[0091] The DC voltage detector B can detect a pulsating voltage Vdc across the DC link capacitor C. For detection of voltage, the DC voltage detector B can include a resistor, an operational amplifier (OP AMP), and the like. The detected voltage Vdc across the DC link capacitor C can be a pulse type discrete signal and can be applied to the controller **230**. An inverter switching control signal Sic can be generated based on the DC voltage Vdc across the DC link capacitor C.

[0092] The inverter **220** can include a plurality of inverter switching elements, and can convert a smoothed DC voltage Vdc into a three-phase AC voltage having a predetermined frequency according to on/off operations of the switching elements, and can output the three-phase AC voltage to the motor **250** which is a three-phase motor.

[0093] Specifically, the inverter **220** includes a plurality of switching elements. For example, in the inverter **220**, upper arm switching elements Sa, Sb, and Sc and lower arm switching element S'a, S'b, and S'c which are connected in series with each other form a pair, and a total of three pairs of upper and lower arm switching elements Sa&S'a, Sb&S'b, and Sc&S'c are connected in parallel with each other. In addition, diodes can be connected in anti-parallel to the respective switching elements Sa, S'a, Sb, S'b, Sc, and S'c.

[0094] The controller **230** can output an inverter switching control signal Sic to the inverter **220** in order to control a switching operation of the inverter **220**. The inverter switching control signal Sic is a pulse width modulated (PWM) switching control signal. The inverter switching control signal Sic can be generated based on an output current io flowing through the motor **250** or a DC link voltage Vdc across the DC link capacitor C, and the generated switching control signal Sic can be output. In this situation, the output current io can be detected by an output current detector E, and the DC link voltage Vdc can be detected by the DC link voltage detector B.

[0095] The output current detector E can detect the output current io flowing between the inverter **220** and the motor **250**. That is, the output current detector E detects a current flowing through the motor **250**. The output current detector E can detect output currents of all phases, namely, output currents ia, ib, and ic. Alternatively, the output current detector E can detect output currents of two phases through balance among three phases.

[0096] The output current detector E can be disposed between the inverter **220** and the motor **250**. For current detection, a current transformer (CT), a shunt resistor, etc. can be used as the output current detector E.

[0097] FIG. **4** is an example internal block diagram illustrating the controller of FIG. **3** according to an embodiment of the present disclosure.

[0098] Referring to FIG. **4**, the controller **430** can include an axis converter **310**, a speed calculator **320**, a current reference generator **330**, a voltage reference generator **340**, an axis converter **350**, and a switching control signal output portion **360**.

[0099] The axis converter **310** receives the three-phase output currents ia, ib, and ic detected by the output current detector E and transforms the received output currents ia, ib, and ic into two-phase currents $i\alpha$ and $i\beta$ of a stationary coordinate system.

[0100] Meanwhile, the axis converter **310** can transform the two-phase currents $i\alpha$ and $i\beta$ of the stationary coordinate system into two-phase currents id and iq of a rotating coordinate system.

[0101] The speed calculator **320** estimates a position $\hat{\theta}_r$ of a rotor of the motor **250** based on the two-phase currents $i\alpha$ and $i\beta$ of a stationary coordinate system which is transformed by the axis converter **310**. In addition, the speed calculator **320** can output a calculated speed $\hat{\Omega}_r$ based on the estimated position $\hat{\theta}_r$ of the rotor of the motor **250**.

[0102] Meanwhile, the current reference generator **330** calculates a speed reference value Ω*r based on the calculated speed $\hat{\Omega}_r$ and a target speed Ω, and generates a current reference value i*q based on the speed reference value Ω*r. For example, a PI controller **435** of the current reference generator **330** can perform PI control based on the speed reference value Ω*r which is a difference between the calculated speed $\hat{\Omega}_r$ and the target speed Ω, and can generate a current reference value i*q. A q-axis current reference value i*q is shown as the current reference value, but unlike the drawing, a d-axis current reference value i*d can also be generated together with the q-axis current reference value i*q. Meanwhile, the d-axis current reference value i*d can be set to 0.

[0103] Meanwhile, the current reference generator **330** can further include a limiter for limiting the level of the current reference value i*q such that the current reference value i*q does not exceed an allowable range.

[0104] Then, the voltage reference generator **340** generates d-axis and q-axis voltage reference values V*d and V*q based on d-axis and q-axis currents id and iq which are transformed by the axis converter into currents in a two-phase rotating coordinate system and the current reference values i*d and i*q generated by the current reference generator **330** and the like. For example, a PI controller **344** of the voltage reference generator **340** can perform PI control based on the difference between the q-axis current iq and the q-axis current reference value i*q to generate a q-axis voltage reference value V*q. In addition, a PI controller **348** of the voltage reference generator **340** can perform PI control based on the difference between the d-axis current id and the d-axis current reference value i*d to generate a d-axis voltage reference value V*d. Meanwhile, the d-axis voltage reference value V*d can be set to 0 corresponding to the situation where the d-axis current reference value i*d is set to 0.

[0105] Meanwhile, the voltage reference generator **340** can further include a limiter for limiting levels of the d-axis and q-axis voltage reference values V*d and V*q so that the d-axis and q-axis voltage reference values V*d and V*q do not exceed allowable ranges.

[0106] Meanwhile, the generated d-axis and q-axis voltage reference values V*d and V*q are input to the axis converter **350**.

[0107] The axis converter **350** receives the calculated position $\hat{\theta}$ and the d-axis and q-axis voltage reference values V*d and V*q from the position estimator **320** to perform axis transformation.

[0108] First, the axis converter **350** performs transformation from a two-phase rotating coordinate system to a two-phase stationary coordinate system. At this time, the position $\hat{\theta}_r$ calculated by the position estimator **320** can be used.

[0109] Subsequently, the axis converter **350** performs transformation from the two-phase stationary coordinate system to a three-phase stationary coordinate system. As a result, the axis converter **350** outputs three-phase output voltage reference values V*a, V*b, and V*c.

[0110] The switching control signal output portion **360** generates and outputs a PWM-based inverter switching control signal Sic based on the three-phase output voltage reference values V*a, V*b, and V*c.

[0111] The output inverter switching control signal Sic can be converted into a gate driving signal by a gate driver and can then be input to a gate of each switching element of the inverter **220**. As a result, the respective switching elements Sa, S'a, Sb, S'b, Sc, and S'c of the inverter **220** perform switching operations.

[0112] FIG. **5** is a diagram illustrating an example of a motor driving apparatus according to an embodiment of the present disclosure.

[0113] Referring to the drawing, a motor driving apparatus **92** of FIG. **5** can include a rectifier **98** configured to rectify a three-phase alternating current (AC) voltage, a reactor Lx for reducing harmonics, a capacitor Cx, and an inverter **220***x* connected between both ends of the capacitor Cx, and configured to output an AC voltage to a motor **250***x* based on a voltage of both ends of the capacitor Cx.

[0114] According to the International Standard for surge protection IEC **61000** that specifies limits for reducing harmonics, the motor driving apparatus **92** of FIG. **5** includes the reactor Lx for reducing harmonics.

[0115] Particularly, in order to reduce a harmonic of an input current, the motor driving apparatus **92** of FIG. **5** can adopt a method of controlling the inverter **220***x* by detecting a voltage applied to the reactor Lx.

[0116] However, the method has a drawback in that harmonics in the inverter **220***x* increase, and it adds a dc reactor Lx, thereby increasing production costs.

[0117] In order to solve the above problem, the present disclosure proposes a scheme for efficiently reducing the output harmonics of the inverter, which will be described below with reference to FIG. **7** and subsequent figures.

[0118] FIGS. **6**A to **6**D are diagrams referred to in the description of the motor driving apparatus of FIG. **3** according to embodiments of the present disclosure.

[0119] First, FIG. **6**A illustrates a DC link voltage Vdc generated when a low-capacitance DC link capacitor C is connected to a rectifier without using a boost converter in the converter **210**.

[0120] As illustrated herein, when the low-capacitance DC link capacitor C is used, the DC link voltage Vdc cannot be smoothed by the low-capacitance DC link capacitor C and, as such, is directly applied in a pulsating state to the inverter **220**.

[0121] In this situation, the pulsating DC link voltage Vdc has an average voltage level of about 0.7VL**1** which is lower than a peak voltage level VL**1**.

[0122] The inverter **220** can generate a 3-phase AC voltage using a voltage of about 0.7 VL**1**. However, it is difficult to achieve smooth motor driving at a voltage level lower than about 0.7 VL**1**. For this reason, voltage usage rate becomes low.

[0123] Meanwhile, when an input voltage has a frequency of about 60 Hz, voltage ripple of about 120 Hz corresponding to twice the frequency of the input voltage can be generated.

[0124] Meanwhile, in the situation where the motor **250** is driven through the inverter **220** using the pulsating voltage as illustrated in FIG. **6**A, torque ripple corresponding to ΔT**1** is generated as illustrated in FIG. **6**B. Such torque ripple causes vibration and noise.

[0125] Meanwhile, if capacitance of the low-capacitance DC link capacitor C decreases, a current thereof is not controlled such that low input power factor characteristics can be exhibited.

[0126] In order to solve the above problem, a three-phase input voltage is used as an input voltage in the present disclosure. By using an input voltage with 3-phase which is higher than single-phase, an actual voltage usage rate can increase.

[0127] Alternatively, in order to solve the above problem, the boost converter can be arranged downstream of the rectifier in the converter **210**.

[0128] FIG. **6**C, including parts (a) and (b), illustrates a DC link voltage Vdc generated using a boost converter and a low-capacitance DC link capacitor C.

[0129] When the DC link voltage Vdc is stepped up by a voltage VL**2** using the boost converter, a pulsating voltage having a minimum voltage level of VL**2** and a peak voltage level of VL**2**+VL**1** is output to a DC link. In this situation, the DC link voltage Vdc has an average voltage level of about VL**1**.

[0130] While the inverter **220** can generate a three-phase AC voltage using a voltage of about VL**1**, it is possible to smoothly drive the motor in a large portion of the overall voltage period. Accordingly, a voltage usage rate increases, and an operation range of the motor increases.

[0131] Meanwhile, when the motor **250** is driven through the inverter **220** based on a DC link voltage Vdc generated using the boost converter and the low-capacitance DC link capacitor C as illustrated in FIG. **6**C, torque ripple corresponding to ΔT**2** can be generated. That is, torque ripple corresponding to ΔT**2** smaller than torque ripple corresponding to ΔT**1** of FIG. **6**A can be generated as illustrated in FIG. **6**D. That is, the torque ripple is significantly reduced in this situation.

[0132] Meanwhile, by using the boost converter, input current Is can be controlled, thereby improving input power factor.

[0133] FIG. **7** is an example circuit diagram illustrating a motor driving apparatus according to an embodiment of the present disclosure, and FIGS. **8**A to **15** are diagrams referred to in the description of FIG. **7**.

[0134] A motor driving apparatus **700** according to an embodiment of the present disclosure includes a rectifier **510** configured to rectify a three-phase alternating current (AC) voltage **201**, a DC link capacitor C configured to store a pulsating voltage Vdc from the rectifier **510**, a harmonic reducer **520** disposed between the rectifier **510** and the DC link capacitor C and including at least one switching element, and configured to reduce a harmonic of the three-phase AC voltage **201**, and an inverter **220** having a plurality of switching elements and configured to output a converted AC voltage to a motor based on a voltage of both ends of the DC link capacitor C.

[0135] Meanwhile, when the voltage of both ends of the DC link capacitor C pulsates due to low capacitance of the DC link capacitor C, the output harmonics of the inverter **220** can be efficiently reduced based on the harmonic reducer **520**.

[0136] Meanwhile, the harmonic reducer **520** is selectively turned on or off based on output power GRb of the inverter **220**. In other words, the harmonic reducer **520** can be dynamically activated or deactivated based on the output power of the inverter **220** to better reduce harmonics.

Accordingly, harmonics of an input current based on the three-phase AC voltage can be reduced.

[0137] Meanwhile, the motor driving apparatus **700** according to an embodiment of the present disclosure further includes a DC link voltage detector B configured to detect the pulsating voltage Vdc stored in the DC link capacitor C, and a controller **230** configured to control operation of the harmonic reducer **520**.

[0138] Meanwhile, the controller **230** can control a switching operation of the switching elements S**1** and S**2** in the harmonic reducer **520** based on a 6th or 12th harmonic component of the pulsating voltage Vdc. Accordingly, harmonics with a specific wavenumber of the input three-phase AC voltage **201** can be efficiently reduced. Further, harmonics of a current flowing through the inverter can be reduced.

[0139] Meanwhile, the controller **230** can generate a current reference based on the 6th or 12th harmonic component of the pulsating voltage Vdc, and can control operation of the harmonic reducer **520** based on the generated current reference. Accordingly, harmonics with a specific wavenumber of the input three-phase AC voltage **201** can be efficiently reduced.

[0140] Meanwhile, the controller **230** can control a turn-on duty of the switching elements S**1** and S**2** in the harmonic reducer **520** to increase as the 6th or 12th harmonic component of the pulsating voltage Vdc increases. Accordingly, harmonics with a specific wavenumber of the input three-phase AC voltage **201** can be efficiently reduced.

[0141] In the drawing, an example is illustrated in which the rectifier **510** includes full-bridge diodes Da, D'a, Db, D'b, Dc, and D'c for rectifying the three-phase AC voltage.

[0142] That is, a first pair of diodes Da and D'a are connected in series to each other, a second pair of diodes Db and D'b are connected in series to each other, and a third pair of diodes Dc and D'c are connected in series to each other, between nodes n**1** and n**2** which are both ends of the DC link.

[0143] Meanwhile, an R-phase AC voltage among three phases is applied to node na between the first pair of diodes Da and D'a, an S-phase AC voltage among three phases is applied to node nb between the second pair of diodes Db and D'b, and a T-phase AC voltage among three phases is applied to node nc between the third pair of diodes Dc and D'c.

[0144] In the drawing, an example is illustrated in which an input current im**1** flows to node nb by the applied S-phase AC voltage.

[0145] Meanwhile, the harmonic reducer **520** can reduce harmonics of the three-phase AC voltage.

[0146] Meanwhile, the harmonic reducer **520** can include an inductor L**1**, a first switching element S**1**, and a second capacitor C**1** which are connected across the DC-DC capacitor C, and a second switching element S**2** having one end connected between the inductor L**1** and the first switching element S**1** and another end connected between the second capacitor C**1** and the DC link capacitor C.

[0147] That is, the inductor L**1** and the second switching element S**2** can be connected across the DC link capacitor C in the harmonic reducer **520**, and the first switching element S**1** and the second capacitor C**1** can be connected across the second switching element S**2**.

[0148] Specifically, a first end of the inductor L**1** is connected to node nl which is one of both ends of the DC link capacitor C, and a first end of the first switching element S**1** is connected to node n**3** which is a second end of the inductor L**1**.

[0149] The second capacitor C**1** is connected between node n**4**, which is a second end of the first switching element S**1**, and node n**2** which is a second end of the DC link capacitor C.

[0150] The second switching element S**2** is connected between node n**3**, which is the second end of the inductor L**1**, and node n**2** which is the second end of the DC link capacitor C.

[0151] Meanwhile, the motor driving apparatus **700** according to an embodiment of the present disclosure can further include a voltage detector F configured to detect a voltage Vc**1** across the second capacitor C**1** in the harmonic reducer **520**, and a current detector G configured to detect a current im**2** flowing through the inductor L**1** in the harmonic reducer **520**.

[0152] Meanwhile, the motor driving apparatus **700** according to an embodiment of the present disclosure can further include an inverter current detector M configured to detect an inverter current im**3** flowing between the DC link capacitor C and the inverter **220**.

[0153] Meanwhile, the operation of the first switching element S**1** or the second switching element S**2** can be controlled by a switching control signal Scc from the controller **230**. For example, the first switching element S**1** and the second switching element S**2** can be selectively turned on or off based on the switching control signal Scc from the controller **230**.

[0154] According to the International Standard for surge protection IEC **61000** described above which specifies requirements for Total Harmonic Distortion (THD) (1st-40th) and Partial Weighted Harmonic Distortion (PWHD) (14th-40th), embodiments according to the present disclosure propose a scheme for reducing 40th and lower harmonics.

[0155] That is, embodiments according to the present disclosure propose a scheme for reducing harmonics to meet requirements for total Harmonic Distortion (THD) and Partial Weighted Harmonic Distortion (PWHD), which will be described in further detail with reference to FIG. **12**A or **12**B.

[0156] FIG. **8** is a diagram referred in the description of operation of a harmonic reducer based on the output power of an inverter according to an embodiment of the present disclosure.

[0157] Referring to FIG. **8**, part (a) of FIG. **8** illustrates an example of a pulsating voltage GRa of the DC link capacitor C, part (b) of FIG. **8** illustrates an example of output power GRb of the inverter **220**, part (c) of FIG. **8** illustrates an example of a turn-on signal GRc for the harmonic reducer **520**, and part (d) of FIG. **8** illustrates an example of a current GRd flowing through the inductor L**1** in the harmonic reducer **520**.

[0158] Referring to the drawing, the harmonic reducer **520** is turned on or off based on the output power GRb of the inverter **220**.

[0159] That is, the controller **230** can control the harmonic reducer **520** to be turned on or off based on the output power GRb of the inverter **220**.

[0160] For example, the controller **230** can calculate output power of the inverter **220** based on the pulsating voltage Vdc of the DC link capacitor C detected by the DC link voltage detector B, and can control the harmonic reducer **520** to be turned on or off based on the output power of the inverter **220**.

[0161] In another example, the controller **230** can calculate output power of the inverter **220** based on the pulsating voltage Vdc of the DC link capacitor C detected by the DC link voltage detector B, and the inverter current im**3** detected by the inverter current detector M, and can control the harmonic reducer **520** to be turned on or off based on the output power of the inverter **220**.

[0162] Meanwhile, the harmonic reducer **520** can be turned on based on the output power GRb of the inverter **220** that increases. In other words, when the output power GRb of the inverter **220** increases or ramps up for a certain period of time, the harmonic reducer **520** can be activated and turned on during this period.

[0163] For example, if the output power GRb of the inverter **220** increases from time Ta**1**, the controller **230** can control the harmonic reducer **520** to be turned on from time Ta**1** to time Ta**2**. Accordingly, the switching elements S**1** and S**2** in the harmonic reducer **520** can perform a switching operation.

[0164] Meanwhile, the harmonic reducer **520** can be turned off based on the output power GRb of the inverter **220** that increases and then decreases. In other words, when the when the output power GRb of the inverter **220** transitions from increasing to decreasing, then the harmonic reducer **520** can be de-activated and turned off during this period.

[0165] For example, if the output power GRb of the inverter **220** increases from time Ta**1** to time Tk, and then decreases from time Tk, the controller **230** can control the harmonic reducer **520** to be turned off from time Ta**2** to time Ta**3**. Accordingly, all the switching elements S**1** and S**2** in the harmonic reducer **520** can be turned off.

[0166] Meanwhile, the harmonic reducer **520** can be turned on based on the output power GRb of the inverter **220** that decreases and then increases. In other words, when the when the output power GRb of the inverter **220** transitions from decreasing to increasing, then the harmonic reducer **520** can be turned back on during this period.

[0167] For example, if the output power GRb of the inverter **220** decreases from time Tk to time Tm and then increases from time Tm, the controller **230** can control the harmonic reducer **520** to be turned on from time Ta**3** to time Ta**4**. Accordingly, the switching elements S**1** and S**2** in the harmonic reducer **520** can perform a switching operation.

[0168] Meanwhile, the controller **230** can control the harmonic reducer **520** to be turned off from time Ta**4** to time Ta**5** based on the output power GRb of the inverter **220** increasing and then decreasing from time To. Accordingly, all the switching elements S**1** and S**2** in the harmonic reducer **520** can be turned off.

[0169] Meanwhile, the controller **230** can control the harmonic reducer **520** to be turned on from time Ta**5** based on when the output power GRb of the inverter **220** decreases and then increases from time Tp. Accordingly, the switching elements S**1** and S**2** in the harmonic reducer **520** can perform a switching operation.

[0170] That is, the harmonic reducer **520** can be turned on during a first period from Ta**1** to Ta**2** based on the output power GRb of the inverter **220** that increases, can be turned off during a second period from Ta**2** to Ta**3** based on the output power GRb of the inverter **220** that increases and then decreases, and can be turned on during a third period from Ta**4** to Ta**5** based on the output power GRb of the inverter **220** that decreases and then increases. Accordingly, harmonic distortion of a current output to the inverter **220** can be reduced, while reducing harmonics of the input three-phase AC voltage **201**.

[0171] Meanwhile, the pulsating voltage Vdc stored in the capacitor C can be lower when the harmonic reducer **520** is turned off than when the harmonic reducer **520** is turned on.

[0172] In the drawing, an example is illustrated in which a level of the pulsating voltage Vdc is higher during a period from Ta**1** to Ta**2**, a period from Ta**3** to Ta**4**, and a period after Ta**5** when the harmonic reducer **520** is turned on, than a level of the pulsating voltage Vdc during a period from Ta**2** to Ta**3** and a period from Ta**4** and Ta**5** when the harmonic reducer **520** is turned off. Accordingly, it is possible to reduce a harmonic of an input current based on a three-phase AC voltage.

[0173] FIGS. **9**A to **9**D are diagrams illustrating various operations of the harmonic reducer **520** while being turned on according to an embodiment of the present disclosure.

[0174] FIG. **9**A illustrates an example in which a first switching element S**1** in the harmonic reducer **520** is turned off, and a second switching element S**2** is turned on, thereby forming a first current path (Ipath a) that flows through the inductor L**1** and the second switching element S**2**.

[0175] FIG. **9**B illustrates an example in which a first switching element S**1** in the harmonic reducer **520** is turned on, and a second switching element S**2** is turned off, thereby forming a second current path (Ipath b) that flows through the inductor L**1**, the first switching element S**1**, and a second capacitor C**1**.

[0176] FIG. **9**C illustrates an example in which a first switching element S**1** in the harmonic reducer **520** is turned on, and a second switching element S**2** is turned off, thereby forming a third current path (Ipath c) that flows through the first switching element S**1**, the inductor L**1**, and the DC link capacitor C.

[0177] FIG. **9**D illustrates an example in which a first switching element S**1** in the harmonic reducer **520** is turned off, and a second switching element S**2** is turned on, thereby forming a fourth current path (Ipath d) that flows through the inductor L**1** and the DC link capacitor C.

[0178] Meanwhile, according to the embodiments of FIGS. **9**A to **9**D, when the harmonic reducer **520** is turned on, the first switching element S**1** and the second switching element S**2** can operate in a mutually complementary manner.

[0179] That is, when the harmonic reducer **520** is turned on, one of the first switching element S**1** and the second switching element S**2** can be turned on, and the other can be turned off. For example, when the first switching element S**1** is on, the second switching element S**2** is off, and vice-versa.

[0180] FIG. **10**A illustrates a waveform of the input current im**1** that is input to the rectifier **510** of FIG. **7**. The input current im**1** can contain all harmonic components.

[0181] That is, the waveform of the input current im**1** of FIG. **10**A can be a waveform corresponding to turning off of the harmonic reducer **520**.

[0182] Then, FIG. **10**B illustrates a waveform of the current im**2** that flows in the inductor L**1** as the harmonic reducer **520** is turned on. The current im**2** flowing in the inductor L**1** can be a compensation current waveform for reducing 1st to 40th harmonics of harmonic components.

[0183] Next, FIG. **10**C illustrates a waveform of an input current imc**1** in which as the harmonic reducer **520** is turned on, a waveform of the input current im**1** of FIG. **10**A is compensated by the waveform of the current im**2** flowing in the inductor L**1**, such that 1st to 40th harmonics are reduced.

[0184] As described above, by reducing the harmonic of the input current based on a three-phase AC voltage, the control stability can be improved during operation of the motor driving apparatus.

[0185] FIG. **11** is an example internal block diagram illustrating the controller of FIG. **3** according to an embodiment of the present disclosure.

[0186] Referring to the drawing, the controller **230** can include an input current reference generator **720**, a power reference generator **730**, a converter **725** (e.g., transformation unit), and a voltage reference generator **740**.

[0187] The controller **230** can filter or extract a 40th or lower harmonic component of the pulsating voltage, and can control the harmonic reducer **520** based on the extracted harmonic current.

[0188] The input current reference generator **720** can extract a 40th or lower harmonic current I*s among input currents Is based on the three-phase AC voltage **201**.

[0189] The converter **725** can perform axis transformation on the three-phase AC voltage Vs based on a rotating coordinate system. The transformed three-phase AC voltage can be input to the power reference generator **730**.

[0190] The power reference generator **730** can include a multiplier for multiplying the 40th or lower harmonic current I*s, which are extracted by the input current reference generator **720**, and the three-phase AC voltage component output by the converter **725**.

[0191] Accordingly, the power reference generator **730** can generate a power reference value P* based on the 40th or lower harmonic current I*s.

[0192] The voltage reference generator **740** can generate a compensation voltage reference value V* based on the power reference value P*.

[0193] Particularly, the voltage reference generator **740** can generate the compensation voltage reference value V* based on the power reference value P* and the 40th or lower harmonic current I*s.

[0194] The controller **230** can control the first switching element S**1** or the second switching element S**2** in the harmonic reducer **520** to operate based on the compensation voltage reference value V*.

[0195] Alternatively, the controller **230** can control the upper arm switching elements Sa, Sb, and Sc and the lower arm switching elements S'a, S'b, and S'c to operate based on the compensation voltage reference value V*.

[0196] FIG. **12**A is an internal block diagram illustrating an example of the controller of FIG. **7** according to an embodiment of the present disclosure.

[0197] Referring to the drawing, a controller **230*a*1** can include a first filter **1204** (e.g., a low pass filter LPF) configured to filter a DC component of the pulsating voltage Vdc, and a second filter **1206** (e.g., a low pass filter LPF) configured to filter a 6th or 12th harmonic component of the pulsating voltage Vdc.

[0198] Meanwhile, the controller **230*a*1** can further include a compensation current generator **1220** configured to generate a compensation current based on a DC component or a fundamental (first-order) harmonic component of the pulsating voltage Vdc from the first filter **1204**, or based on a 6th or 12th harmonic component of the pulsating voltage Vdc.

[0199] For example, the compensation current generator **1220** can generate a compensation current of a 5th or 7th harmonic of an input current corresponding to the 6th harmonic of the pulsating voltage Vdc, or can generate a compensation current of a 11th or 13th harmonic of an input current corresponding to the 12th harmonic of the pulsating voltage Vdc.

[0200] Meanwhile, the controller **230*a*1** can further include a compensation current controller **1230** configured to control a compensation current based on the compensation current generated by the compensation current generator **1220**.

[0201] For example, the compensation current controller **1230** can control the operation of the switching elements S**1** and S**2** of the harmonic reducer **520** in the converter **210**.

[0202] Specifically, the compensation current controller **1230** can control a turn-on duty of the switching elements S**1** and S**2** in the harmonic reducer **520** to increase as the 6th or 12th harmonic component of the pulsating voltage Vdc increases. For example, when the 6th or 12th harmonic component of the pulsating voltage Vdc increases, then the duty cycle of the switching elements S**1** and S**2** in the harmonic reducer **520** can also be increased. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage.

[0203] FIG. **12**B is an internal block diagram illustrating another example of the controller of FIG. **7** according to an embodiment of the present disclosure.

[0204] Referring to the drawing, a controller **230*a*2** can include a first filter **1204** (e.g., a low pass filter LPF) configured to filter a DC component of the pulsating voltage Vdc, a second filter **1206** (e.g., a low pass filter LPF) configured to filter a 6th or 12th harmonic component of the pulsating voltage Vdc, and a third filter **1202** (e.g., a low pass filter LPF) configured to filter a 40th or lower harmonic component of the pulsating voltage Vdc.

[0205] Unlike the controller **230*a*1** of FIG. **12**A, the controller **230*a*2** can further include the third filter **1202**. Accordingly, it is possible to further compensate for the 40th or lower harmonic component of the pulsating voltage Vdc.

[0206] Meanwhile, the controller **230*a*2** can further include a compensation current generator **1220** configured to generate a compensation current based on a DC component or a fundamental (first-order) harmonic component of the pulsating voltage Vdc from the first filter **1204**, or based on a 6th or 12th harmonic component of the pulsating voltage Vdc.

[0207] Meanwhile, the compensation current generator **1220** can also generate a compensation current based on a DC component or a fundamental (first-order) harmonic component of the pulsating voltage Vdc from the first filter **1204**, and based on a 6th or 12th harmonic component of the pulsating voltage Vdc.

[0208] Meanwhile, the compensation current generator **1220** can further include a compensation current controller **1230** configured to control a compensation current based on the compensation current generated by the compensation current generator **1220**.

[0209] For example, the compensation current controller **1230** can control the operation of the switching elements S**1** and S**2** of the harmonic reducer **520** in the converter **210**.

[0210] FIG. 13A is a diagram illustrating an example of reducing harmonics based on the operation of the harmonic reducer 520 and the inverter 220.

[0211] Referring to the drawing, the controller 230 according to an embodiment of the present disclosure can output a switching control signal Scc to the harmonic reducer 520, and can output an inverter switching control signal Sic to the inverter 220.

[0212] Particularly, the controller 230 can control the harmonic reducer 520 to operate based on the switching control signal Scc to reduce a 40th or lower harmonic component and a 6th or 12th harmonic component of the pulsating voltage Vdc.

[0213] Meanwhile, the controller 230 can control the inverter 220 to operate based on the inverter switching control signal Sic to reduce a 40th or lower harmonic component.

[0214] FIG. 13B is a diagram illustrating an example of compensating for a 40th or lower harmonic of the pulsating voltage Vdc and compensating for a 6th harmonic of the pulsating voltage Vdc according to an embodiment of the present disclosure.

[0215] Referring to the drawing, the horizontal axis represents a harmonic order and the vertical axis represents a ratio of harmonic to fundamental.

[0216] That is, in the situation where the controller 230*a*2 compensates for the 40th and lower harmonics, it can be seen that harmonics from 10th to 40th order can be significantly reduced.

[0217] Meanwhile, in the situation where the controller 230*a*2 compensates for the 40th and lower harmonics, a substantial part of 10th and lower harmonic components still remain.

[0218] Thus, the controller 230*a*1 of FIG. 12A or the controller 230*a*2 of FIG. 12B can compensate for a 6th harmonic of the pulsating voltage Vdc.

[0219] Accordingly, it can be seen that by compensating for the 6th harmonic of the pulsating voltage Vdc, the 6th harmonic component can be significantly reduced.

[0220] Accordingly, a 5th or 7th harmonic of the input current corresponding to the 6th harmonic of the pulsating voltage Vdc can be significantly reduced.

[0221] Similarly, in the situation where the controller 230*a* of FIG. 12A or the controller 230*b* of FIG. 12B compensates for a 12th harmonic of the pulsating voltage Vdc, a 11th or 13th harmonic can be significantly reduced.

[0222] FIG. 14, including parts (a), (b) and (c), is a diagram referred to in the description of operation based on output power or load of an inverter according to an embodiment of the present disclosure.

[0223] Referring to the drawing, as illustrated in part (a) of FIG. 14, a level of the pulsating voltage Vdc stored in the DC link capacitor C increases as the output power or load of the inverter increases.

[0224] Accordingly, as illustrated in part (b) of FIG. 14, a harmonic of an input current based on the three-phase AC voltage 201 increases as the output power or load of the inverter increases.

[0225] Accordingly, the controller 230 according to an embodiment of the present disclosure can control a turn-on duty of the switching elements S1 and S2 in the harmonic reducer 520 to increase as the harmonic of the input current based on the three-phase AC voltage 201 increases as illustrated in part (c) of FIG. 14.

[0226] Particularly, the controller 230 can control a turn-on duty of the switching elements S1 and S2 in the harmonic reducer 520 to increase as a 6th or 12th harmonic component of the pulsating voltage Vdc increases. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage.

[0227] FIG. 15 is a diagram illustrating an example of the arrangement of circuit boards of a motor driving apparatus according to an embodiment of the present disclosure.

[0228] Referring to the drawing, the three-phase AC voltage 201 can pass through a filter circuit board 1605 on which a noise filter and the like are disposed, to be input to an inverter circuit board 1620 on which the inverter 220, the DC link voltage detector B, and the like are disposed.

[0229] Meanwhile, the inverter circuit board 1620 can further include the rectifier 510, the DC link capacitor C, and the like of FIG. 7.

[0230] Meanwhile, a main circuit board 1610 can include a voltage dropper 1615 configured to output a voltage of 15V based on a voltage of 220V (e.g., a step down operation), which is an example of a single-phase voltage, from the filter circuit board 1605 and the like.

[0231] Meanwhile, the main circuit board 1610 (e.g., MAIN PCB) can output voltages 15V, 220V, and the like to the inverter circuit board 1620.

[0232] Meanwhile, the main circuit board 1610 can communicate with the inverter circuit board 1620 (e.g., INVERTER PCB) and a fan circuit board 1640 (e.g., FAN PCB) through a plurality of communication terminals TEa and TEb.

[0233] Meanwhile, the inverter circuit board 1620 can drive the compressor motor 250, and the fan circuit board 1640 can drive fan motors FMa and FMb.

[0234] Meanwhile, the inverter circuit board 1620 can communicate with the main circuit board 1610 (e.g., MAIN PCB) through a plurality of communication terminals TEc and TEd.

[0235] Meanwhile, the inverter circuit board 1620 can communicate with a harmonic reduction circuit board 1630 (e.g., HRM PCB) through a plurality of communication terminals TE1 and TE2.

[0236] Meanwhile, the harmonic reduction circuit board 1630 can communicate with the inverter circuit board 1620 through a plurality of communication terminals TE3 and TE3.

[0237] Meanwhile, the harmonic reduction circuit board 1630 can include the harmonic reducer 520, the current detector G, the second voltage detector F, and the controller 230 of FIG. 7.

[0238] Meanwhile, the controller 230 can receive information about the pulsating voltage Vdc from the DC link voltage detector B through communication lines CBc and CBd between the inverter circuit board 1620 and the harmonic reduction circuit board 1630.

[0239] Meanwhile, the controller 230 can control the harmonic reducer 520 based on the pulsating voltage Vdc from the DC link voltage detector B.

[0240] Meanwhile, the controller 230 can receive information about the pulsating voltage Vdc from the DC link voltage detector B and information about the inverter current im3 from the inverter current detector M, through the communication lines CBc and CBd between the inverter circuit board 1620 and the harmonic reduction circuit board 1630.

[0241] Further, the controller **230** can control the harmonic reducer **520** based on the information about the pulsating voltage Vdc from the DC link voltage detector B and the information about the inverter current im3 from the inverter current detector M.

[0242] Specifically, the controller **230** can calculate the output power of the inverter **220** based on the information about the pulsating voltage Vdc from the DC link voltage detector B and the information about the inverter current im3 from the inverter current detector M, and can turn on or turn off the harmonic reducer **520** based on the output power of the inverter **220**. Accordingly, the harmonic of the input current based on the three-phase AC voltage can be reduced.

[0243] FIG. **16** is an example circuit diagram illustrating a motor driving apparatus according to another embodiment of the present disclosure.

[0244] Referring to the drawing, a motor driving apparatus **700***b* according to another embodiment of the present disclosure is similar to FIG. **7**, but is different in that the controller **230** of FIG. **7** is divided into two controllers (e.g., **230** and **230***b*).

[0245] That is, the motor driving apparatus **700***b* according to another embodiment of the present disclosure can include a controller **230** configured to control the harmonic reducer **520** and an inverter controller **230***b* configured to control the inverter **220**.

[0246] Accordingly, as illustrated in the internal block diagram of FIG. **4**, the inverter controller **230***b* can include the axis converter **310**, the speed calculator **320**, the current reference generator **330**, the voltage reference generator **340**, the axis converter **350**, and the switching control signal output portion **360**.

[0247] Meanwhile, the controller **230** of FIG. **16** can perform the operation of the controller described above with reference to FIGS. **8** to **14**.

[0248] Meanwhile, regarding FIG. **15**, the controller **230** configured to control the harmonic reducer **520** can be disposed on the harmonic reduction circuit board **1630**, and the inverter controller **230***b* can be disposed on the inverter circuit board **1620**.

[0249] Meanwhile, the controller **230** in the harmonic reduction circuit board **1630** can communicate with the inverter controller **230***b* in the inverter circuit board **1620** through the plurality of communication terminals TE**3** and TE**3**.

[0250] For example, the controller **230** in the harmonic reduction circuit board **1630** can receive information about the pulsating voltage Vdc from the inverter controller **230***b* in the inverter circuit board **1620** through the communication lines CBc and CBd.

[0251] Meanwhile, the controller **230** can control the harmonic reducer **520** based on the pulsating voltage Vdc from the DC link voltage detector B.

[0252] Meanwhile, the controller **230** in the harmonic reduction circuit board **1630** can receive the information about the pulsating voltage Vdc from the inverter controller **230***b* in the inverter circuit board **1620** and the information about the inverter current im**3** from the inverter current detector M, through communication lines CBc and CBd.

[0253] Further, the controller **230** can control the harmonic reducer **520** based on the information about the pulsating voltage Vdc from the DC link voltage detector B and the information about the inverter current im**3** from the inverter current detector M. Accordingly, the harmonic of the input current based on the three-phase AC voltage can be reduced.

[0254] FIG. **17** is an example circuit diagram illustrating a motor driving apparatus according to yet another embodiment of the present disclosure, and FIG. **18** is a diagram referred to in the description of FIG. **17**.

[0255] A motor driving apparatus **700***c* according to yet another embodiment of the present disclosure includes, a rectifier **510** configured to rectify a three-phase AC voltage **201**, a DC link capacitor C configured to store a pulsating voltage Vdc from the rectifier **510**, a first voltage detector B configured to detect the pulsating voltage Vdc stored in the DC link capacitor C, a harmonic reducer **520** disposed between the rectifier **510** and the DC link capacitor C and including at least one switching element and a second capacitor C**1**, and configured to reduce a harmonic of the three-phase AC voltage **201**, a current detector G configured to detect a current im**2** flowing in the harmonic reducer **520**, a second voltage detector F configured to detect a voltage Vc**1** across the second capacitor C**1** in the harmonic reducer **520**, and an inverter **220** having a plurality of switching elements and configured to output a converted AC voltage to a motor based on a voltage of both ends of the DC link capacitor C, and a controller **230** configured to control the harmonic reducer **520** based on the pulsating voltage Vdc from the first voltage detector B, the current im**2** detected by the current detector G, and the voltage detected by the second voltage detector F.

[0256] Meanwhile, when the voltage of both ends of the DC link capacitor C pulsates due to low capacitance of the DC link capacitor C, the output harmonic of the inverter **220** can be efficiently reduced based on the harmonic reducer **520**.

[0257] Particularly, the motor driving apparatus **700***c* according to yet another embodiment of the present disclosure can reduce the harmonic based on the three-phase AC voltage **201**, without including the input current detector configured to detect an input current when the three-phase AC voltage **201** is input. For example, input current detector A for sensing input current im**1** from FIG. **7** is not included in FIG. **17**, but FIG., **17** includes output current detector E for sensing the output current io.

[0258] In the drawing, an example is illustrated in which the rectifier **510** includes full-bridge diodes Da, D'a, Db, D'b, Dc, and D'c for rectifying the three-phase AC voltage.

[0259] Meanwhile, the harmonic reducer **520** can include the inductor L**1**, the first switching element S**1**, and the second capacitor C**1** which are connected across the DC-DC link capacitor C, and the second switching element S**2** connected between the second capacitor C**1** and the DC link capacitor C.

[0260] Meanwhile, the inverter controller **230***b* can control the switching elements in the inverter **220** based on an output current io from the output current detector E that flows between the inverter **220** and the motor **250**.

[0261] Particularly, the inverter controller **230***b* can output an inverter switching control signal Sic for controlling the switching elements in the inverter **220** based on the output current io from the output current detector E.

[0262] FIG. **18** is a diagram illustrating an example of the arrangement of circuit boards of a motor driving apparatus according to further another embodiment of the present disclosure.

[0263] Referring to the drawing, the three-phase AC voltage **201** can pass through a filter circuit board **1605** on which a noise filter and the like are disposed, to be input to an inverter circuit board **1620** on which the inverter **220** and the like are disposed.

[0264] Meanwhile, the inverter circuit board **1620** can further include the rectifier **510**, the DC link capacitor C, and the like of FIG. **17**.

[0265] Meanwhile, a main circuit board **1610** can include a voltage dropper **1615** configured to output a voltage of 15V based on a voltage of 220V (e.g., a step down operation), which is an example of a single-phase voltage, from the filter circuit board **1605** and the like.

[0266] Meanwhile, the main circuit board **1610** can output voltages 15V, 220V, and the like to the inverter circuit board **1620**.

[0267] Meanwhile, the main circuit board **1610** can communicate with the inverter circuit board **1620** and a fan circuit board **1640** through a plurality of communication terminals TEa and TEb.

[0268] Meanwhile, the inverter circuit board **1620** can drive the compressor motor **250**, and the fan circuit board **1640** can drive fan motors FMa and FMb.

[0269] Meanwhile, the inverter circuit board **1620** can communicate with the main circuit board **1610** through a plurality of communication terminals TEc and TEd.

[0270] A separate communication line may not be provided between the inverter circuit board **1620** and the harmonic reduction circuit board **1630**.

[0271] Accordingly, the harmonic reduction circuit board **1630** can be operated independently, thereby reducing production costs and the like.

[0272] Meanwhile, the harmonic reducer **520**, the current detector G, the first voltage detector B, the second voltage detector F, and the controller **230** can be placed on the first circuit board **1630**, and the inverter **220** can be placed on the second circuit board **1620** spaced apart from the first circuit board **1630**. Accordingly, as the inverter **220** and the harmonic reducer **520** are placed on separate circuit boards, the harmonic reducer **520** can be operated efficiently.

[0273] In this situation, the first circuit board **1630** can be the harmonic reduction circuit board **1630**, and the second circuit board **1620** can be the inverter circuit board **1620**.

[0274] Meanwhile, the rectifier **510** and the DC link capacitor C can be further placed on the second circuit board **1620**.

[0275] FIG. **19** is an example circuit diagram illustrating a motor driving apparatus according to yet another embodiment of the present disclosure.

[0276] Referring to the drawing, a motor driving apparatus **700***cb* according to yet another embodiment of the present disclosure is similar to FIG. **17**, but is different in that the motor driving apparatus **700***cb* further includes a second current detector M configured to detect a second current im**3** flowing between the DC link capacitor C and the inverter **220**.

[0277] In this situation, the second current im**3** can be referred to as a DC-link current.

[0278] Meanwhile, the controller **230** can control the harmonic reducer **520** based on the pulsating voltage Vdc from the first voltage detector B, the current im**2** detected by the current detector G, and the voltage Vc**1** detected by the second voltage detector F, and the second current im**3** from the second current detector M, thereby reducing a harmonic without detecting an input current when the three-phase AC voltage **201** is input.

[0279] Meanwhile, the harmonic reducer **520**, the current detector G, the first voltage detector B, the second current detector M, the second voltage detector F, and the controller **230** can be placed on the first circuit board **1630**, and the inverter **220** can be placed on the second circuit board **1620** spaced apart from the first circuit board **1630**. Accordingly, the harmonic reducer **520** can be operated efficiently.

[0280] Meanwhile, the controller **230** can control the harmonic reducer **520** based on the information about the pulsating voltage Vdc from the DC link voltage detector B and the information about the inverter current im**3** from the inverter current detector M.

[0281] Specifically, the controller **230** can calculate the output power of the inverter **220** based on the information about the pulsating voltage Vdc from the DC link voltage detector B and the information about the inverter current im**3** from the inverter current detector M, and can control the harmonic reducer **520** to be turned on or turned off based on the output power of the inverter **220**. Accordingly, the harmonic of the input current based on the three-phase AC voltage can be reduced.

[0282] FIG. **20** is an example circuit diagram illustrating a motor driving apparatus according to yet another embodiment of the present disclosure. For example, various detectors can be placed at different locations according to embodiments.

[0283] As described above, a motor driving apparatus and the air conditioner including the same according to an embodiment of the present disclosure includes a rectifier configured to rectify a three-phase alternating current (AC) voltage, a capacitor configured to store a pulsating voltage from the rectifier, a harmonic reducer disposed between the rectifier and the capacitor and including at least one switching element, and configured to reduce a harmonic of the three-phase AC voltage, and an inverter including a plurality of switching elements, and configured to output a converted AC voltage to a motor based on a voltage of both ends of the capacitor, in which the harmonic reducer is turned on or turned off based on output power of the inverter. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0284] Meanwhile, the harmonic reducer can be turned off based on increase and then decrease of the output power of the inverter, and can be turned on based on decrease and then increase of the output power of the inverter. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0285] Meanwhile, the harmonic reducer can be turned on based on increase of the output power of the inverter. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0286] Meanwhile, the harmonic reducer can be turned on during a first period of time based on increase of the output power of the inverter, the harmonic reducer can be turned off during a second period of time based on increase and then decrease of the output power of the inverter, and the harmonic reducer can be turned on during a third period of time based on decrease and then increase of the output power of the inverter. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0287] Meanwhile, the pulsating voltage stored in the capacitor can be lower when the harmonic reducer is turned off than turned on. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0288] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a voltage detector configured to detect the pulsating voltage stored in the capacitor, and a controller configured to control operation of the harmonic reducer, in which based on a 6th or 12th harmonic component of the pulsating voltage, the controller can be configured to control a switching operation of the switching element in the harmonic reducer. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage. Further, it is possible to reduce harmonic distortion in a current flowing through an inverter.

[0289] Meanwhile, the controller can be configured to generate a current reference based on the 6th or 12th harmonic component of the pulsating voltage, and to control operation of the harmonic reducer based on the generated current reference. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage.

[0290] Meanwhile, the controller can be configured to increase a turn-on duty of the switching element in the harmonic reducer as the 6th or 12th harmonic component of the pulsating voltage increases. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage.

[0291] Meanwhile, the controller can include a first filter configured to filter a DC component of the pulsating voltage, and a second filter configured to filter the 6th or 12th harmonic component of the pulsating voltage. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage.

[0292] Meanwhile, the controller can include a first filter configured to filter a DC component of the pulsating voltage, a second filter configured to filter the 6th or 12th harmonic component of the pulsating voltage, and a third filter configured to filter a 40th or lower harmonic component of the pulsating voltage. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage.

[0293] Meanwhile, the harmonic reducer can include an inductor, a first switching element, and a second capacitor which are connected between both ends of the capacitor, and a second switching element connected to a first node between the inductor and the first switching element and a second node between the second capacitor and the capacitor. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0294] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a voltage detector configured to detect the pulsating voltage stored in the capacitor, and a controller configured to control operation of the harmonic reducer, in which the controller can be configured to extract a 40th or lower harmonic component of the pulsating voltage, and to control the harmonic reducer based on the extracted harmonic voltage. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0295] Meanwhile, the controller can include a current reference generator configured to extract a 40th or lower harmonic component of the pulsating voltage, a power reference generator configured to generate a power reference value based on the 40th or lower harmonic component, and a voltage reference generator configured to generate a compensation voltage reference value based on the generated power reference value, in which an operation of the first switching element or the second switching element in the harmonic reducer can be controlled based on the compensation voltage reference value. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0296] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a voltage detector configured to detect the pulsating voltage stored in the capacitor, a controller configured to control operation of the harmonic reducer, and an inverter controller configured to control the inverter. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0297] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a first voltage detector configured to detect the pulsating voltage stored in the capacitor, a current detector configured to detect a current flowing in the harmonic reducer, a second voltage detector configured to detect a voltage of both ends of the second capacitor in the harmonic reducer, and a controller configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, and the voltage detected by the second voltage detector. Accordingly, it is possible to reduce a harmonic without detecting an input current when the three-phase AC voltage is input.

[0298] Meanwhile, the harmonic reducer, the current detector, the first voltage detector, the second voltage detector, and the controller can be placed on a first circuit board, and the inverter can be placed on a second circuit board spaced apart from the first circuit board. Accordingly, as the inverter and the harmonic reducer are placed on separate circuit boards, the harmonic reducer can be operated efficiently.

[0299] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a second current detector configured to detect a second current flowing between the capacitor and the inverter, in which the controller can be configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, the voltage detected by the second voltage detector, and the second current detected by the second current detector. Accordingly, it is possible to reduce a harmonic without detecting an input current when the three-phase AC voltage is input.

[0300] Meanwhile, the motor driving apparatus and the air conditioner including the same can further include a third current detector configured to detect a third current flowing between the rectifier and the capacitor, in which the controller can be configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, the voltage detected by the second voltage detector, and the third current detected by the third current detector. Accordingly, it is possible to reduce a harmonic without detecting an input current when the three-phase AC voltage is input.

[0301] A motor driving apparatus and an air conditioner including the same according to another embodiment of the present disclosure includes a rectifier configured to rectify a three-phase alternating current (AC) voltage, a capacitor configured to store a pulsating voltage from the rectifier, a harmonic reducer disposed between the rectifier and the capacitor and including at least one switching element, and configured to reduce a harmonic of the three-phase AC voltage, an inverter including a plurality of switching elements, and configured to output a converted AC voltage to a motor based on a voltage of both ends of the capacitor, a voltage detector configured to detect the pulsating voltage stored in the capacitor, and a controller configured to control operation of the harmonic reducer, in which based on a 6th or 12th harmonic component of the pulsating voltage, the controller is configured to control a switching operation of the switching element in the harmonic reducer. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage. Particularly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage. Further, it is possible to reduce harmonic distortion in a current flowing through an inverter.

[0302] Meanwhile, the controller can be configured to increase a turn-on duty of the switching element in the harmonic reducer as the 6th or 12th harmonic component of the pulsating voltage increases. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage.

[0303] Meanwhile, the controller can include a first filter configured to filter a DC component of the pulsating voltage, and a second filter configured to filter the 6th or 12th harmonic component of the pulsating voltage. Accordingly, it is possible to efficiently reduce a specific order harmonic of an input current based on the three-phase AC voltage.

[0304] Meanwhile, the harmonic reducer can include an inductor, a first switching element, and a second capacitor which are connected between both ends of the capacitor, and a second switching element connected to a first node between the inductor and the first switching element and a second node between the second capacitor and the capacitor. Accordingly, it is possible to reduce a harmonic of an input current based on the three-phase AC voltage.

[0305] It will be apparent that, although the preferred embodiments have been shown and described above, the present disclosure is not limited to the above-described specific embodiments, and various modifications and variations can be made by those skilled in the art without departing from the gist of the appended claims. Thus, it is intended that the modifications and variations should not be understood independently of the technical spirit or prospect of the present invention.

What is claimed is:

1. A motor driving apparatus, comprising:

a rectifier configured to rectify a three-phase alternating current (AC) voltage;

a first capacitor configured to store a pulsating voltage from the rectifier;

a harmonic reducer disposed between the rectifier and the first capacitor, the harmonic reducer including at least one switching element, and the harmonic reducer being configured to reduce a harmonic of the three-phase AC voltage; and

an inverter including a plurality of switching elements, the inverter being configured to output a converted AC voltage to a motor based on a voltage of both ends of the first capacitor, wherein the harmonic reducer is turned on or turned off based on an output power of the inverter.

2. The motor driving apparatus of claim **1**, wherein the harmonic reducer is turned off based on the output power of the inverter increasing and then decreasing, and

wherein the harmonic reducer is turned on based the output power of the inverter decreasing and then increasing.

3. The motor driving apparatus of claim **1**, wherein the harmonic reducer is turned on based on the output power of the inverter increasing.

4. The motor driving apparatus of claim **1**, wherein the harmonic reducer is turned on during a first period of time when the output power of the inverter increases,

wherein the harmonic reducer is turned off during a second period of time when the output power of the inverter increases and then decreases; and

wherein the harmonic reducer is turned on during a third period of time when the output power of the inverter decreases and then increases.

5. The motor driving apparatus of claim **1**, wherein the pulsating voltage stored in the first capacitor is lower when the harmonic reducer is turned off than when the harmonic reducer is turned on.

6. The motor driving apparatus of claim **1**, further comprising:

a voltage detector configured to detect the pulsating voltage stored in the first capacitor; and

a controller configured to:

control a switching operation of the at least one switching element in the harmonic reducer based on a 6th harmonic component of the pulsating voltage or a 12th harmonic component of the pulsating voltage.

7. The motor driving apparatus of claim **6**, wherein the controller is further configured to:

generate a current reference based on the 6th harmonic component of the pulsating voltage or the 12th harmonic component of the pulsating voltage, and

control operation of the harmonic reducer based on the current reference.

8. The motor driving apparatus of claim **6**, wherein the controller is further configured to:

increase a turn-on duty of the at least one switching element in the harmonic reducer when the 6th harmonic component of the pulsating voltage or the 12th harmonic component of the pulsating voltage increases.

9. The motor driving apparatus of claim **1**, wherein the harmonic reducer includes:

an inductor, a first switching element and a second capacitor connected between both ends of the first capacitor; and

a second switching element connected to a first node between the inductor and the first switching element and a second node between the second capacitor and the first capacitor.

10. The motor driving apparatus of claim **9**, further comprising:

a voltage detector configured to detect the pulsating voltage stored in the first capacitor; and

a controller configured to:

extract a 40th or lower harmonic component of the pulsating voltage to obtain an extracted harmonic voltage, and turn the harmonic reducer on or off based on the extracted harmonic voltage.

11. The motor driving apparatus of claim **1**, wherein the first capacitor is a film capacitor.

12. The motor driving apparatus of claim **1**, further comprising:

a voltage detector configured to detect the pulsating voltage stored in the capacitor;

a controller configured to control operation of the harmonic reducer; and

an inverter controller configured to control the inverter.

13. The motor driving apparatus of claim **1**, further comprising:

a first voltage detector configured to detect the pulsating voltage stored in the first capacitor;

a current detector configured to detect a current flowing in the harmonic reducer;

a second voltage detector configured to detect a voltage of both ends of the second capacitor in the harmonic reducer; and

a controller configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, and the voltage detected by the second voltage detector.

14. The motor driving apparatus of claim **13**, wherein the harmonic reducer, the current detector, the first voltage detector, the second voltage detector, and the controller are disposed on a first circuit board, and

wherein the inverter is disposed on a second circuit board spaced apart from the first circuit board.

15. The motor driving apparatus of claim **13**, further comprising a second current detector configured to detect a second current flowing between the first capacitor and the inverter,

wherein the controller is further configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, the voltage detected by the second voltage detector, and the second current detected by the second current detector.

16. The motor driving apparatus of claim **13**, further comprising a third current detector configured to detect a third current flowing between the rectifier and the first capacitor,

wherein the controller is further configured to control the harmonic reducer based on the pulsating voltage from the first voltage detector, the current detected by the current detector, the voltage detected by the second voltage detector, and the third current detected by the third current detector.

17. A motor driving apparatus, comprising:

a rectifier configured to rectify a three-phase alternating current (AC) voltage;

a first capacitor configured to store a pulsating voltage from the rectifier;

a harmonic reducer disposed between the rectifier and the first capacitor, the harmonic reducer including at least one switching element, and the harmonic reducer being configured to reduce a harmonic of the three-phase AC voltage;

an inverter including a plurality of switching elements, and configured to output a converted AC voltage to a motor based on a voltage of both ends of the first capacitor;

a voltage detector configured to detect the pulsating voltage stored in the first capacitor; and

a controller configured to control operation of the harmonic reducer,

wherein based on a 6th or 12th harmonic component of the pulsating voltage, the controller is configured to control a switching operation of the switching element in the harmonic reducer.

18. The motor driving apparatus of claim **17**, wherein the controller is configured to increase a turn-on duty of the switching element in the harmonic reducer as the 6th or 12th harmonic component of the pulsating voltage increases.

19. The motor driving apparatus of claim **17**, wherein the harmonic reducer comprises:

an inductor, a first switching element, and a second capacitor which are connected between both ends of the first capacitor; and

a second switching element connected to a first node between the inductor and the first switching element and a second node between the second capacitor and the first capacitor.

20. An air conditioner comprising:

the motor driving apparatus of claim **1**;

a compressor configured to compress a refrigerant; and

a heat exchanger.

21. A motor driving apparatus for driving a compressor of an air conditioner, the motor driving apparatus comprising:

a rectifier configured to rectify an alternating current voltage;

a first capacitor configured to store a voltage based on the alternating current voltage;

a harmonic reducer connected between the rectifier and the first capacitor, the harmonic reducer including a second capacitor, at least one switching element and an inductor;

an inverter including a plurality of switching elements, and configured to output a converted alternating current voltage based on a voltage of the first capacitor; and

a controller configured to:

turn on and turn off the at least one switching element in the harmonic reducer based on an output power of the inverter.

22. The motor driving apparatus of claim **21**, wherein the controller is further configured to:

turn on the at least one switching element in the harmonic reducer during a first time period when the output power transitions from increasing to decreasing,

turn off the at least one switching element in the harmonic reducer during a second time period when the output power transitions from decreasing to increasing, and

turn on the at least one switching element in the harmonic reducer during a third time period when the output power transitions from increasing to decreasing.

23. The motor driving apparatus of claim **21**, wherein the controller is further configured to:

increase a duty cycle of the at least one switching element in the harmonic reducer as a harmonic component of the voltage stored in the first capacitor increases.

24. The motor driving apparatus of claim **21**, further comprising:

at least one current detector connected between the rectifier and an input of the alternating current, between the inductor and the first capacitor, or between the first capacitor and the inverter.

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