



History of inverter technology

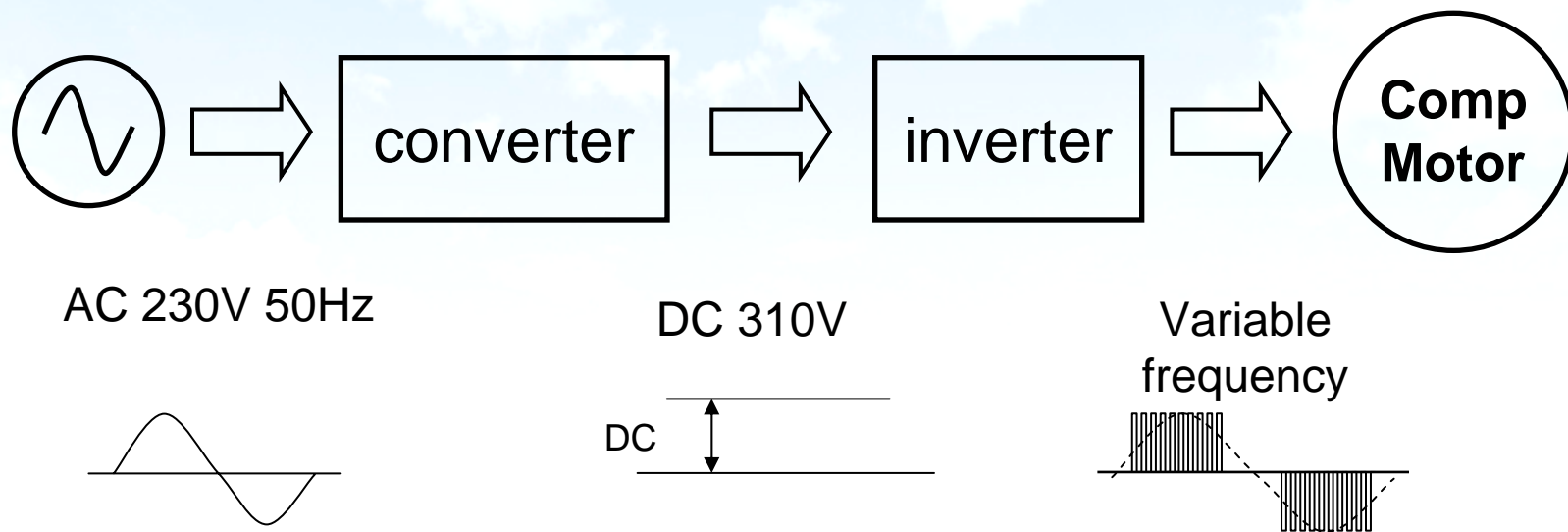
1. What is Inverter technology?
2. Basic structure of inverter device
3. History of Inverter technology
 0. Transition of inverter technology
 1. What is the difference between AC inverter and DC inverter
 2. Why the inverter technology evolved from AC to DC?
 3. **DC inverter with PAM converter (DC PAM inverter)**
 4. **Vector control DC inverter**
 5. Which technology is applied to our products?

History of inverter technology

1. What is Inverter technology?

Inverter is a device which supplies variable frequency of power supply on equipments

Thanks to this function, motor revolution speed can be controlled and it leads to reduce energy consumption.



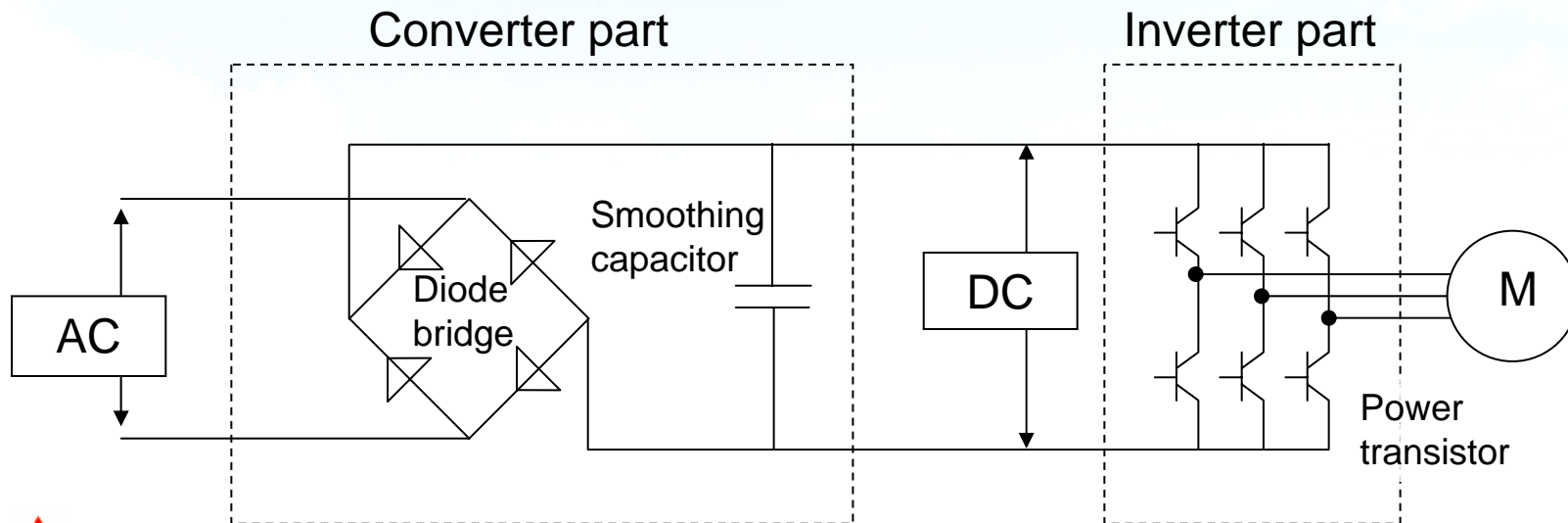
History of inverter technology

2. Basic structure of inverter device

Inverter device consists of mainly two parts; converter and inverter

Originally the meaning of “Inverter” is changing DC power source into AC power source.

In order to make supplied frequency variable, once the AC power source is changed into DC at Converter part.



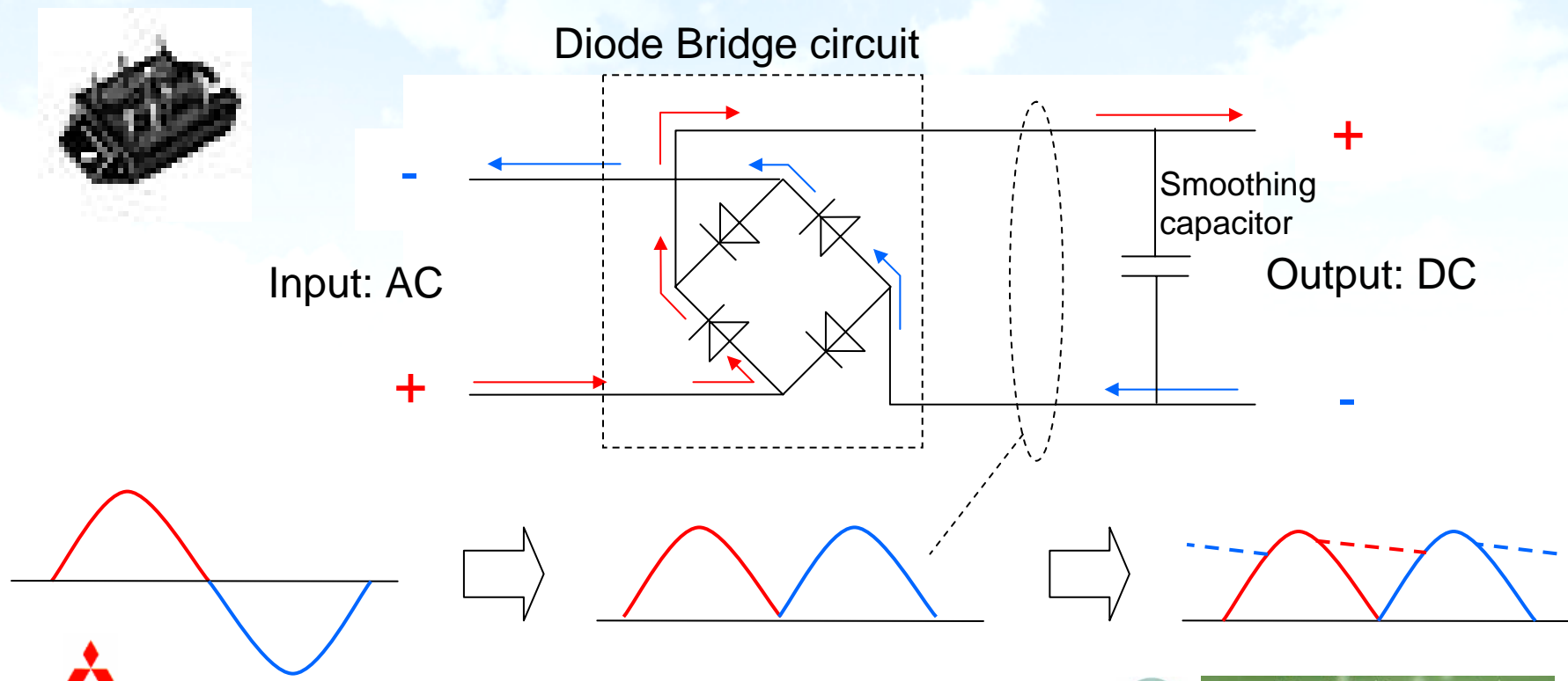
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2. Basic structure of inverter device

2-1 Function of Converter

Converter part converts AC power supply into DC thanks to Diode bridge circuit

Diode: electrical component which allows current go through on one way.

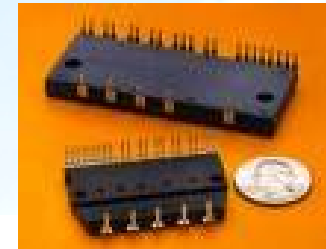
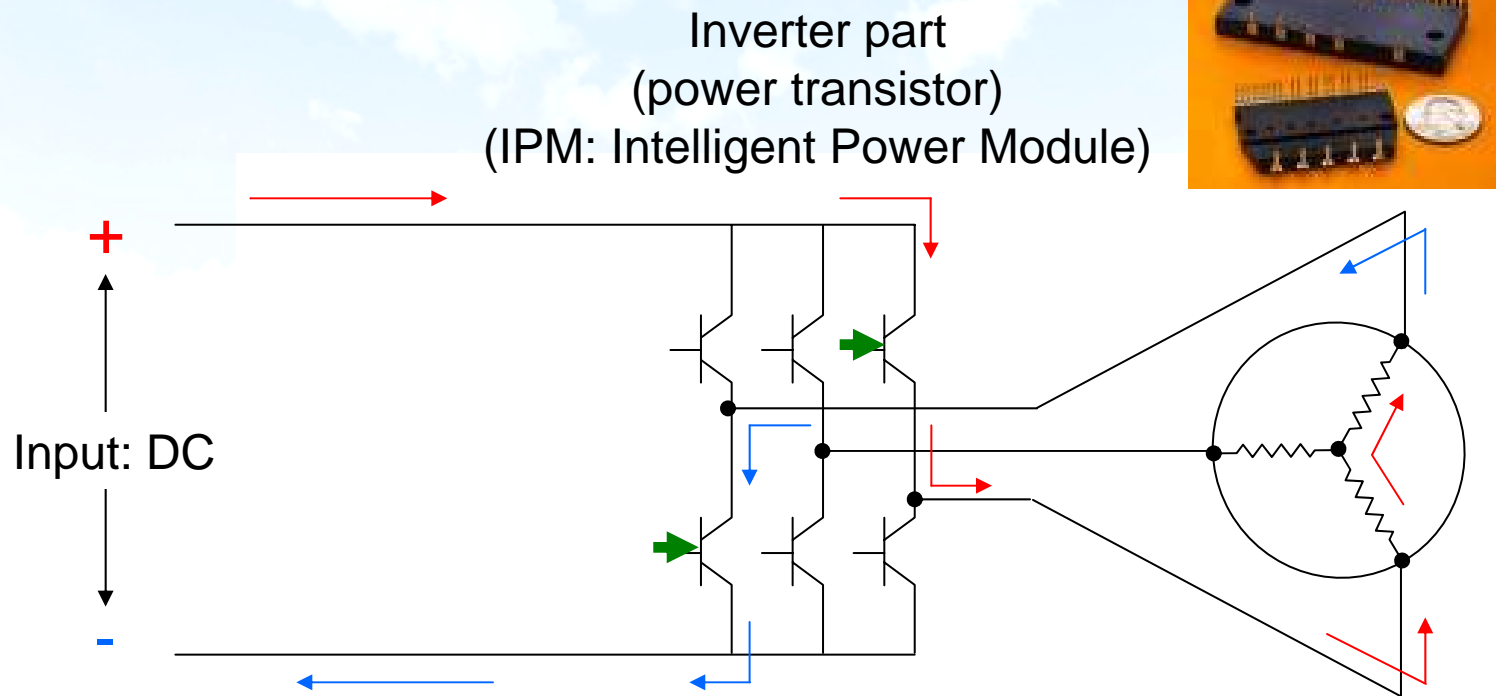


History of inverter technology

2. Basic structure of inverter device

2-1 Function of Inverter

By signal being input on each transistor, current will go through the motor. This signal input format is different according to the motor (AC inverter / DC inverter)



History of inverter technology

3. History of Inverter technology

0. Transition of inverter technology

1. What is the difference between AC inverter and DC inverter?

<feature of AC motor / DC motor>

- > Structure
- > Principle
- > Advantage and disadvantage

2. Why the inverter technology evolved from AC to DC?

3. DC inverter with PAM converter (DC PAM inverter)

- > What is PAM?
- > What is the necessity of PAM?


4. Vector control DC inverter

5. Which technology is applied to our products?

History of inverter technology

3-0 Transition of inverter technology

Inverter technology evolved along the technological innovation as shown below.



	Comp motor	Modulation	Voltage Waveform
AC inverter	AC motor	PWM	180degree
DC inverter	DC motor	PWM	120degree
DC inverter with PAM converter	DC motor	PWM + PAM	120degree
DC inverter with vector control	DC motor	PWM (+ PAM)	180degree

History of inverter technology

3-1 What is the difference between AC and DC inverter

There are two main types of inverter system:

One is **AC inverter**, and
the other is **DC inverter**

Basically only the **difference is the motor** is driven by the inverter, not the inverter device itself.

The inverter that drives an AC motor is called “AC inverter”, and the one which drives DC motor is called “DC inverter”.

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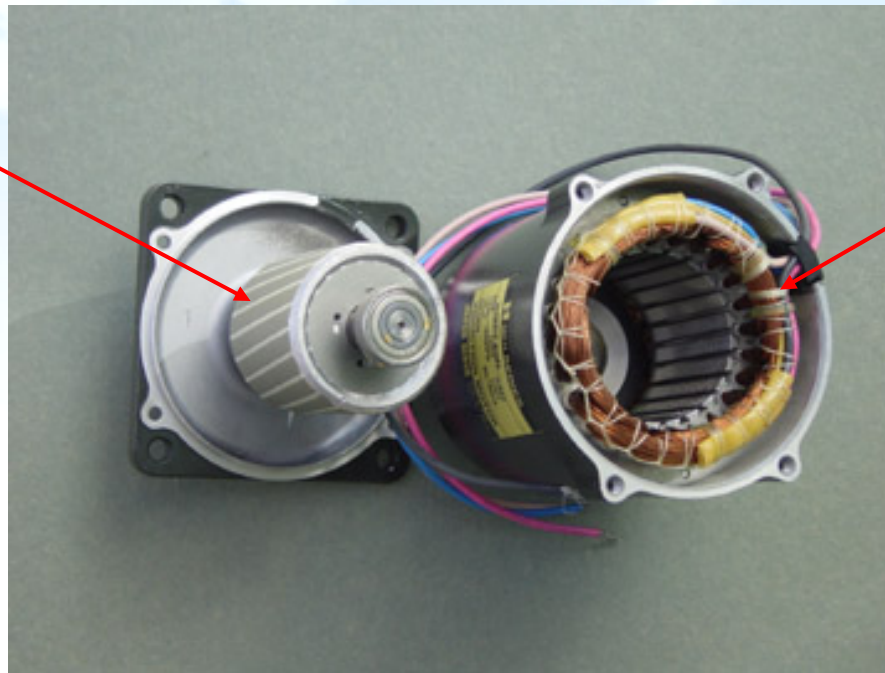
3-1 What is the difference between AC and DC inverter

<What is the difference between AC motor and DC motor?>

Structure of AC motor

Rotor

(Squirrel Cage
made of conductor)

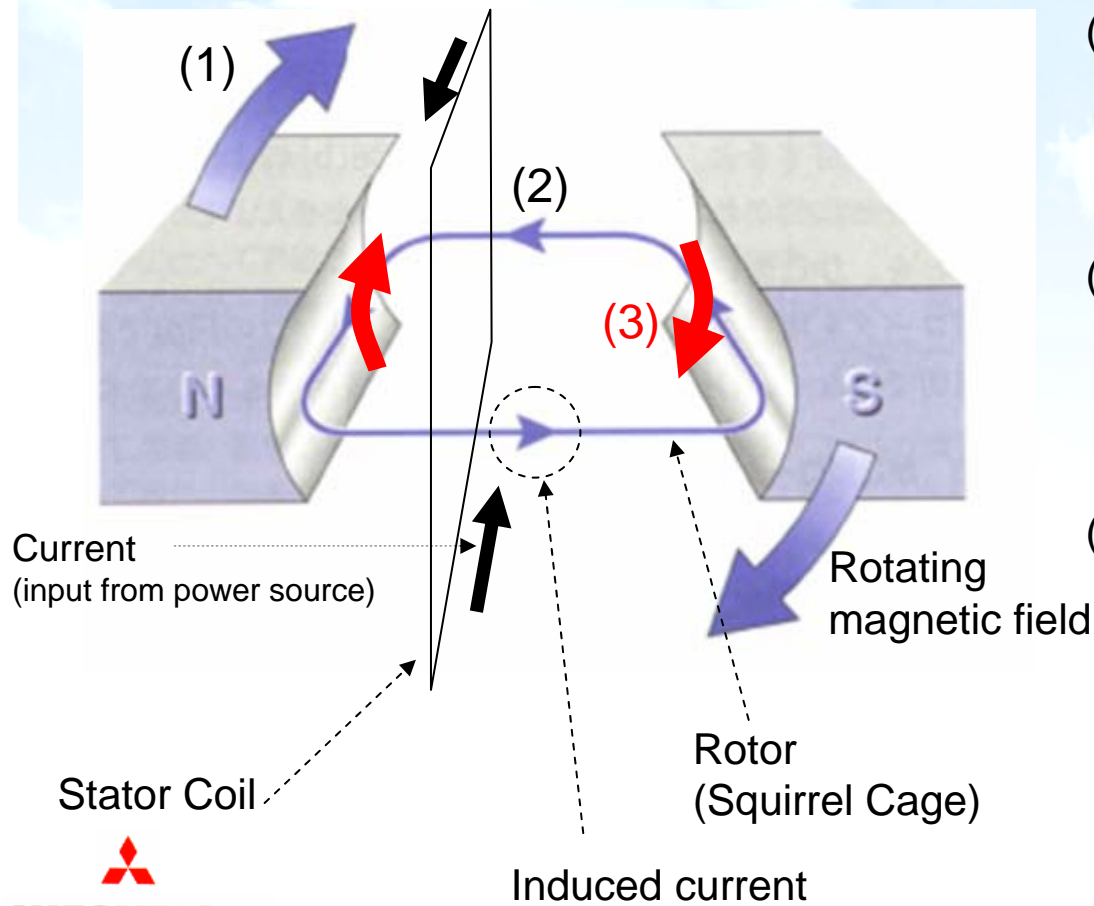


Stator
(coil)

History of inverter technology

3-1 What is the difference between AC and DC inverter

Principle how AC motor works?



- (1) Current goes through the coil on the stator and the rotating magnetic field is generated
- (2) Being induced by the rotating magnetic field, induced current is generated on the Squirrel Cage.
- (3) According to **the interaction force** between current and magnetic field (Fleming left hand's law), the Cage on which the induced current goes through turns around.

History of inverter technology

3-1 What is the difference between AC and DC inverter

Advantage and disadvantage of AC motor

Advantage

Simple structure

Easy to control

induction current is generated on the cage according to the rotating magnetic field, so the rotor will be driven accordingly without detecting rotor position.

Disadvantage

Less efficiency caused by

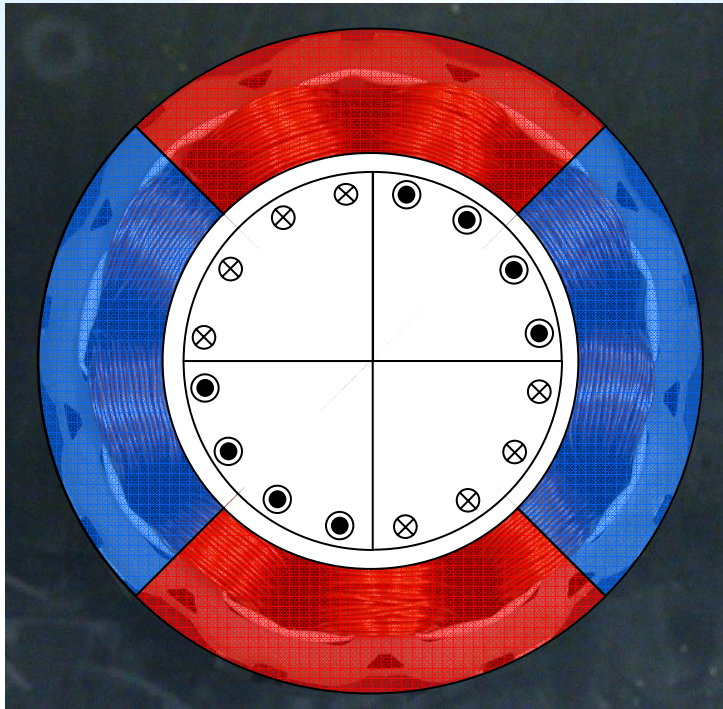
- > induction current loss
- > motor slip

History of inverter technology

3-1 What is the difference between AC and DC inverter

Advantage and disadvantage of AC motor

What is motor slip?



The principle how the rotor drives is interaction force between rotating magnetic field and induction current.

So, it is not necessary to synchronize the revolution speed of rotating magnetic field and rotor.

And rotor speed is always slower than that of rotating magnetic field.

This gap is called “motor slip”.

In general, the rotor speed is 3% slower than rotating magnetic field.

History of inverter technology

3-1 What is the difference between AC and DC inverter

Structure of DC motor

Rotor
(made of permanent
magnet)



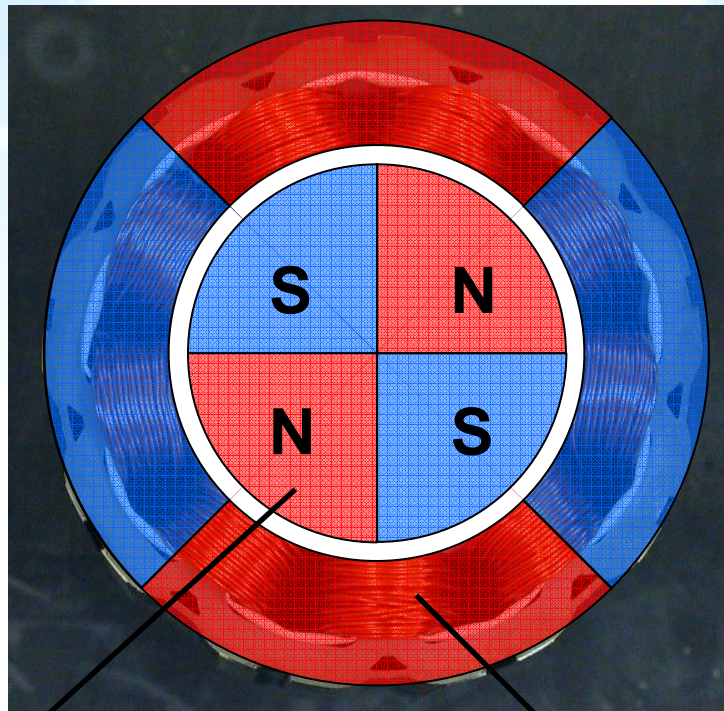
Stator (coil)

The biggest and only difference is that **rotor is made of permanent magnet**, but the principle of the operation is completely different from that of an AC motor.

History of inverter technology

3-1 What is the difference between AC and DC inverter

Principle how DC motor works?



Rotor
(made of permanent magnet)

Stator (coil)

(1) Current goes through the coil on the stator and rotating magnetic field is generated (same as AC)

(2) By the interaction of the pole of the magnet, rotor will turn.

History of inverter technology

3-1 What is the difference between AC and DC inverter

Advantage and disadvantage of DC motor

Advantage

Less loss and better efficiency than AC motor because of

- > no motor slip
- > no induced current loss

Disadvantage

Needs enough knowledge to drive

Rotor position needs to be detected anytime to drive it and stator coil should be energized accordingly to the rotor position.

History of inverter technology

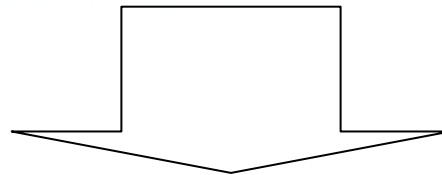
3-2 Why the inverter technology evolved from AC to DC?

Demand for more efficient, less energy consumption in air-conditioners becomes stronger and stronger year by year.

In order to attain better efficiency, it is not enough only to apply (AC) inverter technology so as to reduce the compressor speed, but also to reduce energy consumption when in partial load conditions.

DC motor has been known as much more efficient motor than AC, and its efficiency is roughly double compared to AC.

(it means energy consumption becomes half at the same condition.)



DC inverter technology is a good solution for reducing energy consumption.

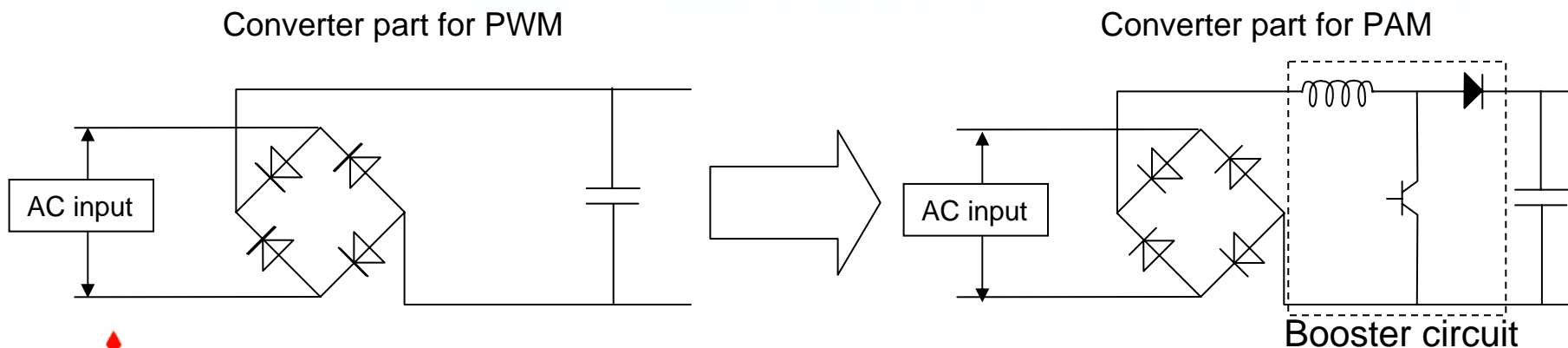
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3-3 DC PAM inverter

Recently PAM technology is also introduced in order to improve the efficiency of air-conditioner.

What is “PAM”?

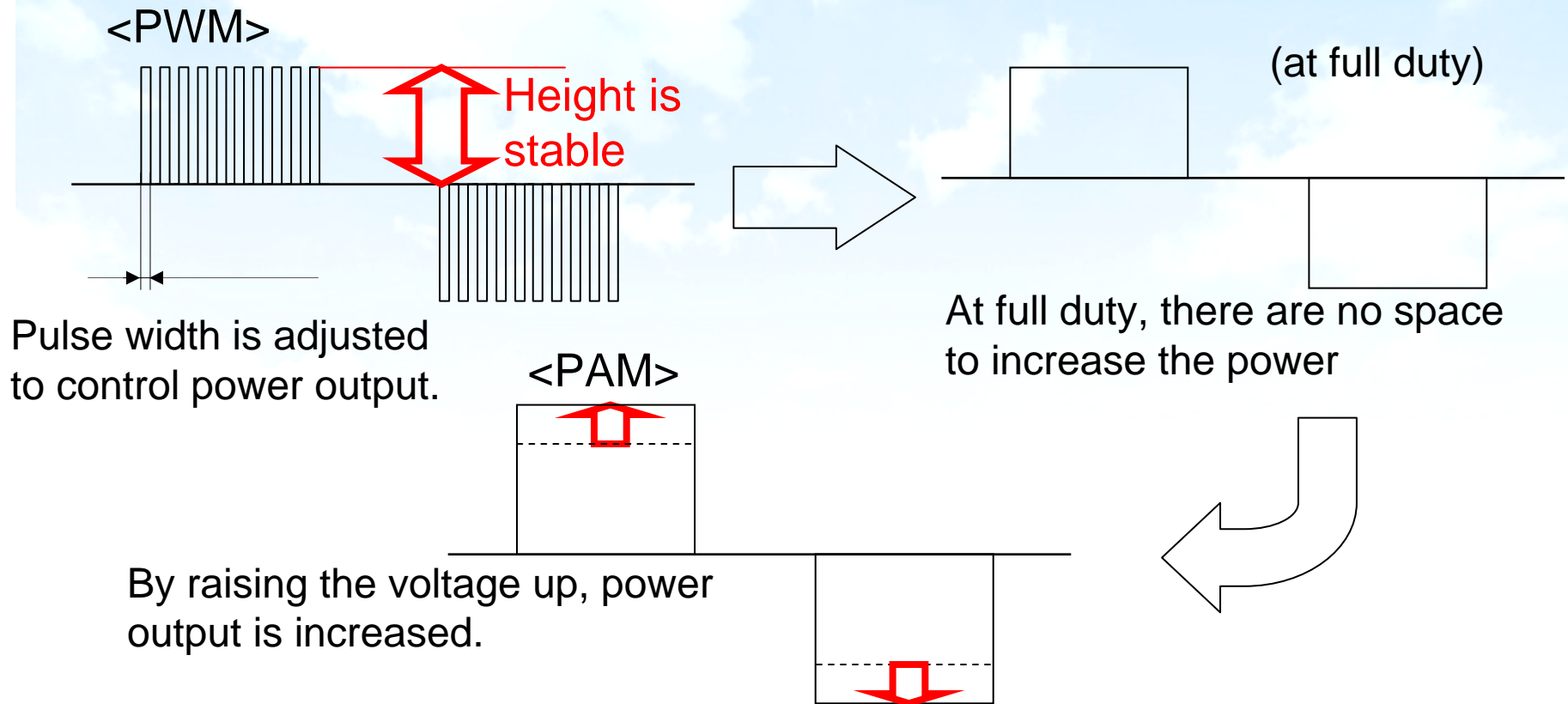
“PAM” is abbreviation of **P**ulse **A**mplitude **M**odulation. Compared to conventional PWM (**P**ulse **W**idth **M**odulation), booster circuit is added on the converter part to raise up DC voltage.



History of inverter technology

3-3 DC PAM inverter

How it works? (voltage waveform)



History of inverter technology

3-3 DC PAM inverter

What is the necessity for PAM control?

In short, “in order to apply more efficient DC motor”

Generally speaking, a motor which have larger number of winding on one slot has better efficiency because it can generate stronger magnetic field.

However, there is a disadvantage that it cannot accept bigger current because the diameter of the wire should be thin.

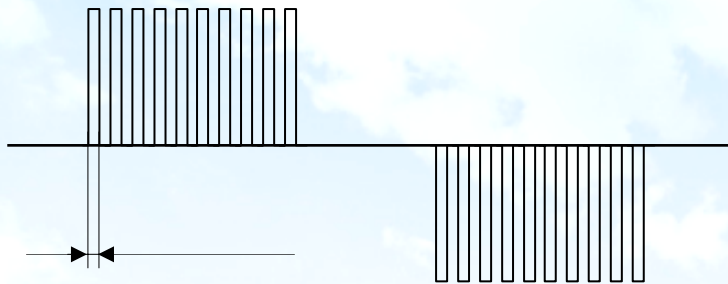
In order to overcome the disadvantage of the motor, by raising input voltage up, making the total input same without increasing current, and become possible to drive the compressor at higher torque.

$$W \text{ (Watt)} = E \text{ (Voltage)} \times I \text{ (Current)}$$

History of inverter technology

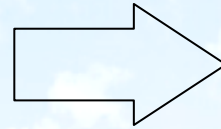
3-4 Vector control DC inverter How it works? (voltage waveform)

<Conventional PWM>

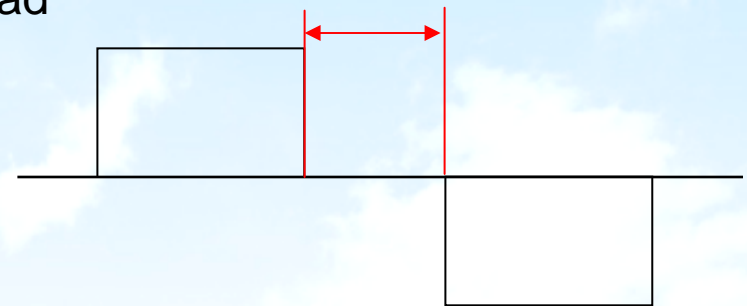


Pulse width is adjusted to control power output.

At full load

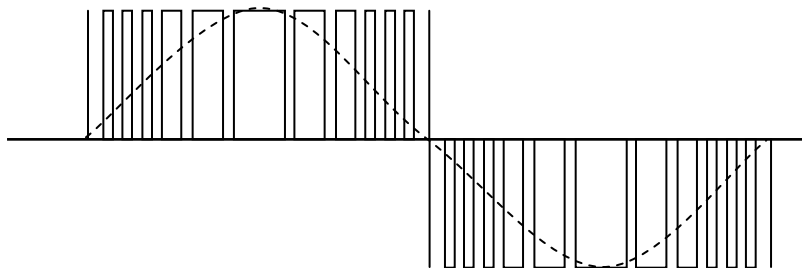


Non-energized period



In conventional PWM drive, non-energized period is necessary to detect rotor position.

<Vector control>



Rotor position can be detected without non-energized period and inputting appropriate voltage accordingly in order to create approximate sinusoidal wave form.

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3-4 Vector control DC inverter

Advantage of Vector control

Vector control is a cutting-edge technology of the inverter control in order to let the compressor give the better performance by generating sinusoidal current wave form.

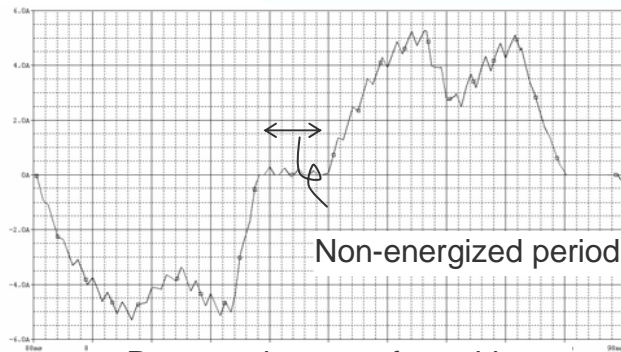
① less compressor starting failure

Thanks to the control, it becomes to be able to detect the rotor position correctly, and it lead to improve compressor starting.

② Downsizing and high efficiency

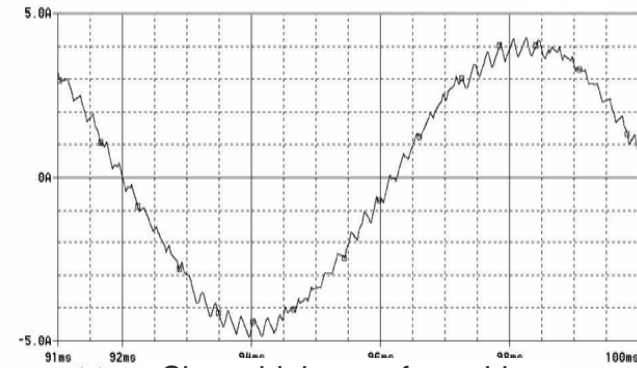
High revolution operation on high efficiency (high turn motor) compressor became possible thanks to the sinusoidal wave form drive,

Current wave form comparison



Rectangular wave form drive

fig 1-1 120deg rectangular wave drive



Sinusoidal wave form drive
fig 1-2 vector control

History of inverter technology

3-4 Vector control DC inverter

What is the necessity for Vector control?

In short, **“in order to apply more efficient DC motor”**

This is as same story as applying DC PAM inverter.

Generally speaking, a motor which has a larger number of windings on one slot has better efficiency because it can generate a stronger magnetic field.

However, there is a disadvantage in that it cannot accept a bigger current because the diameter of the winding wire.

In a conventional PWM inverter, there is a non-energized period and it leads to increase peak current.

In Vector control, there is no non-energized period and it leads to reduce peak current that can make a more efficient compressor DC motor

$$W \text{ (Watt)} = E \text{ (Voltage)} \times I \text{ (Current)}$$

History of inverter technology

3-5 Which technology is applied to our products?

1) AC inverter (no longer used)



KX2

2) DC inverter



KX4



PAC inverter
(8 – 10HP)

3) DC inverter with PAM



PAC inverter
(1.5 – 2.5HP)



RAC inverter

4) DC inverter with Vector control



PAC inverter
(3 – 6HP)

Which control is applied is decided a balance between feasibility, cost, and effect.