Inverter_Energy_Saving_ENG

MITSUBISHI ELECTRIC
Changes for the Better

Inverter
Energy Saving Course

This course will help you understand how inverters enable energy saving operation.

L(NA)00198ENG

Introduction Purpose of the course

Through the lessons in this course you will learn:

- Why an inverter driven motor can save energy
- How high-efficiency motors enable further energy saving

This course requires a basic knowledge of inverters.
It is recommended that you start with the beginners course, "FA Equipment for Beginners (Inverters)".

Introduction Course structure

The contents of this course are as follows.

Chapter 1 - Trends in Energy Saving

Learn about the trends in energy saving.

Chapter 2 - Principle of Energy Saving with Inverters

Learn about the principle of energy saving to understand why inverters are used for this purpose.

Chapter 3 - Useful Energy-Saving Functions in the FR-F800/700 Series

Learn about the useful energy-saving functions available in the FR-F800/700 series.

Chapter 4 - High-Efficiency Motor Regulations

Learn about the regulations on high-efficiency motors.

Chapter 5 - Superline Premium Series SF-PR

Learn about the Superline premium series SF-PR.

Chapter 6 - Energy Saving with Inverters and IPM Motors

Learn about energy saving with the combined use of inverters and IPM motors.

Final Test

Pass grade: 60% or higher

Inverter_Energy_Saving_ENG

Introduction How to use this e-Learning tool

Go to the next page		Go to the next page.
Back to the previous page		Back to the previous page.
Move to the desired page	TOC	"Table of Contents" will be displayed, enabling you to navigate to the desired page.
Exit the learning		Exit the learning.

Cautions for use

Safety precautions

When you learn based on using actual products, please carefully read the safety precautions in the corresponding manuals.

Precautions in this course

The displayed screens of the MELSOFT engineering software that you use may differ from those in this course.

Chapter 1 Trends in Energy Saving

This chapter explains the trends in energy saving and the percentage of motor energy use in the world's energy consumption.

1.1 Trends in Energy Saving

There are growing concerns about environmental problems due to the increase in the average temperature around the globe, such as abnormal climate change, decline in crop productivity, impact on ecosystems, and habitat change resulting from rising sea levels.
Energy-saving actions are urgently needed to prevent global warming (to reduce CO_2 emissions).

Europe

- **2001 Directive on *the promotion of electricity produced from renewable energy sources in the internal electricity market* was established.**
  Renewable energy targets by country were defined.
- **2009 Directive on *the promotion of the use of energy from renewable sources* was established.**
  This directive sets targets for all EU countries with the overall aim of making renewable energy sources around 20% of the EU's energy consumption by 2020.

France

- **2005 *Energy Act* was established.**
  This act defines the following targets:
  - A 75% reduction in greenhouse gases by 2050.
  - Improvement of the energy efficiency by at least 2% per year on average by 2015 and 2.5% per year on average between 2015 and 2030.

USA

- **2011 The state law entitled *Renewable Portfolio Standards (RPS)* was introduced.**
  Thirty states and territories have adopted the RPS to promote the use of energy from renewable sources. The goal is 33% of electricity retail sales be served by renewable energy sources.

China

- **2006 *Renewable Energy Law* was established.**
  The goal is 15% of the total energy use to be served by renewable energy sources by 2020.
- **2011 *The 12th Five-Year Plan (FYP)* was established.**
  The targets of this plan include:
  - A 17% reduction in CO_2 emissions by 2015.
  - Increasing non-fossil energy to 11.4% of the total energy use.

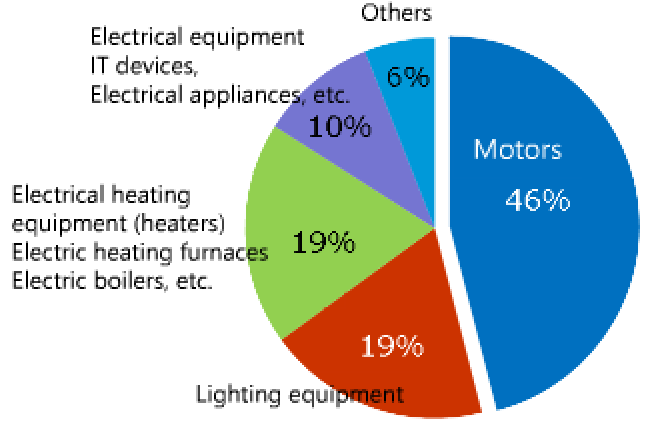
1.2 Percentage of Motor Energy Use in World Energy Consumption

Motors are used everywhere in our daily life.
For example, motors are used for:

- Air-conditioning equipment
  (for buildings, shopping centers, factories, etc.)
- Elevators/escalators
- Machine tools
- Conveyors
- Multi-story car parks

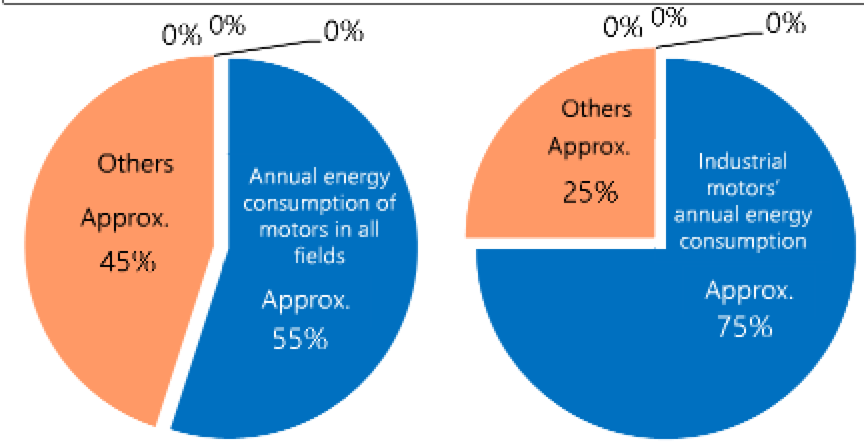
Since motors are used for many different types of equipment, the energy consumed by electric motor systems accounts for 46% of the world's energy consumption.
(About 55% in Japan.)
If all the motors currently being used were replaced with energy-saving motors, the energy consumption would be far lower than it is today.

Shares of World Energy Consumption (21.4 trillion kWh in 2010).



Source: MOTOR SUMMIT 2012 - Key World Energy STATISTICS 2012

Shares of Japan's Energy Consumption (1 trillion kWh in 2009).



Source: IAE-0919107 (2009 Survey report on the actual situation of energy-consuming equipment)

1.3 Summary

In this chapter, you have learned:

Points

Trends in Energy Saving	There are growing concerns about environmental problems due to the increase in the average temperature around the globe, such as abnormal climate change, decline in crop productivity, impact on ecosystems, and habitat change resulting from rising sea levels. Prompt energy-saving action is urgently needed to prevent global warming (to reduce CO_2 emissions).
Percentage of Motor Energy Use in Japan's Energy Consumption	Since motors are used for many different types of equipment, the energy consumed by electric motor systems accounts for 46% of the world's energy consumption. If all the motors currently being used were replaced with energy-saving motors, the energy consumption would be far lower than it is today.

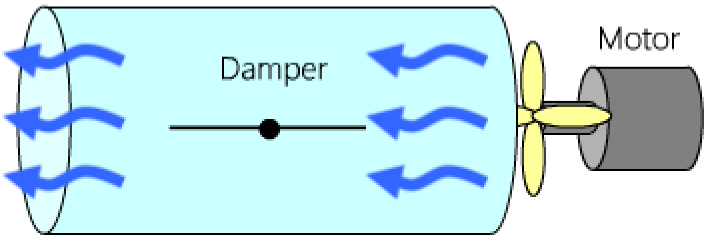
Chapter 2 Principle of Energy Saving with Inverters

This chapter explains the principle of energy saving with inverters.

2.1 How to Change Speed with Standard Motors

Air Volume Control Using Commercial Power Supply

The air volume is controlled with a shielding plate called a damper.
Since the motor speed is constant, decreasing the air volume does not greatly reduce the energy consumption.

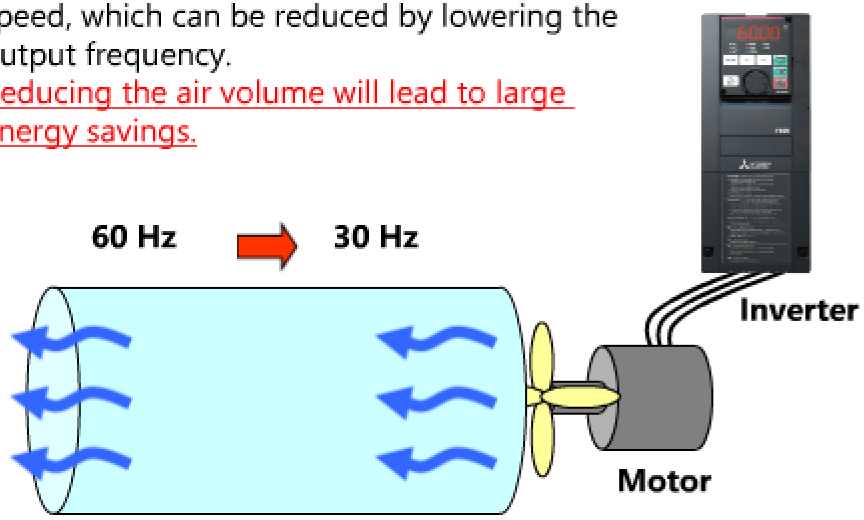


Generally, the speed of a standard motor cannot be changed. The motor speed usually changes by means of a coupling, which is installed between the motor and the load to create a sliding effect. For a variable-torque load, dampers or valves are normally used to reduce the air or water flow.
However, since the rotation speed of a standard motor is almost constant, the motor output does not change much even when the load speed or air/water volume changes. Therefore, the remaining power after subtracting the required power from the motor output is consumed as heat loss at the coupling or damper.

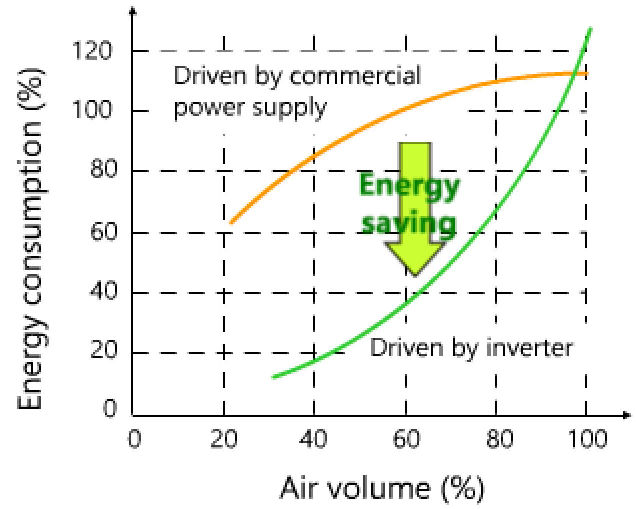
2.2 Driving Standard Motors with Inverters

Air Volume Control by Controlling Motor Speed (Inverter Control)

The air volume is controlled by the motor speed, which can be reduced by lowering the output frequency.
Reducing the air volume will lead to large energy savings.

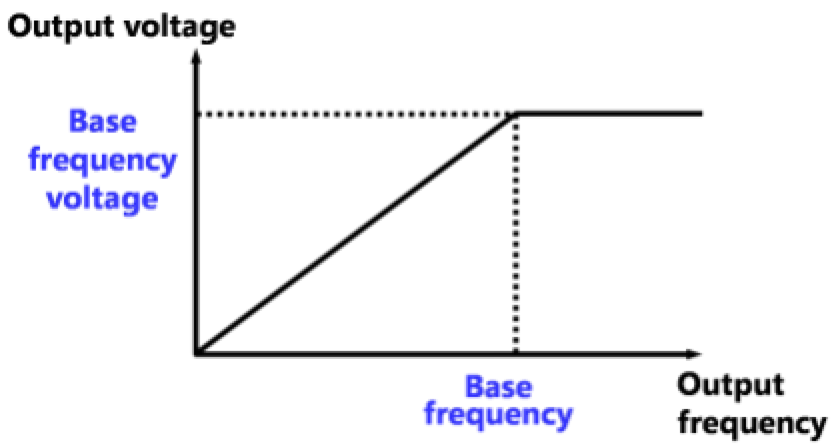


[Blower Operation Characteristics Curve]



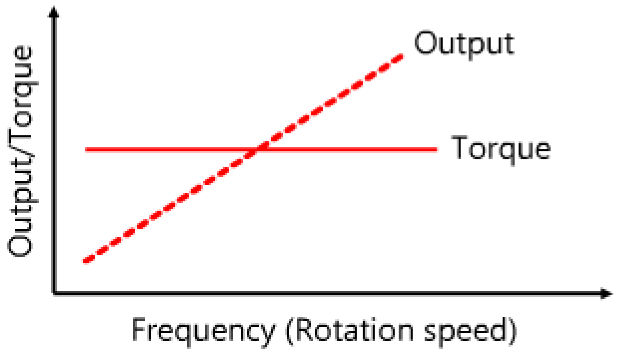
■ Why can inverter-driven motors save energy?

When a motor is driven by an inverter at a medium speed, the voltage is reduced in proportion to the motor speed regardless of the current flow. This contributes to energy saving. It can be said that in any application, driving a variable-speed motor with an inverter can reduce the energy consumption.
This means that driving a variable-speed motor with an inverter can save far more energy than driving a standard motor with a commercial power supply and applying brakes to reduce its speed to a medium speed.

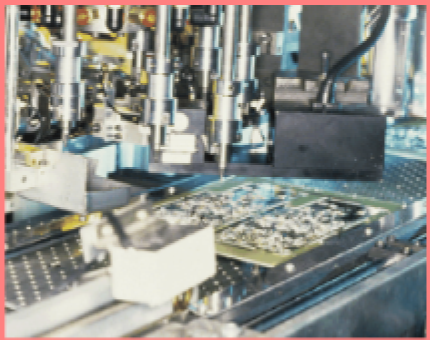


2.3 Load Torque Characteristics

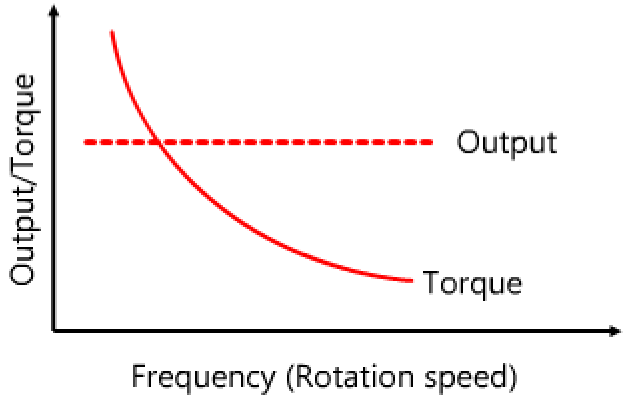
■ **Constant-torque load: The torque does not change much even if the motor speed changes.**



Main applications: Conveyors, carriers, etc.



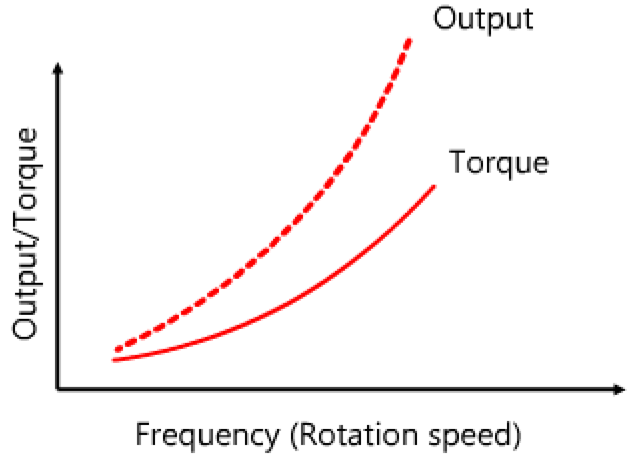
■ **Constant-output load: As the rotation speed increases, the torque becomes smaller.**



Main applications: Machine tools, winders, etc.

2.3 Load Torque Characteristics

■ **Variable-torque load: As the rotation speed decreases, the torque becomes smaller.**



Large energy savings can be expected when a machine with a variable-torque load is controlled using an inverter, compared to when it is controlled using a commercial power supply.

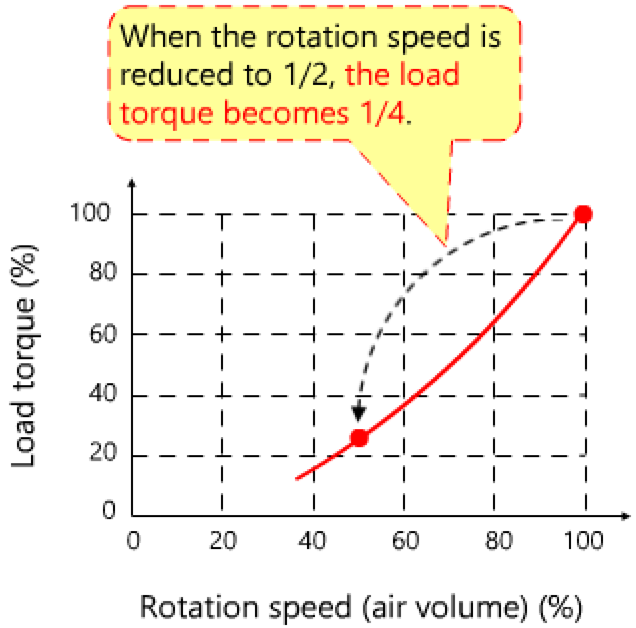
Main applications: Fans, pumps, blowers, etc.

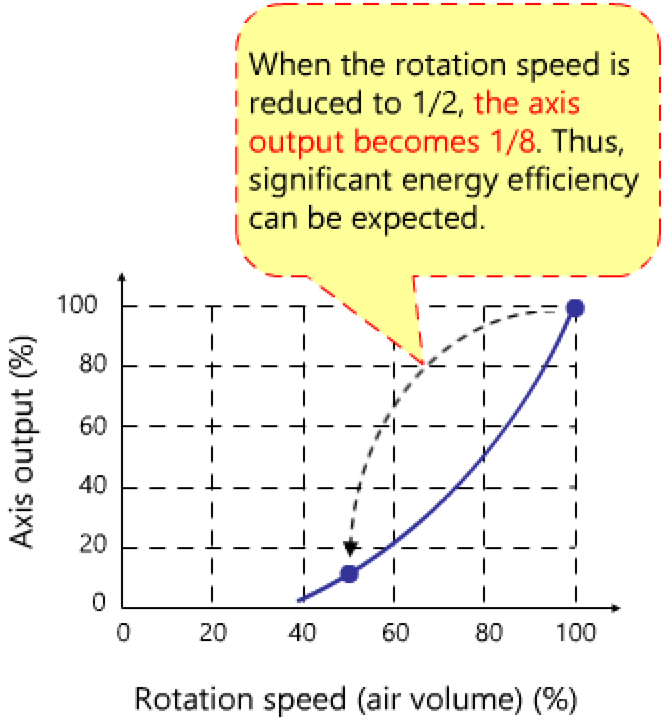
2.3 Load Torque Characteristics

For fans and pumps (variable-torque load characteristics)

Load torque: Proportional to the square of the rotation speed (air volume) $T \propto N^2$
Axis output: Proportional to the cube of the rotation speed (air volume) $P \propto N^3$

Specifically, as shown in the following graphs, when the rotation speed is reduced to 50%, the motor axis power decreases to (1/2)^3 = 1/8.





2.4 Concept of Energy Saving Calculation

Total energy and electricity charges to be saved per year can be calculated by obtaining the difference in annual energy consumption between a motor driven by a commercial power supply and a motor driven by an inverter.
For details about the calculation method, refer to *TECHNICAL NOTE No. 27 ENERGY SAVING CALCULATION USING INVERTERS*.

2.5 Summary

In this chapter, you have learned:

Points

How to Change Speed with Standard Motors	The air volume is controlled with a shielding plate called a damper. Since the motor speed is constant, decreasing the air volume does not greatly reduce the energy consumption.
Driving Standard Motors with Inverters	The air volume is controlled by the motor speed, which can be reduced by lowering the output frequency. Reducing the air volume will lead to large energy savings.
Load Torque Characteristics	Large energy savings can be expected when an inverter controls a machine with a variable-torque load (e.g., fan, pump, or blower), as the axis output is reduced to 1/8 compared to when it is operated using a commercial power supply.
Concept of Energy Saving Calculation	It is important to calculate the total energy and electricity charges to be saved per year by obtaining the difference in annual energy consumption between a motor driven by a commercial power supply and a motor driven by an inverter.

Chapter 3 Useful Energy-Saving Functions in the FR-F800/700 Series

This chapter explains the FR-F800 and FR-F700PJ series, and their functions that contribute to saving energy.

In this chapter, the following icons are used to indicate the series in which the function is available.

Icon	Corresponding Inverter
F800	FR-F800
F700PJ	FR-F700PJ

3.1 Introduction of FR-F800 and FR-F700PJ Series

■ FR-F800 Series – Next-generation Inverters with Enhanced Energy-Saving Control

The FR-F800 series inverters are easy and safe to use, and support a wide range of energy-saving applications, offering a variety of functions ideal for fans and pumps.
The FR-F800 series offers next-generation energy-saving inverters ideal for fans and pumps.

- A newly developed advanced optimum excitation control delivers a large starting torque while maintaining the same motor efficiency as under the conventional optimum excitation control.
- Both standard motors and IPM motors are supported. IPM motors achieve even higher energy efficiency than standard motors.
  The motor to be used can be switched between a standard motor and an IPM motor by only a single setting.
- The tuning function enables the inverter to support both general-purpose and PM motors of other manufacturers(*1), which increases the range of inverter applications for energy saving.
- With the 24 VDC external power supply, the input MC signal can be turned OFF after the motor is stopped, and turned ON before the motor is activated.
  The inverter enables self power management to reduce standby power.

*1: Depending on the characteristics of the motor to be used, tuning may not be feasible.

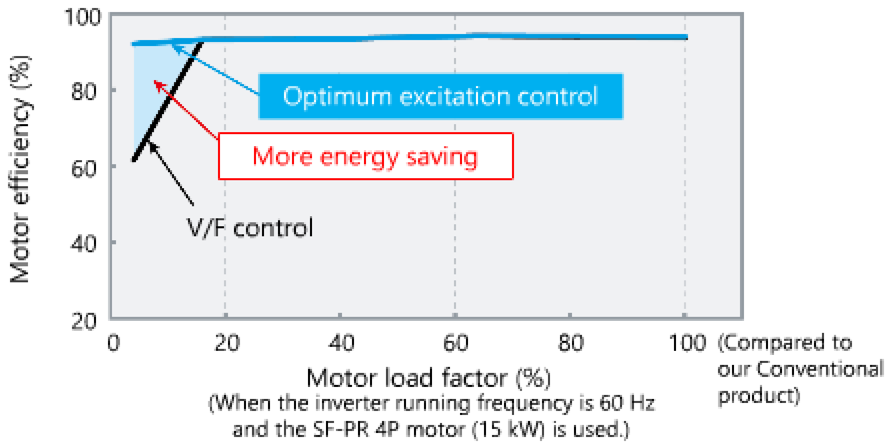
■ FR-F700PJ Series – Compact Inverters Suitable for Air Conditioning Systems

Functions ideal for fans and pumps enable energy saving. The built-in filter pack achieves a compact design with reduced wiring.

- The adopted rotation speed control for controlling the air volume saves energy.
- The energy saving efficiency can be easily checked on the energy-saving monitor or with the square wave of the output power.
- Both standard motors and IPM motors are supported. IPM motors achieve even higher energy efficiency than standard motors.
  The motor to be used can be switched between a standard motor and an IPM motor by only a single setting.

3.2 Enhanced Energy-Saving Operation F800

A newly developed Advanced optimum excitation control delivers a large starting torque while maintaining the same motor efficiency as under the conventional Optimum excitation control. Rapid acceleration is enabled without troublesome parameter settings (e.g., torque boost, acceleration/deceleration time). Energy-saving operation with maximum motor efficiency is possible during operation at a constant speed.

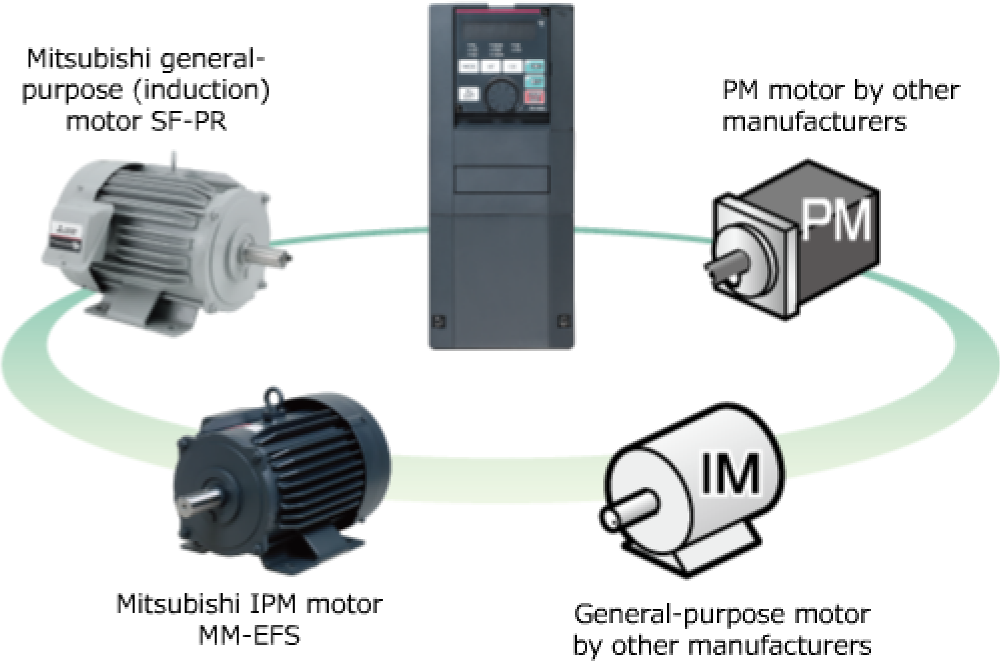


3.3 Compatibility with Motors of Other Manufacturers

F800

The offline auto tuning function to measure circuit constants of the motor enables optimal operation of motors even when motor constants vary, when a motor of other manufacturers is used, or when the wiring distance is long. As well as Mitsubishi general-purpose motors, Mitsubishi PM motors (MM-EFS, MM-THE4), sensorless operation can be performed for other manufacturers' general-purpose motors* and other manufacturers' permanent magnet (PM) motors*.
The tuning function enables the Advanced optimum excitation control of other manufacturers' general-purpose motors*, which increases the use in the energy saving applications.

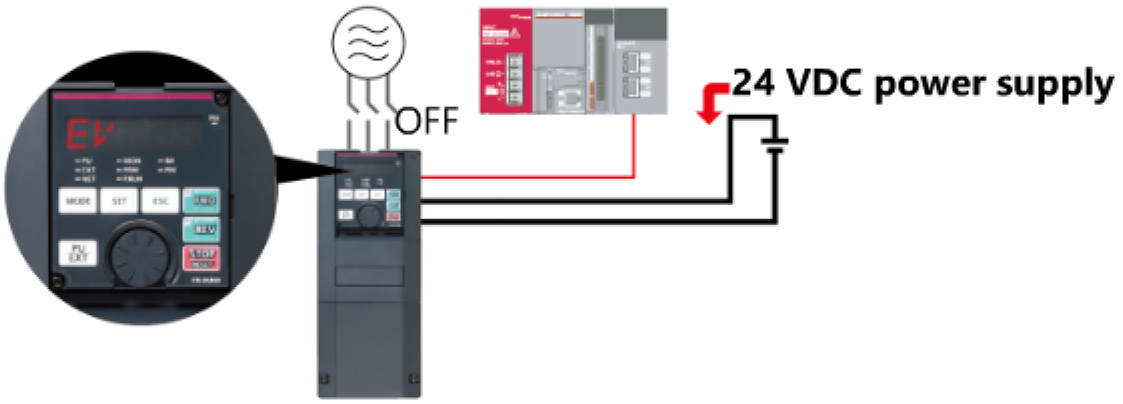
*: Depending on the characteristics of the motor to be used, tuning may not be available.



3.4 Standby Power Reduction

TOC

In addition to the control power supply to R1 and S1 (AC), 24 VDC input is also equipped.
Since the 24 VDC external power supply allows the control circuit to operate independently, parameter setting and communication are possible even after turning off the main power. This contributes to the reduction of standby power, enabling safe maintenance work. **F800**



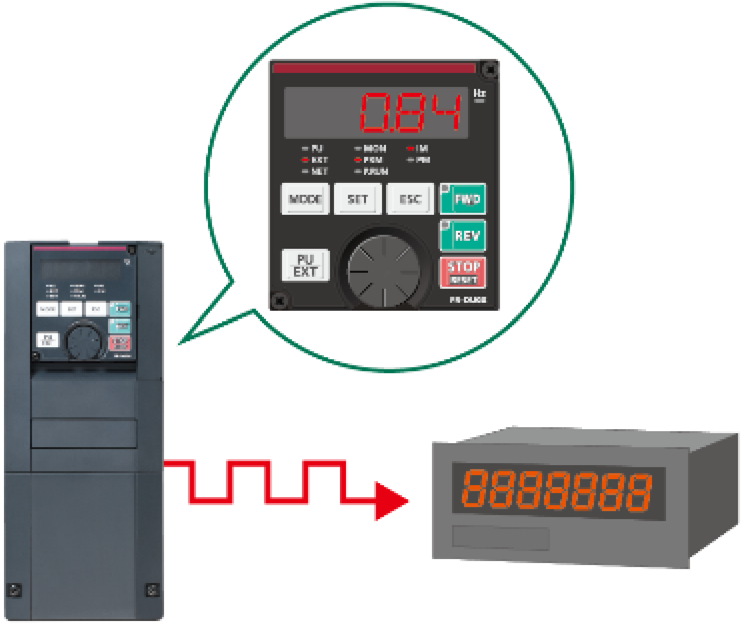
- With the 24 VDC external power supply, the input MC signal can be turned OFF after the motor is stopped, and turned ON before the motor is activated.
  The inverter enables self power management to reduce standby power. **F800**

- The inverter cooling fan can be controlled in response to changes in the temperature of the inverter cooling fins. Since signals can be output in response to the operation of the inverter cooling fan, a fan installed on a panel can be operated in synchronization with the inverter cooling fan. Unnecessary energy consumption while the motor is not in service can be reduced. **F800** **F700PJ**

3.5 Energy Saving at a Glance

F800 F700PJ

- Energy saving monitor is available. The energy saving effect can be checked using an operation panel, output terminal, or network.
- The output power amount measured by the inverter can be output in pulses. The cumulative power amount can be easily checked.
- With the Mitsubishi energy measuring module, the energy saving effect can be displayed, measured, and collected.



3.6 Summary

In this chapter, you have learned:

Points

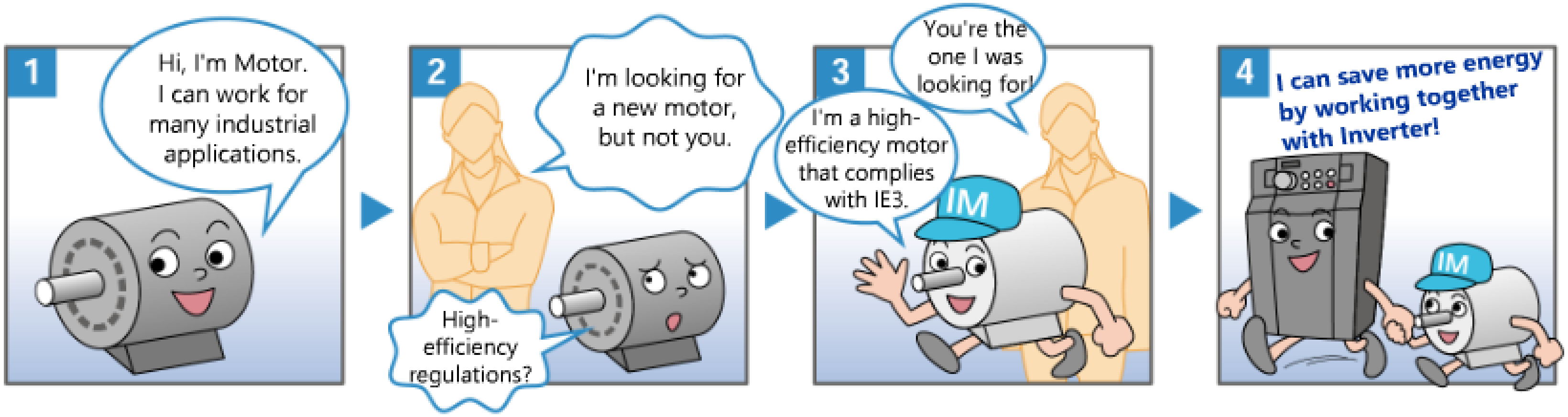
Introduction of FR-F800 and FR-F700PJ Series	Both standard and IPM motors are supported.
Enhanced Energy-Saving Operation	A large starting torque can be delivered while maintaining the same motor efficiency as under the conventional optimum excitation control.
Compatibility with Motors of Other Manufacturers	The auto-tuning function for automatically calculating the motor constant promises motor operation with the optimum characteristics even when there is discrepancy in the motor constants, the motor is from another manufacturer, or the installed wiring is long.
Standby Power Reduction	A 24 VDC external power supply allows the control circuit to operate independently, which reduces the standby power.
Energy Saving at a Glance	The energy saving monitor is available and the output power amount can be output in pulses. The energy saving effect can be checked.

Chapter 4 High-Efficiency Motor Regulations

This chapter explains the regulations related to high-efficiency motors.

4.1 About High-Efficiency Motor Regulations

Large energy savings can be achieved by improving the efficiency of motors, or by using motors combined with inverters. As it is estimated that nearly 60% of the world's electric power is consumed by motors, the effect of such improvement can lead to large energy savings. The introduction of regulations for mandatory use of high-efficiency motors is being promoted worldwide due to the increasing awareness of the need for energy saving to prevent global warming.



4.2 What is IE?

IE is the abbreviation for International Efficiency Standard Level and it defines the international standards for motor efficiency.

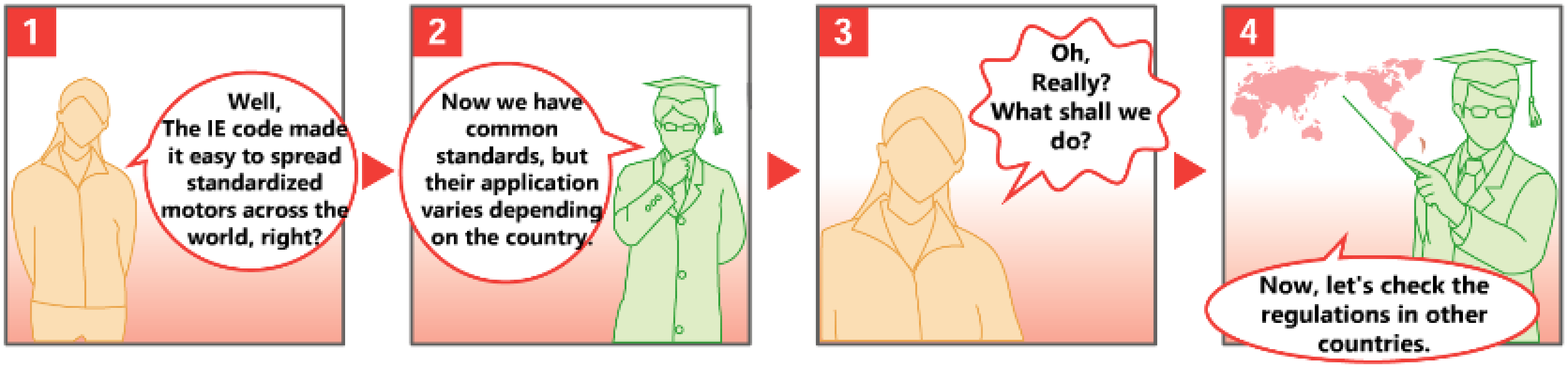
The global trend towards improving efficiency is accompanied by rising demand for high-efficiency motors. To increase the use of high-efficiency motors worldwide, it was necessary to integrate the motor efficiency standards that had been uniquely defined according to individual countries.

In October 2008, the IEC established the international standard IEC 60034-30 (Efficiency classes for single-speed squirrel-cage induction motors). This standard defines the IE codes. The IE codes include four classes.

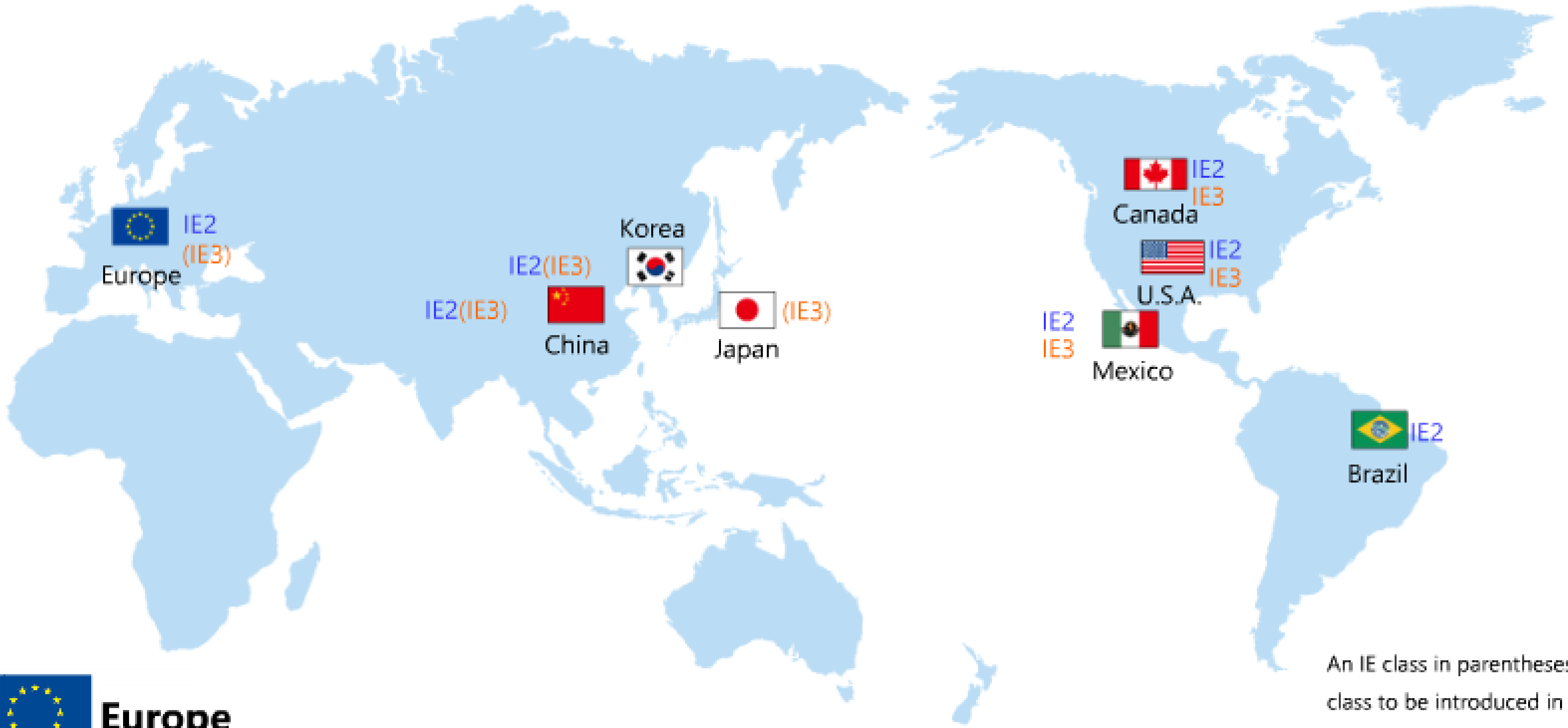
High — Efficiency — Low

Efficiency class IEC 60034-30	Mitsubishi motor efficiency	
	General-purpose motor	IPM motor
IE4 (super premium efficiency) *3	—	Premium high-efficiency IPM (M-EFS, MM-THE4)
IE3 (premium efficiency)	Superline premium series (SF-PR)	—
IE2 (high efficiency)	Superline eco series (SF-HR)	—
IE1 (standard efficiency)	Superline series (SF-JR)	—
Below the class		—

*3 The details of IE4 are defined in IEC 60034-31.



4.3 World's High-Efficiency Motor Regulations



An IE class in parentheses indicates a class to be introduced in the future.

Europe

In Europe, regulations stipulating that motors must meet the IE2 efficiency level have been enforced since June 16, 2011. However, the following motors are excluded: brake motors, motors designed to operate while wholly immersed in liquid, motors integrated into a product (where energy performance cannot be tested independently), and motors designed to operate in a specific environment (such as altitudes exceeding 1000 m above sea level, or ambient air temperatures above 40°C). When using a motor in Europe, it is important to check the specification details of the motor. The regulation was updated on January 1, 2015, stipulating that motors from 7.5 to 375 kW must meet the IE3 efficiency level. Starting on January 1, 2017, motors from 0.75 kW to 375 kW must meet the IE3 efficiency level. Our SF-PR-EU motors are applicable.

China

A regulation was enacted on July 1, 2011 stipulating that motors must be certified as Grade GB2 (equivalent to IE2) instead of the previous Grade GB3 (equivalent to IE1). The regulation also applies to explosion-proof motors. Since the regulation applies to commercial motors, it is necessary to keep an eye out for any changes to the regulation. A regulation was enacted on January 1, 2016 stipulating that motors from 7.5 kW to 375 kW must meet the Grade GB2 (equivalent to IE3) efficiency level. Starting on January 1, 2017, motors from 0.75 to 375 kW must meet the GB2 (IE3) efficiency level. Our SF-PR-CN motors are applicable.

4.3 World's High-Efficiency Motor Regulations

Korea

A regulation was introduced in July 2008 requiring an efficiency level equivalent to IE2. The organizations for which certification is mandatory are limited to companies that have their factories in Korea. The regulation was updated on January 1, 2015, stipulating that motors must meet the IE3 efficiency level. The power range of the motors to which the regulation applies will be extended in stages. Our SF-PR-KR motors are applicable.

U.S.A.

Motors were originally regulated by the EPAct to provide for improved energy efficiency equivalent to IE2. EPAct was followed by the Energy Independence and Security Act ("EISA"), which came into effect in December 2010. The major amendments are as follows:

- Motors must meet the efficiency level equivalent to IE3 instead of the previously applied IE2 level.
- The regulation has been extended to make the IE2 level mandatory for motors that were previously outside the scope of the EPAct.

Our SF-PR motors are applicable.

Canada

Since January 2011, higher energy efficiency has been pursued within the range of regulations that follow those enforced in the U.S.A.

Mexico

The revised energy efficiency regulation came into force in January 2011. Basically, North and Central America have tried to achieve high efficiency levels within the range of regulations that follow those enforced in the U.S.A. However, when exporting motors, attention must be paid to exceptions that may be included in the regulations. Our SF-PR-MX motors are applicable.

Brazil

Being a member of the BRICS group, Brazil ranks 8th in the world in primary energy consumption. As of December 8, 2009, motors must be certified as almost the same energy efficiency class as required by EPAct (i.e., equivalent to IE2). In addition, labeling is mandatory for the certified products.

Japan

Further improvement of high energy efficiency of the motors themselves has been under discussion since November 2009. In 2012, the criteria were announced for evaluating energy efficiency based on the Energy Conservation Law, and the Law concerning the Rational Use of Energy (Energy Conservation Law) was enacted in April 2015. As a result, motors to be supplied must meet the Top Runner standard in principle. Our SF-PR motors are applicable.

4.4 Summary

In this chapter, you have learned:

Points

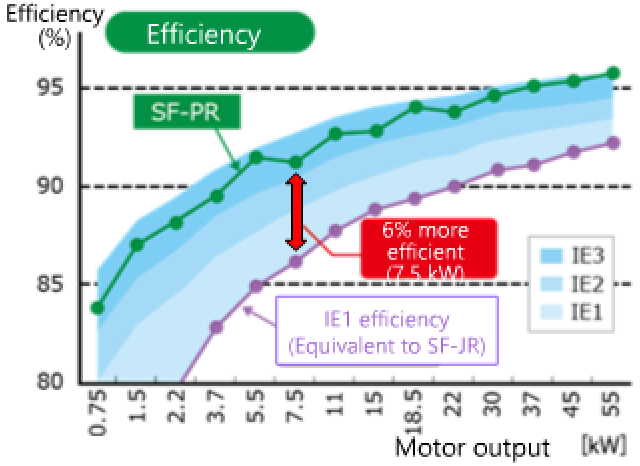
High-Efficiency Motor Regulations	Introduction of regulations for mandatory use of high-efficiency motors is being promoted globally.
What is IE?	IE is the abbreviation for International Efficiency Standard Level and it defines the international standards for motor efficiency. In October 2008, the IEC established the international standard IEC 60034-30 (Efficiency classes of single-speed, cage-induction motors), in which the IE codes are defined.
World's High-Efficiency Motor Regulations	An increasing number of countries throughout the world have been introducing regulations on high-efficiency motors; however, Japan lags slightly behind Europe and the U.S. in terms of efforts to introduce such regulations.

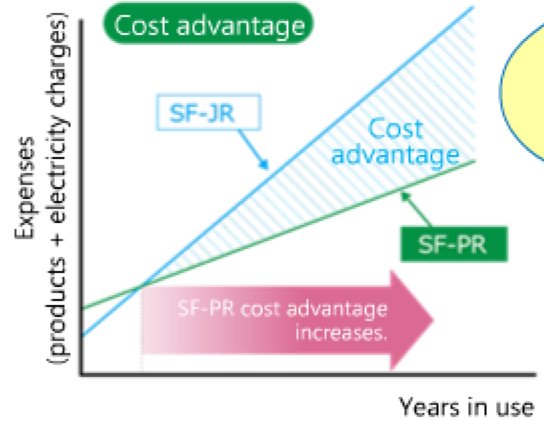
Chapter 5 Superline Premium Series SF-PR

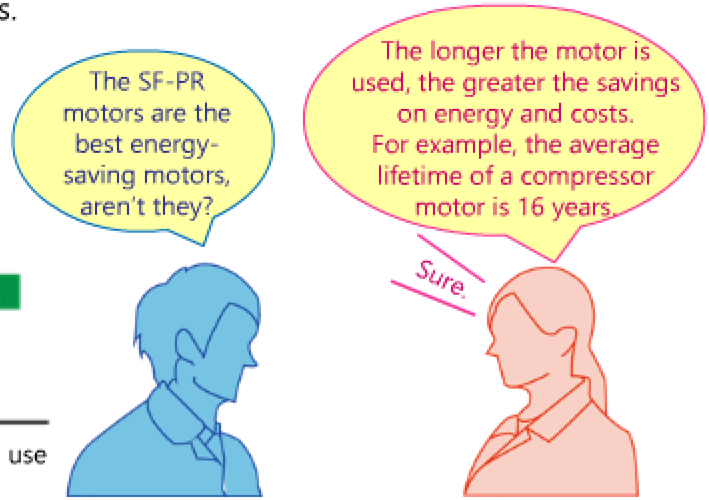
This chapter explains the superline premium series SF-PR compatible with IE3 premium efficiency.
When used in combination with the FR-A800 inverter, the motor continuously operates from a low speed.

5.1 Comparison of Energy-Saving Efficiency between the SF-PR and the SF-JR

The SF-PR motor conforming to Japan's unique Top Runner Program Standards (equivalent to IE3) achieves 6% higher energy efficiency than the SF-JR standard motor. (7.5 kW)
Energy-saving operation can reduce electricity charges, reducing running costs.







Calculated in Japanese yen.

Annual savings (electricity charges)

$$\text{Output (kW)} \times \left(\frac{100}{\text{Efficiency of current motor (\%)}} - \frac{100}{\text{Efficiency of SF-PR motor (\%)}} \right) \times \text{Number of motors} \times \text{Hours of use (h/day)} \times \text{Days of use (days/year)} \times \text{Electricity charges (yen/kWh)}$$

[For 7.5 kW]

$$7.5\ \text{(kW)} \times \left(\frac{100}{85.6(\%)\ \boxed{\text{SF-JR}}} - \frac{100}{91.2(\%)\ \boxed{\text{SF-PR}}} \right) \times 1\ \text{(motor)} \times 24\ \text{(h/day)} \times 365\ \text{(days/year)} \times 16\ \text{(yen/kWh)}$$

= 75,406 yen

With a 6% increase in efficiency
Approx. 75,000 yen/year in electricity charges can be saved.

If 100 motors are used,

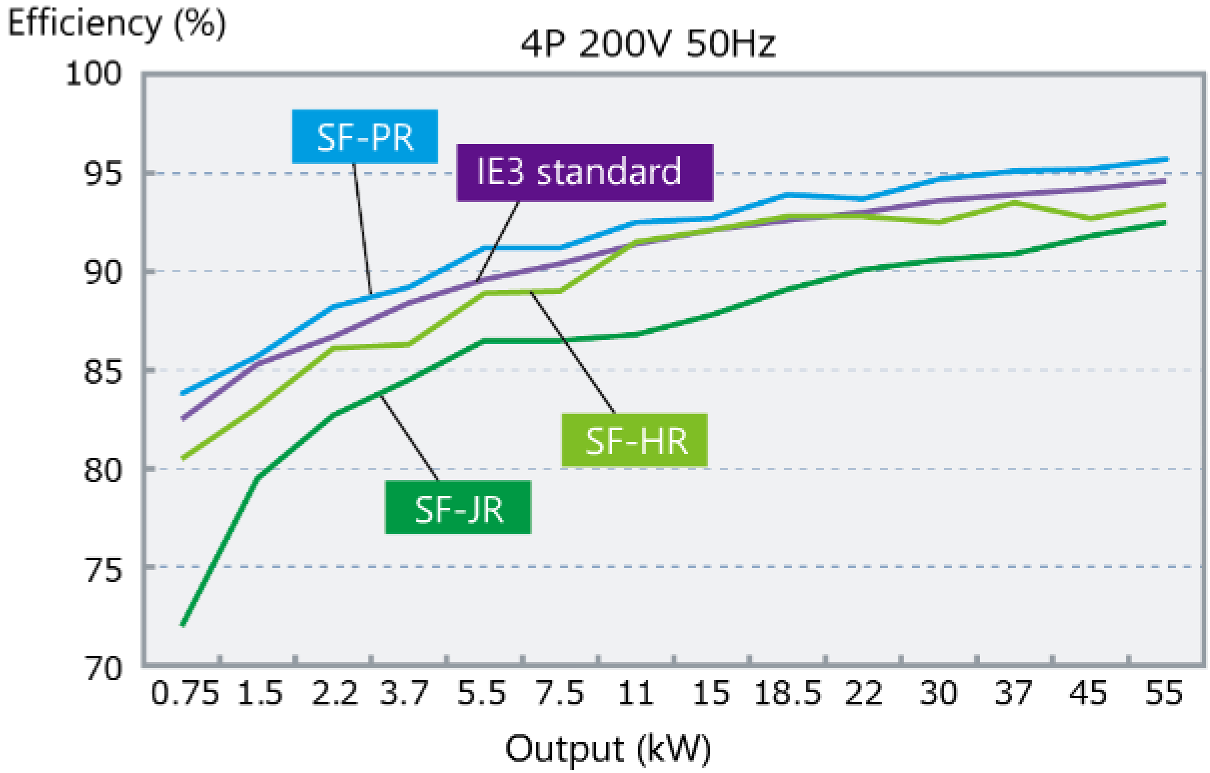
Approx. 7.5 million yen can be saved per year.

5.2 SF-PR Motor Best Suits the FR-F800 Series

If you want to drive an SF-PR motor by an FR-F800 inverter, all you have to do is set the SF-PR motor parameters (70, 73, 74) in Pr.71 Applied motor.
Since the motor constants have been internally set to the FR-F800 inverters, no complicated settings are required.
In addition to the conventional high-efficiency energy-saving motors, it can also be used as an alternative to an inverter-driven constant-torque motor.

■ Ideal, high-efficiency motor

Since the motor constants have been internally set to the FR-F800 inverters, energy-saving operation is possible by simply setting the parameters.
The SF-PR motor, which adheres to Japan's unique Top Runner Program Standards (equivalent to IE3), allows energy-efficient operation and reduced electricity charges, thus reducing running costs.



5.3 Estimation of SF-PR Motor Energy-Saving Effect

■ Energy-saving effect in our design building

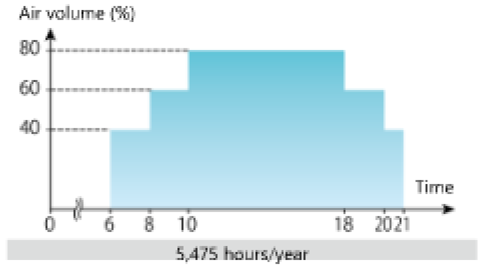
(Inverter + general-purpose motor (SF-JR) → Inverter + general-purpose motor (SF-PR)

Conditions

[Units to drive]

- ●Ventilator (Blower)
  - 0.75 kW × 3 units
  - 1.5 kW × 1 unit
  - 2.2 kW × 3 units
- ●Air conditioner
  - 15 kW × 1 unit
  - 18.5 kW × 1 unit
  - 30 kW × 2 units

Operation patterns



- ● With SF-JR motor
  Approx. 250,000 kWh
  Approx. 3.44 million yen
- ● With SF-PR motor
  Approx. 230,000 kWh
  Approx. 3.2 million yen/year.

The effect of replacing conventional system with inverter driven SF-PR motors

●Annual energy-saving effect (differences in the amount and cost)

Approx. 17,000 kWh

Approx. 240,000 yen

●Annual reduction in CO_2 emissions

Approx. 17,000 kWh **9.5 ton**

Calculated in Japanese yen.

5.4 Simulation on SF-PR Motor Life-Cycle Cost (LCC)

■ **Usage conditions** **Motor capacity: 15 kW; Air volume: 70%;**
Hours of operation: 16 hours/day × 250 days/year = 4,000 hours/year

	Standard motor driven by commercial power supply (Damper control)	**Inverter-driven high-efficiency motor**	Remarks
Motor capacity	15kW		The initial cost of the damper control is the same as the standard price of a standard motor. The initial cost of introducing an inverter-driven standard motor or an inverter-driven IPM motor includes the standard price of the motor to be introduced and its installation cost (motor + inverter) × 0.5.
Inverter model name	Not used	FR-F840-15K	
Initial cost	291,000 yen	1,396,800 yen	
Air volume (%)	70 %		
Annual electricity consumption (kWh)	64,800 kWh	29,400 kWh	
Annual electricity charges	907,200 yen	411,600 yen	14 yen/kWh
Bearing replacement cost	120,000 yen	120,000 yen	The replacement cost varies depending on the circumstances.
Bearing replacement cycle (*)	5 years	5 years	
Inverter replacement cycle		10 years	
Difference in electricity charges compared to IPM	571,200 yen	75,600 yen	The annual energy-saving effect after introducing a premium IPM motor (1,000 kWh ≒ 0.555 ton-CO_2 emissions)
Difference in reduction of CO_2 emissions (ton) compared to IPM	**22.6 ton**	**2.9 ton**	
LCC (in 1,000 yen)	14,259	8,153	LCC for 15 years

(*) The bearing grease service life has been extended.

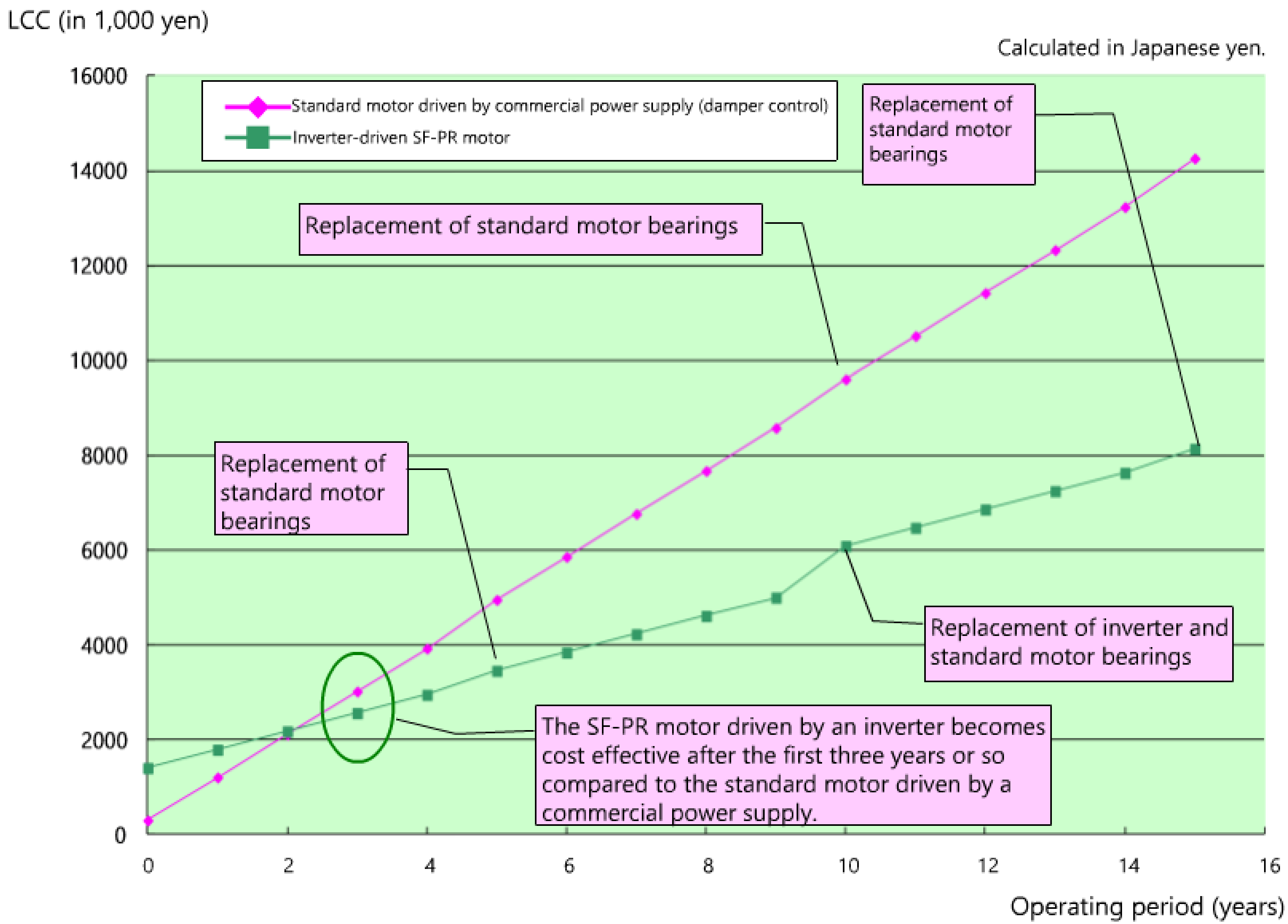
Calculated in Japanese yen.

Since the rotor seldom generates heat, the bearing temperature is kept low. This extends the service life of the bearing grease.

* The service life of the motor bearings is largely affected by temperature. It is estimated that a temperature drop of 10°C doubles the service life.

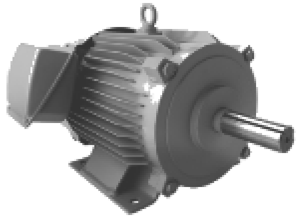
5.4 Simulation on SF-PR Motor Life-Cycle Cost (LCC)

■ **Usage conditions** **Motor capacity: 15 kW; Air volume: 70%;**
Hours of operation: 16 hours/day × 250 days/year = 4,000 hours/year



5.5 SF-PR Motor Lineup

Compatibility in motor installation dimensions (frame number) between the SF-PR series and the SF-JR series makes it easy to replace a motor.



■ Model name

S F - PR □ □ □

Symbol	Structure
S	Superline series

Symbol	Protective structure
F	Enclosed type

Symbol	Series
PR	Premium series Steel frame

Symbol	Mounting method
Not used	Horizontal type with legs
V	Vertical type
F	Flange type

Symbol	Classification
Not used	Indoor
O	Outdoor
P	Dust- and waterproof

Symbol	Classification
Not used	Without brake
P	With brake

■ Available range

Model name		SF-PR			SF-PRV			SF-PRF		
Number of poles		2P	4P	6P	2P	4P	6P	2P	4P	6P
Output [kW]	0.75	●	●	●	●	●	●	●	●	●
	1.5	●	●	●	●	●	●	●	●	●
	2.2	●	●	●	●	●	●	●	●	●
	3.7	●	●	●	●	●	●	●	●	●
	5.5	●	●	●	●	●	●	●	●	●
	7.5	●	●	●	●	●	●	●	●	●
	11	●	●	●	●	●	●	●	●	●
	15	●	●	●	●	●	●	●	●	●
	18.5	●	●	●	●	●	●	●	●	●
	22	●	●	●	●	●	●	●	●	●
	30	●	●	●	●	●	●	●	●	●
	37	●	●	●	●	●	●	●	●	●
	45	●	●	●	●	●	●	●	●	-
	55	●	●	-	●	●	-	-	-	-

5.6 Summary

In this chapter, you have learned:

Points

Comparison of Energy-Saving Efficiency between the SF-PR and the SF-JR	The SF-PR motor conforming to Japan's unique Top Runner Program Standards (equivalent to IE3) achieves 6% higher energy efficiency than the SF-JR standard motor. (7.5 kW) Energy-saving operation can reduce electricity charges, reducing running costs.
SF-PR Motor Best Suits the FR-F800 Series	Since the motor constants have been internally set to the FR-F800 inverters, energy-saving operation is possible by simply setting the parameters. The SF-PR motor, which adheres to Japan's unique Top Runner Program Standards (equivalent to IE3), allows energy-efficient operation and reduced electricity charges, thus reducing running costs.
Estimation of SF-PR Energy-Saving Effect	Replacing a standard motor (SF-JR) with a high-efficiency motor (SF-PR) reduces both electricity charges and CO_2 emissions.
Simulation on SF-PR Motor Life-Cycle Cost (LCC)	The initial cost of introducing a high-efficiency motor (SF-PR) is expensive; however, its high efficiency and reduced power consumption will realize more cost-effective operation after the first two years compared to using a commercial power supply (damper control).
SF-PR Motor Lineup	Compatibility in motor installation dimensions (frame number) between the SF-PR series and the SF-JR series makes it easy to replace a motor.

Chapter 6 Energy Saving with Inverter and IPM Motor

This chapter explains energy saving with the combined use of an inverter and an IPM motor.

6.1 What is an IPM Motor?

■ About IPM Motors

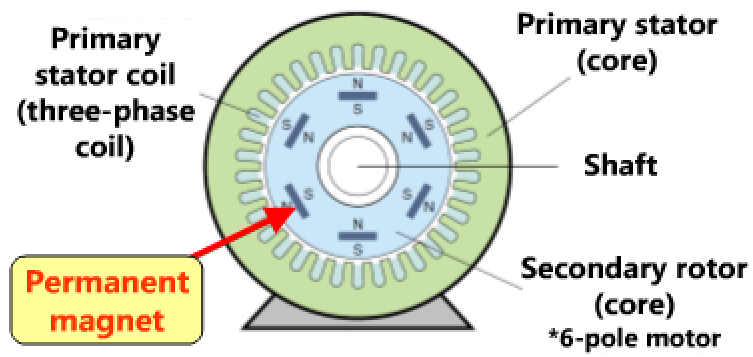
IPM is the abbreviation for Interior Permanent Magnet. IPM motors with permanent magnets embedded in the rotor have higher efficiency than induction motors, and meet the customers' needs for further energy saving.

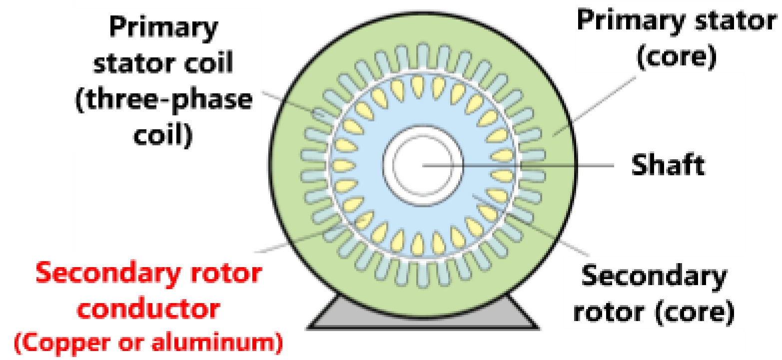
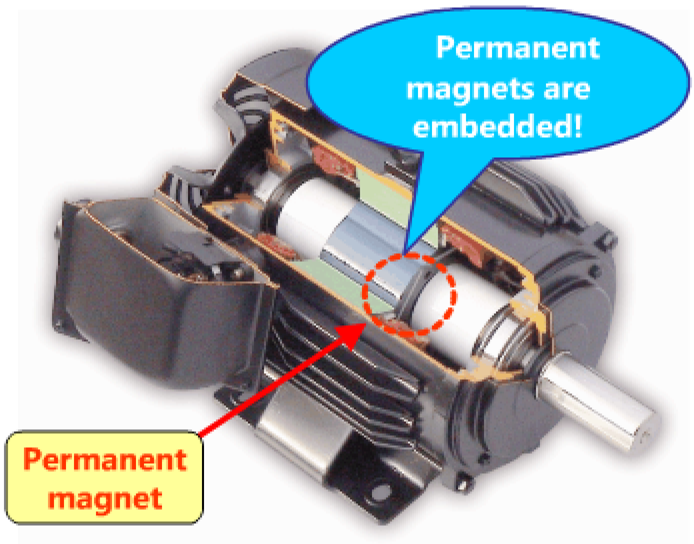
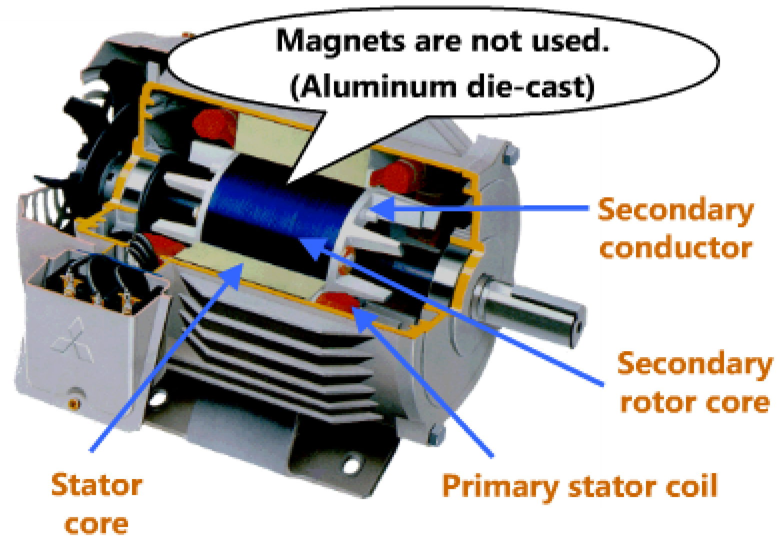
IPM Motor

■ Types of AC motors

- **Synchronous motor**
  - **Permanent magnetic system**
    - **Embedded magnetic type: IPM (IPM: Interior Permanent Magnet)**
    - Surface permanent magnetic type: SPM (SPM: Surface Permanent Magnet)
- Induction motor
  - Squirrel-cage type
  - Coil type

6.2 Structure and Operating Principle of IPM Motors

<table>
<tr><th></th><th>IPM motor (synchronous motor)</th><th>General-purpose motor (induction motor)</th></tr>
<tr><td>Structure (Section view)</td><td>

*The number of poles varies depending on the motor capacity.</td><td>
</td></tr>
<tr><td>Operating principle</td><td>The rotating magnetic field of the stator and the magnetic fields of the embedded magnets in the rotor generate the torque to produce rotation power.</td><td>When power supply voltage is applied to the stator, the rotating magnetic field appears, and a current is induced in the rotor conductor. Torque is generated between this current and the rotating magnetic field to produce the rotation power.</td></tr>
<tr><td>Cut-away model</td><td>
</td><td>
</td></tr>
</table>

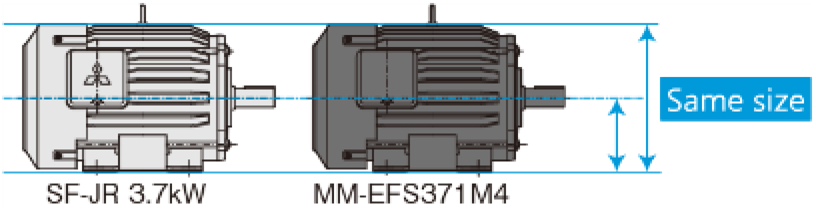
6.3 IPM Motors (MM-EFS and MM-THE4)

■ Compatible with the FR-F800/F700PJ series inverters

Mitsubishi IPM motors (MM-EFS and MM-THE4) are compatible with the FR-F800 series and FR-F700PJ series. Since the FR-F800 and FR-F700PJ series support both IPM motors and standard motors, the first choice for improving energy efficiency is to introduce an inverter for operating a standard 3-phase motor. After introducing the system, it can be improved in stages for higher energy efficiency, such as by replacing only the motor with an IPM motor.

■ Common frame numbers (55 kW or lower) between premium high-efficiency IPM motors and induction motors (4-pole)

The motor can be replaced without making any modifications to the motor mounting frame of a machine designed for an induction motor.



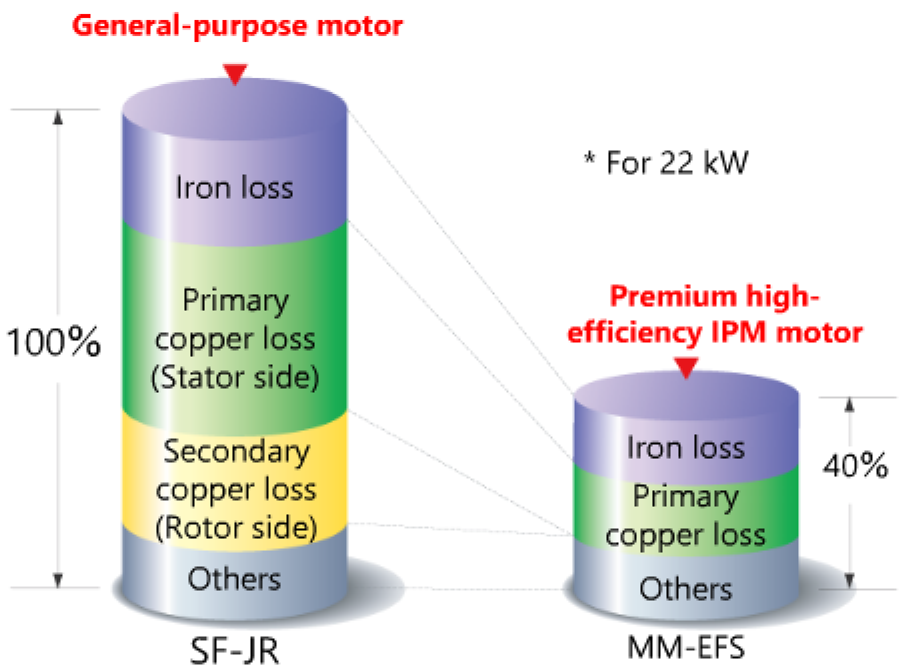
6.4 Why are IPM Motors More Efficient than Induction Motors?

Since no current flows through the rotor side (secondary side), there is no secondary copper loss. This reduces the energy loss. ⇒ The efficiency is improved.

$$\textbf{Efficiency} = \frac{\textbf{Output}}{\textbf{Input}} \times 100\ [\%] = \frac{\textbf{Output}}{\textbf{Output} + \textbf{Loss}} \times 100\ [\%]$$

Comparison of loss in motors

*Each of the following charts shows the breakdown of the motor internal loss.
(Compared to our company's products)

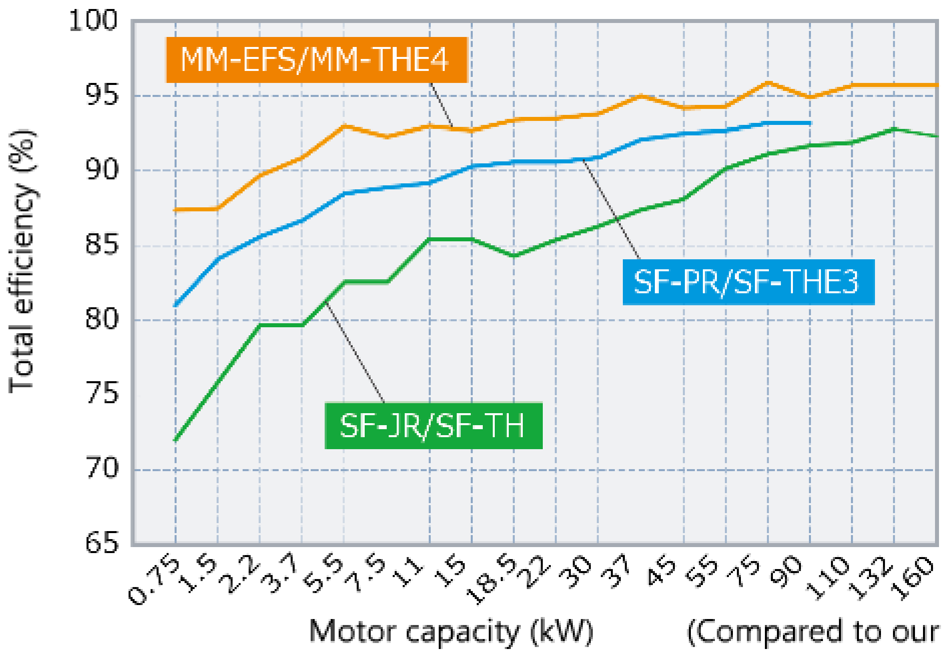


6.5 Comparison of Efficiency between IPM Motor Drive and Standard Motor Drive

If a standard motor (induction motor) is operated with an inverter at the same rotation speed as when it was operated using a commercial power supply, then the energy loss occurs only in the inverter.
Meanwhile, when an IPM motor is operated with an inverter at the same speed as when it was operated using a commercial power supply, then the total energy loss in the IPM motor and the inverter becomes smaller than that when a standard motor is driven with a commercial power supply (55 kW or lower).

IPM motors enable energy-saving operation even when the rotation speed is not changed and remains constant.

Comparison of Efficiency in Combinations of IPM Motor, Standard (Induction) Motor, and Commercial Power Supply



(Compared to our conventional products)

* Efficiency: The IPM motor and the standard motor were operated with the inverter at the rated speed (1800 r/min); the total efficiency is the sum of the motor efficiency and the inverter efficiency under the rated load.
In the combination of a standard motor and commercial power supply, the efficiency was calculated while the motor was driven by the commercial power supply (220 V, 60 Hz) .

6.6 Simulation on IPM Motor Life-Cycle Cost (LCC)

■ **Usage conditions** **Motor capacity: 15 kW; Air volume: 70%;**
Hours of operation: 16 hours/day × 250 days/year = 4,000 hours/year

	Standard motor driven by commercial power supply (Damper control)	Inverter-driven high-efficiency motor	Inverter-driven premium high-efficiency IPM motor (MM-EFS)	Remarks
Motor capacity	15kW			The initial cost of the damper control is the same as the standard price of a standard motor. The initial cost of introducing an inverter-driven standard motor or an inverter-driven IPM motor includes the standard price of the motor to be introduced and its installation cost (motor + inverter) × 0.5.
Inverter model name	Not used	FR-F840-15K		
Initial cost	291,000 yen	1,396,800 yen	1,738,800 yen	
Air volume (%)	70 %			
Annual electricity consumption (kWh)	64,800 kWh	29,400 kWh	24,000 kWh	
Annual electricity charges	907,200 yen	411,600 yen	336,000 yen	14 yen/kWh
Bearing replacement cost	120,000 yen	120,000 yen	150,000 yen	The replacement cost varies depending on the circumstances.
Bearing replacement cycle (*)	5 years	5 years	10 years	
Inverter replacement cycle		10 years	10 years	
Difference in electricity charges compared to IPM	571,200 yen	75,600 yen		The annual energy-saving effect after introducing a premium IPM motor (1,000 kWh ≒ 0.555 ton-CO_2 emissions)
Difference in reduction of CO_2 emissions (ton) compared to IPM	**22.6 ton**	**2.9 ton**		
LCC (in 1,000 yen)	14,259	8,153	7,511	LCC for 15 years

(*) The bearing grease service life has been extended.

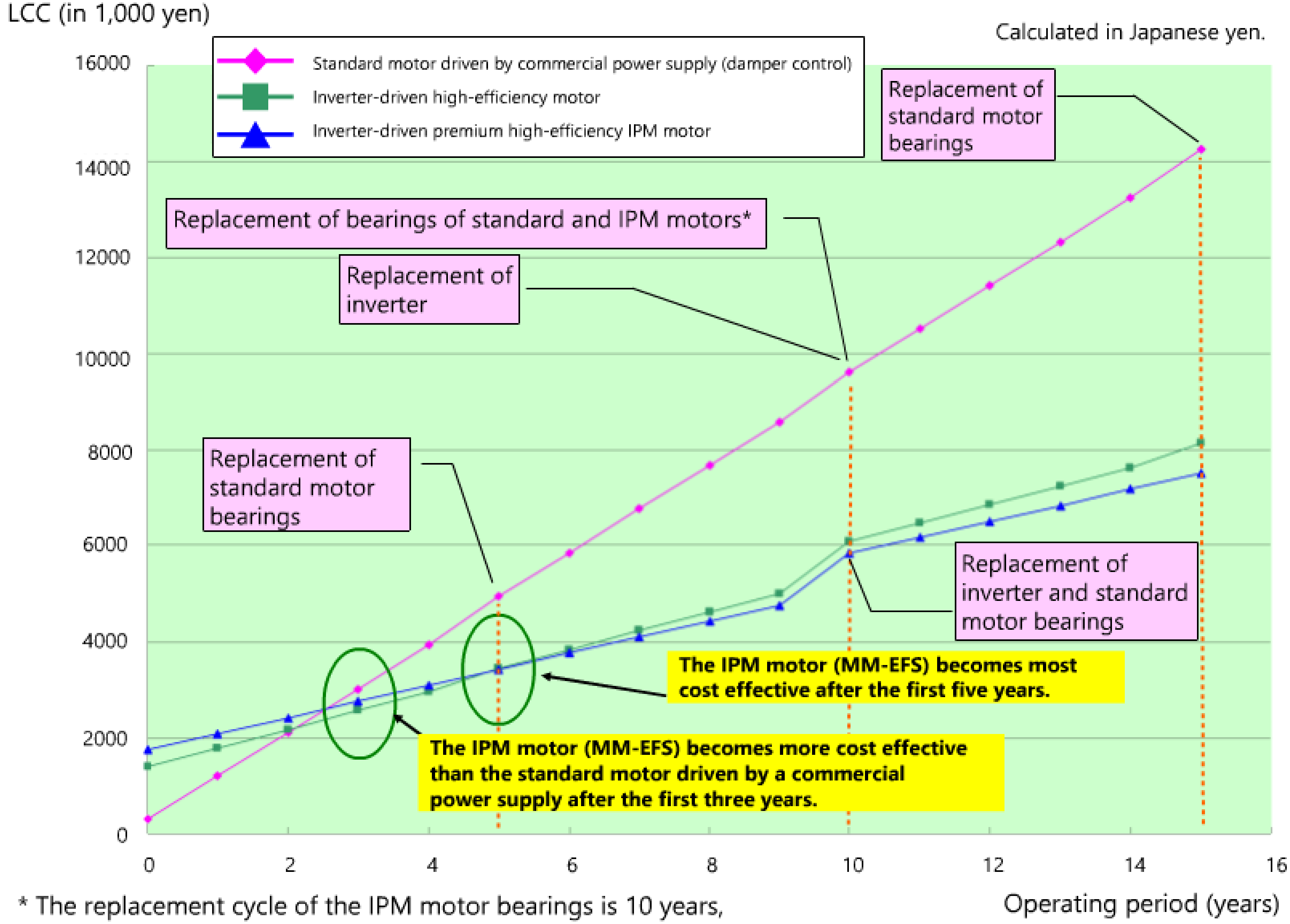
Calculated in Japanese yen.

Since the rotor seldom generates heat, the bearing temperature is kept low. This extends the service life of the bearing grease.

* The service life of the motor bearings is largely affected by temperature. It is estimated that a temperature drop of 10°C doubles the service life.

6.6 Simulation on IPM Motor Life-Cycle Cost (LCC)

■ Usage conditions **Motor capacity: 15 kW; Air volume: 70%;**
Hours of operation: 16 hours/day × 250 days/year = 4,000 hours/year

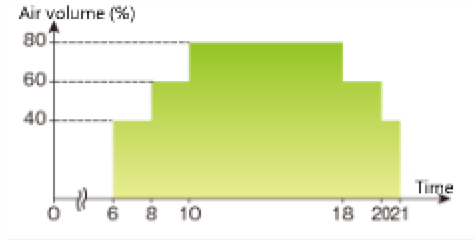
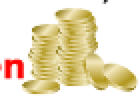


* The replacement cycle of the IPM motor bearings is 10 years, which is twice as long as that of the standard motor bearings.

6.7 Estimation of IPM Motor Energy-Saving Effect

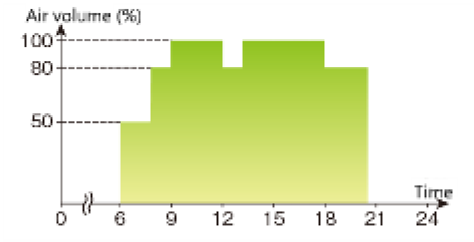
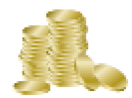
■ Energy-saving effect in our design building

(Inverter + general-purpose motor (SF-JR) → Inverter + IPM motor (MM-EFS))

Conditions	Operation patterns	The effects of replacing conventional systems with inverter driven IPM motors
[Units to drive] ● Ventilator (Blower) 0.75 kW × 3 units 1.5 kW × 1 unit 2.2 kW × 3 units ● Air conditioner 15 kW × 1 unit 18.5 kW × 1 unit 30 kW × 2 units 	 5,475 hours/year ● With standard motor Approx. 250,000 kWh Approx. 3.44 million yen ● With IPM motor Approx. 220,000 kWh Approx. 3.02 million yen	● **Annual energy-saving effect (differences in the amount and cost)** Approx. 30,000 kWh **Approx. 420,000 yen**  ● **Annual reduction in CO_2 emissions** Approx. 30,000 kWh **16.7 ton**

Calculated in Japanese yen.

■ Air conditioner for buildings (Inverter + general-purpose motor (SF-JR) → Inverter + IPM motor (MM-EFS))

Conditions	Operation patterns	The effects of replacing conventional systems with inverter driven IPM motors
[Units to drive] ● Fans for air conditioner 5.5 kW × 10 units 7.5 kW × 10 units 3.7 kW × 100 units 	 5,110 hours/year ● With general-purpose motor Approx. 2.39 million kWh Approx. 33.42 million yen ● With IPM motor Approx. 2.1 million kWh Approx. 29.43 million yen	● **Annual energy-saving effect (differences in the amount and cost)** Approx. 280,000 kWh **Approx. 3.99 million yen**  ● **Annual reduction in CO_2 emissions** Approx. 280,000 kWh **158 ton**

Calculated in Japanese yen.

6.8 MM-EFS and MM-THE4 Lineup

Premium high-efficiency IPM motor

55 kW or lower

MM-EFS [7] [1M] [4] [ ] [ ]

Symbol	Output	Symbol	Output	Symbol	Output
7	0.75 kW	75	7.5 kW	30K	30 kW
15	1.5 kW	11K	11 kW	37K	37 kW
22	2.2 kW	15K	15 kW	45K	45 kW
37	3.7 kW	18K	18.5 kW	55K	55 kW
55	5.5 kW	22K	22 kW		

Symbol	Rated speed *1
1M	1500 r/min

Symbol	Voltage class
Not used	200 V
4	400 V

Symbol	Specifications *2
Not used	Standard
Q	Class B

Symbol	Specifications *2
Not used	Standard
P1	Outdoor

*1: Can be used for applications at a rated speed of 1800 r/min.
*2: The outdoor type and class B are semi-standard models.

75 kW or higher

MM-THE4

- The motor can be used for application which required the rated speed of 1500 r/min and 1800 r/min.
- For dedicated motors, such as the outdoor type, long-axis type, flange type, waterproof and outdoor type, and the salt-damage proof specification type, contact your sales representative.

Rated output (kW)		0.75	1.5	2.2	3.7	5.5	7.5	11	15	18.5	22	30	37	45	55	75	90	110	132	160
Motor model name		7	15	22	37	55	75	11K	15K	18K	22K	30K	37K	45K	55K	—	—	—	—	—
200V class	MM-EFS□1M	●	●	●	●	●	●	●	●	●	●	●	●	●	●	—	—	—	—	—
400V class	MM-EFS□1M4	●	●	●	●	●	●	●	●	●	●	●	●	●	●	—	—	—	—	—
200V class	MM-THE4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—
400V class	MM-THE4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●	●	●	●	●

■Caution
- The IPM motor MM-EFS/MM-THE4 series cannot be driven by the commercial power supply.
- The total wiring length for IPM motors should be 100 m or less.
- Only one IPM motor can be connected to each inverter.
- For a belt drive with a MM-EFS of 11 kW or higher, contact us.

●: Available; –: Not available

6.8 MM-EFS and MM-THE4 Lineup

Premium high-efficiency IPM motor (3000 r/min)

15 kW or lower

MM-EFS [7] [3] [ ]

Symbol	Output	Symbol	Output
7	0.75 kW	55	5.5 kW
15	1.5 kW	75	7.5 kW
22	2.2 kW	11K	11 kW
37	3.7 kW	15K	15 kW

Symbol	Rated rotation speed
3	3000 r/min

Symbol	Voltage class
Not used	200 V
4	400 V

■Caution
- The IPM motor MM-EFS series cannot be operated with a commercial power supply.
- The total wiring length for IPM motors should be 100 m or less.
- Only one IPM motor can be connected to each inverter.
- IPM motors with a capacity of 11 kW or higher are dedicated for direct connection.

●: Available; –: Not available

6.9 Summary

In this chapter, you have learned:

Points

What is an IPM Motor?	IPM motors are synchronous motors with a rotor in which permanent magnets are embedded. IPM motors can provide higher performance and energy efficiency compared to induction motors.
Structure and Operating Principle of IPM Motors	The rotating magnetic field of the stator and the magnetic fields of the embedded magnets in the rotor generate the torque to produce rotation power.
IPM Motors (MM-EFS and MM-THE4)	Mitsubishi IPM motors (MM-EFS and MM-THE4) can be used for the FR-F800 series and FR-F700PJ series. The motor can be replaced without making any modifications to the motor mounting frame of a machine designed for an induction motor.
Why are IPM Motors More Efficient than Induction Motors?	Since no current flows through the rotor side (secondary side), there is no secondary copper loss. This reduces the energy loss.
Comparison of Efficiency between IPM Motor Drive and Standard Motor Drive	Meanwhile, when an IPM motor is operated with an inverter at the same rotation speed as when it was operated with a commercial power supply, the total loss of the IPM motor and the inverter becomes smaller than that when a standard motor is operated with a commercial power supply (55 kW or lower).
Simulation on IPM Motor Life-Cycle Cost (LCC)	The initial cost of introducing a premium high-efficiency IPM motor (MM-EFS) is expensive; however, its high efficiency and reduced power consumption will realize the most cost-effective operation after the first five years.
Estimation of IPM Motor Energy-Saving Effect	Replacing a standard motor (SF-JR) with an IPM motor (MM-EFS) reduces both electricity charges and CO_2 emissions.
MM-EFS and MM-THE4 Lineup	Explains the MM-EFS and MM-THE4 lineup.

Test Final Test

Now that you have completed all of the lessons in the **Inverter Energy Saving** course, you are ready to take the final test.
If you are unclear on any of the topics covered, please take this opportunity to review those topics.
There are a total of 5 questions (20 items) in this Final Test.
You can take the final test as many times as you like.

How to score the test

After selecting the answer, make sure to click the **Answer** button. Your answer will be lost if you proceed without clicking the Answer button. (Regarded as unanswered question.)

Score results

The number of correct answers, the number of questions, the percentage of correct answers, and the pass/fail result will appear on the score page.

Correct answers: 5

Total questions: 5

Percentage: 100%

To pass the test, you have to answer **60%** of the questions correct.

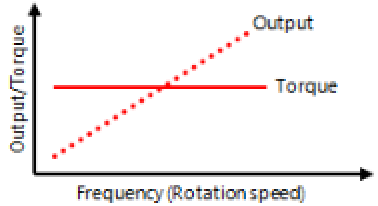
Proceed | Review

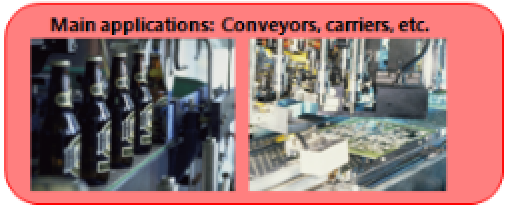
- Click the **Proceed** button to exit the test.
- Click the **Review** button to review the test. (Correct answer check)
- Click the **Retry** button to retake the test again.

Test | Final Test 1

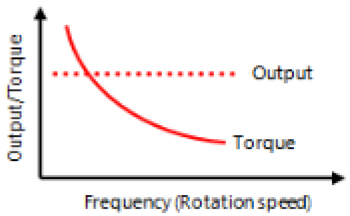
The following shows the load torque characteristics. Choose the correct answer for each graph.

--Select-- : The torque does not change much even if the motor speed changes.

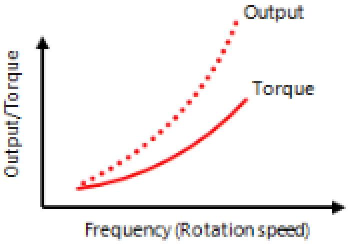




--Select-- : As the rotation speed increases, the torque becomes smaller.



--Select-- : As the rotation speed decreases, the torque becomes smaller.



Answer | Back

Test Final Test 2

Choose the correct torque load that delivers a significant improvement in energy efficiency when a motor is driven by an inverter instead of a commercial power supply.

- [Constant-torque load]
- [Constant-output load]
- [Variable-torque load]

Answer Back

Test Final Test 3

The following explains the functions of the FR-F800 series inverters. Choose the correct answer to complete the explanation.

- A newly developed --Select-- delivers a large starting torque while maintaining the same motor efficiency as under the conventional optimum excitation control.
- Both --Select-- and --Select-- are supported, and IPM motors achieve even higher energy efficiency than standard motors. The motor to be used can be switched between a standard motor and an IPM motor by only a single setting.
- The --Select-- function enables the inverter to support both general-purpose and PM motors of other manufacturers, which increases the range of inverter applications for energy saving.
- With the --Select-- , the input MC signal can be turned OFF after the motor is stopped, and turned ON before the motor is activated.

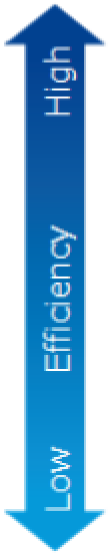
  The inverter enables --Select-- to reduce standby power.
- Energy saving monitor is available. The --Select-- can be checked using an operation panel, output terminal, or network.
- The output power amount measured by the inverter can be output in puin pulses.

  The --Select-- can be easily checked.
- With the Mitsubishi energy measuring module, --Select-- .

Answer Back

Test Final Test 4

The following table lists the IE efficiency classes in the order from highest to lowest. Choose the correct name of a motor for each class.



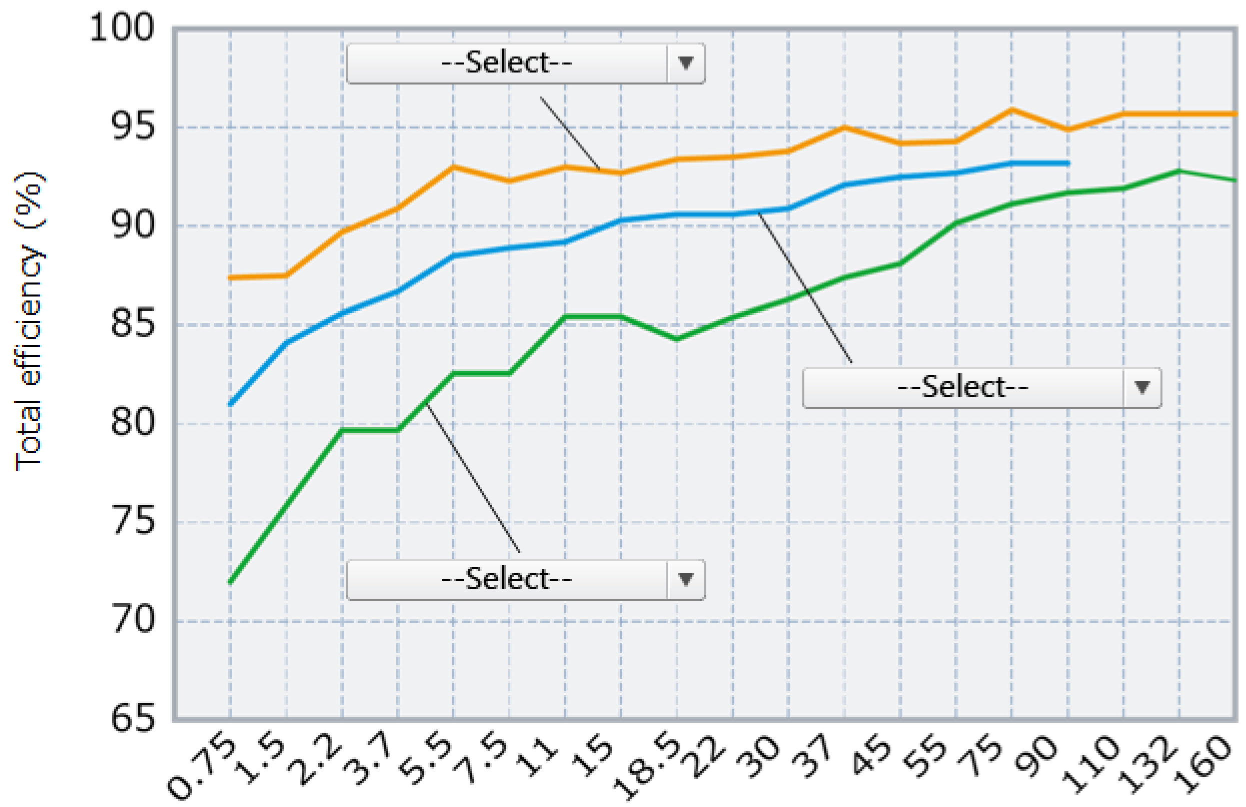
IE4 (super premium efficiency)	--Select--
IE3 (premium efficiency)	--Select--
IE2 (high efficiency)	--Select--
IE1 (standard efficiency)	--Select--
Below the class	

Answer Back

Inverter_Energy_Saving_ENG

Test **Final Test 5**

The following chart shows the comparison of efficiency between an IPM motor and a standard motor (induction motor) driven by a commercial power supply. Choose the correct name of a motor that corresponds to each line in the graph.



Answer Back

Motor capacity (kW) [Compared to our conventional products]

Test | Test Score

You have completed the Final Test. You results area as follows.
To end the Final Test, proceed to the next page.

Correct answers:	5
Total questions:	5
Percentage:	100%

Proceed Review

Congratulations. You passed the test.

Inverter_Energy_Saving_ENG

You have now completed the **Inverter Energy Saving** course.

Thank you for taking this course.

We hope you enjoyed the lessons and the information you acquired in this course will be useful in the future.

You can review the course as many times as you want.

Review

Close