# Inverter Drive Solutions Enhancing Plant Facilities' Energy Efficiency

Hisayuki Matsumoto
Takashi Yabutani
Atsushi Sugiura
Keizo Shimada

*OVERVIEW: Techniques that improve the operating efficiency of plant facilities, where electrical machinery such as electrical motors have become huge consumers of energy, are attracting attention from the viewpoint of countering global warming. That is because they can implement energy savings in plant facilities and, as a result, restrain $CO_2$ emissions. The Hitachi Group has spent a few decades in developing and commercializing an inverter-fed AC drive system as one power-consumption-reducing technique for electrical motors. We have applied this technique to plant facilities in various industries and have achieved results, and we have also established an energy saving service that has techniques for visualizing energy savings and reductions in $CO_2$ emissions, and have contributed those techniques as environment and energy-saving technological support in Yunnan Province in China which is a focus of Japan-China goodwill. In the future, we intend to contribute further to energy saving and $CO_2$ emission reduction through the development of new techniques.*

## INTRODUCTION

COUNTERMEASURES against global warming have become an urgent issue worldwide. $CO_2$ emission reduction targets have been set for each industrial field and it is essential that we achieve those targets.

Electrical machinery such as electrical motors within plant facilities have become huge consumers of energy, so that making them operate more efficiently will implement energy savings and thus enable some restraint of $CO_2$ emissions.

The Hitachi Group has spent a few decades in developing and commercializing an inverter-fed AC (alternating current) drive system as one power-consumption-reducing technique for electrical motors, to implement energy savings and realize reductions in $CO_2$ emissions.

This paper describes some of the wide range of achievements of this system, such as our energy saving service HDRIVE that has techniques for visualizing energy saving amounts and $CO_2$ emission reduction amounts, a case study of $CO_2$ emission reduction technology achieved by replacing steam turbine driven centrifugal compressors with inverter-fed AC drive, one of our contributions to the Yunnan Province Japan-China cooperation energy-saving and environmental conservation projects, and energy saving service solutions for thermal power plants and steel rolling plants (see Fig. 1).

## ENERGY SAVING REQUIREMENTS BY INVERTER-FED AC DRIVE

There are two ways of conserving energy with machines such as fans, pumps, and blowers: by modifying their mechanical properties or by implementing energy-saving control (see Fig. 2).

Energy savings due to modifications of mechanical properties are greatly cost-effective but their control range is limited. For that reason, plant facilities that are required to operate flexibly in response to the market situation have increasing need for energy savings by rotational speed control, although that is relatively expensive.

In comparison with throttling control, rotational speed control can promise significant energy-saving effects. The greatest energy-saving effect is achieved by rotational speed control of electrical motors by inverter-fed AC drive (see Fig. 3). Inverter-fed AC drive has other advantages from various viewpoints, such as control range, rate of change of speed, and serviceability(1).

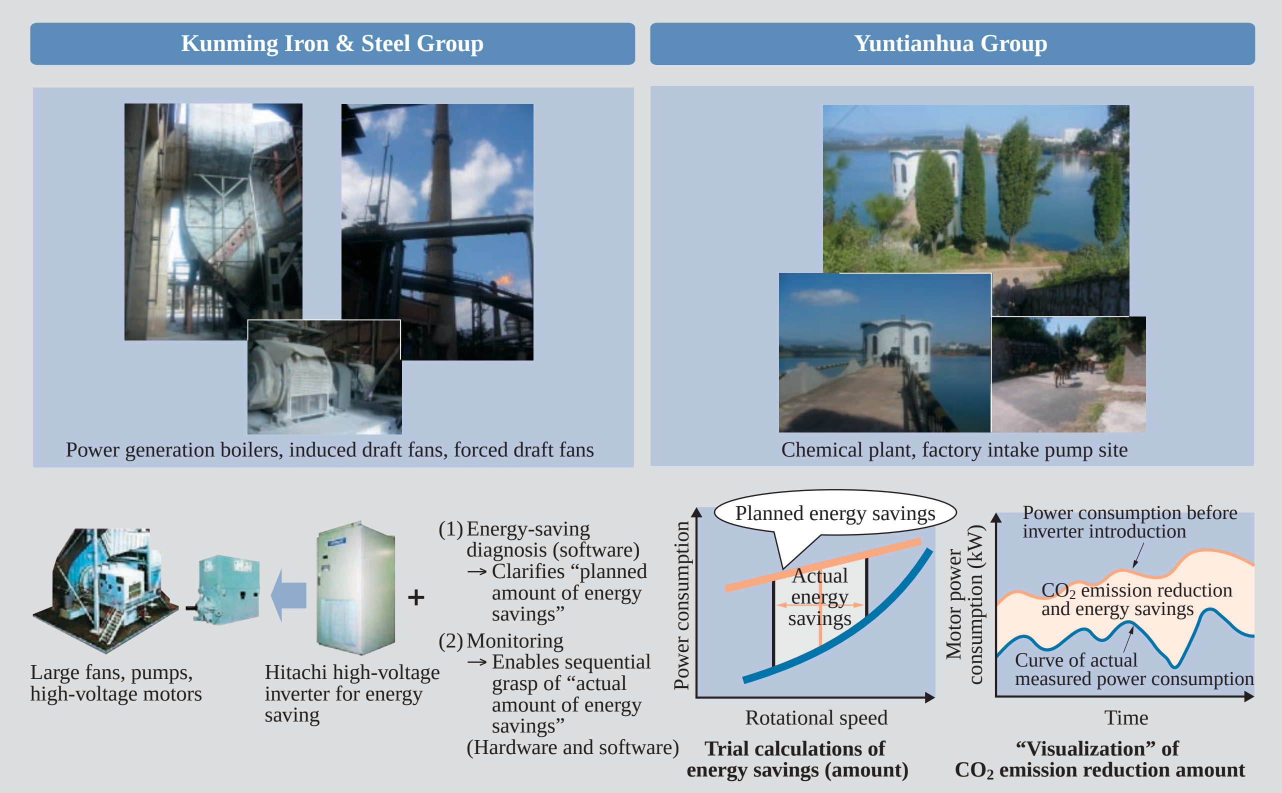


*Fig. 1—Corporations and Facilities Intended for Energy-saving Model Project in China's Yunnan Province.*
*This is one part of the Japan-China energy-saving and environment business promotion model project, showing facilities in projects in China's Yunnan Province. The Hitachi Group delivered inverters to the facilities of the steel manufacturer Kunming Iron & Steel Group Co., Ltd. and the chemical manufacturer Yuntianhua Group Co., Ltd. of Yunnan Province, and gained expectations of at least an average of 20% reduction in the yearly energy consumptions of both companies. The features of those projects are the analysis of power consumptions before the installation (before the energy-saving measures) and the monitoring of energy savings after the start-up.*

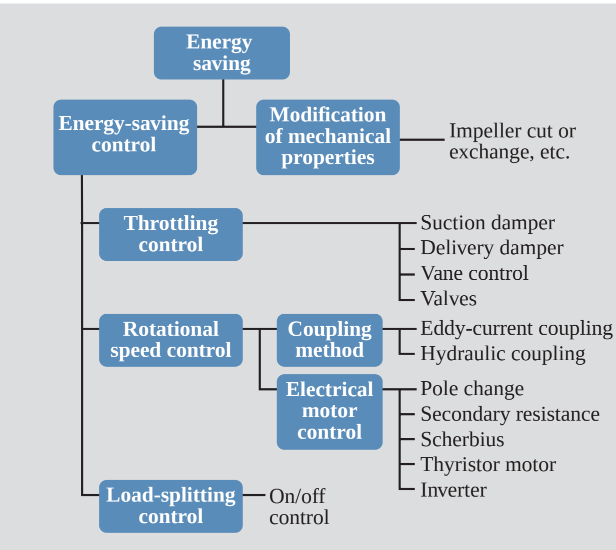


*Fig. 2—Breakdown of Energy-saving Methods for Fluid-moving Equipment.*
*There are two ways of conserving energy with fluid-moving equipment: by modifying mechanical properties or by implementing energy-saving control.*

## CONTRIBUTIONS TO ENERGY SAVINGS AND $CO_2$ EMISSION REDUCTION IN INDUSTRY THROUGH INVERTER-FED AC DRIVE

### New Approach to Industry by "HDRIVE"

Among the various types of energy-saving control, the extremely efficient inverter-fed AC drive and Hitachi's high-voltage motor drive energy saving, "HDRIVE" service, the business model for which we pioneered, have been attracting the attention of customers (see Fig. 4).

HDRIVE is a business model that deducts service charge of inverter systems from actual energy savings value that fluctuates each month. It makes use of core techniques that enable a "visualization" of the amount of $CO_2$ emission reduction, by (1) engineering knowhow that makes provisional calculations of energy savings (amount) through behavior analysis of the amount of electrical power consumed by motors before the introduction of inverters, and (2) grasping the amount of energy saving that can be implemented

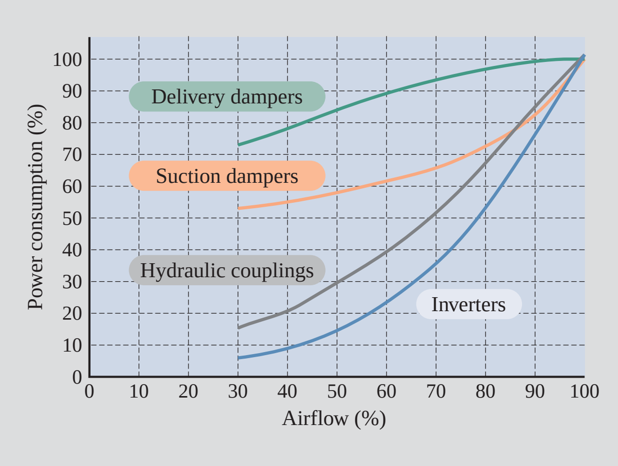


*Fig. 3—Comparison of Power Consumption for Each Control Method (Using Fans as Case Study).*
*Amid energy-saving control methods, the greatest energy-saving effect is achieved by inverters.*

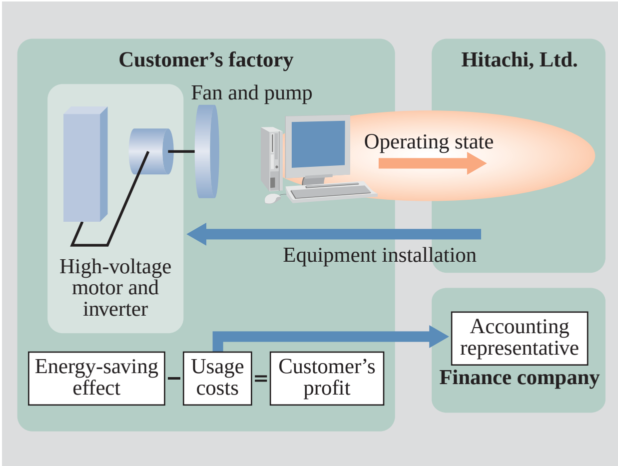


*Fig. 4—Overview of HDRIVE Service.*
*We install motors and inverters with no initial costs (initial investment costs) necessary, usage costs are paid to Hitachi from the energy savings that are implemented each month, and the remainder is profit to the user.*

by monitoring the amount of electrical power consumed by motors after the adoption of inverters. It has already achieved success in reducing $CO_2$ emissions in a large number of facilities.

### Contributions to Yunnan Province Japan-China Cooperation Energy-saving and Environmental Conservation Projects

The two core techniques described above have attracted Japanese government (the Ministry of Economy, Trade and Industry), citing environmental and energy saving technological support to China as part of ongoing Japan-China goodwill, and have been nominated for an energy-saving and environment business promotion model project between Japan and China. At the same time, the reliability of Hitachi-made inverters and the two core techniques described above were evaluated by the Yunnan provincial government and representative businesses in Yunnan Province, in cooperation with the China Center for Business Cooperation and Coordination of the China National Development and Reform Commission and Hitachi (China) Ltd., which has concluded a "memorandum of agreement and partnership in the promotion of cooperation in the energy-saving and environmental conservation fields."

As a result, this was selected as one of ten model projects at the Second Japan-China Energy Conservation Forum held in the Great Hall of the People, Beijing, on September 21, 2007. Inverters intended for the steel manufacturer Kunming Iron & Steel Group Co., Ltd. and the chemical manufacturer Yuntianhua Group Co., Ltd. of Yunnan Province are expected to achieve energy savings and $CO_2$ emission reductions of an average of at least 20%, and started operation at the Kunming Iron & Steel Group this spring.

In the future, we plan to expand this solution to other businesses and agencies within Yunnan Province and all over China, and simultaneously apply our $CO_2$ emission reduction amount "visualization" technique to contribute to energy saving and $CO_2$ emission reduction in China.

## ENERGY SAVINGS AND $CO_2$ EMISSION REDUCTION TECHNIQUE BY DRIVE SOLUTIONS — RETROFIT CASE STUDIES OF REPLACING STEAM TURBINE DRIVEN CENTRIFUGAL COMPRESSORS WITH INVERTER-FED AC DRIVES

### Effects of Retrofitting in Oil and Gas Markets

Retrofitting means upgrading existing equipment and installing new components (equipment).

At the moment, steam turbine driven centrifugal compressors delivered in the 1960s are operating in many of oil and gas facilities within Japan. There is potential for implementing significant energy saving and $CO_2$ emission reductions by bypassing the existing centrifugal compressors and replacing the steam turbine facilities with a combination of electrical motors and

inverters. Retrofitting has the following advantages:
(1) Energy-saving effect by improvement in operating efficiency due to replacement with electrical motors and inverters
(2) $CO_2$ emission reduction effect due to halting of boiler equipment or appropriate operation
(3) Shortened maintenance time

Electrical motors and inverters can reduce maintenance time, in comparison with steam turbine facilities. It therefore becomes possible to shorten the down time of equipment and reduce maintenance costs.
(4) Improved controllability

It is impossible for steam turbine facilities to operate without first generating steam in the boiler equipment. In addition, since the turbines are usually exhaust pressure turbines, the process steam is divided to drive a number of steam turbines. For that reason, implementing control on just a single unit will upset the balance of the steam lines, so that control has to be through by bypass valves and energy losses will increase. When an electrical motor and inverter drive are installed instead, the system can be operated or halted comparatively simply and individual units can be operated, which also enables variable control.

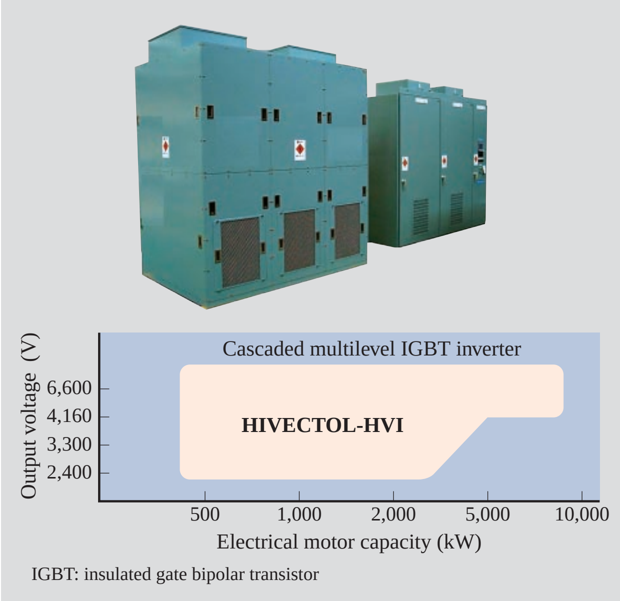


*Fig. 5—External View of Hitachi High-voltage Direct Inverter, and Capacity Ranges of Electrical Motors.*
*This corresponds to electrical motors in the 400 to 8,000 kW range, with rated output voltages of 2.4 to 6.6 kV.*

## Application Case Study

(1) Efficiency improvement

Since it is not easy to compare efficiencies between steam and electricity directly, we will compare and discuss a pre-retrofit steam turbine (exhaust pressure turbine) of this application case study and a steam turbine (condensing turbine) for power generation.

The pre-retrofit installation data is as follows:
(a) Shaft power: 2,155 kW
(b) Main steam pressure: 1.9 Mpa
(c) Exhaust pressure: 0.51 Mpa
(d) Main steam flow: 48 t/h (48,000 kg/h)

From the above, we calculate that the steam rate is the main steam flow divided by shaft power, which is 48,000/2,155, or approximately 22.3 kg/kWh.

With a steam turbine (condensing turbine) for power generation, on the other hand, this is 3.8 to 4.85 kg/kWh. Dividing the exhaust pressure turbine steam rate by the condensing turbine steam rate gives 22.3/4.85 or approximately 4.60, which means that an exhaust pressure turbine requires 4.6 times the amount of steam as a condensing turbine.

Since an exhaust pressure turbine shares process steam with other exhaust pressure turbines, a direct comparison cannot be done, but the use of a condensing turbine in power generation is efficient for the same capacity of steam used, and it is thought that electrifying the centrifugal compressor drive (adding an electrical motor and inverter) will also be most efficient.
(2) Problems with application

The effects of retrofitting are as described above, but there are a number of challenges that have to be investigated within this application case study. Some of them are:
(a) Countermeasures to shaft voltages due to higher harmonics
(b) Countermeasures to pulsating torque (shaft vibration)

Hitachi makes full use of all its resources to manufacture all of these compressors, motors, and inverters in-house, analyze and use simulation techniques on them all as an overall system, and also take advantage of plant control technology to suit projects both in and outside Japan.

## Inverter-fed AC Drive

The drive device used in retrofitting is the 3.3 kV, 3,000 kVA “HIVECTOL-HVI.” This product is commercialized as a series with rated voltages ranging from 2.4 kV to 6.6 kV. The capacity ranges of the electrical motors used in this study are shown in Fig. 5.

The HIVECTOL-HVI is a cascaded multilevel inverter that uses ordinary IGBTs (insulated gate bipolar transistors), and is said to be the ideal inverter when considered as either a power source or an electrical motor, since there are few input higher harmonics and the output voltage waveform is close to being a sine wave.

## APPLICATION CASE STUDIES OF ENERGY-SAVING SOLUTION SERVICE IN OTHER PLANT FACILITIES

### Thermal Power Plant

In a thermal power plant, components such as the forced draft fans or induced draft fans of the boilers and the feed-water pumps and circulating water pumps that form the circulation system for water and steam between the boilers and the turbines are driven by large-capacity electrical motors of the several-kilowatt class. This equipment has to be able to produce outputs that fluctuate in answer to the power output of the plant.

An inverter was applied to each forced draft fan (two fans, each of 6.6 kV and 5,500 kW) at the Anegasaki Thermal Power Station No. 3 (gas- and oil-fired plant with rated output of 600 MW and minimum output of 90 MW) of Tokyo Electric Power Co., Inc., and the modified setup has been in actual operation since February 2007. An energy-saving effect is observed at each output level, but has been confirmed that large energy-saving effects are obtained particularly at low output levels (see Fig. 6)(2).

Since a power generation plant has large output fluctuations, depending on the time of day and the climate, this shows potential for large energy-saving effects and the application of inverters can be expected to accelerate in the future, from the viewpoint of $CO_2$ emission reductions as well.

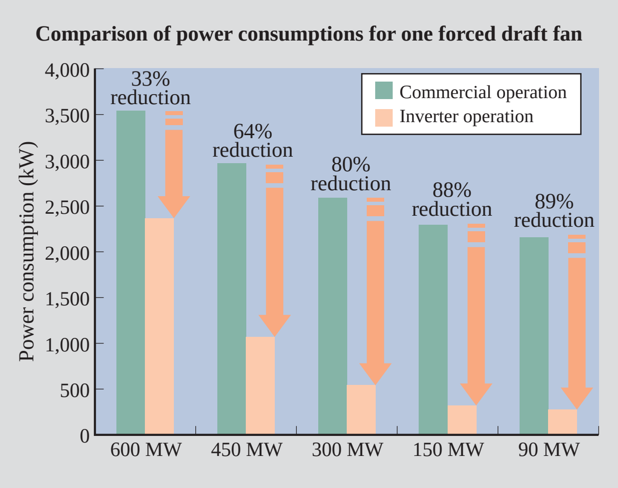


*Fig. 6—Results of Measuring Energy-saving Effect.*
*This shows a comparison of the power consumed by forced draft fans at the Anegasaki Thermal Power Station No. 3 of Tokyo Electric Power Co., Inc., under commercial operation and inverter operation.*

### Steel Rolling Mill Plant

In a steel rolling mill plant there is a large number of electrical motors that drive the rolling mills, in order to produce high-quality sheet steel, and these motors are required to have highly accurate and responsive speed control. In a previous age, thyristor converters and DC (direct current) electrical motors were common. Nowadays, progress in power electronics technology has made combinations of AC electrical motors and IGBT inverters with digital control more common. The replacement of DC drive system by AC drive system does not just improve serviceability and controllability; energy efficiency is also increased. This is not just because an AC motor is highly efficient in comparison with a DC motor; there's also the effect of an increase in efficiency of the power supply system caused by the adoption of IGBT converter technology that makes the power factor of the power source 1, so that a 5 to 8% improvement in overall system efficiency is implemented by updating an old DC system to the latest AC system.

## CONCLUSIONS

In this paper, we have discussed Hitachi's energy saving service "HDRIVE" that has techniques for visualizing energy savings and $CO_2$ emission reductions from a wide range of actual results, Hitachi's contributions to Japan-China cooperation energy-saving and environmental conservation projects in Yunnan Province, case studies of $CO_2$ emission reduction techniques that were enabled by replacement of the steam turbine driven centrifugal compressors by inverter-fed AC drives, and applications of energy saving service solutions to a thermal power plant and a steel rolling mill plant.

There are great hopes for inverter-fed AC drives in various industries and plants, in response to the needs of society for energy savings and reductions in $CO_2$ emissions.

The Hitachi Group will improve the reliability of our drive products and also propose drive solutions aimed at saving energy and reducing $CO_2$ emissions from a system viewpoint.

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## ABOUT THE AUTHORS

Hisayuki Matsumoto

*Joined Hitachi, Ltd. in 1981, and now works at the Electrical & Automation Systems Engineering Department, the Electrical Control Systems Division, the Information & Control Systems Division, the Information & Telecommunications Systems. He is currently engaged in coordinating and promoting the sales of industrial electrical equipment and automations in and outside Japan.*

Takashi Yabutani

*Joined Hitachi, Ltd. in 1980, and now works at the China Energy-saving Promotion Department, the Green Drive & Solution Business Promotion Division, the Industrial Systems. He is currently engaged in energy-saving business sales promotion in China.*

Atsushi Sugiura

*Joined Hitachi, Ltd. in 1991, and now works at the Overseas Business Promotion Office, the Industrial Electric & Machine Systems Division, the Public & Industrial Systems Division, the Industrial Systems. He is currently engaged in the planning and sales promotion of inverter drives for steam turbines.*

Keizo Shimada

*Joined Hitachi, Ltd. in 1984, and now works at the Electrical & Automation Systems Engineering Department, the Electrical Control Systems Division, the Information & Control Systems Division, the Information & Telecommunications Systems. He is currently engaged in the planning and sales promotion of industrial inverters in and outside Japan.*