High-voltage Direct Inverter Applied to Induced Draft Fan Motor at Takehara Thermal Power Station No. 3 of Electric Power Development Co., Ltd.

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OVERVIEW: Finding ways to save energy has become an increasingly urgent concern of the power industry. One strategy with enormous energy saving potential is to reduce the supply power of large auxiliary motors at power plants. Inverters have been used in the past for variable speed control over auxiliary motors, but the output voltage and capacity of conventional inverters are relatively small, so there has been little incentive to apply inverters to the larger scale auxiliary motors used by commercial thermal power plants. This motivated a joint research project between Electric Power Development Co., Ltd. and Hitachi, Ltd. to develop an 8,250-kVA high-voltage direct inverter that could be applied to high-voltage high-capacity large auxiliary motors. The direct inverter was connected to a 7,000-kW-capacity induced draft fan motor at Electric Power Development Co., Ltd.'s Takehara Thermal Power Station No. 3 and subjected to extensive field trial testing. In pursuing the project we also developed a system configuration and control methods to ensure that the plant continues to operate stably even when disturbances occur from the power supply system, and the system demonstrated a high degree of reliability. It was found that substantial energy could be saved by using the inverter. For example, compared to a conventional configuration, motor power consumption could be reduced by as much as 70% when operating at an output capacity of 50% by using the inverter.

INTRODUCTION

POWER output of power stations is adjusted to accommodate varying demand for power by opening and closing dampers and values that are used to adjust large fans and pumps. The drive motor that performs this work runs all the time at a constant speed which is unrelated to the power output of the station. Consequently, substantial energy is lost when the power output level is low because the damper and values are closed.

Since the energy consumed by the motor is proportional to rotation speed cubed, the power consumption can be greatly reduced by using an inverter to regulate the speed of the drive motor (see Fig. 1). The primary drawback of conventional inverters is that their output voltage and capacity are too small. This means that a boost-up transformer must be separately implemented, an approach that yields only a modest efficiency gain, so there has been little incentive and little progress to incorporate inverters in large-scale equipment.

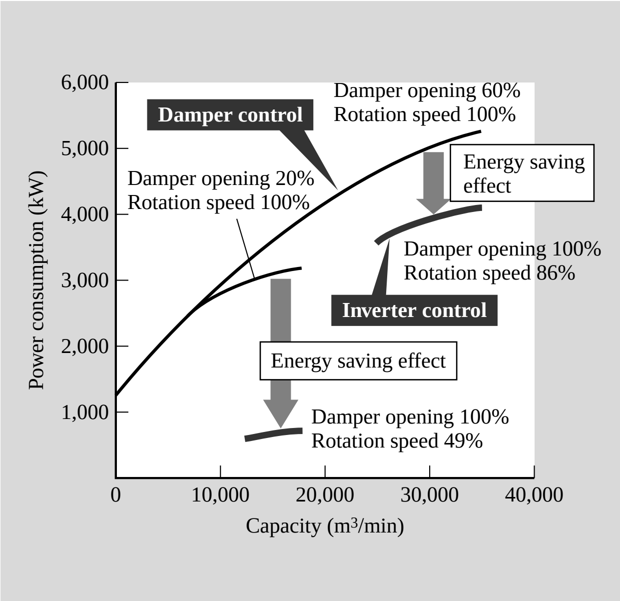

Fig. 1—Power Consumption Reduction Effect with Inverter Control.
Reducing the rotation speed with the inverter control reduces the power consumption more than the damper control.

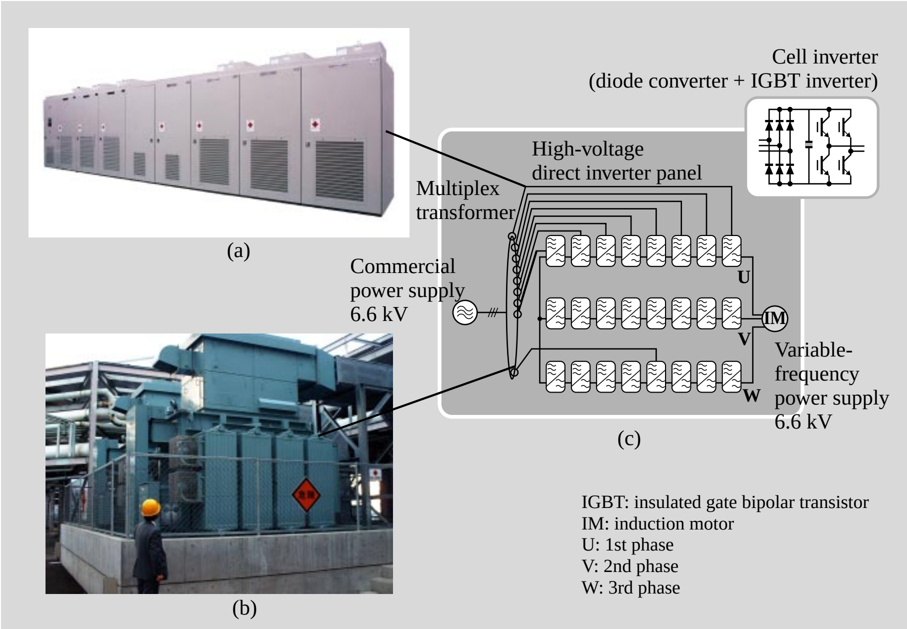

Fig. 2—High-voltage Direct Inverter Panel (a), Multiplex Transformer (b), and the Circuit Configuration (c).
The high-voltage direct inverter panel consists of many cell inverters including IGBT elements. It converts a multi-phase power supply to a three-phase variable-frequency power supply for output. The multi-phase transformer inputs a commercial power supply and converts it to a multi-phase power supply.

This motivated Electric Power Development Co., Ltd. and Hitachi, Ltd. to jointly develop a high-voltage high-capacity direct inverter that can also be applied to large auxiliary motors (see Fig. 2). The new inverter was applied to Electric Power Development Co., Ltd.'s Takehara Thermal Power Station No. 3 and excellent results have been obtained in the trial operation.

Here we will present an overview of this high-voltage director inverter and its performance.

FEATURES AND RELIABILITY OF HIGH-VOLTAGE DIRECT INVERTER

Features

The new high-voltage direct inverter can be applied to large auxiliary motors up to 6,600 V, and has a number of significant advantages beyond its impressive efficiency and large capacity:

(1) Can be used with existing motors

Applying a multi-stage connection to a single-phase inverter, near sine wave voltage is output. The harmonic can also be controlled so there is no concern that the inverter might cause motor insulation to deteriorate, and it can be used to drive existing motors.

(2) Minimal restraint affecting power system

Using a multiple winding transformer, the harmonic component input current is suppressed. This minimizes the impact on the power system.

(3) Enhanced Inverter efficiency

By eliminating the need for a boost-up transformer on the output side, inverter efficiency is enhanced to 98%.

Excellent Reliability When Applied to Large Auxiliary Equipment at Power Plants

Considering the enormous adverse effects that can result when power plant equipment fails, a very high standard of reliability is critically important. The system was designed to provide very high reliability with special consideration for the following conditions:

(1) Plant control and stable operation

Control methods were implemented that permit stable inverter operation when starting and stopping and when running under normal load conditions.

(2) Continuous operation when disturbances occur

Control methods were implemented enabling the plant to continue operating even in the event of a power system outage or other disturbance or in the event that the inverter fails.

SYSTEM CONFIGURATION, PLANT CONTROL METHODS, AND SYSTEM RELIABILITY

System Configuration

(1) The high-voltage direct inverter was connected to an IDF (induced draft fan), an auxiliary system in power plants of the largest capacity and thus offering the greatest potential energy savings (see Table 1).

(2) Legacy equipment has been retained for the generating equipment and the IDF (rated: 7,000 kW × 2 units, voltage: 6,600 V), and the inverter system consisting of multiple winding transformer and high-voltage direct inverter panel is installed close to the IDFs.

TABLE 1. High-voltage Direct Inverter Specifications
With high-voltage large-capacity specs, speed control can be applied to power plant large auxiliary equipment.

Model	Hitachi's high-voltage direct inverter
Control system	Robust speed sensorless vector control
Rated capacity	8,250 kVA
Rated voltage	6,600 V, 60 Hz
Speed control range	20 – 100%
Inverter efficiency	98%
Input side transformer	24-phase (8 stages × 3 phases) transformer, separate installation

(3) Commercially available circuitry has also been retained so, in the event that the inverter fails, the inverter is bypassed and the IDF continues to operate (see Fig. 3).

Plant Control System

Conventional IDFs rotate at a constant rate, the inlet damper is activated by commands from APC (automatic plant control) system, and the furnace draft is controlled to be stable even if the boiler load fluctuates.

However, with the installation of the inverter, the furnace draft fluctuations are absorbed by IDF inlet damper, and the IDF speed is regulated by a program control scheme to match the boiler load.

Moreover, the IDF speed is programmed to reduce the IDF speed when the inverter is operating to maximize the energy savings.

Superior System Reliability

The inverter includes sophisticated circuitry to detect any kind of problem as well as protect-interlock circuitry which permits highly stable plant operation and excellent system reliability even if a disturbance from the power supply system should occur.

(1) Operation monitoring and fault detection

Displays and alarms have been implemented so the operational state of the inverter system can be monitored from the station's central control room. The inverter equipment also features a comprehensive set of built-in fault detection circuits [momentary power failures, overcurrent spikes, fuse breaks, overloading, cooling fan breakdowns, power failures, problems with the CPU (central processing unit), etc.] that enable early detection of any abnormality.

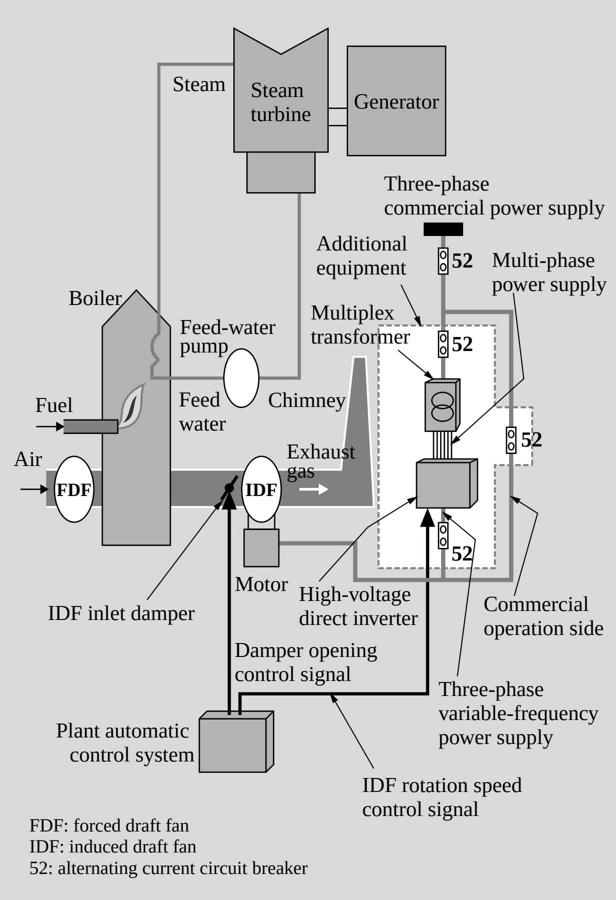

Fig. 3—System Configuration.
The multiplex transformer and high-voltage inverter are installed between the commercial power supply and the legacy motor. Signals from the automatic plant control system enable variable-speed control of the IDF motor.

(2) Inverter reliability functions

Excellent reliability is achieved by enhancing the protect-interlock and control functions so the plant continues to operate normally even if voltage fluctuations or ground faults occur, or if a part fails. The primary functions supporting this enhanced reliability are a voltage fluctuation correction function, an overload control function, speed rate control function, and a motor trouble detection function.

(3) Restarting after momentary outages

A method of estimating the motor rotation speed under free-running conditions has been implemented, so the motor can be smoothly restarted within a short period after the power source experiences a momentary outage.

(4) Inverter/commercial operation switching control

When switching to commercial, the rotation speed increases rapidly, and this results in large furnace draft

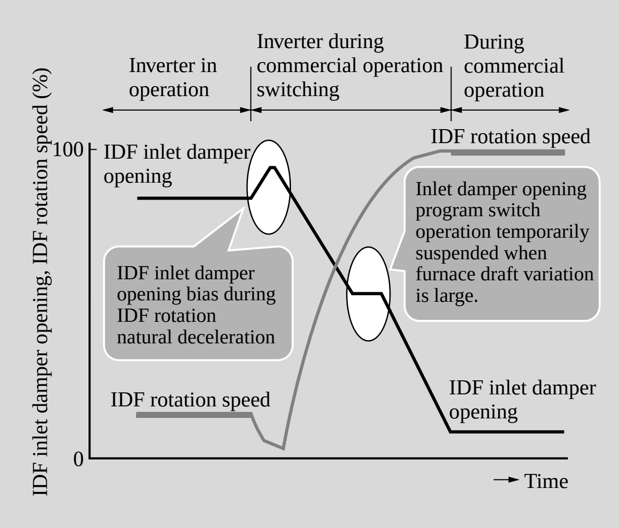

Fig. 4—Overview of Inverter and Commercial Operation Switching Control.
The switching control effectively suppresses furnace draft fluctuations when IDF speed increases by closing down the IDF inlet damper opening.

fluctuations. We have implemented a control method that effectively minimizes the furnace draft fluctuations (see Fig. 4).

TEST RESULTS AND APPLICATION EFFECTS

Test Results

The high-voltage direct inverter was connected to an IDF motor at a power plant in May 2001, subjected to extensive in-operation testing, and it performed very well. In evaluating the inverter, we conducted the following tests:

(1) Performance verification testing (voltage fluctuation, temperature increase)
(2) Operability, controllability verification testing (starting and stopping, load fluctuations, restarting after momentary outages, harmonics measurement)
(3) Abnormal operation testing (inverter and commercial operation switching, half-side operation)
(4) Verification of other effects (noise verification, speed deceleration effect)

Current was also measured when starting up the inverter. It was found that the inverter starting current was relatively small and the inverter started up smoothly even though the starting current when starting the motor and during commercial operation was about 5 times the rated current (see Fig. 5).

Based on actual measurements of the content of power harmonics included in the output, it was confirmed that the range of operating values fell well within the Guideline for Reduction of Harmonic Emission published by the Ministry of Economy, Trade and Industry (see Fig. 6).

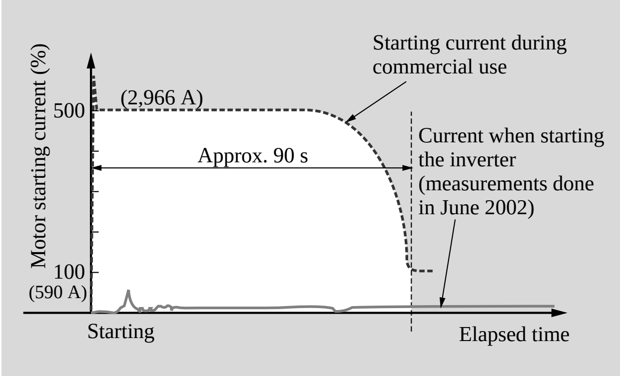

Fig. 5—IDF Starting Current Test Results with Inverter.
Compared to commercial operation, motor starting current is reduced by the inverter.

Energy Saving Effects

Comparing the operation using the inverter with commercial operation, it was found that power consumption was reduced by 70% when operating at 50% power output and by 20% when operating at a power output of 100%.

Moreover, considering that the IDF gas flow and IDF inlet damper opening vary depending on the season and type of coal, it was found that the energy savings could be further improved by adopting a control method that supports operation while reducing the rotation speed of the IDF as much as possible.

Other Effects from Adopting Inverter

In addition to the energy saving effects already mentioned, installing the inverter had a number of other beneficial effects:

(1) Reduced power reduces CO_2 emissions and thus has a beneficial environmental effect.
(2) Reduced motor speed means less noise.
(3) Reduced motor startup current mitigates disturbance on the power system and results in less stress on the motor.

CONCLUSIONS

This paper detailed a number of significant beneficial effects that were achieved by connecting a high-pressure direct inverter to a forced-draft fan motor at No. 3 of Takehara Thermal Power Station operated

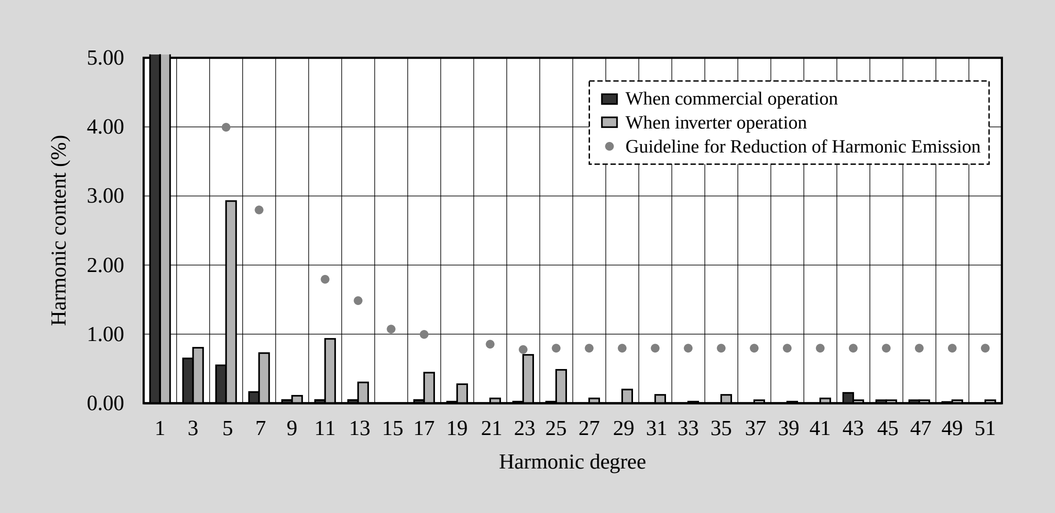

Fig. 6—Harmonic Component Test Results.
The harmonic component is reduced by the inverter to well below the figure recommended in the Guideline for Reduction of Harmonic Emission.

by Electric Power Development Co., Ltd. It was shown that substantial energy savings were realized by using the inverter, and the system performed very well (starting, stopping, and various other functions) in extensive long-term trials.

Developed as a joint research project by Electric Power Development Co., Ltd. and Hitachi, Ltd., the inverter was subjected to extensive field trials that were concluded in October 2003, and has performed flawlessly since the inverter was subsequently put into service.

The high-pressure direct inverter saves considerable energy and thus has a beneficial effect on the environmental, so we intend to deploy the system at other power plants.

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