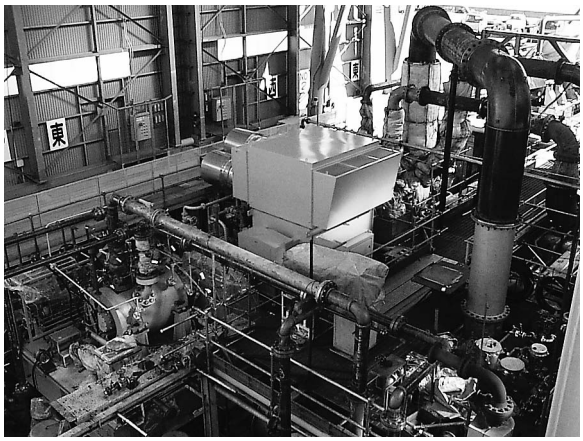

Verification of Reliability for Variable Speed Motor Drive System of Compressor

TATSUFUMI AOI*1
HIDETOSHI HORI*2
YOSHIYUKI OKAMOTO*2

Using a motor for driving centrifugal compressor instead of a gas turbine has a large number of merits such as "high efficiency," "gentle to environment," etc. The demand for motor is increasing recently also in the gas field. The Hiroshima Machinery Works of Mitsubishi Heavy Industries, Ltd. (MHI) has introduced an electrical power system exclusively for motor operation. By this system, we can supply centrifugal compressor unit driven by highly reliable large-size variable speed motor to the customers. When requested by the customer, we conduct load test through combination of motor and centrifugal compressor inside the works before delivering the product. Further, a tool for analyzing the effect on the power supply system while conducting the actual shop test has been developed and put to operation. As a result, it can be predicted in advance whether the test can be carried out or not, contributing to preventing the trouble occurrence.

1. Introduction

With the concern about environmental problems getting increased in global scale in recent years, the main role in the field of energy is also shifting from petroleum to natural gas-a cleaner energy source. The production bases of LNG plant are getting newly built or added at a high rate to respond to the expanded demand of natural gas in global scale. In this situation, the drive equipment requiring high torque (such as the large-size centrifugal compressor for liquefied natural gas where gas turbine was conventionally used) is being replaced by large-size motors and inverters by adopting centralized electrical power generation (high-efficiency combined cycle power generation). The motor and inverter are easy to handle and have less emission of CO_2. Further, at a place within a distance of 3 000 km from the natural gas extracting area, since gas supply using pipeline is more economical than the transport of LNG, the construction of pipeline is rampant all over the world. In the field of pipeline also, the trend is shifting toward motor drive as in the case of LNG.

2. Features of centrifugal compressor driven by variable speed motor

Fig. 1 shows the configuration of a compressor unit driven by a large-size variable speed motor. The large-size variable speed motor excels the gas turbine in the following points.

(1) High efficiency

Compared in terms of a simple drive unit, the efficiency of the gas turbine is approximately 35% against 95% of the motor. In practice, however, it is necessary in the case of motor drive to make a total economical assessment including the power generation cost or electrical power purchasing cost. In the case of motor drive, since the gas turbine for power generation with higher capacity can be used as compared with the distribution type (where a gas turbine is needed for every individual service), it is possible to adopt a gas turbine with higher efficiency.

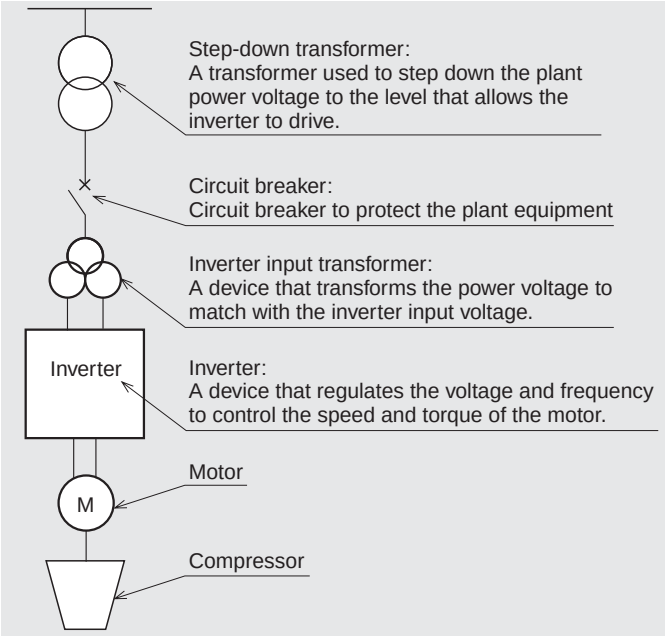

Fig. 1 Configuration of compressor unit driven by large-size variable speed motor
Indicates the system configuration of compressor unit driven by large-size variable speed motor.

*1 Hiroshima Research & Development Center, Technical Headquarters
*2 Hiroshima Machinery Works

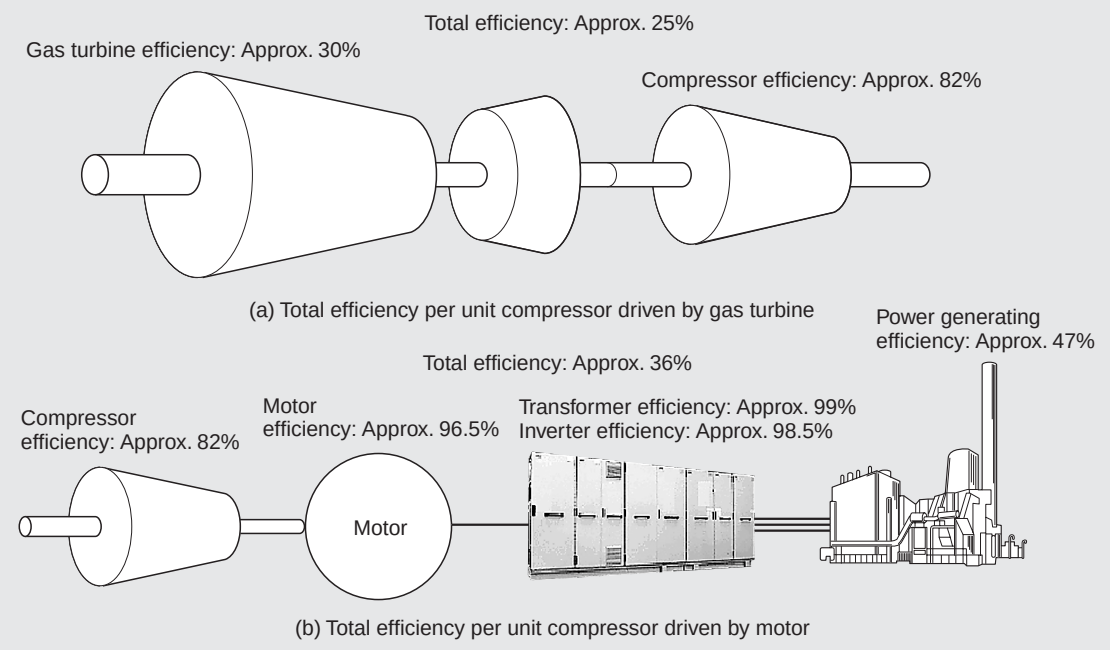

Fig. 2 Efficiency per unit of centrifugal compressor driven by motor and gas turbine
Indicates total efficiency for motor and gas turbine respectively

In **Fig. 2** the efficiency per unit centrifugal compressor is compared when driven by gas turbine and by motor, indicating the efficiency to hit the level of approximately 36% for motor drive against 25% of gas turbine drive.

(2) Reduction in CO_2 emission

Since a large-size gas turbine can be installed at one place for centralized power generation in the case of motor drive, the environmental countermeasures against exhaust gas, etc. can be easily taken. In addition to this, since the motor is run by electricity, there is no emission of CO_2.

(3) Shortening of maintenance time

While the gas turbine has to have its hot parts regularly replaced, the motor needs almost no maintenance, contributing to the reduction in maintenance cost.

(4) Simplification of plant configuration

Since the required utilities include only electric power and air for purging, there is no need of large-scale supplementary facilities.

(5) Easy for remote control

Since the motor is controlled by the inverter, the control for operation is simple. Further, compared with the gas turbine, the motor has wider speed operation range. The motor has higher response rate than the gas turbine.

The other merits of motor drive are omitted here, except for the following ones.

(6) Needs less initial investment.

(7) Construction and installation schedule can be shortened.

(8) Noise is low.

(9) Environmental conditions have less effect on operating conditions

3. Execution of combination test of centrifugal compressor and motor

In case the plant is located in desert, etc., where established service system is less available, the occurrence of problem in the site inflicts larger effect on the entire process of the plant. It is necessary to make sure that there is no problem whatsoever through combined operational test of the centrifugal compressor with the motor before delivering the product to the customer.

Further, in the field of injection, etc., where high-pressure and high-density gas is used, it is necessary to conduct full-load test by using actual gas in order to confirm the design validity of the mechanical characteristics before delivering the product to the customer.

In order to meet such demands and to improve the reliability of the product, MHI has introduced the electrical power system exclusively for motor to carry out combined operation of motor and centrifugal compressor.

4. Advantages of combined operation at MHI

The customer can have the advantages given below by the combined operation carried out at MHI.

(1) The reliability of the product gets improved through verification of the mechanical and electrical performances by the combined operation of centrifugal compressor and motor.

(2) Since the actual gas is used, the operational test of the motor and centrifugal compressor can be carried out under the conditions closer to those at the site.

(3) Compared to the pre-shipment test for motors by a motor manufacturer, MHI can conduct the test under larger electric load, taking longer time. As a result, more reliable aging for the electric element of a motor is possible.

Further, in order to respond to various needs of customers, the points given below are taken into consideration in introducing the equipment.

(1) Power distribution transformer is designed to have wider range of taps to correspond to the different voltage levels in different countries to enable export to various countries in the world.

(2) The current-source type inverter can be operated without a harmonic filter.

Since the total harmonic voltage distortion in MHI plant is restrained to 3% or under, the test running can be carried out without having to install a harmonic filter.

(3) The test running of motors with specified power frequency 50 Hz or 60 Hz can be carried out.

The testing equipment is mainly for variable speed motors. Hence, it is possible to conduct test without being affected by power frequency as in the case of a fixed speed motor, since the inverter is used for speed control.

5. Analysis of characteristics at motor start and operation

Since the electrical power system experiences voltage drop at the time of motor start and operation, the centrifugal compressor may not start because of the lack of torque required to drive the compressor. Further, the harmonic noise from the inverter may cause the power equipment in the plant to get burned. A tool has therefore been developed to analyze the characteristics at motor start and operation in order to verify the aforesaid items.

Further, the actual harmonic is measured at the time of plant test and is compared with the standard level specified by the customer to verify in advance that the harmonic from the inverter inflicts no effect.

The characteristics at motor start and operation are analyzed in the following manner.

(1) Calculation of harmonic voltage distortion

The calculation of harmonic voltage distortion can be carried out according to the equipment used for test operation, enabling prediction of risk at test running.

(2) Calculation of voltage drop

It is possible to predict the voltage drop caused by increased load, enabling prediction in advance of the adjustment of voltage tap of the power supply equipment. The frequency of trial and error for motor adjustment can be reduced.

6. Example of combined test

MHI carried out verification in advance by using the calculation tool before conducting combined test in the gas injection project, with the contents described below in detail.

Fig. 3 shows the system diagram for shop test and

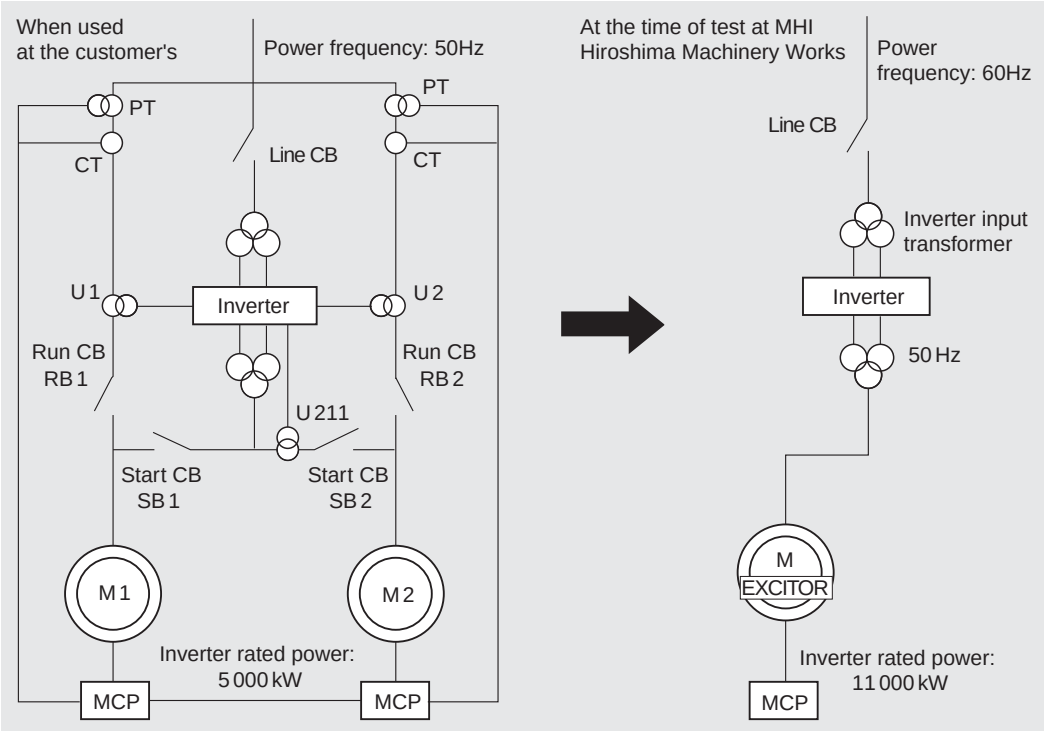

Fig. 3 Gas injection project system diagram
Indicates the power system at the customer's and the power system diagram at MHI Hiroshima Machinery Works.

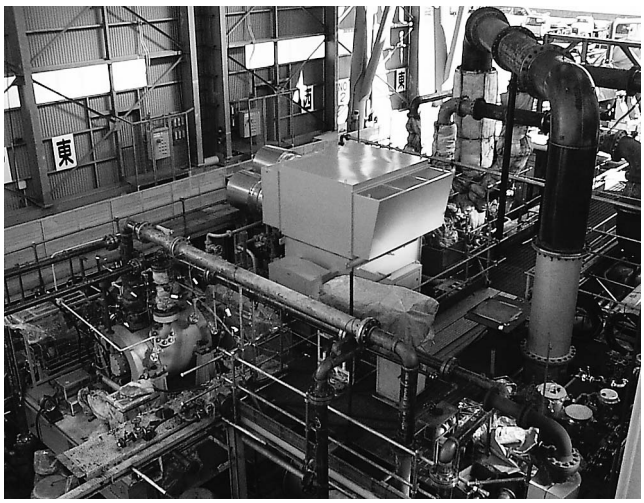

Fig. 4 State of combined test of gas injection project
Indicates the state of combined test of gas injection project at MHI Hiroshima Machinery Works.

Fig. 4 shows the state of shop test. When used at the customer's plant, the inverter functions as a soft starter used only for starting. The rated power of the inverter is 5000 kW. The specification at the time of test could be used also for rated operation, while the switch gear which is customers scope of supply is omitted. Further, the inverter is specified to be capable of rated operation at 11000 kW in a short time.

Table 1 Results of combined test of gas injection project

Item	Pre-verification result	Measurement result
Total harmonic voltage distortion (THD) (at the power receiving point at MHI Hiroshima Machinery Works)	3% or under	3% or under
Maximum voltage drop (at the primary side of inverter input transformer)	Less than 20%	Less than 20%

As a result, the testing equipment could be simplified, and a motor with power frequency 50 Hz could be operated using the 60 Hz power supply. The test results are given in **Table 1**. The calculated values and actually measured values are within the permissible levels, thus verifying the validity of the calculating method.

7. Conclusion

The merits of motor driven centrifugal compressor and the activities of MHI to this regard have been introduced in this technical report. The activities taken by MHI not only provide enhanced added value for the customer but also contribute to the intensification of competitive power of the product. MHI is further expanding the power supply equipment to ensure more intensified competitive power of the product, so that the product may be applied to a larger number of projects in the future.


Tatsufumi Aoi


Hidetoshi Hori


Yoshiyuki Okamoto