Advancement of Compressor Plant Training Simulator

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We have accepted over 1600 trainees since opening the Turbo Machinery Training Center in Hiroshima Machinery Works of Mitsubishi Heavy Industries, Ltd. (MHI). As a part of training program, the simulator has been utilized for effective operation training. However, since it became old fashioned, we developed an advanced compressor plant training simulator in order to comply recent control system’s requirements. The new simulator features (1) a steam turbine model operated by electronic governor, (2) real DCS control and CRT operation, and (3) training capability in dry-gas seal system and gas turbine drive compressor plants.

1. Introduction

Because of the high reliability of the component machines, the compressor plants have recently come to be operated continuously over a long time. As a result, the operators have fewer chances to practice such plant operations as start/stop, and emergency measures.

Training programs using simulator similar to the actual machines have, therefore, become increasingly necessary in order to maintain and improve the skill of the operators.

We have so far accepted a large number of trainees from our customers in Japan and abroad in the Turbo Machinery Training Center in MHI Hiroshima Machinery Works ever since the center was established, and the effective training programs there using the training simulator have gained high reputation.

However, with the equipment becoming outdated and because of the advancement made in compressor plant technology, we had to develop a more sophisticated training simulator.

The main functions newly added to the simulator are given below.
(1) Adoption of digital control unit
(2) Correspondence with training for dry gas seal system
(3) Correspondence with gas turbine driven compressor
(4) Installation of steam turbine model operated by electronic governor similar to the actual equipment

Fig. 1 shows the appearance of the new training simulator system.

This paper introduces the configuration, main functions, operational form etc. of the new training simulator system.

2. Corresponding Process

The compressor plant training simulator is designed mainly for the operational training of the gas process using centrifugal compressor, the driver, the lubricating oil system, and seal system treated as a product in MHI Hiroshima Machinery Works. Table 1 shows the systems and component machines for simu-

Fig. 1  Compressor plant training simulator
The appearance of steam turbine model and graphic panel of compressor plant training simulator equipment is shown.

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lation. It is possible to select make-up gas process/refrigeration process in the gas process, steam turbine/gas turbine/electric motor in the driver, and oil film seal system/dry gas seal system in the seal system. As shown in Fig. 2, these can be combined to enable the simulation of eight different patterns of plant configuration. This time, gas turbine and dry gas seal system were newly added. Because of the enhanced reliability, gas turbines have recently come to be increasingly adopted as drivers. Further, the dry gas seal system has become the mainstream because of the advantages such as: easy operation, less gas leakage, no contamination of process gas due to oil, and small number of component machines leading to low cost and easy maintenance.

3. System Configuration

Next, the configuration of the training simulator system is described below.

**Fig. 3** shows the training simulator system configuration.

![Fig. 3](image)

**Fig. 3** Compressor process pattern selection
The mesh sections are the newly developed parts, allowing 8 patterns of plant configuration through combination.

<table>
<thead>
<tr>
<th>System classification</th>
<th>System name</th>
<th>Abbreviation of system name</th>
<th>System outline</th>
<th>Machines for modeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas process</td>
<td>Make-up gas process</td>
<td>G1</td>
<td>Cracked gas five-stage compression</td>
<td>Compressor, gas cooler, gas separator, etc.</td>
</tr>
<tr>
<td></td>
<td>Refrigeration process</td>
<td>G2</td>
<td>Propylene side stream type compressor</td>
<td>Compressor, suction drum, cooler, receiver, etc.</td>
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<tr>
<td>Driver</td>
<td>Steam turbine system</td>
<td>G3</td>
<td>Extraction condensing turbine with electronic governor</td>
<td>Turbine, condenser, ejector, condenser pump (steam turbine driven, motor driven), trip and throttle valve (TTV), governing valve (GV), extraction pressure control valve (ECV), turning motor, process trip circuit, etc.</td>
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<tr>
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<td>Gas turbine system*</td>
<td>GT</td>
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<tr>
<td>Lubricating oil system</td>
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<td>G4 (Partial)</td>
<td>Lubricating oil for compressor and driver</td>
<td>Oil reservoir, lubricating oil pump (steam turbine driven/motor driven), oil filter, etc.</td>
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<td>Seal system</td>
<td>Oil film seal system</td>
<td>G4 (Partial)</td>
<td>Supply of seal oil (high-pressure, middle-pressure, low-pressure)</td>
<td>Oil cooler, seal oil pump (steam turbine driven/motor driven), oil filter, seal oil head tank, oil trap, etc.</td>
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<td>Dry gas seal system*</td>
<td>G5</td>
<td>Seal gas and separation gas</td>
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*: newly developed item.

Table 1 Simulated process equipment

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(1) Graphic panel
It is a large panel with the machines and piping diagrams drawn on it, and the field measuring instruments, lamps, snap switches, volume switches and others installed to enable operational simulation of field machines. Simulation is carried out by ON/OFF operation of the snap switches for valves operated either at OPEN or CLOSE mode, and by using volume switches for the manual control valves needing partial opening. Actual one-loop controllers are installed as field controllers enabling training for auto/manual adjustment of the control signal and adjustment of control parameters. It is possible to carry out simulation of the field equipment operation of five systems: make-up gas process (G1), refrigeration process (G2), steam turbine system (G3), lubricating oil and oil film seal system (G4) and newly added dry gas seal system (G5).

(2) Field instrument panel
The field instrument panel is equipped with the switches for manual stop of the compressor driver and start/stop of the turning motor, process value indicators and alarm display devices.

(3) Steam turbine model
The steam turbine model is a model for steam turbine control mechanism. Similar to the actual plant, it is composed of the trip and throttle valve (TTV), governing valve (GV), extraction control valve (ECV), control lever, and solenoid valve for trip, etc. and is driven by electro-hydraulic actuator and link using...
control oil as in the case of an actual machine. The EH actuator operates due to control signal of the electronic governor, with the lift value fed back to the host computer through the process controller to be used in the calculation of steam turbine rotational speed, and extraction flow.

(4) Electronic governor

The electronic governor used here is similar to that used in an actual plant. It receives the process values such as steam turbine speed, extraction pressure from the host computer before transmitting the control signals to the EH actuators of GV and ECV. It enables the lever set adjustment training for maintenance personnel in addition to the operation training of electronic governor.

(5) Operator station

The operator station is equivalent to the one installed in the central control room in an actual plant, enabling CRT touch operation. The station is capable of displaying the monitoring and operating screens, controller screen, alarm monitoring screen, interlock monitoring screen, historical trend screen, compressor performance curve screen, etc. The examples of make-up gas process and dry gas seal system monitoring screens are shown in Fig. 4 and Fig. 5 respectively.

(6) Process controller

A digital process controller similar to the one adopted in an actual plant is used here. It receives the operation signals of valves, pumps, etc. of the field devices such as graphic panel, field instrument panel,
turbine model and the process value signal from the host computer before transmitting the necessary control signals to various instruments. The input and output points are: analog input/output: 188 points and digital input/output: 544 points. The communication of signals among the graphic panel, turbine model, sound effect generator, host computer, operator station, and instructor station is carried out using this process controller.

The main control systems in a compressor plant are: suction drum level control, compressor inlet and outlet pressure control, gas cooler temperature control, compressor anti-surge control and so on.

7) Instructor station

Located in the instructor room, it is a terminal (station) used by the instructor during training to select the plant configuration pattern for simulation, to set the initial conditions, and to transmit the signals for run/freeze and malfunction, etc.

8) Host computer

The host computer is used for task control of simulator system, mathematical process model calculation of the whole plant, for processing the request from the instructor station and for communication of data with the process controller, etc. It computes the plant behavior according to the operation input from the operator station and graphic panel through the process controller.

9) Sound effect generator

It produces the sound effect of the compressor driver and auxiliary pumps, etc. in accordance with the running condition of the plant. The 5 speakers are installed on the graphic panel, steam turbine model, and ceiling and produce 11 different sound effects to heap up the realistic feelings of the field operation.

4. Simulator Function

1) Process response model

This computes the plant response against the running operation. This is a simulation model based on the exclusive know-how of MHI as a plant maker. The model ensures both the accuracy and real-time response required for the operational training on start/stop of plant and malfunction occurrence, etc. The systems and machines for simulation are given in Table 1. The process response model is applicable also to the up-to-date plant configuration with the dry gas seal system and gas turbine simulation model added to the conventional plant model.

2) Process pattern selection

The plant configuration can be selected from a to-
tal of eight patterns through combination of gas process, driver, and seal system.

(3) Initial condition
This is a function to set the initial data at the time of starting the simulator training.

(4) Run/freeze function
This is a function to start or freeze (bring to a pause) the simulation. It is used to retain the status halfway through the training.

(5) Malfunction generation
This function is capable of generating various malfunctions (plant abnormalities) likely to occur during actual operation on the basis of the knowledge of MHI supervisors. The function can generate more than 100 types of malfunctions such as pump stop, instrument error, thus enabling the trainees to experience the malfunctions that rarely happen during the actual operation of the plant, repeatedly.

5. Examples of Simulator Operation

5.1 Running example
Fig. 6 and Fig. 7 are the trend graphs in start-up and malfunction operation of the compressor plant composed of the make-up gas process, steam turbine, and dry gas seal. Fig. 6 clearly indicates that the compressor outlet gas pressure rises as the compressor rotational speed increases, with the rated operation (compressor outlet pressure: 37 kgf/cm²G, compressor inlet gas flow rate: 145 kNm³/h, compressor rotational speed: 5 200 rpm) attained approximately 30 minutes after the compressor starts. Later, an abnormality of excessively "high compressor outlet gas temperature" is observed when "compressor outlet gas cooler capacity down" malfunction is occurred. When such malfunction occurs, operators should check the place of trouble and if needed takes measures such as increasing the cooling water flow rate, reducing the compressor rotational speed, etc. Fig. 7 shows the trend graph of dry gas seal system in start-up and malfunction operation. Here, the filter differential pressure rises as the gas filter clogging occurs due to the malfunction after the compressor starts, but changing over to the spare filter as a countermeasure causes the situation to return to normalcy.

5.2 Operation example
An example of a typical training program is shown in Table 2. The typical training curriculum is a course of about 10 days, with the first half used for the lectures on the functions, constructions, and performances of plant component machines, and the second half for the operational education using simulator, practical training on performance calculation, and troubleshooting, etc.

6. Conclusion
The compressor plant training simulator is designed to ensure harmony between the CRT operation in the central control room and the field operation, and is equipped with the control devices equivalent to the actual plant to enhance the realistic feelings and training effect. We have already accepted trainees from our customers in Japan and abroad, and the training programs using the simulator are gaining high reputation. Hopefully the substantial training with effective use of the equipment will contribute to improving customers' reliability toward MHI and to expanding the business of MHI.

Reference
(1) Tanba, A. et al., Training Simulator for Compressor plants, Mitsubishi Juko Giho Vol.16 No.5 (1979-9)