A Rotary Machine Monitoring System for Oil Refineries

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1. Introduction

Safety operation is the largest challenge facing oil refineries. Scheduled maintenance, early detection of abnormalities, measure to counteract said abnormalities and the prediction of future problems are extremely important. The efficient inspection and maintenance of rotary machines, such as pumps, mixers and blowers which are distributed over a large area in an oil refinery, will contribute greatly to safe operation.

Fuji Electric has recently developed and put into use a system which has the unprecedented features of being able to monitor the signals of up to 1,000 rotary machines, and can accurately diagnose these machines through an analysis of vibration frequency. The following signals of the rotary machine are monitored: vibrations (velocity and acceleration), bearing temperatures, leaks of mechanical seals (gas, oil and temperature detection), and suction/delivery pressures. Fuji Electric has shipped this system via Mitsubishi Oil Engineering Co., Ltd. to Sendai Refinery of Tohoku Oil Co., Ltd. A summary of this system is presented in this paper.

2. System Objectives and Development Goals

2.1 System objectives

General objectives are to improve the inspection and maintenance efficiency of rotary machines through advanced monitoring for safe operation and to decrease risks and expenses through scheduled maintenance. The following four items are specific objectives.

(1) Improvement of safety

The early detection of abnormalities allows countermeasures to be put in place which prevent the abnormalities from spreading.

Measurement of the rotary machine vibration with high-speed scanning for 0.2 seconds at start-up will determine whether the performance of the rotary machine has deteriorated.

(2) Standardizing inspections

Constant data, without differences based on the individual who collected it, can be obtained for inspection such as the measurement of vibration. Inspection omission are also prevented.

(3) Reducing on site patrols

By monitoring with V.D.Ts. (CRT terminals), the number of on site patrols can be reduced.

(4) Improving management

The trend monitoring and inspection histories of all rotary machines are integrally managed such that every section can reference the same information and diversified information will be supplied.

2.2 Development goals

The development goals of this system are to establish an advanced trend monitoring system and an accurate diagnostic system based on a large high-speed online monitoring system, and to form the basis of an extended function operation support system.

3. Function and Configuration of the System

A configuration of the system is shown in Fig. 1. Signals from various on site monitoring sensors are input to local control panels, and transmit through optical multiplex transmission to a central site. Monitoring sensor signals which are input to an existing DCS (Distributed Control System) are collected by a central panel. All monitoring sensor data is batch processed and managed by servers to monitor various trend. Alarm status and trend monitoring is displayed on V.D.Ts. (personal computers).

3.1 System functions

The system has the following functions.

(1) Data collection

The signal from each sensor is normally scanned (at interval of 0.2 sec, 2 sec and 3 min). Data is collected and stored in an instantaneous value file or a trend file.

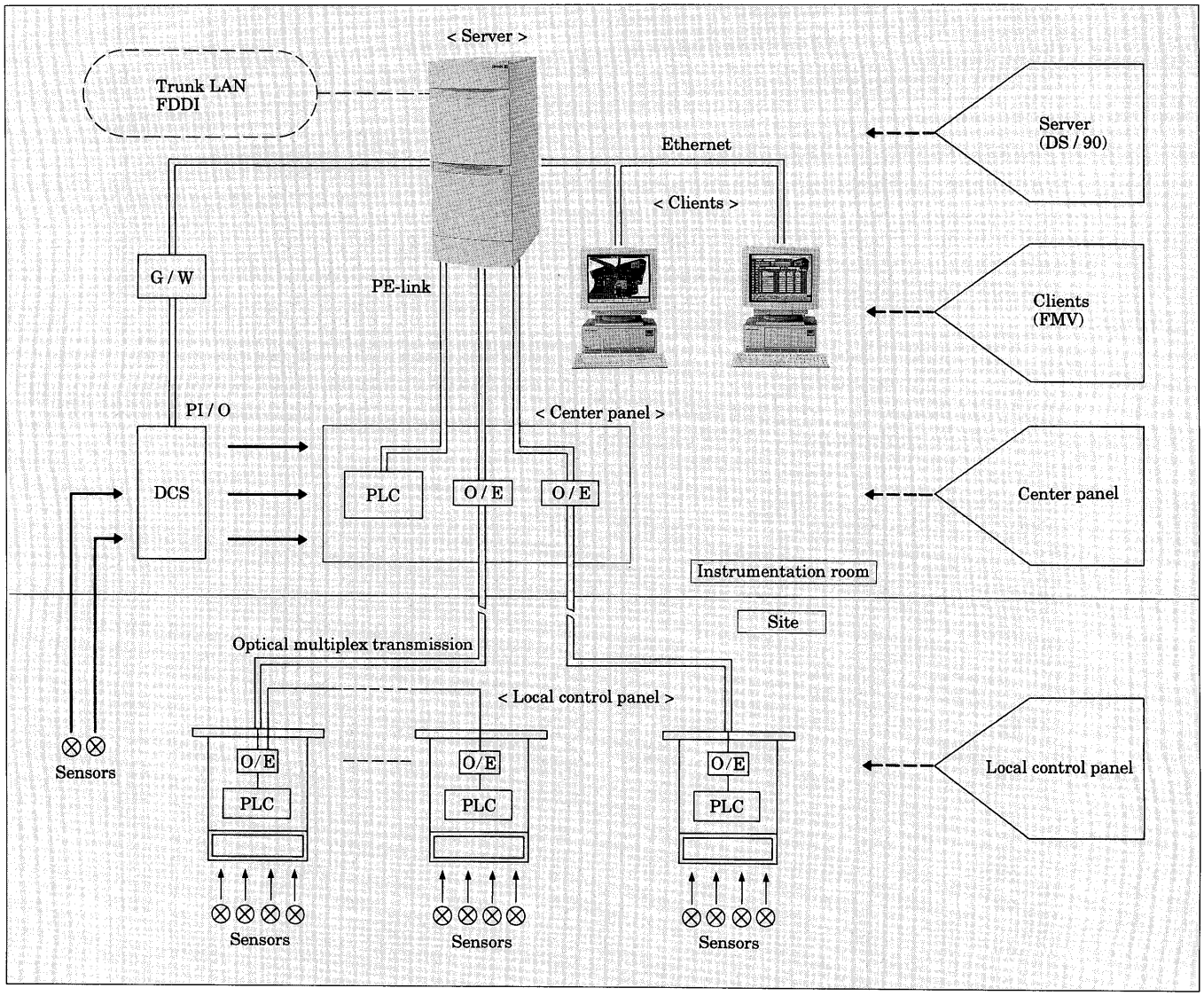
(2) Monitoring

The instantaneous values, alarm status, alarm summary, operating time and number of operations, etc. are shown on the displays, and can be recorded as color hard copies.

(3) Trend monitoring

Real time trends and historical trends are dis-

Fig. 1 System configuration



played. In addition, the estimated number of days until each machine reaches a warning point (set value on the panel) is calculated and displayed on a graph.

3.2 Client/server system

A client/server system is used in data processing and man-machine interfaces to expand the scope of both hardware and software. The DS90, a super minicomputer, is used as a server, and FMVs, DOSV personal computers, are used as clients (as monitoring personal computers). Optical signal transmission between the server and the clients is performed through Ethernet.*1

3.3 Optical multiplex transmission

The data links (PE-link and T-link) of the programmable controller (MICREX-F) are used for optical multiplex transmissions between the center and the sites.

The transmission path has a loop form in the trunk line, and multi-drop forms in the branch lines. These forms are highly reliable since a fault at one point does not spread to the whole system. The optical multiplex transmission increased the efficiency of construction work, and improved on site safety. Resistance to inductive interference also improved the reliability of field transmission. For safety reasons, the local control panels have pressurized, explosion-proof enclosures.

4. System Features

The system has the following features.

4.1 Large scale on-line monitoring

This system has the capacity to normally monitor on-line signals of up to 5,120 sensors. This number of sensors corresponds to approximately 1,000 rotary machines. The number of sensors can be successively increased up to 5,120. The sensors can be scanned at 0.2 sec, 2 sec or 3 min intervals and these period may be changed for each sensor in the operation. Monitoring

*1 : Ethernet is a registered trademark of XEROX, USA.

functions include present value display and alarm monitoring of upper and lower limits. When an alarm occurs, regardless of the panel being displayed, the alarm information is displayed in a pop-up window and stored in an alarm summary panel.

Two points (a warning value and a notice value) can be set at levels lower than the upper limit, and their history of occurences stored in a special summary display. During maintenance, each alarm can be individually masked so as not to go off, and the lower limit alarm for the pump delivery pressure can be disabled so as not to detect when the concerned rotary machine is stopped.

4.2 Free choice of sensor manufacturers

Since the interfaces between the local control panel and the sensors handle standardized instrumentation signals of 4 to 20 mA DC, sensors are not restricted to certain manufacturers. Therefore, a user can select the most suitable sensor model or manufacturer for each location. Improvement can be made in the future by changing the manufacturer or model without changing the system. The system has many possibilities for expansion and is extremely flexible.

4.3 Advanced trend monitoring functions

(1) Real time trend

Trends of up to 4 specified signals can be displayed. The sampling period of the signal is 0.2 sec, and the renewal time is 2 sec. The behavior of vibrations during critical timings such as the start-up after a pump repair can be monitored. The stored data from this time can be compared with later vibration data to judge deterioration.

(2) Historical trends

Five types of historical trends with sampling periods of 2 sec, 3 min, 1 day, 1 week and 1 month can be displayed to learn the trends of past data.

(3) Predicted trends

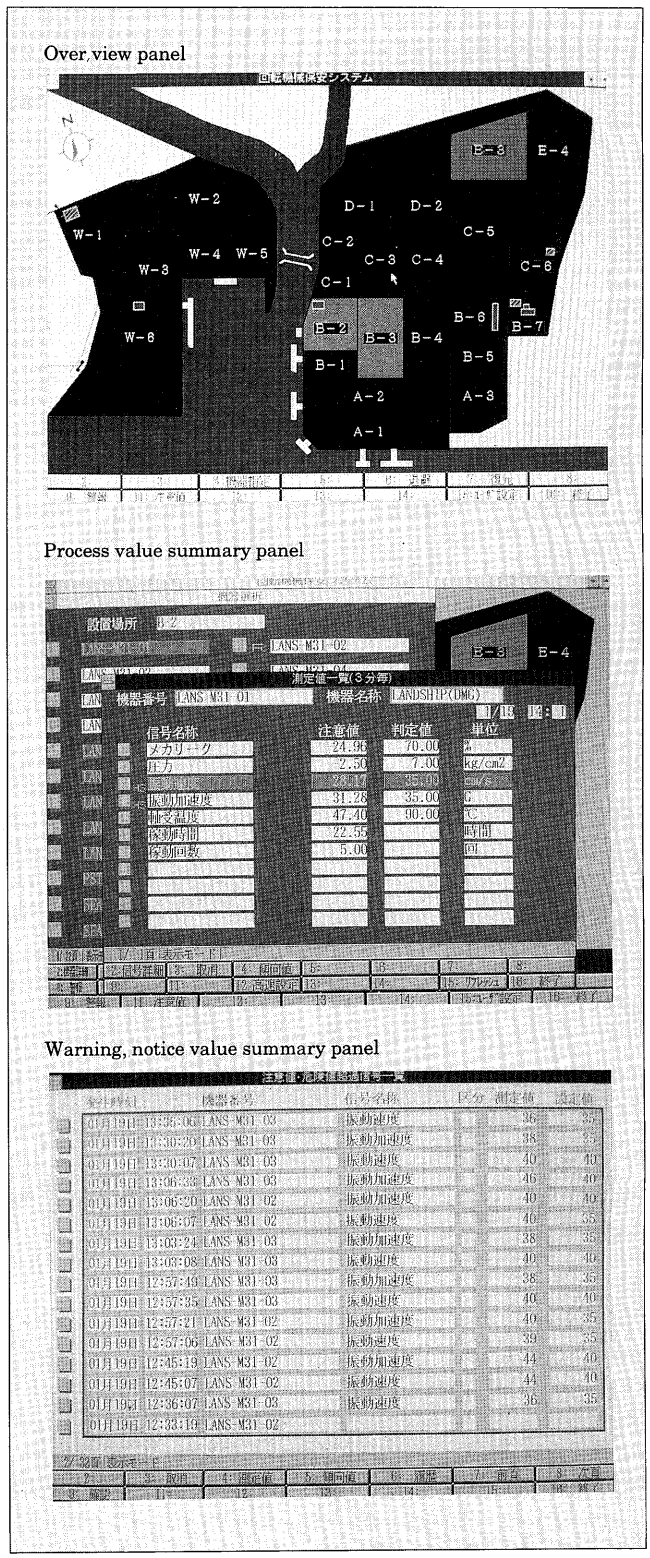
The predicted number of days until reaching the warning level set on the display is indicated by a curve extrapolated from the trends of past data transitions. With this prediction, precise inspection and maintenance of the rotary machine in question can be performed before any signs of abnormality are shown.

The data used for the prediction has its end point fixed at the present and the beginning point may be freely determined on the display. The predicted curves are calculated through a regression calculation of primary, secondary and exponential logarithmic functions. All three curves are displayed at the same time. The degree of conformity is inverted by the functions and expressed as a % to show the validity of the regressions.

4.4 Operation management

The number of operations and operation time are cumulatively indicated to acquire the result of the operation. There are two methods to detect operation. In one method, the trigger is a running answer back signal. In the other method, the trigger is a combination of vibration magnitude and its continuing time. The method of triggering by vibration is an effective means for detecting operation of rotary machines in which the running answer cannot be removed because it would

Fig. 2 Example of V.D.T. panel



require either complex modification of the electrical circuit or high costs, since the operation can be detected without any alteration of the existing machines and equipment.

4.5 Hierarchy of window operation

The client panels are all prepared on Windows*2, and are structured in hierarchy. An example of the panels is shown in Fig. 2.

It is unnecessary for the operator to normally monitor the panels if there is no panel of special interest. When an alarm is issued, the operator has only to click with a mouse on a pop-up window that indicates the alarm on a red colored area in the over view panel. This will change the machinery summary panel to a signal summary panel, and allow the operator to confirm the machinery issuing the alarm and the type of alarm signal. An alarm summary can be displayed with a single action.

4.6 Maintenance ease

The range and designation of all signals, such as Tag No. etc, can be changed on-line. Monitoring sensors can be added by stopping a specific local control panel without having to stop the whole system. Further, since the monitoring sensors on site and the existing DCS are isolated, maintenance can be perform and operation increased without any regard for plant operation system such as DCS.

4.7 Open system

The operation systems (O/S) of this monitoring system use UNIX*3 in the server and Windows in the clients. Ethernet is used as the network between clients and server. Since these are permanent worldwide standard, this system will be able to smoothly link with higher order or other systems in the future.

4.8 Extended functions

This system is designed to be able to add the following extended functions.

(1) Operation support: Operational diagnosis and mechanical diagnosis utilizing AI technology
(2) Maintenance support: Maintenance advice from an expert system utilizing AI technology
(3) Others: Decentralized server and intelligent alarms

4.9 Low introductory cost

Since this system can be provided with a minimal hardware structure for data processing in the server and for optical multiplex transmission, and since it can be successively enlarged, the introductory cost of this system is held low. In addition, this system can be built up by adding local control panels and clients without the need to change basic software. Therefore, the cost of increasing the system will also be low.

5. Conclusion

This system has been smoothly operating since April 1995, and all the initial aims have been achieved.

This year, we are busy with the construction of one of the aforementioned extended functions, an operation support system that uses AI technology to combine operational diagnosis and mechanical diagnosis.

We at Fuji Electric believe that this system will be applied not only to oil refineries but to various process industries as a prediction maintenance tool for rotary machines, which are very important for safe operation.

The authors would like to express appreciation to the engineers of Tohoku Oil Co., Ltd., Mitsubishi Oil Engineering Co., Ltd. and Optomation Co., Ltd. for guidance and cooperation during the manufacturing, factory testing and trial runs of the system.

*2 : Windows is a registered trademark of Microsoft, USA.
*3 : UNIX is a registered trademark of X / Open Company Ltd.