

Operation Optimization Solutions for Steel Plants

TOMITA, Yoshinori* YOSHIKAWA, Hajime* NARUMI, Katsunori*

ABSTRACT

The materials industry as represented by the steel industry is facing new challenges due to the diversification of customer needs. Operation optimization solutions for steel plants are one of the pillars of a Fuji Electric business model. We are providing solutions based on leading technologies that contribute to creating new value while solving the challenges of achieving stable and safe plant operations, product quality improvements, reduction in specific energy consumption and operation know-how transference, which are among the most important management indicators for corporations.

1. Introduction

New technologies such as the Internet of Things (IoT) and big data analysis have the potential to revolutionize the industrial structure and bring changes to the forms of business of companies. In addition, they may lead to creation of new demand and changes in the cost structure. They are also expected to create new business models in response to the need for further quality improvement that is required for stable and safe operations and after-sales services.

The steel industry has driven the entire industry technologically and economically as one of the representative material industries. It is now faced with new issues such as excessive supply due to a slowdown in economic growth in China, the biggest consumer, and diversification of customer needs for strength enhancement, weight reduction and cost cutting.

This paper presents the operation optimization solutions for steel plants, which Fuji Electric sees as one of the pillars of its business model. Among the most important management indicators for corporations, the focus is placed on stable and safe plant operations, product quality improvements, reduction in specific energy consumption and operation know-how transference and the respective approaches are described.

2. Approach to Stable and Safe Operations of Steel Plants

2.1 Background

Recently, the environment surrounding production equipment has been going through dizzying changes for reasons such as changes in the social and business

environments, technological innovation and international standardization. Meanwhile, the importance of stable and safe plant operations is continually increasing. Against this background, Fuji Electric has been making efforts for various approaches contributing to stable and safe operations of plants including steel plants.

2.2 Examples of solutions

- (1) Stabilization of operation of oxygen converter gas recovery system

The Linz-Donawitz converter gas (LDG) generated during blowing in a converter is a high-temperature combustible gas consisting primarily of CO and containing a large amount of dust. It poses the risk of explosion in the event of an air inflow as well as a hazard to humans and the risk of environmental pollution if it leaks, which makes it an important control point for stable operations. In addition, LDG is used as fuel for various types of equipment in a steelworks and improvement in its recovery rate is another important management indicator. Fuji Electric has been providing New Control of P0 (NCP0), which minimizes disturbances to keep the pressure at the converter mouth $P0$ constant. However, measuring the CO and O₂ concentrations with the conventional sampling-type analyzer, which is used for NCP0, had a problem of recovery loss due to delayed response.

To deal with this problem, Fuji Electric has commercialized the world's first cross stack laser gas analyzer capable of measuring the concentrations of 2 components (CO and O₂) with a single unit. Fuji Electric is promoting its application to an oxygen converter gas recovery system (OG) as shown in Fig. 1. This gas analyzer features excellent response and maintainability and can measure the concentrations of CO and O₂ in LDG simultaneously and at a high speed. Also, the

* Industrial Infrastructure Business Group, Fuji Electric Co., Ltd.

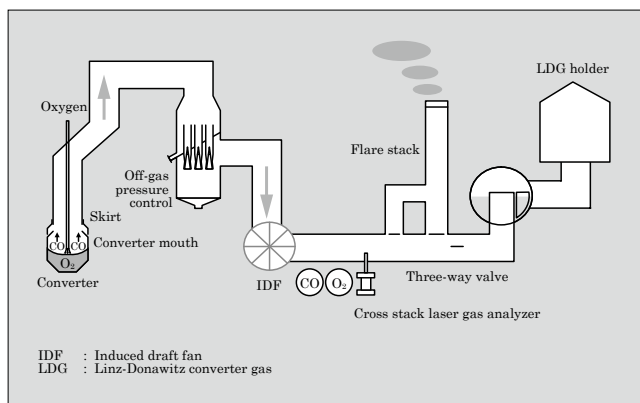


Fig.1 Oxygen converter gas recovery system

LDG recovery rate is significantly better than that of a conventional sampling-type analyzer. Furthermore, an energy center^{*1} also allows real-time monitoring of the concentrations of the CO and O₂ in LDG, which improves the accuracy of energy supply-demand forecasting for an entire steelworks.

(2) Stabilization of operation of heating furnace equipment

Recently, quantification of safety levels, safety design, safety approval and safety management have been progressing in line with the functional and machine safety standards that started in Europe. Activities have been promoted for ensuring safety for entire systems. In response, in Japan, the JIS B 8415 General safety code for industrial combustion furnaces was revised in November 2008. Fuji Electric has been strengthening its activities for safety to keep up with these trends.

Heating furnace equipment is used for heating material before processing billets and handles and consumes large quantities of fuel. Accordingly, the point is how to improve the combustion efficiency while preventing explosions and adverse effects on humans and environmental pollution due to leakage of toxic gas. The controller of Fuji Electric's information and control system "MICREX-NX" (see Fig. 2) has been approved for SIL3^{*2} and conforms to the JIS. In addition, it features the capability to accommodate both safety control and regular control in the same controller. This allows a safety circuit, which was conventionally built using hardware, to be realized using software for integration with high-functionality combustion control. This in turn allows the construction of a combustion safety system combining high combustion efficiency and safety with a compact system configuration.

(3) Equipment maintenance optimization with IoT

*1: Energy center: Intended for centralized management of large amounts of various types of energy at a steelworks for integrated management of energy saving, labor saving, streamlining, environmental management, etc.

*2: SIL3: refer to "Supplemental explanation 1" on page 205.

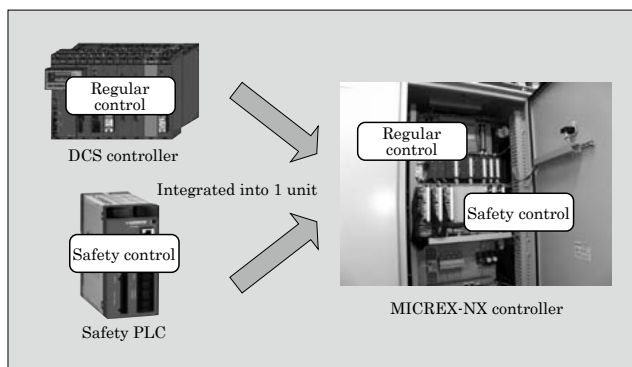


Fig.2 "MICREX-NX" controller

Maintenance of plant equipment and devices can be roughly classified into breakdown maintenance, which is repair after the occurrence of accidents or failures, and preventive maintenance, which is systematically conducted before the occurrence of accidents or failures. For stable and safe operations of plants, preventive maintenance is important. Preventive maintenance can be further classified into time-based maintenance (TBM), which is inspection and repair at regular intervals, and condition-based maintenance (CBM), which is repair and replacement based on the prediction of deterioration conditions and failure location and timing of equipment and devices. Up to now, TBM has been the mainstream but it has posed a challenge of achieving both a reduction in maintenance costs and prevention of accidents and failures. In addition, IT has recently made remarkable progress and equipment maintenance using the IoT is becoming widespread. Accordingly, Fuji Electric started cloud-based equipment maintenance services based on the technologies and track record it has achieved over many years (see Fig. 3). The services provide optimized maintenance by CBM that uses history data of equipment and devices and their analysis algorithm.

The cloud-based equipment maintenance services are a result of integrating operation monitoring, equipment diagnosis, abnormality sign analysis, equipment management support and maintenance work support. These were conventionally constructed with individual systems, but they have been merged into a common cloud environment. This can improve equipment capacity utilization and production efficiency, optimize maintenance plans, improve maintenance operation efficiency, systematize the maintenance know-how, ensure stable plant operation and minimize the life cycle cost. Furthermore, we are working on deterioration diagnosis and life expectancy prediction of drive devices such as motors and inverters, for which prediction of accidents and failures was difficult in the past (refer to "Service Solutions to Support the Stable Operation of Equipment" on page 165).

(4) Operation stabilization of high-speed drive control systems

Many electric motors are used in producing steel

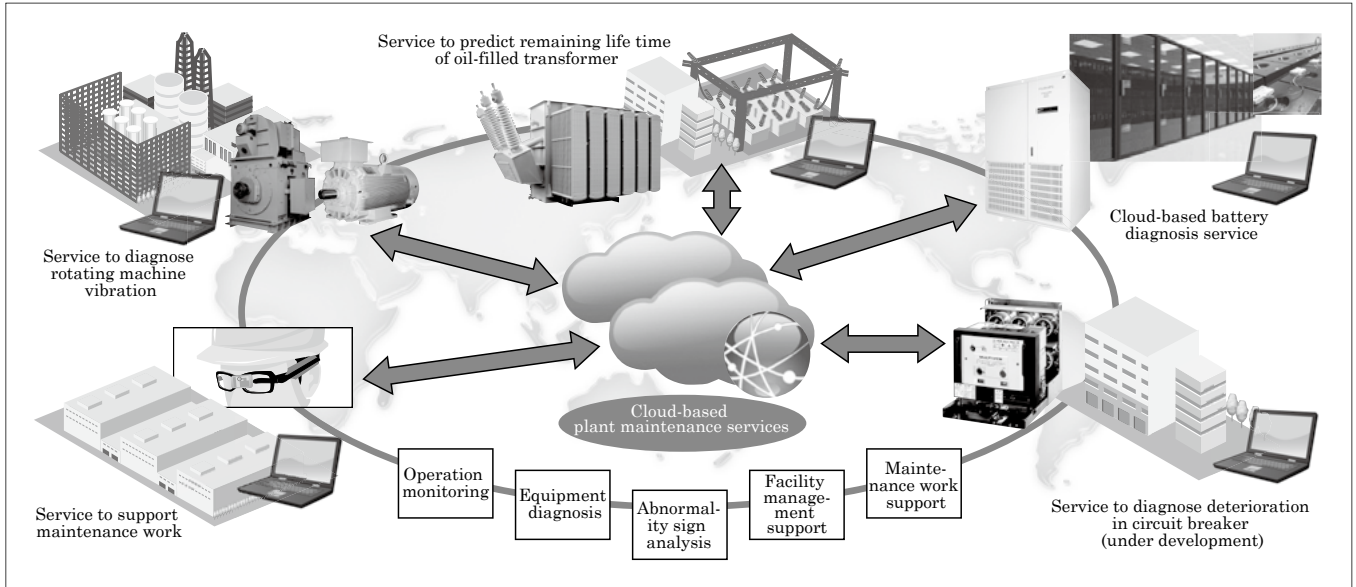


Fig.3 Cloud-based equipment maintenance services

products with shapes and characteristics suited for various applications. In particular, for rolling equipment, annealing equipment and surface treatment equipment for plating, coating, etc., tens to hundreds of electric motors are controlled at high speed and with high precision. Fuji Electric provides these various high-speed drive control systems to help stabilize operations.

Figure 4 shows an example of the configuration of a high-speed drive control system. A drive master controller (DMC) is a controller capable not only of high-

speed control of up to 64 drives but also of continuously monitoring the statuses of the drives and electric motors. Connecting a DMC with a maintenance PC via a network allows constant remote monitoring.

The “f(s)NISDAS” and process data collection system (PDCS) are systems used to collect plant operation data. The f(s)NISDAS is connected with a programmable logic controller (PLC) and DMC, which are controllers, via a high-speed network. It can chronologically record plant control information at a high speed and is a useful tool for analyzing device malfunctions and control failures. Meanwhile, the PDCS is a package that records plant operation data for production control and quality assurance for each production lot. Data can be collected for realizing product traceability and stabilizing operations by comparing production instructions and results with operation data to record what took place in which process of the product manufactured.

3. Approach to Product Quality Improvement

3.1 Background

Quality degradation may lead to situations that have a decisive impact on the performance of a company. Recent products are manufactured by using more advanced and complicated technologies than before and ensuring quality across all manufacturing processes is an essential issue in the manufacturing industry.

Accordingly, in order to ensure the quality of each process, it is necessary to acquire quality information, identify and analyze problems and predict and track quality for feeding the results back to the manufacturing processes. A quality improvement cycle from the acquisition of information to feedback can utilize quality data analysis and quality prediction⁽¹⁾.

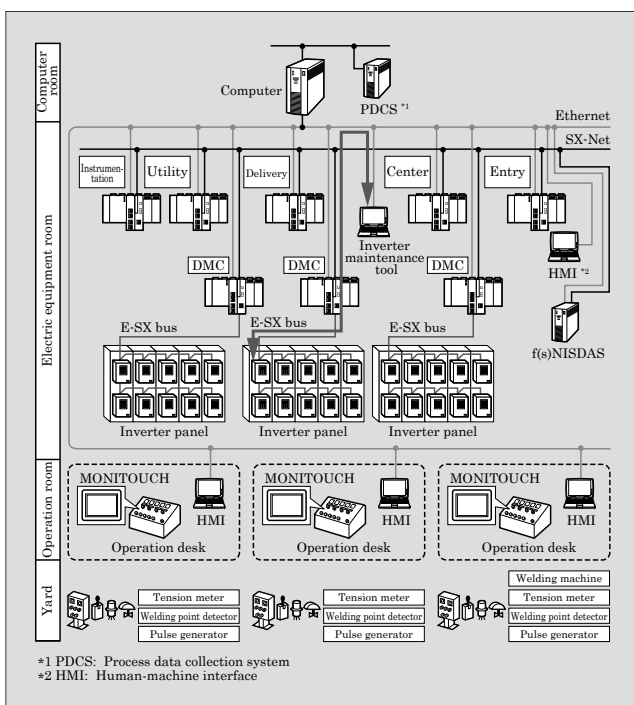


Fig.4 Example of configuration of high-speed drive control system

3.2 Examples of solutions

(1) Quality data analysis

A processing line, which is one of the steel manufacturing processes, includes equipment for various types of processing of coils^{*3} such as annealing and galvanizing. By welding the trailing end of one coil with the leading end of the next coil, multiple coils are continuously processed at a high speed (over 100 to 1,000 m/min). During coil processing, data are received from many sensors at regular cycles (1 to 10 s). They correspond to certain positions on certain coils and correspondences are indicated in the form of a mesh along the longitudinal direction of coils. Such data are used as the quality data (mesh data). Mesh data were conventionally created manually, though was very cumbersome and prone to many errors.

Fuji Electric provides a PDCS that analyzes the manufacturing and quality information of a processing line and automatically creates mesh data with a resolution of 10 m. It allows not only easy new installation but also simple introduction into existing equipment. Figure 5 shows a functional configuration and the following explains the main features of the PDCS.

(a) Setting registration support function

To make it easier to register equipment information such as the type of quality data to be collected and sensor positions, template Excel^{*4} sheets are prepared.

(b) Elongation correction function

Coils may be elongated by applying tension to correct any coil distortion or warp, causing discrepancies in the position information of the quality data. To deal with this problem, the percentage of elongation specified for the tension applied is used for correcting the position information of the quality data.

(c) Mesh data graph display and Excel output

Relations between and trends of quality data of different types can be grasped for the individual positions on coils by displaying a graph of the mesh

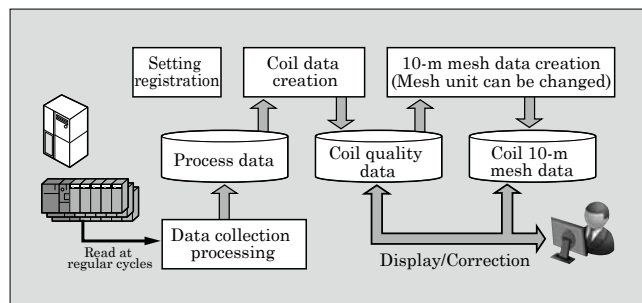


Fig.5 Functional configuration of PDCS

*3: Coil: Sheet steel rolled thin and wound into circles

*4: Excel: Trademark or registered trademark of Microsoft Corporation

data collected. Items can be specified for Excel output, which allows arbitrary analysis.

By introducing the PDCS, data between different units of equipment can be automatically collected in real time for each coil. This allows prompt cause investigation and feedback to operations when any abnormality is found in quality. In addition, data can be extracted and analyzed with various conditions such as for each steel grade, which allows easy tuning of operation parameters (annealing and other parameters) when a new plant is launched or when production of a new product is started.

(2) Quality prediction (quality meter for manufacturing lines)

If quality can be predicted based on the current operation data, it significantly contributes to stabilizing quality.

The quality meter for manufacturing lines is a system that is capable of visualizing and predicting the quality state by online quality analysis in a processing line. Figure 6 shows a functional configuration.

(a) Function overview

From the past operation result data, factors are automatically extracted that have close cause-and-effect relationships with the quality to be measured, and they are used as the basis for building a plant model.

By providing this plant model with new operation result data, primary factors that may adversely affect the quality during manufacturing can be extracted and the rate of occurrence of events such as failures can be predicted.

(b) System features

(i) Automatic following of changes in equipment and operation

For quality analysis using a normal plant model, coefficients, etc. need to be revised

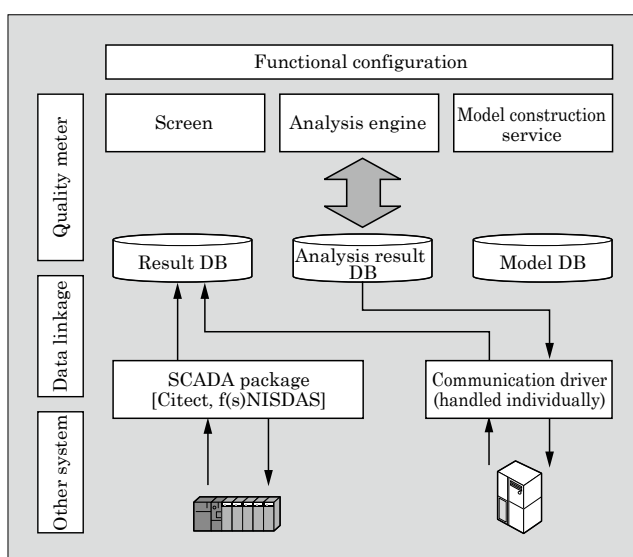


Fig.6 Functional configuration of quality meter for manufacturing lines

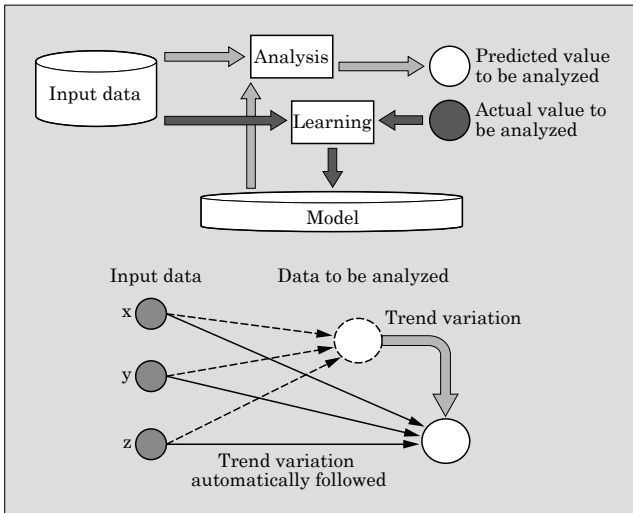


Fig.7 Concept of quality prediction model by Bayesian multivariate analysis technique

according to changes in equipment and operation. This system is equipped with a model reconstruction function based on learning function. It is also capable of analysis with an up-to-the-minute prediction model by constantly following changes in the equipment and operation. Figure 7 shows the concept of a quality prediction model that uses a Bayesian multivariate analysis technique.

(ii) Visualization of analysis results

The cause-and-effect relationships between analysis results or data to be analyzed and input data can be graphically displayed and the screen can be customized according to the characteristics of the data to be analyzed.

4. Approach to Reduction in Specific Energy Consumption (Demonstration in India)

4.1 Background

Energy consumption of the Japanese steel industry accounts for as much as 13% of all energy consumed domestically and almost all steelworks have an energy center intended for saving energy by optimally utilizing it. As a result, the specific energy consumption in the Japanese steel industry is far lower than overseas⁽²⁾. In addition, overseas steelworks do not implement energy-saving operation by optimum operation of energy for all related equipment but only energy management for the individual units of equipment such as power generation equipment. As international energy saving and environmental measures are expected to progress, in India, among others, energy saving in the respective industrial sectors has been promoted by the Energy Conservation Act enforced in 2001.

4.2 Examples of solutions

In the “Demonstration Project of Technology/System for International Energy Consumption Efficiency

etc.,” a demonstration project supported by the New Energy and Industrial Technology Development Organization (NEDO), Fuji Electric has provided India with the energy center optimum control technology, which is Japan’s leading-edge technology, as a steel EMS solution, to work on the grasping of energy conditions of an entire steelworks and overall optimization of energy demand and supply.

After demonstrating through this project the effect of various systems as measures contributing to future diffusion, we intend to work for diffusion of the energy center optimum control technology in steelworks in India. Figure 8 shows the system configuration in the demonstration project. With the aim of achieving a reduction of energy consumption of 25,400 kL/year in terms of heavy oil and a reduction of greenhouse gas emissions of 71,400 t-CO₂/year (approximately 11% reduction annually respectively), we will apply, of the energy center optimization control technologies, the following 5 major functions to steelworks in India.

(1) Optimum operation technology for power generation equipment

Based on the prediction of generation and usage of various types of energy such as electric power and heavy oil and by-product gas delivery from a gas holder, optimum operation plans in view of the equipment capacity of multiple generators are made for effective use of the by-product gases and maximization of the electric power output.

(2) Optimum operation technology for oxygen equipment

Based on the prediction of oxygen usage, optimum oxygen generation plans for multiple oxygen plants are formulated. This minimizes the electric power energy consumption to reduce the excess oxygen emission rate.

(3) Optimum operation technology for gas holder equipment

Energy-saving operation is realized by minimizing the emission rate of the excess by-product gases and variation of the amount of its delivery from the gas holder.

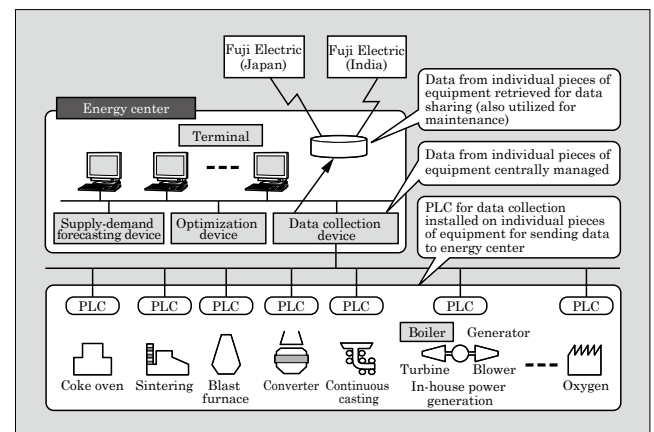


Fig.8 System configuration in demonstration project

- (4) Overall optimum operation technology for crude steel production and energy usage

Based on the generation and usage prediction of various types of energy, the energy demand of the plant is met while the crude steel production is maintained and daily and monthly optimum allocation plans are made for the respective types of energy including electric power, by-product gases and steam. This minimizes the energy consumption and greenhouse gas emissions.

- (5) Technology for visualizing potential energy savings linked with production plans

By applying our proprietary mathematical modeling technology, how much energy saving is possible for the equipment capacity is analyzed in advance to visualize potential energy savings as compared with the current energy operation (refer to “Mathematical Application Technology for IoT Solutions” on page 198).

5. Approach to Operation Know-How Transference

5.1 Background

Fuji Electric has delivered many monitoring and control systems for steel plants. Many of them have been installed for over 15 years after the delivery and are ready for replacement. For replacement of an existing system, inheritance of the operability and maintainability of the existing model on the latest technical platform and incorporation of the operation know-how into the system provide significant benefits to customers. There are issues including decrease of trained technicians in Japan and prompt development of local

engineers required by expansion of local production for local consumption outside Japan and there is a growing need for strengthening of the on-site capabilities by skill succession.

5.2 Examples of solutions

- (1) Inheritance of operability and engineerability

The amount of capital investment has been decreasing in recent years and, for gradual replacement of customer assets while keeping the costs low, replacement on the individual layers of a control system (operator station, control network, controller and I/O) in order is required. The latest monitoring and control system “MICREX-VieW XX” released in 2014 is based on concepts including effective utilization of existing assets (refer to “Evolving of Monitoring and Control System ‘MICREX-VieW XX (Double X)’” on page 186). It is designed to allow, in a replacement project, migration into a new system while inheriting the operability and engineerability with which the customer is familiar (see Fig. 9). For that purpose, MICREX-VieW XX provides the following functions.

- (a) Inheritance of application assets of existing system

The operability and maintainability are inherited by applying (converting) the monitoring screens and controller applications of the existing model to use as applications of the new system.

- (b) Connection with existing system network

Gradual replacement can be achieved by connecting the new system with the control network of the existing model to allow monitoring and control.

- (2) Abnormality sign detection and avoidance proce-

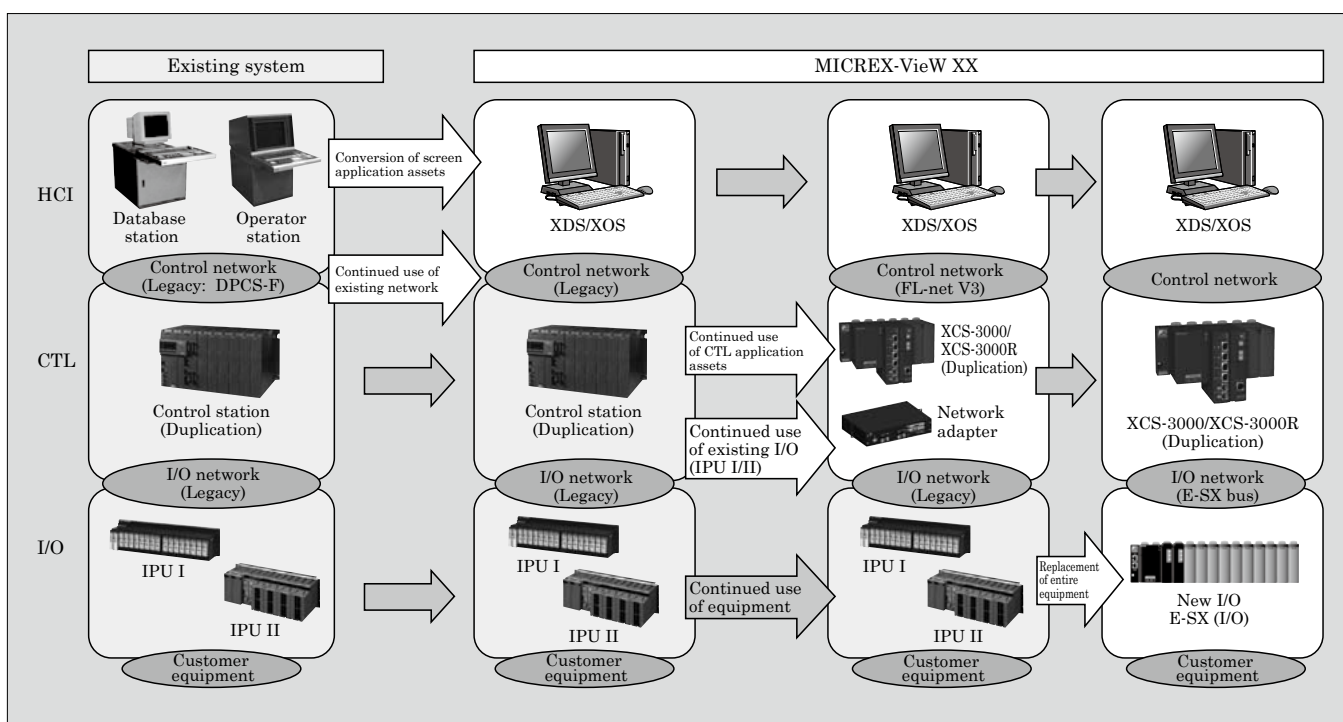


Fig.9 Gradual replacement by MICREX-VieW XX

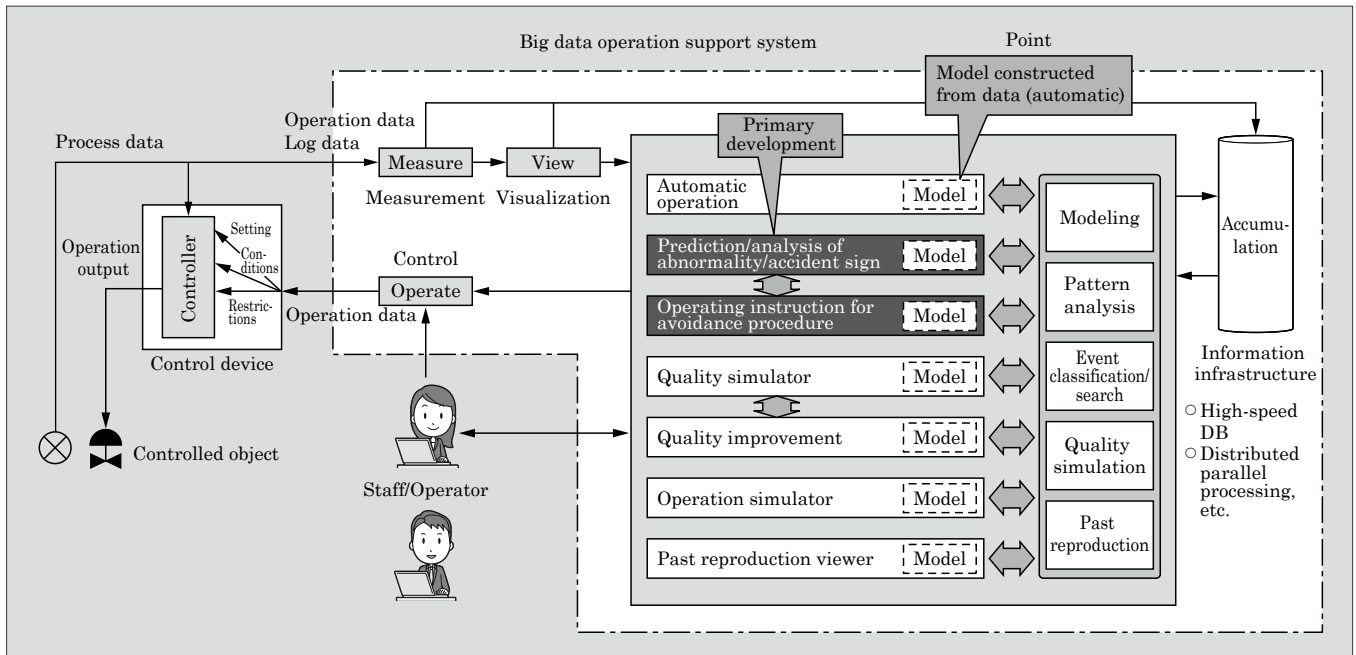


Fig. 10 Overview of operation support system

dure instruction for heating furnace

One of the biggest issues for customers is a shortage of skilled operators. For example, direct checking on the combustion conditions in a heating furnace is difficult and the statuses of various sensors are checked on the monitoring screen during operation. However, the combustion conditions may vary between individual burners because of the effect of the burners themselves and fuel piping. For this reason, incomplete combustion may occur even if the operation looks stable on the screen. For preventing abnormalities like this, in many cases, skilled operators with various types of know-how in relation to operation judge the conditions and take necessary measures. However, aging of skilled operators is progressing, which poses an issue of know-how transference for non-steady-state or emergency operation such as detecting signs of abnormalities in advance to implement avoidance operation.

Over many years of operation, a variety of data (big data) including operation data and operation and alarm logs are accumulated by control and other devices. Fuji Electric makes use of these big data to work on the development of an operation support system (see Fig. 10). This system itself automatically learns adjustment of the fuel flow rate and operation for avoiding abnormalities and facilitates stable operation without depending on operators' experience. Models created from process data of steady-state operation and operation history of operators are compared with the behavior of process data and operation by operators before and after the occurrence of an abnormality. In this way, it analyzes what types of abnormalities can occur along with the changes in the process data and notifies operators of them before actual abnormalities occur, thereby securing a time for abnormal-

ity avoidance operation. In addition, it presents the abnormality avoidance operation implemented in the past to allow the plant to be maintained in safe conditions without depending on workers' skills.

(3) Maintenance know-how transference

As with operation, maintenance also has an essential issue of know-how transference. Fuji Electric provides a system of giving support and guidance to workers by connecting in real time the glasses-type wearable device (equipped with a camera and small monitor) worn by an on-site worker with the base in a remote location where a skilled engineer is via the

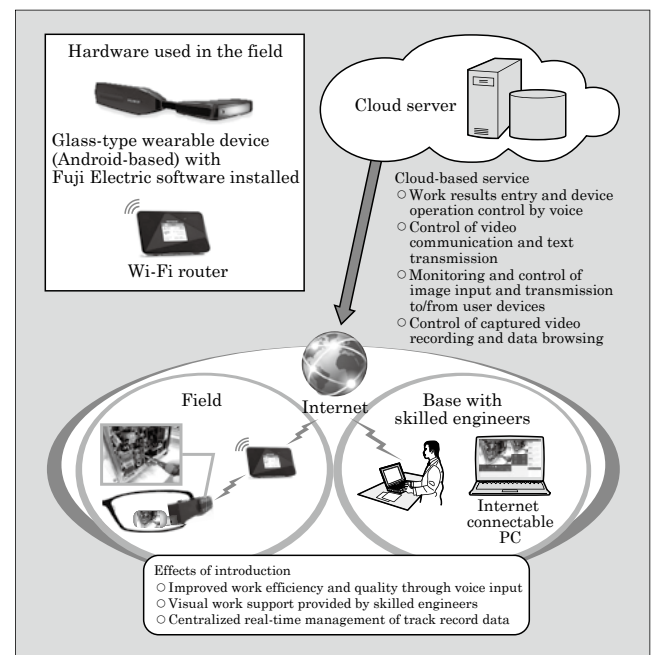


Fig.11 Wearable remote operation support package

Internet (see Fig. 11). The skilled engineer can give work instructions by images and voice while sharing the conditions with the on-site worker through the glasses-type wearable device and the hands-free operation allows the on-site worker to use both hands to work. This contributes to improvement of work quality and efficiency and skill succession (refer to “Service Solutions to Support the Stable Operation of Equipment” on page 165).

6. Postscript

This paper has described operation optimization solutions for steel plants by presenting the current approaches with the focus on stable and safe plant operations, product quality improvements, reduction in

specific energy consumption and operation know-how transference. In order to meet the needs that are becoming increasingly sophisticated and complicated, further functional enhancement is required of instrumentation and control systems. For continuing to meet the needs of users, we are committed to making contributions to further added value creation.

References

- (1) Shobayashi, N. et al. Instrumentation and Control System Solutions to Support Stable Operation, Energy Efficiency and Environmental Conservation. FUJI ELECTRIC REVIEW. 2014, vol.60, no.1, p.10-15.
- (2) Narumi, K. et al. “Steel EMS Package” Optimizing Energy Management at Steelworks. FUJI ELECTRIC REVIEW. 2013, vol.59, no.3, p.165-169.





* All brand names and product names in this journal might be trademarks or registered trademarks of their respective companies.