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Advances in Steel Industry Control Systems in Era of IoT

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OVERVIEW: Hitachi has long taken advantage of the benefits and expandability of autonomous decentralization to build control systems for steel industry equipment that is subject to frequent retrofitting and modification(1). The current practice is to work on advances in control by utilizing ICT to include extensive data collection and analysis functions and provide feedback to control systems. Specific work by Hitachi includes a new thickness control system and an IoT drive system. In the future, Hitachi intends to extend the use of the PDCA cycle by expanding the scope of information use and providing feedback to control systems based on the symbiotic autonomous decentralization concept.

INTRODUCTION

STEEL prices are currently depressed due to global production of raw steel exceeding demand. The challenges for producers in such an environment include how to improve revenue by producing higher-added-value products, and how to boost cost-competitiveness and reduce business risks (see Fig. 1). Examples of business risks include problems with product quality, unanticipated equipment outages caused by faults or accidents, and missing sales opportunities. These challenges, especially things like producing higher-added-value products and reducing business risks, need to be addressed by making further advances in production and control systems.

To meet these needs, Hitachi is utilizing information and communication technology (ICT) to develop new product functions in terms of both hardware and software based on the concept of autonomous decentralization. In particular, it is establishing practices for generating new added value by utilizing a wide variety of plant data in control systems.

This article describes autonomous decentralized systems in the steel industry, examples of ICT use, and the outlook for steel industry control systems.

AUTONOMOUS DECENTRALIZED SYSTEMS

Hitachi has promoted the use of the autonomous decentralized system as the architecture of control systems. This architecture results in distributed systems in which the network is treated as a data field by sharing plant data between nodes so that the control servers, controllers, and other nodes connected to the

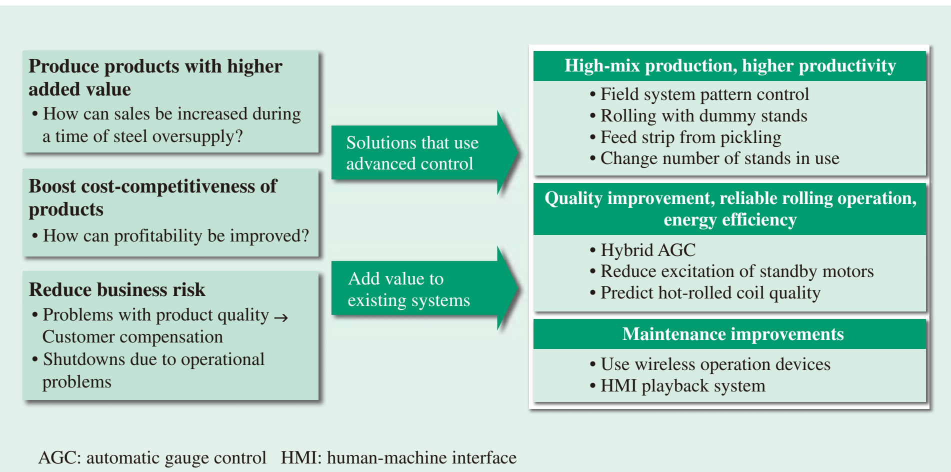

Fig. 1—Challenges Facing Steel Industry and What Hitachi is Doing.
Hitachi has commercialized numerous solutions for the challenges facing the steel industry as they have changed over time.

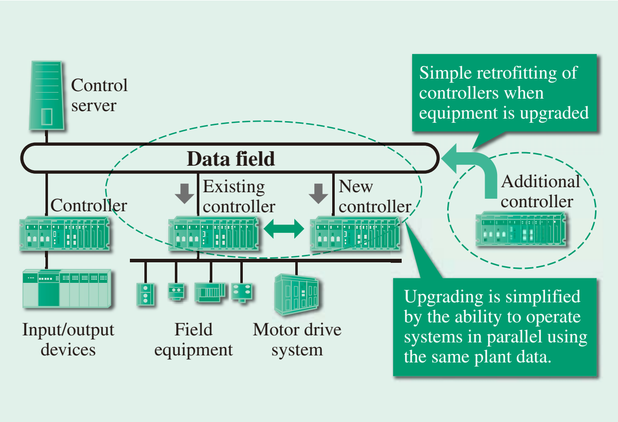

Fig. 2—Autonomous Decentralized Systems and Their Characteristics.
The autonomous decentralized system architecture has played an important role over many years in retrofit and modification projects at steel mills.

network can function autonomously by accessing this shared data to perform their roles. This autonomous decentralized system architecture has the following benefits for steel industry control systems used in production processes that are subject to frequent modifications (see Fig. 2).

The first is that, when software changes or the retrofitting or modification of hardware is considered, use of an autonomous decentralized system that shares data across nodes means that existing data can still be retrieved without difficulty even by components that have been added or modified. Another benefit is that, while testing upgrades to existing equipment, it simplifies the process of operating systems in parallel* by providing shared access to data in the data field. It also facilitates redundancy by allowing a single standby controller to serve as a backup to multiple in-service controllers. In this way, the features of autonomous decentralized systems make them ideal for steel industry control systems.

APPLICATION OF ADVANCES IN ICT

Example Uses of Data at Steel Mills

An autonomous decentralized system is made up of plant machinery, control servers, controllers, and a data field for shared access to plant data. The sequence of data use involves first accessing data in the data field (“sensing”), using the data to consider how to resolve issues (“thinking”), and then making improvements to the actual control systems (“acting”). Control systems can be improved by working through this loop.

The following describes the specific sequence of data use at a steel mill (see Fig. 3).

The sensing step makes the plant data in the data field visible. The plant data that flows through the data field is collected by a process data analysis (PDA) data acquisition system, and the detailed internal control data from the controllers is collected by a trace function. The collected data is stored in a plant database and can be displayed simultaneously using a single tool.

* The verification of updates by inputting the same data into an operational node and a new node and operating them in parallel.

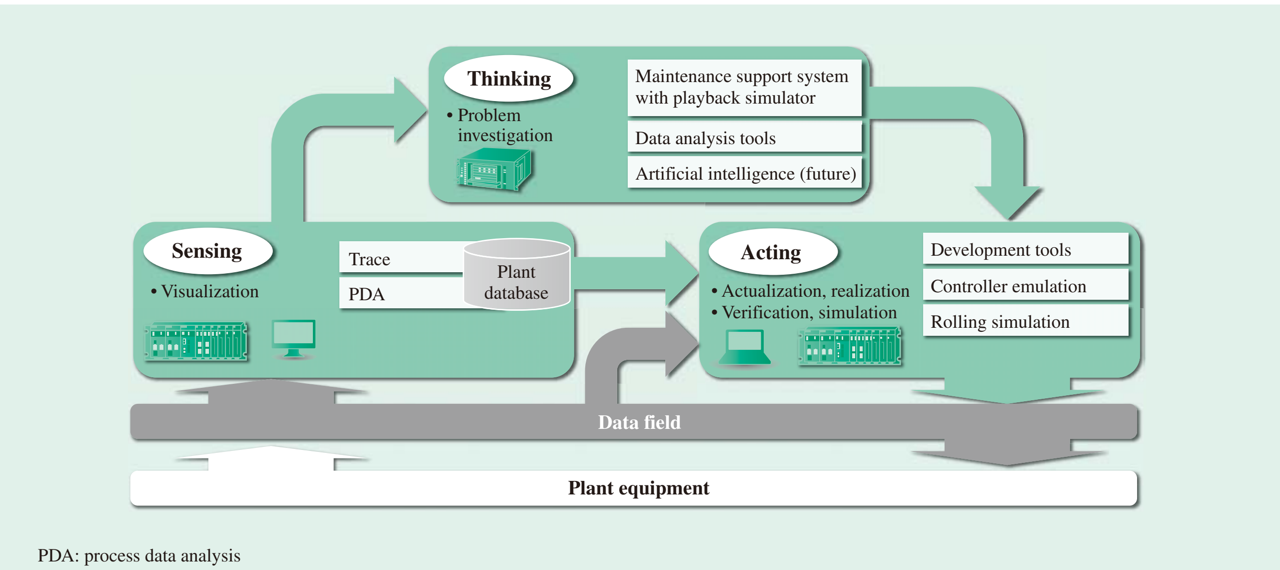

Fig. 3—Use of Data to Improve Product Quality.
Ways of making ongoing use of data from plant equipment are essential for improving the quality of steel products.

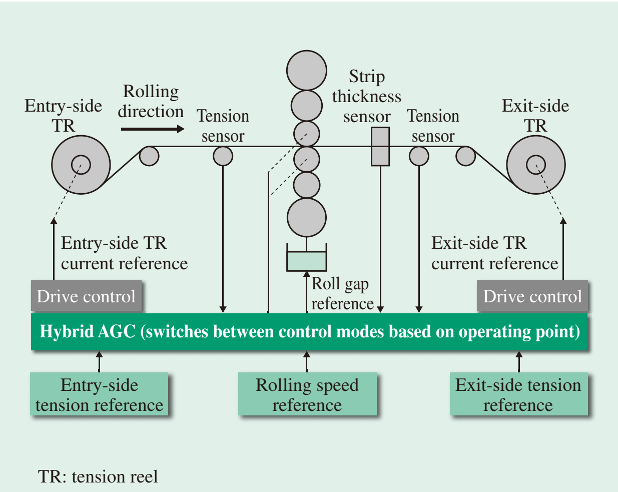

Fig. 4—Control Structure for Hybrid AGC (Single-stand Mill).
Hybrid AGC is a control technique that significantly improves the accuracy of strip delivery thickness by switching between the roll gap and TR current reference, as appropriate, based on actual rolling data.

The thinking step involves using resources such as the Hitachi maintenance support system with playback simulator and proprietary Hitachi data analysis tools to investigate problems and their solutions based on the collected data. This system can also use video camera recordings, with simultaneous playback of data and video so that problems can be investigated from a wider range of perspectives. These features are also available at remote sites away from the plant.

The acting step involves testing on control systems based on the solution hypotheses formulated in the thinking step. The development of algorithms, models, etc. is performed by importing data from the plant database or actual data field data into a development tool. The efficacy of an algorithm is verified by using tools such as a controller emulator or rolling simulator that run on a personal computer (PC) together with data from the data field (or plant database). Once the algorithm has been shown to work, the changes can be quickly incorporated into the control system using the controller's online logic modification function.

Accordingly, autonomous decentralized systems are also suitable for use in terms of facilitating the ongoing development of a steel mill based on the plan, do, check, act (PDCA) cycle, and Hitachi has been working on innovations in system technology and control techniques that incorporate the latest ICT[2]. The following section describes two initiatives Hitachi has undertaken in recent years: the implementation of a hybrid automatic gauge control (AGC) and an Internet of things (IoT) drive system.

Hybrid AGC

A hybrid AGC for a single-stand rolling mill provides an example of acting on the data that has been collected and analyzed in the sensing and thinking steps (see Fig. 4).

The previous control system used the roll gap to control strip thickness and tension reel current to control strip tension. Unfortunately, the system had a problem with long fluctuations from several seconds to ten or more seconds on the exit side of the mill due to interference between thickness and tension control when rolling thin strip at high speed.

In response, a new control technique called hybrid AGC was used to minimize these fluctuations by switching between use of roll gap or tension reel current based on factors including past rolling performance and the current operating point, making it possible to produce higher-quality products (with higher added value).

The first step in the development of this control technique was to collect and analyze data about the problem using the sensing and thinking tools previously developed by Hitachi to determine the changes described above in the degree of influence due to rolling conditions. Next, the benefits of incorporating the technique into the control system were demonstrated through simulation using a rolling model (an acting tool) and by testing on the actual mill.

IoT Drive System

This section describes an IoT drive system that provides another example of data use. The converter panels for motor drive systems used in the steel industry consist of control boards that control the motors that drive the rolling mill and a main drive unit that performs electrical conversion. Hitachi has made progress over time on downsizing these components. In addition to combining cell units (blocks of capacity) to enable flexible configuration of the main drive unit to deliver the capacity required by the customer, Hitachi has also used them to build large and medium-sized panels for the steel industry by increasing the capacity of the individual cell units and making them smaller to reduce the overall size of the panel[3], [4], [5].

Hitachi is also continuing to develop the control boards and is planning reliability, availability, and serviceability (RAS) enhancements that utilize the IoT. In addition to the motor drive system, the IoT drive system also includes a control system (controller) and data analysis units that handle various forms of data acquisition. A variety of issues can be investigated

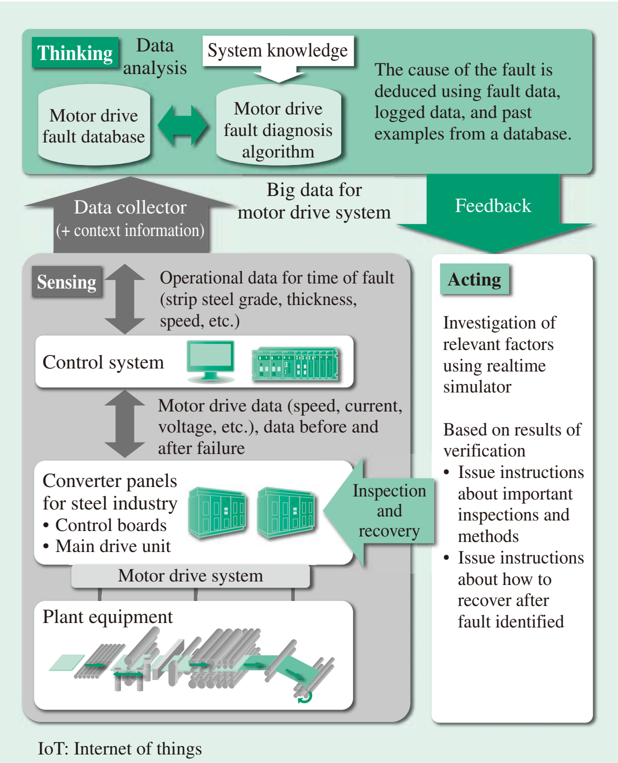

Fig. 5—Fault Analysis Flow for IoT Drive System.
By visualizing associating various types of data when a fault occurs and performing data analysis, the cause of the fault can be deduced and checked to achieve a quick recovery.

by linking information relating to motor control held by the motor drive system (speeds, current, voltage, and so on) to operational data held by the supervisory control system (strip steel grade, thickness, speed, and so on), and the results can be incorporated into the motor drive system.

Fig. 5 shows the flow of fault analysis that was conducted in a case where the motor drive system shut down for some reason during plant operation.

Sensing functions include a function in the control board for recording fault data such as overcurrent or overvoltage when a fault or shutdown occurs, and a function for recording data from before and after a fault in memory. Insights into the conditions associated with the fault are obtained by linking this data with operational data held by the controller. The data analysis unit that provides the thinking functions performs high-speed retrieval of this data via the Internet or other means, and determines the cause of the fault using diagnostic algorithms based on system knowledge and a database of past fault histories. The acting step involves verifying this cause on a realtime simulator. Faults that have occurred during plant operation can be replicated and tested in realtime by building a model (simulator) to replicate the fault cause identified by the thinking step and running this in parallel with the same control board as used in the plant where the fault occurred, including the control programs and parameters held for the plant by the control board. Based on the results of testing, the plant can also be informed of what checks to perform or how to recover from the fault.

By utilizing IoT technology in the motor drive system this way, it is possible to achieve rapid fault diagnosis and recovery, and to minimize plant downtime. Moreover, it is also possible to prevent unanticipated plant shutdowns due to equipment faults by working through the analysis cycle described above on a regular basis.

OUTLOOK FOR STEEL INDUSTRY CONTROL SYSTEMS

Two potential developments for steel industry control systems based on the autonomous decentralization concept are as follows (see Fig. 6).

(1) Fusion of information and control using the IoT

This development involves using the IoT for the collection and analysis on information systems of large quantities of big data (strain, vibration, and so on) from equipment and processes, as well as human data (people’s actions, audio, and so on) that conventional control systems find difficult to utilize. It will be utilized in approaches for further developing steel industry control systems that combine both information and control, including the resolution of problems for which the causes were previously unknown and the generation of know-how from new insights.

(2) Adoption of symbiotic autonomous decentralization, which extends the concept of autonomous decentralization throughout the business.

This involves establishing cooperating fields (shared access platforms) that provide for the coexistence of stakeholders, who represent a system in their own right, with head office and other business systems as well as the control and information systems at the steel mill. By using these cooperating fields to share data, and by providing a view of overall efficiency based on the situation at particular factories or external changes in the business environment obtained by considering the entire supply chain, it becomes possible to devise solutions that optimize this efficiency. This results in the maximization of business efficiency and enables participants to achieve a high level of profitability.

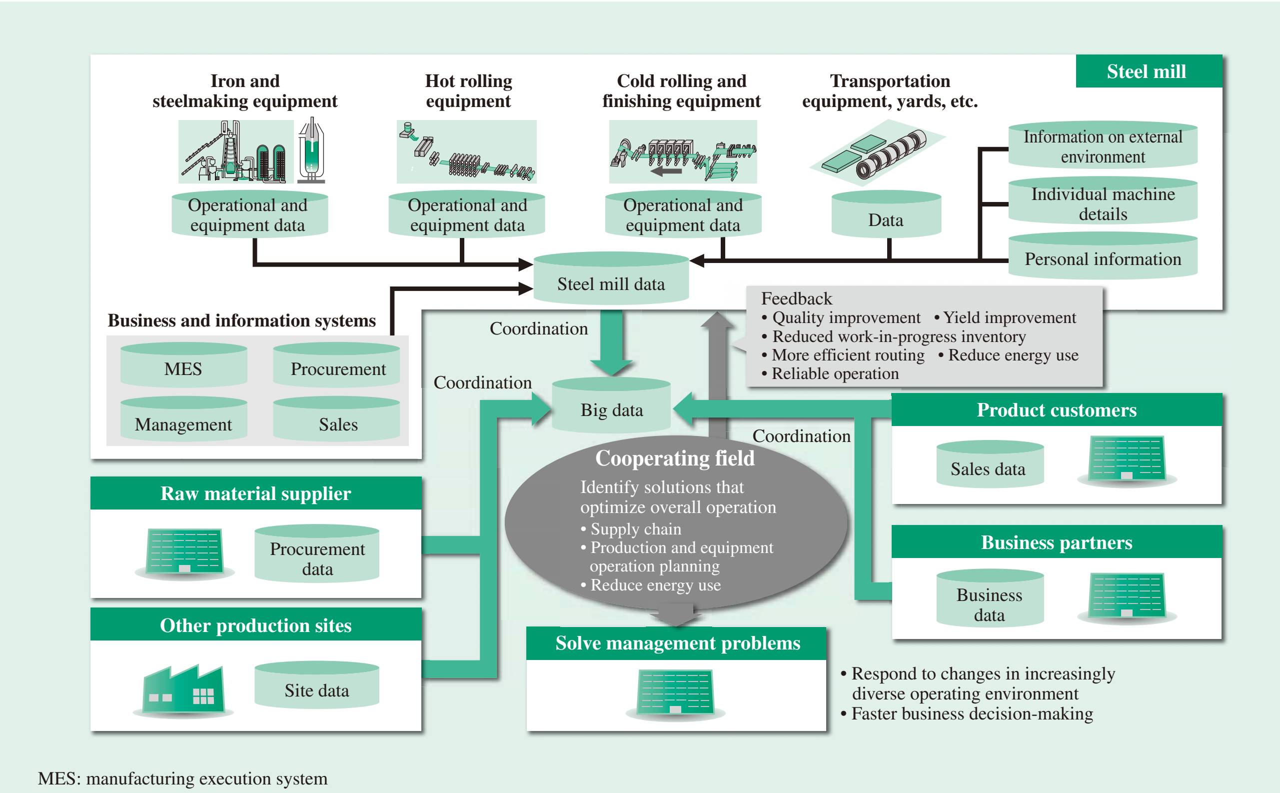

Fig. 6—Further Development of Steel Industry Control Systems.
Solutions that optimize all activities at a customer's company are devised by adopting cooperating fields (shared access platforms). This makes it possible to maximize business efficiency for the purpose of improving profitability.

CONCLUSIONS

Recent years have seen changes in such global trends as the use of the IoT and other forms of ICT for industrial restructuring aimed at more advanced manufacturing. It is anticipated that there will be increasing demand for and momentum behind a shift from the optimization of individual systems to the optimization of overall efficiency, including in the case of steel industry control systems that have undergone ongoing development in the past through the independent implementation of systems for production and control.

Hitachi intends to continue supplying control systems that contribute to the ongoing development of the steel industry and to resolving its problems by pursuing the latest technology with reference to technical developments.

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