Featured Articles

Use of EAM and Equipment Operation Technology for Sophisticated Operation and Maintenance of Electric Power Distribution Equipment

Kazuhiro Hiraki
Shigehiro Eda
Yuichi Mashita
Yoshio Maruyama
Shinichi Imai

OVERVIEW: With the aging of electric power distribution systems that were installed or built in North America prior to the 1970s, the use of efficient maintenance to enhance power distribution quality is an important challenge. Tokyo Electric Power Company, Inc. and Hitachi are working together to overcome this problem by utilizing the information they have and the associated operating technologies to identify faulty equipment and analyze signs of potential failure. In particular, Hitachi intends to combine EAM technology with the equipment operation technology and maintenance management know-how of TEPCO to develop new solutions and deploy them in North America where demand is strong.

INTRODUCTION

IN the 1960s and 70s, North America experienced a period during which the growth in population led to an expansion in suburban living. A large amount of electric power distribution equipment covering a wide area that was installed on the basis of the industrial policies of that time is now reaching the end of its product life. The maintenance staff recruited during that period are also approaching retirement age. Electric power distribution equipment, which was installed at great cost, requires measures for dealing with aging so that it can withstand natural disasters such as frequent tornados. Meanwhile, the installation and operation of new "smart grid" distribution equipment based on recent industrial development policies is ongoing, making distribution systems more diverse and creating a need for new maintenance and management arrangements to be put into place.

The increasing scale and diversity of distribution equipment mean that the run-to-failure (RTF) approach of dealing with maintenance after the equipment has failed is now reaching its limit. It is anticipated that information and operational technologies can be utilized to overcome this challenge. Accordingly, Japanese power companies have built up know-how through their operation of power distribution systems based on information technology (IT) and advanced maintenance technologies and systems that utilize the collection and analysis of equipment fault data. They are now taking steps to deploy this accumulated operational know-how outside Japan.

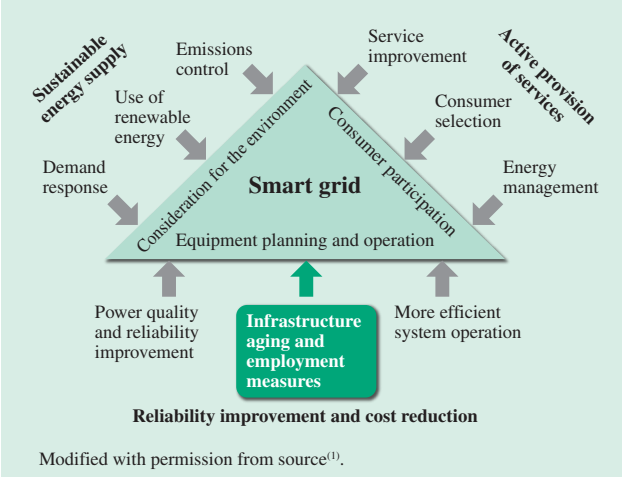
This article describes advanced maintenance and operation initiatives for power distribution equipment being undertaken jointly by Tokyo Electric Power Company, Inc. (TEPCO) and Hitachi, as well as the enterprise asset management (EAM) and equipment operation systems that play a core role in services.

ISSUES AND CHALLENGES FACING POWER DISTRIBUTION EQUIPMENT MANAGEMENT

Challenges

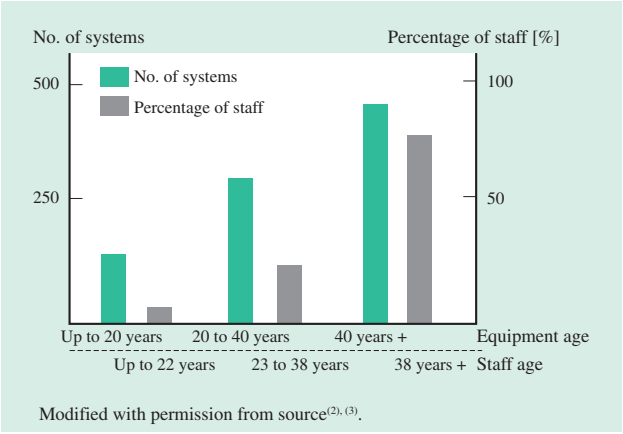
Electric power must be supplied to consumers reliably, and within predetermined voltage ranges. Achieving this requires not only distributing power correctly, but also new measures for maintenance management that do not impact on the distribution of power itself by determining and managing the equipment status, and repairing or replacing it before it fails in cases when warning signs are present. Industrial development policies in the USA refer to smart grids that are designed to improve the reliability and quality of the supply of electric power, and emphasize the emerging problem of how to deal with aging infrastructure so that smart grids can be built (see Fig. 1).

In response, Hitachi has recognized that measures for dealing with aging equipment constitute a market where there is scope for the application of Japanese



Modified with permission from source[1].

Fig. 1—Smart Grid Challenges.
The figure shows the challenges for smart grids defined in terms of equipment planning and operation, consumer participation, and consideration for the environment.



Modified with permission from source[2], [3].

Fig. 2—Distribution of Key Equipment and Maintenance Staff Ages in North America.
More than 50% of distribution equipment has been in service for 40 years or more. Likewise, experienced maintenance staff are due for retirement, raising concerns about workforce shortages.

technology, systems, and operation in collaboration with Japanese power companies, and has conducted a market analysis. This analysis has identified the following five challenges.

(1) Dealing with the aging of large amounts of equipment installed over a wide area

The existence of a large amount of aging power distribution equipment makes efficient maintenance and management essential in North America.

Fig. 2 shows the age of distribution equipment in one particular state in the USA. Since the lifespan of distribution equipment is typically about 40 years, the graph shows an imminent need for the upgrade of equipment at the end of its life. However, the large quantity of this equipment and the fact that it is installed over a wide area make it difficult to upgrade all at the same time. To achieve this, it is important to determine the condition of equipment accurately and to manage maintenance in a planned and efficient manner.

(2) Measures for building new distribution infrastructure

Smart grids feature the interoperation of existing distribution infrastructure with renewable forms of energy such as photovoltaic power and wind power. This means managing the maintenance of new distribution infrastructure along with existing distribution equipment.

(3) Passing on maintenance management know-how to the next generation of maintenance staff

Maintenance staff recruited at the time when the equipment was originally installed are now approaching retirement. This means it is important to transfer the know-how and skills in maintenance management that has been built up over this time to the next generation. However, because the total number of younger maintenance staff is insufficient due to the lower birth rate and aging population (see Fig. 2), there is a need for efficient ways of passing on large amounts of maintenance management know-how. Also, the presence of a large amount of aging distribution equipment means that there is a limit to how far the RTF approach of dealing with equipment after it fails can be applied, making it important to identify any warning signs of potential failure early so that something can be done before a problem occurs.

(4) Dealing with increasing prevalence of natural disasters

Climate change in recent years has increased the prevalence of natural disasters such as lightning strikes and tornados, increasing the impact these have on distribution equipment also. This makes it necessary to identify quickly where damage has occurred so that maintenance staff can be dispatched promptly and repairs implemented efficiently.

(5) Measures for improving the cost-benefit ratio for maintenance and management expenses

Electricity market deregulation in North America has encouraged the upgrading of distribution equipment and has caused spikes in the purchase price of electric power. This has led to the use of regulation to limit rises in the purchase price of electric power, together with a need to take account of severe cost-benefit requirements in the maintenance and management of distribution equipment.

Solutions to Challenges

What is needed to overcome the challenges described above is the ability to identify the condition of distribution equipment at an early stage, and to respond promptly when a problem is found. To this end, Hitachi intends to deploy the following three key solutions based on new information and operation technology (IT & OT).

(1) Centralized management and utilization of information on distribution equipment

Distribution equipment comes in many types and is supplied by a large number of different vendors. Distribution equipment will also be used in more complex configurations in the future, with a need to incorporate information on renewable energy systems. This involves using databases to store diverse information about distribution equipment so that information about the best ways to go about repairing or replacing it can be obtained quickly, and also so that correlations between equipment can be identified. It also makes it possible to keep databases updated and to obtain up-to-date information about equipment condition by using the latest mobile devices to obtain this information and store it in a database.

(2) Use fault prediction as a basis for implementing preventive maintenance

When dealing with large amounts of distribution equipment spread over a wide area, only responding to failures after they occur is bad for power supply reliability and quality improvement. Accordingly, what is needed is to identify the warning signs of potential failures so that action can be taken before they occur. In the past, information about failure warning signs has largely relied on the informal knowledge of maintenance staff, with inadequate use being made of this information. In response, Hitachi uses databases to store and utilize information such as that obtained from monitoring sensors attached to distribution equipment or the large amounts of accumulated information on maintenance and management know-how. This information takes the form of big data based on accumulation over time. This allows accurate maintenance to be performed by analyzing big data on maintenance and management to identify similarities between problems and the warning signs of potential failures.

(3) Integration of maintenance, management, and operation

A fragmented market means that power distribution companies in North America are often small. This has led to cases of inadequate investment in distribution equipment and insufficient maintenance staff. One way to overcome this is to allow the outsourcing of distribution equipment maintenance and management to specialist companies. This makes it possible to implement efficient measures for dealing with aging equipment by passing on and integrating equipment information from different power distribution companies. It can also optimize the allocation of the outsourcing company's maintenance staff and reduce maintenance and management costs for the power distribution companies.

EAM SOLUTION

The following sections describe the technologies and systems developed and operated to implement the solutions described above.

Hitachi is developing an EAM solution package. By providing centralized management of information about a company's equipment assets throughout their life cycle, the package consists of business improvement solutions that provide visibility, standardization, and greater efficiency for this equipment and the tasks associated with it.

The aims of EAM are to maximize and optimize the value of a company's equipment assets by balancing the trade-offs between equipment quality (risk), economics (cost), and utilization (performance).

Main Functions of Hitachi EAM Solutions

Hitachi's EAM solutions have both plant-based and area-based functions to suit different types of social infrastructure, such as electric power or railway transportation. Plant-based functions apply to specific sites and area-based functions apply to equipment that is spread over a wide area. The main functions for power distribution companies that operate over a wide area are listed below (see Fig. 3).

(1) Equipment management

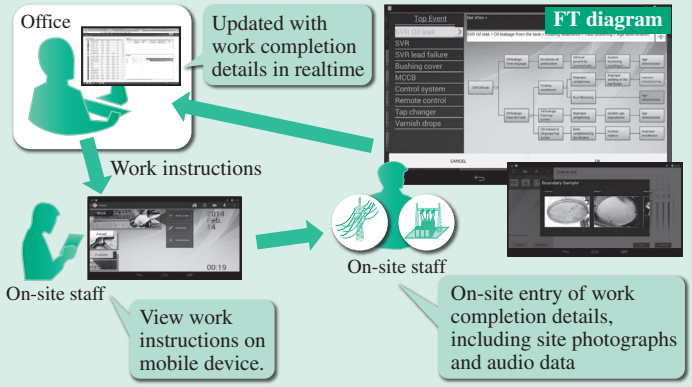
This provides a common platform for the centralized management of such information as equipment use and installation details. To provide centralized data management and make operation easier, it features a geographic information system (GIS) as a user interface so that equipment information can be viewed on a map.

(2) Fault analysis

This function supports analysis and report generation using information on equipment faults.

(3) Maintenance management

This function manages maintenance planning, execution, and outcomes based on periodic inspections



EAM: enterprise asset management FT: fault tree

Fig. 3—Overview of Hitachi EAM.
Hitachi is developing EAM products for the efficient management of equipment maintenance and modifying them for use by power distribution companies that operate over wide areas.

and equipment condition, and with reference to previous performance and maintenance results.

(4) Work resource management

This function manages all work and provides centralized management of such things as the procedures for each task; equipment, personnel, and other resources; and also cost. It manages the location and circumstances of staff dispatched to work in the field, and calculates appropriate staff numbers and work allocations when new tasks arise.

(5) Work design support

This function uses a map-based user interface to support equipment work planning. It automatically generates information on materials and tasks based on equipment standards, and calculates the cost of work.

(6) Equipment investment support

This function performs statistical analysis of data on different items of equipment to support decision making on equipment investment and maintenance strategies.

These six functions can be downloaded to a mobile device for use in the field.

Fault Analysis Function

This section describes a distinctive function of EAM solutions provided by Hitachi that supports the collection and analysis of information on equipment faults.

Mobile devices such as tablets are used to collect fault information. Field staff carry the mobile device with them so that they can access equipment information while they work. Templates are used to indicate the information to be collected when a fault occurs on a particular type of equipment, ensuring that all necessary information is acquired. Collected fault information is forwarded to those responsible for identifying and analyzing the cause, and information on the progress of fault-finding is shared among the people involved.

The fault analysis function includes the ability to manipulate a fault tree (FT) diagram generated by the analysis of fault causes and effects. The FT diagrams produced for each type of equipment are stored, and newly arising faults can be analyzed in a variety of ways by relating them to the causes in the FT diagram. Hitachi intends to enhance this function further by drawing on know-how from TEPCO, as described below.

EQUIPMENT OPERATION SYSTEM

To reduce costs in response to more stringent investment constraints since the deregulation of high-voltage distribution systems in the 1990s, and to deal with the fall in workforce numbers due to the wholesale retirement of maintenance staff, TEPCO has sought to install new IT equipment and adopt more sophisticated operating arrangements. Its Equipment and Engineering (E&E) Center has a core role in these operations. The following provides an overview of the E&E Center and its main functions.

Overview

TEPCO established the E&E Center in 1998 to implement more advanced preventive maintenance practices for distribution equipment in anticipation of factors such as more complex field maintenance resulting from the installation of new IT equipment. Since then, it has established a database of information on distribution equipment and set up mechanisms for the collection, analysis, use, and management of fault information. It has put in place a system for identifying the causes of faults by collecting and analyzing fault

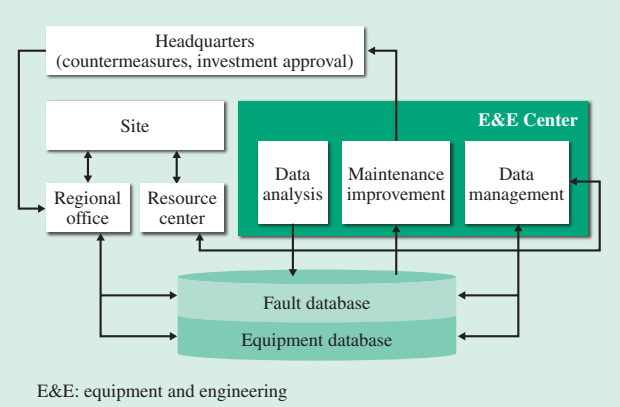


Fig. 4—Structure of E&E Center.
The E&E Center collects and manages distribution equipment information and analyzes it for potential equipment faults. The information is used for preventive maintenance.

information. It has also defined which maintenance management information needs to be stored, and established procedures for collecting fault information and analyzing causes together with flow charts that specify how it is to be used.

In particular, the center is responsible for identifying equipment weaknesses through the analysis of the major causes of faults, identifying issues with maintenance and management, and proposing things like revisions to maintenance, installation, and inspection methods; improvements to equipment; and training practices (see Fig. 4). The costs and benefits of proposed requirements are assessed to determine whether they should be implemented in practice and then deployed at each regional office.

Main Functions

The main functions of the E&E Center are as follows.

(1) Data management

The Center maintains and manages a database containing information collected by maintenance staff, such as details of equipment faults and inspection results. Data quality is checked periodically.

(2) Maintenance improvement

Information stored in the fault and equipment databases is used to consider improvements to patrols and inspections, work practices, reuse, and equipment specifications.

(3) Data analysis

This involves using large amounts of fault data to analyze the main causes of equipment faults and propose countermeasures.

CONCLUSIONS

This article has described the business challenges facing electric power distribution in North America, and their solutions. It has also described Hitachi's EAM system and the TEPCO E&E Center, both of which offer solutions to these challenges.

In the future, Hitachi intends to combine the IT used for EAM with the operational technologies of the E&E Center that are based on its maintenance schemes and know-how and offer it in the form of IT&OT systems that are customized for North America. In particular, Hitachi intends to contribute to things like the construction of smart grids and the reliable supply of electric power by deploying these together with consulting services that extend from identifying workplace issues to deciding what to do about them; and are based around maintenance and management services for dealing with aging power distribution equipment, which is the biggest challenge facing North America.

REFERENCES

(1) H. Tram, "Developing Smart Grid Enabled Engineering & Operations Strategy," Quanta Technology's Online Newsletter (Jan. 2011).
(2) R. Wernsing, "Asset Management and Strategy for Operational Excellence," Proceedings of DistribuTECH (Jan. 2013).
(3) Center for Energy Workforce Development, "Industry Outlook Energy Workforce of the Future, Grid," Proceedings of GridWeek 2009 (Sep. 2009).

ABOUT THE AUTHORS

Kazuhiro Hiraki

Service Platform Division, Smart Information Systems Division, Services Division Group, Information & Telecommunication Systems Company, Hitachi, Ltd. He is currently engaged in the EAM solutions business. Mr. Hiraki is a member of the PM Society.

Shigehiro Eda

Smart Business Strategy Planning, Smart Information Systems Division, Services Division Group, Information & Telecommunication Systems Company, Hitachi, Ltd. He is currently engaged in operational improvement and cooperative business improvement with operators of social infrastructure.

Yuichi Mashita

Service Platform Solutions Department, Service Platform Division, Smart Information Systems Division, Services Division Group, Information & Telecommunication Systems Company, Hitachi, Ltd. He is currently engaged in the design and development of smart city platforms and EAM, and in managing this work.

Yoshio Maruyama

Energy Solution Business Development & Management Center, Energy Solutions Business Management Division, Hitachi, Ltd. He is currently engaged in energy solution business development & management.

Shinchi Imai

Joined Tokyo Electric Power Company, Inc. in 1989. Having been posted to THE Power Grid Solution Ltd. in 2013, he is currently engaged in the overseas deployment of operational technologies for power transmission and distribution. He was appointed manager of the Power System Operation Department, Power Grid Company of Tokyo Electric Power Company, Inc. in June 2014.