A Framework for Optimal Planning Systems on the EMS Platform

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ABSTRACT

To promote further energy savings, the demand for electrical, thermal and other types of energy and the amount of energy supplied by self-generation facilities must be integrally managed and planned. Fuji Electric has developed a framework for optimal planning systems that runs on the integrated EMS platform. This framework has a uniform energy network model that automatically generates a plant model according to the arrangement and connection of equipment on a display screen, and an optimal planning function that develops operational plans. As a result, the configuration and properties of the equipment can be changed and maintenance can be performed without the need for a professional engineer, and operational planning becomes easier.

1. Introduction

As global energy demand and CO_2 emissions are increasing, efforts to implement renewable energy and to conserve energy (energy saving) are promoted to realize a sustainable society. An increasing number of utility customers, such as plants and buildings, are not only replacing their facilities with conventional energy saving equipment but also implementing private power generation equipment, such as photovoltaic power generation equipment and cogeneration equipment. Achieving further energy saving requires the development of a scheme for centrally controlling and handling the amount of energy (electricity and heat) in demand and the amount of energy supplied by utility facility (electric power generation equipment, heat sources and other equipment that supply energy to plants, offices, etc.). Thus, a function for planning and controlling the operation of a utility facility based on energy supply amount prediction and energy demand prediction (optimal operation planning function) must play a more important role than before in addition to the function of the conventional energy management system (EMS) which is intended mainly to visualize energy.

Fuji Electric Co., Ltd. has so far developed optimal operation planning functions focusing on energy supply and demand in a wide range of sectors, such as electric power, steel, water treatment, industry and retail distribution[1][2]. To make it possible to provide operation planning systems in a timely manner in response to future needs, which are expected to be more diverse, Fuji Electric developed an optimal operation planning function construction framework. It runs on an integrated EMS platform, and has been developed based on knowledge and data concerning the optimal operation of energy on the utility customer side, which were obtained through past development projects. This framework is characterized by a high level of usability achieved by plant model creation and simulation functions, and the capability of formulating plans with excellent serviceability through the flexible selection of the planning functions.

This paper describes an overview of the integrated EMS platform, and describes the features of the optimal operation planning function construction framework and its application examples.

2. Integrated EMS Platform

Figure 1 shows the configuration of the integrated EMS platform and its peripheral functions[3]. The integrated EMS platform is the middleware forming the core of the construction of an EMS. It is provided with the functions of an ordinary EMS, such as result data management and driver management responsible for the management of communication with sensors, controllers and other field devices, as well as the following three functions:

(1) High-speed program linkage service, “Fuji Service Bus”

The server configuration of EMS comes in various forms, from single server configuration to distributed server configuration consisting of several dozen servers, according to the scale of system to be controlled, the number of required functions, the monitoring and control cycle and the redundancy of the server. Fuji Service Bus functions to link processing among programs installed in distributed servers or among programs and Web screens, regardless of these server

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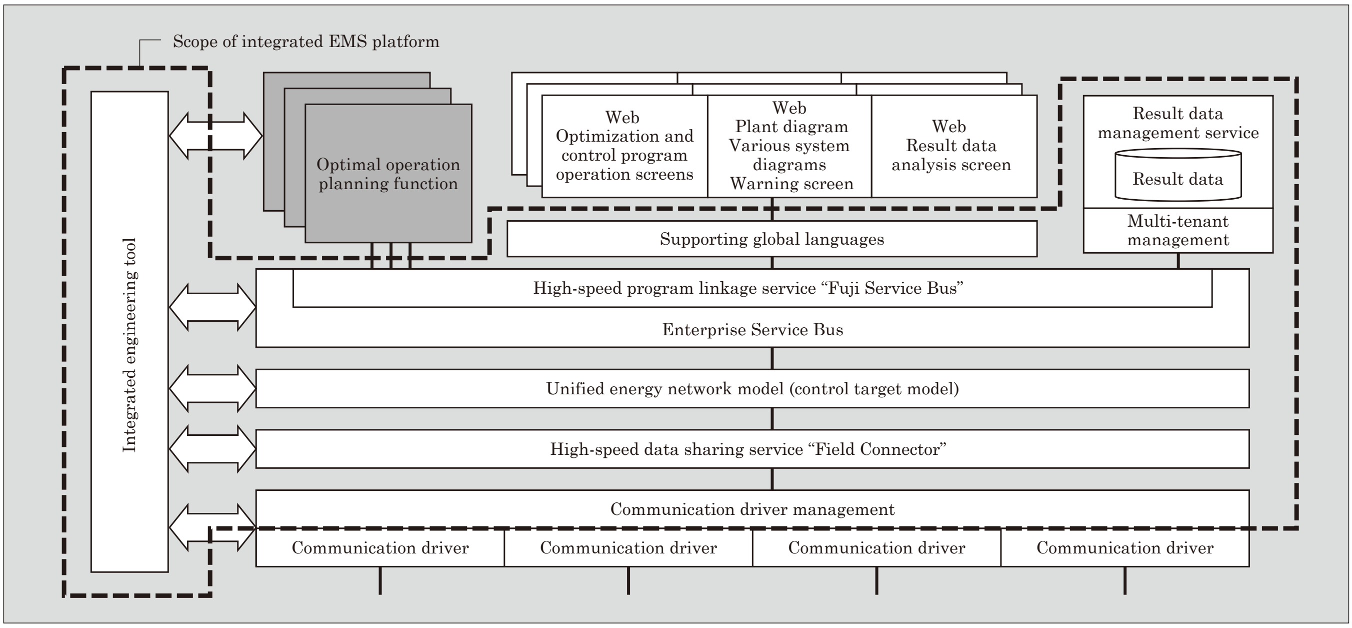

Fig.1 Configuration of integrated EMS platform and its peripheral functions

configurations. This function enables users to expand or delete program functions on the integrated EMS platform.

(2) Unified energy network model

The unified energy network model defines how energy, such as electricity, gas and steam, is converted and transferred in/among the control target devices. It is intended to plan the operation of in-plant utility facilities that produce or consume electricity, gas, steam, or another form of thermal energy.

(3) High-speed data sharing service, "Field Connector"

The Field Connector is a function that enables programs on the integrated EMS platform to refer to online data and give control instructions, irrespective of the server configurations. This function manages online data, result data and prediction data with the aid of TAG management (system designed to manage data with TAG names, such as "TAG001" and TAG values).

3. Optimal Operation Planning Function Construction Framework

The optimal operation planning function construction framework is an aggregate of programs for developing optimal operation planning functions that run on the integrated EMS platform. Below are the main features of the framework.

(a) The framework provides a group of functions required to construct planning systems, such as the unified energy network model and a planning algorithm (optimal operation planning function).

(b) Plant models are created by the unified energy network model from the viewpoint of the energy flow, whatever the type of plant and energy to be controlled. The framework provides tools for analyzing and converting these plant models.

(c) The optimal operation planning function provides an optimization algorithm with the minimization of energy cost, including power consumption and CO_2 emissions, as the objective function to plan the operation of a utility facility. For this optimization algorithm, a suitable system for the characteristics of the plant concerned, such as the input and output characteristics and constraints of equipment, can be selected from among multiple systems at the stage of programming.

3.1 Configuration of the optimal operation planning function construction framework

The configuration of the optimal operation planning function construction framework and its peripheral functions is shown in Fig. 2. The optimal operation planning function construction framework consists of the components described below.

(1) Optimal operation plan drawing up function

The optimal operation plan drawing up function formulates an optimal operation plan and is made up of the following elements:

(a) Structured data [extensible markup language (XML) file]

Structured data is an output file of the unified energy network model for plant modeling.

(b) Model analysis part

The model analysis part analyzes the XML file and converts it into the model format (definition for optimal calculation model) requested by the optimization calculation part.

(c) Data gathering part

The data gathering part collects result data and prediction data required for the planning of opera-

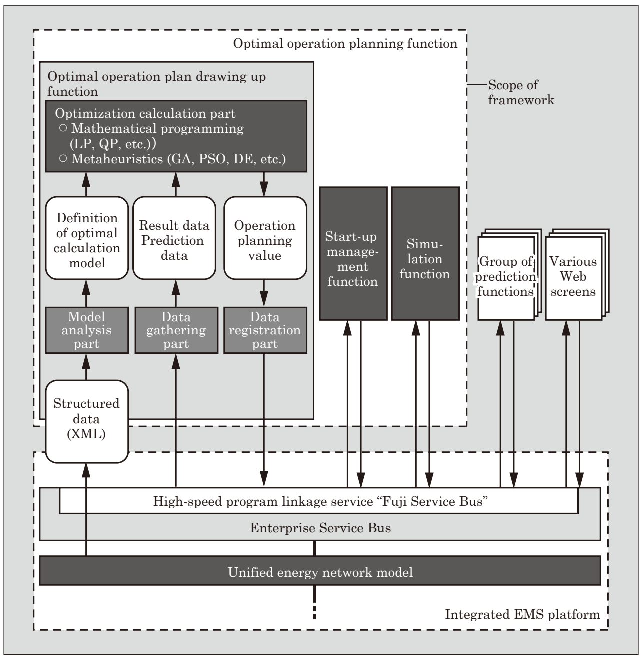

Fig.2 Configuration of optimal operation planning function construction framework and its peripheral functions

tion from the database under the integrated EMS platform.

(d) Optimization calculation part

The optimization calculation part carries out optimal calculations and draws up operation plan based on the definition of optimal calculation model and the gathered data.

(e) Data registration part

The data registration part stores the calculated operation planning values in the database under the integrated EMS platform.

(2) Start-up management function

The start-up management function manages coordinated start-up of the prediction and other functions as well as the start-up timing of the optimal operation planning function.

(3) Simulation function

The simulation function calculates the operation plan in multiple operation cases and displays it on the screen in order to validate the operation planning values before actual operation.

Other functions that are not included in the optimal operation planning function construction framework but are important in operation planning are provided as a group of prediction functions for predicting electric power demand, or the amount of electric power generated by photovoltaic power generation, etc.; and various Web screens related to the optimal operation planning function and prediction functions.

3.2 Unified energy network model

An operation plan aiming to minimize energy costs, including electric power consumption or CO_2 emissions is formulated using the optimization algorithm. This step requires describing the transfer relationship of energy, for which a plan will be drawn up in the form of an equation. In the past, an engineer well versed in optimization performed modeling by selecting a model representation system suitable for the algorithm and directly describing the equation. This approach, however, required corrections to the mathematical model each time the number of units of equipment inside the plant increased or decreased or any of the characteristics changed due to aging, etc.

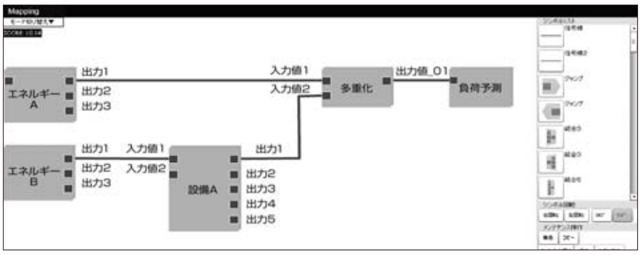

Fig.3 Example of definition screen of unified energy network model

As a solution to this problem, Fuji Electric developed a unified energy network model, which enables ordinary users to define plants and automatically create plant models through simple operations.

The unified energy network model shows the energy flow of a plant in graphic form. Tree-structured points (nodes) in the graph represent the devices, and branches indicate the relationships of connection among them.

Figure 3 shows an example of the definition screen of the unified energy network model. The user selects nodes from the symbol list displayed at the right-hand end of the screen, places them in the model definition window in the center of the screen and opens the property input window to input values such as the coefficient of conversion efficiency and upper and lower limit characteristics. The relationships of connection among the devices are defined by connecting the input/output of the placed nodes with signal lines. The model defined in this way will be output as XML data, which is then converted by the model analysis part into the file format requested by the optimization calculation part.

3.3 Optimization calculation part

The optimization calculation part is the core function of the planning algorithm. Based on the plant information entered in the unified energy network model, result data and prediction data, this part outputs an operation plan relating to utilities inside the plant that minimize energy costs or CO_2 emissions.

Optimization of an operation plan for a utility facility is an optimization problem to simultaneously determine the start-up and stop (discrete quantity) and output (continuous quantity) of the devices that minimize the operation cost or CO_2 emissions, while taking into account the supply and demand balance of each type of energy and the mechanical and operational constraints. Such optimization problem of operation plans were once resolved by linearizing the characteristics and constraints of devices and then formulating as a mixed integer programming problem. To obtain an operational solution that is more effective in saving energy and that can be used in actual operation, however, the strict characteristics of appliances and field operation rules and other constraints must be considered. If these factors are not considered, the calculated value of energy consumption will deviate from the actual value, and operation planning values not complying with the operation rules will be output, which will result in failure to achieve intended energy saving, or other problems will occur. It is, therefore, necessary to formulate an operation plan as a mixed integer nonlinear programming problem considering the nonlinear characteristics of the devices and the operation rules. In general, an optimal solution to such an issue is said to be difficult to obtain efficiently.

Fuji Electric developed an original algorithm to resolve this problem. This algorithm combines leading-edge metaheuristics optimization techniques, such as the particle swarm optimization (PSO) method[4] and differential evolution (DE)[5, 6], as the core of optimal solution search methods, with know-how on the operation planning of utility facilities. This algorithm makes it possible to obtain highly accurate solutions to mixed integer nonlinear programming problems, which were difficult to solve in practical calculation time, within 30 minutes (assuming 30-minute balancing).

In addition to the abovementioned algorithm, Fuji Electric has a mathematical programming algorithm available, which solves the problem in a shorter time when the input and output characteristics or constraints of utility facilities can be modeled by linear functions or quadratic functions.

With regard to CPUs mounted in computers, the design policy has been shifting from the one aimed at increasing processing performance of the CPU by clock frequency to the one aimed at increasing computation performance of the CPU by using multiple cores, and, in consequence, multi-core CPUs are becoming popular. In response to this trend, Fuji Electric is committed to research and development of the parallelization of optimization algorithms to obtain high-quality solutions even to large-scale problems within the desired time, allowing high-speed calculations with multi-core CPUs.

3.4 Start-up management function

The optimal operation planning function receives a start-up request at fixed cycles of 30 minutes or an hour and plans the operation of a utility facility based on the demand value predicted by the prediction function or the operation planning value planned by another operation planning program.

The start-up management function requests the prediction function and the abovementioned optimal operation planning function to start up according to the predefined start-up cycle (30 minutes, an hour, etc.) and the start-up sequence (electric power generation prediction, demand prediction, operation planning function, etc.). This function manages and executes a series of tasks, from prediction and calculation to optimal operation planning, at fixed cycles.

3.5 Simulation function

Whenever an operation planning system is implemented or there is a change in the facility after implementation, the energy saving performance and serviceability of the drawn up operation plan must be verified using data assuming various operating states. In this verification, we execute the operation planning function by batch processing, and confirm the planned result with the simulation function.

The simulation function consists of a function to convert data input by the optimal operation planning function into desired data and calls it up in a batch, and the function to verify the result on the screen.

The simulation function uses the data input screen shown in Fig. 4 as the means to input data of various patterns. Input data will be obtained from the pre-planned group of prediction data at preset given time. If the given data is improper for the contents verified, the user can adjust it by changing the value displayed in the data input field to any value.

There are two means available to verify operation planning results. One is verification of data values on the screen, and the other is verification on a graph. Data values can be verified on the data input screen; and in the case of verification on a graph, the data to be graphed or the type of graph to be used depend on the type of the plant and the event to be evaluated and studied. Thus, the simulation function is designed to be capable of outputting various graphs by predefining types of data and graphs through an operation called graph definition, which links operation planning data for evaluation and study to these predefined types of data and graphs. Graph definition is executed on the graph definition screen shown in Fig. 5, where general

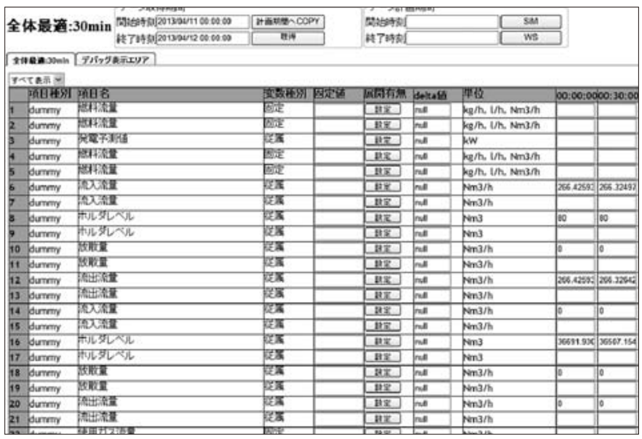

Fig.4 Data input screen of simulation function

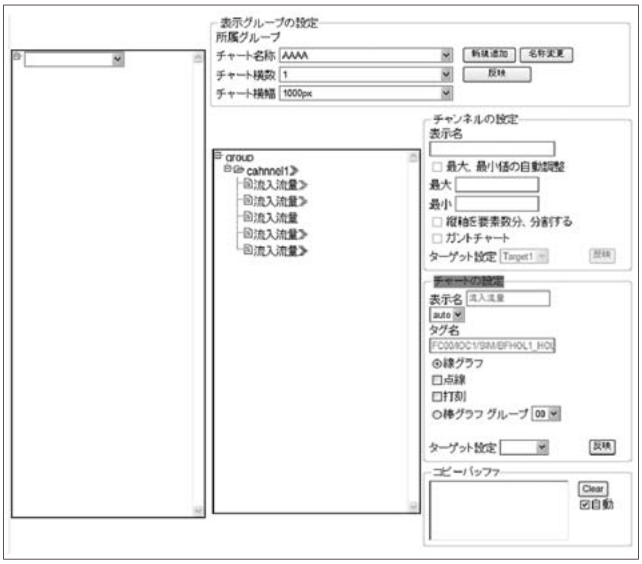

Fig.5 Graph definition screen of simulation function

setting items relating to the creation of graphs can be selected.

4. Application to EMS for Steelworks

This section describes the EMS package for steelworks "Steel EMS Package," which was developed using the optimal operation planning function construction framework, as an application example (see "'Steel EMS Package' Optimizing Energy Management at Steelworks" on page 165).

The "Steel EMS Package" consists of a group of optimal operation planning functions, a start-up management function, a simulation function and a prediction function, as the system configuration is shown in Fig. 6. The group of optimal operation planning functions includes holder facilities optimal operation, oxygen facility optimal operation, power generation facility optimal operation and overall optimal operation. The prediction function is made up of demand prediction, which predicts the demanded quantity of gas and electric power consumption within the steelworks. Optimization by each function of the group of optimal operation planning functions is linked to demand prediction to formulate an operation plan based on the predicted generated and consumption of energy planned by the relating prediction function.

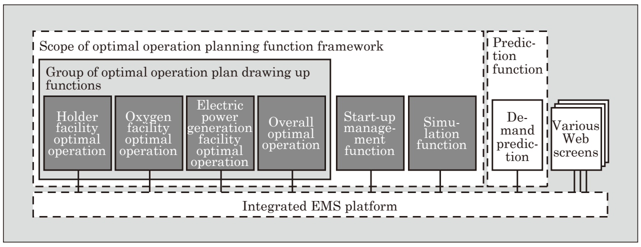

Fig.6 System configuration of "Steel EMS Package"

Holder facilities optimal operation, oxygen facility optimal operation and power generation facility optimal operation are required to perform high-speed calculations every five minutes. Thus, oxygen facility optimal operation and electric power generation facility optimal operation are achieved by applying an algorithm capable of performing high-speed calculations. Holder facilities optimal operation ensures high-speed calculations by using parallelization metaheuristics for the algorithm. Overall optimal operation starts up at fixed cycles of once a day. However, since operation planning expands in scale, this function also achieved high-speed calculations by parallelization processing of the multi-core CPU.

In addition, even the Steel EMS Package requires verification whenever a trial calculation of the effect is performed or any equipment parameter is changed, and therefore validity of the operation plan can be checked in advance by applying the simulation function described above.

5. Postscript

In this paper, the optimal operation planning function construction framework running on the integrated EMS platform was described.

We will continue working to add the latest optimization calculation algorithms, and develop integrated energy network models, simulation functions and other engineering tools; while enhancing their usability and help to realize a sustainable society through the sophistication of operation planning functions.

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