Design and Implementation of Small Scale Electric Power Management System

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Abstract

Conventional electric-power grids generally have unidirectional power flows from the power plant to the consumers. At small factories, however, the problem is that they inefficiently consume electricity because they consume the electrical power depending on the time of day (e.g., on-peak usually during the day and off-peak usually at night time). In this paper, we try to improve the existing energy management system and propose an energy management system that mainly focuses on the efficiency of electricity consumption. In the proposed management system, PMU (Power Management Unit) installed in switchboard is allowed to collect electric power data in a real time. We also use data mining method, which is applied to analyze the collected data for improving energy efficiency. Also, our proposed energy management system is designed to efficiently control electricity between PMU and management system in case of a shortage of electricity or surplus electricity. Through the experiment, we demonstrate that our proposed system improves the efficiency of electric power of small scale power plant.

Keywords: *smart grid, electric power, electric control, data mining, PMU*

1. Introduction

In recent, green IT issue is one of the emerging issues. Especially, many com-panies are now interested in power management of IT equipment, improving energy efficiency by building data center, and developing eco-friendly products. With this trend, smart grid technology is considered as one of the key green IT technology to improve the electric power efficiency [1].

In this paper, we provide the issues of design and implementation for an efficient power management system, which can be applied to a small size of factory. With this power management system, we can not only reduce the usage of electricity but also improve the energy efficiency. We demonstrate the efficiency of our proposed power management system through two stages of verification: i) data collection and measurement and ii) performance verification. At the first stage, we observe and collect the power data from the factory. Then, we perform the electric power data analysis. At the second stage, we design power energy monitoring system to enable efficient management and implementation for small-scale

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factories. The remainder of this paper is organized as follows. In Section 2, we provide a communication technology and data mining method for efficient data management. Section 3 includes the system configuration and detailed information for our electrical power management system (EPMS). This is then followed by a performance evaluation in Section 4. Finally, we conclude this paper in Section 5.

2. Key Technologies for Proposed Electric Control System

In this section, we provide a summary of three key technologies for our proposed electric management system: i) wide-area monitoring and control system, ii) metering data management system, and iii) clustering based data mining technology.

2.1. Wide-Area Monitoring and Control System

Wide-area monitoring and control system is the technology to perform a real-time monitoring and controlling the generation and transmission of power system in a wide range. At the aspect of smart grid system, it is highly necessary to be done with the convergence of information and communication technology (ICT) and renewable energy and distributed generation integration. In order to implement efficient electric management, we take advantage of ICT integration such as communications networks, related equipment, computing, and system control software. In addition, renewable and distributed generation integration is a type of technology, which is related to renewable energy and distributed grid-connected and control systems. Energy management system (EMS) and geographic information systems (GIS) are the examples of renewable and distributed generation integration [2].

2.2. Metering Data Management System (MDMS)

We also utilize a metering data management system, which is one of the methods to optimize power efficiency and real-time rates on the basis of two-way real-time electric power information. MDMS manages the energy profile based on each accommodating tens of data. Since existing telecommunication companies have had large amounts of data processing system for tens of millions of consumers, the technology we only need is an applied technology for smart grid system. Currently, many governments are planning to provide the IHD (In Home Display) services [3, 4].

2.3. Clustering based Data Mining Technology

Data mining is a process of analyzing data from different perspectives and summarizing it into useful information by using automated or semi-automated tools. Note that a variety of analytical methods are constantly being developed in this field. Among these technologies, clustering is one of the useful techniques to check a group of potential interests and the distribution of interesting data. This clustering technique is the process of a set of objects grouped into classes of objects. In this case, the objects belonging to the same cluster have a similarity while the objects belonging to the different clusters have a complementarity. Figure 1 presents the clustering process for given a set of objects [5].

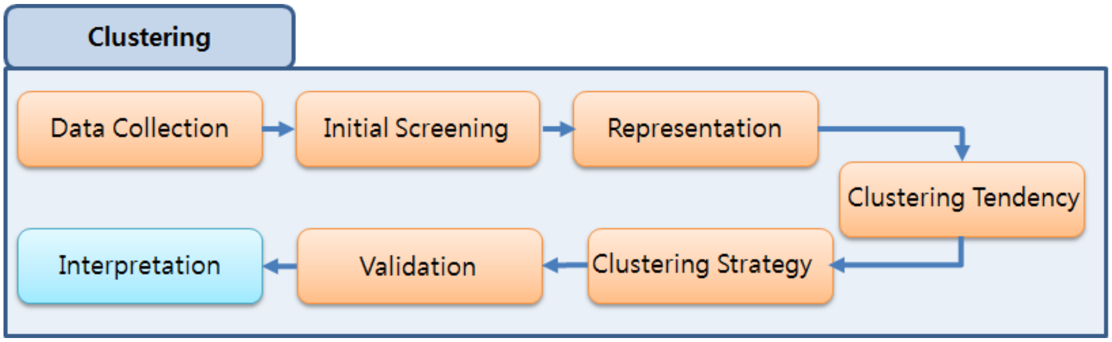

Figure 1. Clustering process from data collection to interpretation

3. Implementation of Electric Power Management System

Electric power management system provides the efficient methods for analyzing collected data from a set of PMU. Also, this system provides the safety and the efficiency of the power management by controlling PMU directly through two-way communications in the case of power shortages and power surplus problems. Figure 2 shows a basic configuration of our proposed power management system. As shown in Figure 2, PMU attached in the power breaker transmits 36 types of electric power data such as active power, reactive power, power factor, and so on by using RS-485 communication to the converter. This converter is connected to a maximum of five PMU and it retransmits data which has been received from PMU to the TCP/IP server. Once the server receives the data from the converter, we can statically provide daily, weekly, monthly, and yearly electric power data for the analysis. This is our basic system configuration for power management system.

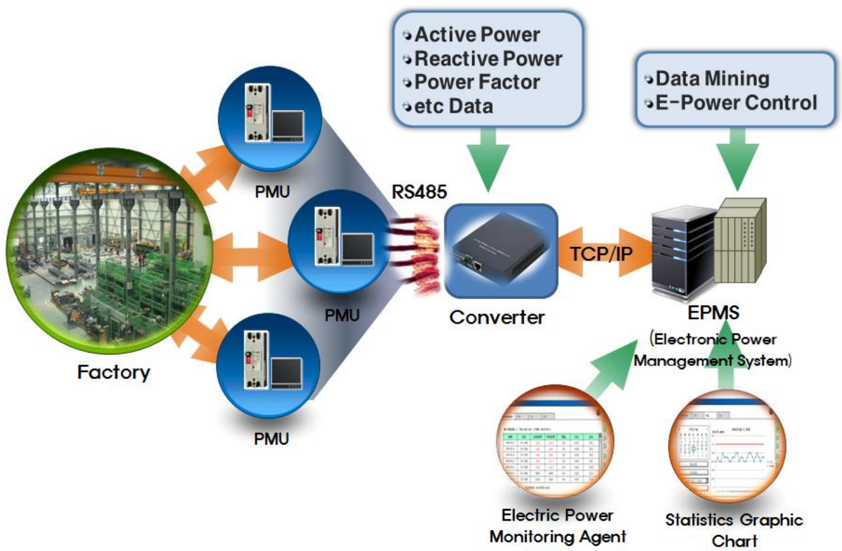

Figure 2. A configuration of the proposed power management system (This system includes i) gathering power data such as active power, reactive power, power factor through PMU, ii) efficient power usage management through data mining, iii) PMU control remotely.)

Table 1. Data structure for request and response data format

(a) Request Data Format

Slave Addr.	Func	Start Addr.	Word Count	Error Check
1	1	2	2	2

(b) Response Data Format

Slave Addr.	Func	Byte Count	Data Word(1)	...	Error Check
1	1	2	2	...	2

36 types of electric power data from PMU in which the measurements are recorded in Data Word field are sent to the server.

Table 2. PMU Measurement Data

Measurement Entry		Addr	Range	Measurement Entry		Addr	Range
Ave.	Ave. Voltage	0	0.00~999.99k	Electric Energy (Total)	Electric Power	9	0.00~999.99k
	Ave. Electric Current	1	0.00~999.99k		Active Power	10	0.00~999.99k
Load Current	R Phase Electric Current	2	0.00~999.99k		Reactive Power	11	0.00~999.99k
	S Phase Electric Current	3	0.00~999.99k		…	…	…
	T Phase Electric Current	4	0.00~999.99k	Harmonics	R Phase Frequency	27	0.00~999.99k
Branch Voltage	RS Line to Line Electric Current	5	0.00~999.99k		…	…	…
	ST Line to Line Electric Current	6	0.00~999.99k		Apparent Power	36	0.00~999.99k
	TR Line to Line Electric Current	7	0.00~999.99k				
	MAX Line to Line Voltage	8	0.00~999.99k				

3.1. Network Configuration between PMU and EPMS

Depending on both the size of the factory and the number of switch board, PMU attached to the power breaker could be installed up to N at the factory. In this case, if PMU are directly connected to the data server, it sometimes would give a heavy load on the server for the data processing. In order to prevent giving a heavy load to the server, the converter is installed between PMU and the data server. The converter then transmits 36 types of power data. We emphasize here that these 36 types of power data use group index, which has been granted to the PMU. Between the converter and the server, we use TCP/IP protocol for data communication. Note that since PMU data has the index group, it is easy to store and classify data from the server using the index group.

3.2. Electric Power Data Mining

At the power management system, there are 36 types of collected electric power data from one PMU. The data transfer rate of PMU is an average of 30 seconds, and PMU receives from 1 to N index group. If this mechanism is applied, we would receive lots of data during one day. Therefore, it is meaningless to show all the data received for 24 hours. Consequently, we propose to use the data mining technique, which allows the system administrator to easily check certain data changes and abnormalities. Based on this method, we can efficiently manage the electric power system for small-scale factories.

Figure 3 shows the data mining method for electric power. At first, we classify 36 types of data collected by PMU into ITEM SET 1 to ITEM SET N based on time and the order of data input. Then, we compare each class with the threshold that we set to in advance. Finally, we provide the week, month, and year graphs as a summarization.

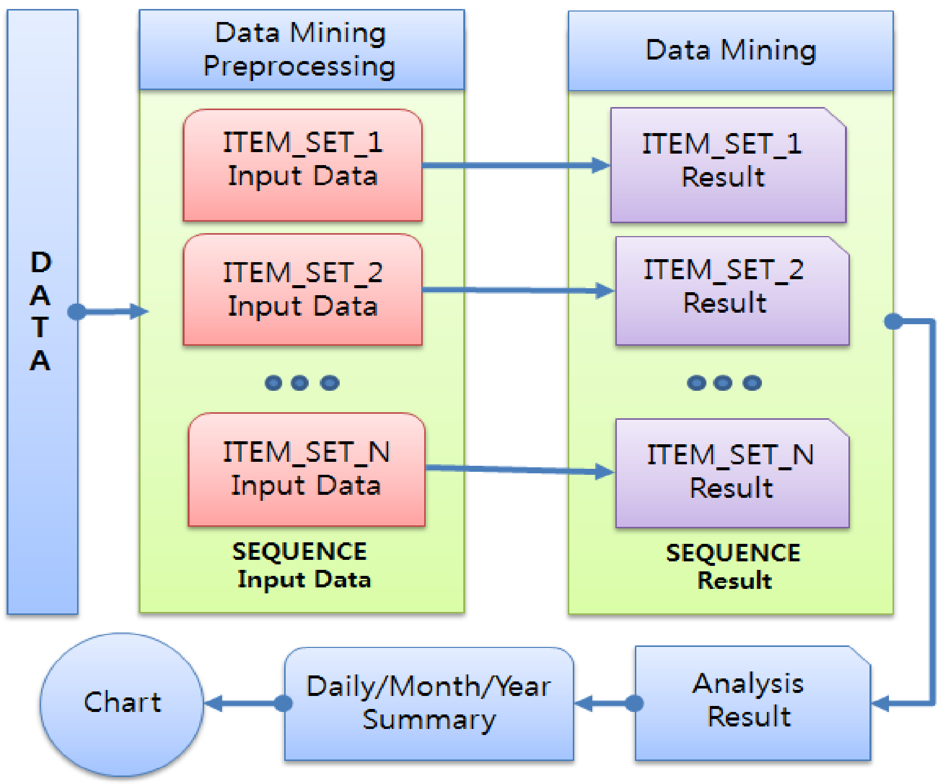

Figure 3. Data mining for electric power

4. Experiment and Evaluation

To configure power management system, we use a PC with Intel Core2 Duo 2.26GHz, 2G RAM, and Windows XP(32bit), 4 PMU, and one converter for our experiment.

First, we perform an error detection test for voltage and electric current. In order to evaluate it, we put the random errors of voltage and electric current, then we check a PMU operation. The results are given in Figure 4. In this experiment, the index range of PMU is 1 to 4 and overflow and underflow of the voltage and current of the items included in each index group are only extracted. Our experiments are conducted in total of 50 times during 1 minute. During the experiment, we successfully detect voltage and current error for whole experimental time. However, at the 31st data, it is seen that we are failed to control PMU. The reason is that the transferred data was deleted because it was regarded as noise when the data is transferred from the converter to the PMU.

N	PMU Index	Field	Error Data	EMPS	
				Error detection	PMU Control Success
3	1	Voltage	90	Alert	OK
8	3	Electric Current	45	Alert	OK
19	1	Electric Current	22	Alert	OK
24	4	Voltage	258	Alert	OK
30	2	Voltage	260	Alert	OK
31	1	Electric Current	2	Alert	NO
37	2	Voltage	91	Alert	OK
42	3	Voltage	95	Alert	OK
47	4	Electric Current	29	Alert	OK
50	3	Voltage	92	Alert	OK

Figure 4. Error detection test of EPMS

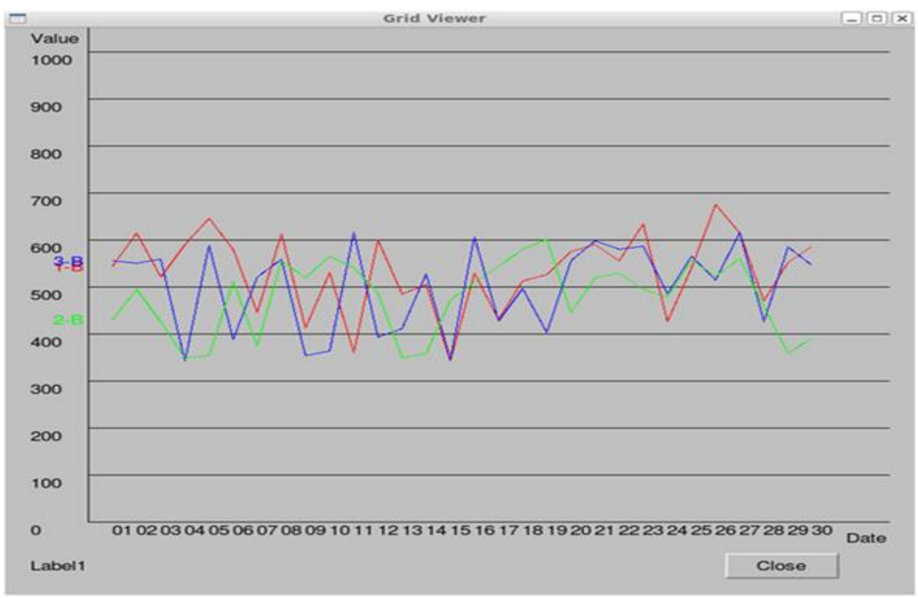

Figure 5. A comparative result graph for the data items collected from PMU 1 to PMU 3 for 1 month

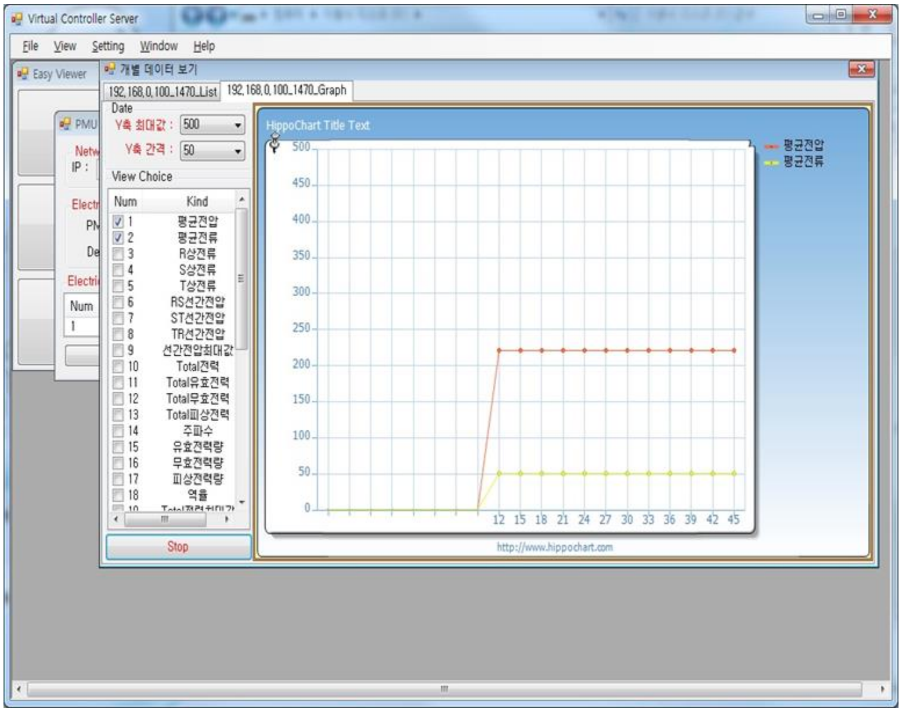

Figure 6. Real-time electric power data at EMPS

Figure 5 shows the experimental comparative analysis for efficient power supply through data mining based pattern analysis for items within a certain range in EMPS. As shown in Figure 5, this is not simply a mean for monitoring system because it efficiently provides statistical analysis for a variety of combinations to the desired data. On the basis of this statistical analysis, we can suggest solution for the efficient electric power operation. Figure 6 represents the real-time electric power data at EMPS.

5. Conclusions

Smart grid system is the one of the core technology for the eco-friendly next generation power system. This technology has been already applied in the United States and Europe. In this paper, we considered design and implementation issues of the power management system, which can be applied to a small size of factory. The main goal of our proposed system is to improve the power efficiency of small company, not to gather the power consumption data for billing system. Through our experiments, we showed that the proposed management system improves the power efficiency by effectively analyzing power consumption and utilizing a control technique.

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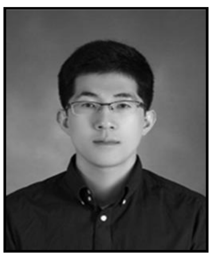

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