PRACTICAL STUDY ON ENERGY SAVING METHOD APPLIED TO EXISTING HVAC SYSTEM - CASE OF CEPCO GIFU BRANCH OFFICE –PART.2: OPERATIONAL IMPROVEMENT BY UTILIZING USER-ORIENTED ANALYSIS OF BEMS DATA

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Abstract: We are always anxious for the arrival of the real smart **B**uilding **E**nergy **M**anagement **S**ystems（BEMS）when we analyze the data of energy conservation studies. We tried to make up a reasonable BEMS to realize the energy conservation of high efficiency air conditioning systems in G-building Project. As they say, in order to develop the smart BEMS, there are so many aspects, hardware, software, communication network, and so on. At first, we focus how to analyze the building energy data for suitable tuning on operation Stage. We picked up the several terms for energy saving by Testing, Adjusting and Balancing (TAB) in this report.

Keyword: BEMS, energy saving, Re commissioning

1 INTRODUCTION

They said that HVAC operation is one of the most important issues in building facilities management. But there are many constraints such as personnel, time and money, so they cannot get sufficient data for suitable analysis.
Hardware such as measuring point, precision, technique, and data communication was summarized in a manual published at SHASE (SHASE Manual[*1]). However, we have underdeveloped analysis methods and software to handle these measured data for the suitable operation and management.
We tried to define the practical Graph format for adjusting data and evaluation of performance in this building's central monitoring system. We call it "Smart Visualization". We introduce the procedure and some examples in this report.

2 PROBLEMS OF MEASUREMENT METHODS AND PROCEDURES ON ENERGY MANAGEMENT

The problems of measurement techniques and procedures in the operations management are

listed below.

2.1 Measuring point and interval

I. Measuring point which is required for evaluation is not measured.
II. Measuring cycle is not unified, such as temperature measured in a minute and electric power measured in hours.
III. Short measuring scan cycle, such as one minute, is difficult to analyze.

2.2 Difficulty to make a smart chart for system performance review

I. The many types of central monitoring are handmade, so it is difficult to add or modify in terms of functionality and cost.
II. The almost all central monitoring system is able to generate routine type graph format, but cannot print out flexible graph format.
III. Fully automated data handling is impossible to use because it always requires manual data handling to confirm the measured data exactly.
IV. There are not so many graph tools for analysis and evaluation of building equipment.

3 FLOW OF MEASUREMENT DATA IN CENTRAL MONITORING SYSTEM

Table 1 shows measurement points of central monitoring system, and
Fig **1** shows the data flow and processing procedures for energy management.
One-minute data from monitoring system was converted to a monthly record at once, because it is difficult to use for energy management data by its interval.
We extract the necessary parts for performance evaluation as 10 minutes data, and aggregate to make the graph chart.
They often adopt general business software such as EXCEL in this case. But they have some problems for energy management. Concrete challenges are followings.
I. Combining multiple charts to one chart.
II. Representing over 3 axes to the Y axis.
III. Making a graph in which many items are assembled in parallel.
IV. Showing the colored contour map of frequency distribution in the scatter graph of data.
V. Indicating the status information of the system under the X axis.
We always use conventional spreadsheet software for analysis in the system evaluation. In this building, we adopted auxiliary software to make a graph chart. Evaluation indexes used in this report are suggested in a manual published at SHASE (SHASE Manual[i]), and the file names of analysis in this building is determined by copying the naming code in this manual (see the file name in Table 2).

Table 1 Measurement Points of central monitoring system

Item	Number	Note
Temperature of Heat source, status	173	
Temperature & Humidity of AHU, status	178	
Electric energy	65	

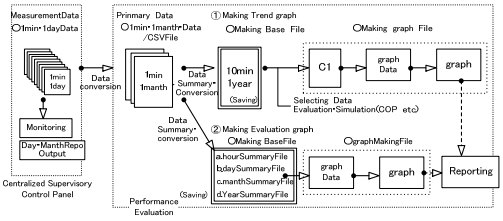


Fig 1 data flow and operation procedures and evaluation

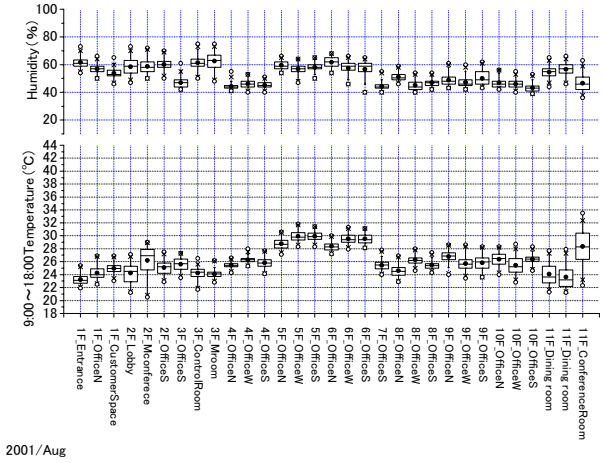
Table 2 Evaluation criteria and analysis graph chart

	Componets	Graph	Outline	File name
Hourly	Heat source・Total	Thermal balance Graph	①Cooling modeThermal balance Graph ②Cooling・Heating modeThermal balance Graph	①Gr_h_HSTBL1.opj ②Gr_h_HSTBL2.opj
	Heat source	Heat source Status Graph	Watet-cooling Heat Pump Chiller	Gr_h_WHP.opj
			Air sourcr eatPumpChiller	Gr_h_AHP.opj
	Thermal storage tank	Temperature profile Graph	Time Level	Gr_h_HST1.opj
			Position Level	Gr_h_HST2.opj
	Secondary	Secondary Pump Status Graph	①Coolingload （Chiller-water） ②Heatingload （source）	Gr_h_CP.opj Gr_h_HP.opj
	AHU	AHUStatusGraph	①AC-801 ②AC-802 ③AC-803 ④AC-804 ⑤AC-805 ⑥AC-806 ※CO2 density	①Gr_h_AC801.opj ②Gr_h_AC802.opj ③Gr_h_AC803.opj ④Gr_h_AC804.opj ⑤Gr_h_AC805.opj ⑥Gr_h_AC806.opj
	Indoor Environment	Indoor Environment Graph	Indoor Environment Trend	Gr_h_RMTH.opj
	Building	Building Electric Energy Status Graph	Use of Electric　Energy	Gr_h_ELC.opj
Daily	Heat source	Heat source System Graph	Heat source System Status ・Heat source output・Nighttime Shift rate・Drivung time ・Heat source System Electric Energy ・COP・SystemCOP ※R-01, R-02, R-03, R-04, Heat source etc	Gr_d_GEN.opj
	Thermal storage tank	Thermal storage tank Temperature Graph	Daily Utilization of Thermal storage tank	Gr_d_HST.opj
	Secondary	Secondary load Status Graph	Secondary heart load,Pump status ・Secondaryload・Electric　Energy・WTF	Gr_d_2JI.opj
	AHU	AHUStatusGraph	8F AHU status Indoor heat load・ATF・Electric　Energy・driving time	Gr_d_AC.opj
	Building	Building Electric Energy Status Graph	Use of Electric　Energy・maximun Electric power	Gr_d_ELC.opj
Mnonthly	Heat source	Heat source System Graph	Heat source System status ・output・Nighttime Shift rate・Drivung time ・Heat sourceSystemElectric　Energy ・COP・SystemCOP ※R-01, R-02, R-03, R-04, Heat source, etc	Gr_m_GEN.opj
	Secondary	SecondaryloadStatusGraph	Secondary heat load, Pump status	Gr_m_2JI.opj
	Indoor Environment	Indoor Environment Graph	Indoor Environment Trend	Gr_m_RMTH.opj
	AHU	AHUStatusGraph	8F AHU status Indoor heat load・ATF・Electric　Energy・driving time	Gr_m_AC.opj
	Building	Building Electric Energy Status Graph	Use of Electric　Energy・maximun Electric power	Gr_m_ELC.opj
Annual	Heat source	Heat sourceSystem Graph	Heat source System status ・output・Nighttime Shift rate・Drivung time ・Heat sourceSystemElectric　Energy ・COP・SystemCOP ※R-01, R-02, R-03, R-04, Heat source, etc	Gr_y_GEN.opj
	Secondary	Secondary heat loadStatus Graph	Secondary heat load, Pump status	Gr_y_2JI.opj
	Building	Building Electric Energy Status Graph	Use of Electric　Energy・maximun Electric power	Gr_y_ELC.opj

4 APPLICATIONS OF GRAPH SET IN THIS BUILDING

4.1 Change of indoor environment by operation improvement

Indoor environment at completion (2001) and re-adjusted (2008) are shown in Fig 2 , Fig 3, and the legend is in Fig 4.
Temperature deviation between the every room which occurred at completion as shown in Fig 2 had improved in 2009 as shown in Fig 3, and it has become a more appropriate humidity environment. Also we can't see increase in energy consumption.
In the conventional assessment of indoor environment, we have shown the data of room temperature and humidity of every room in a graph having two-axis of temperature and humidity.
When we list more than one room, we often represent a different color or symbol for each room, but we can't express the frequency of the thermal environment of all room into one graph chart. We can take a look at indoor environment of all rooms in this building by using definition in Fig 4.



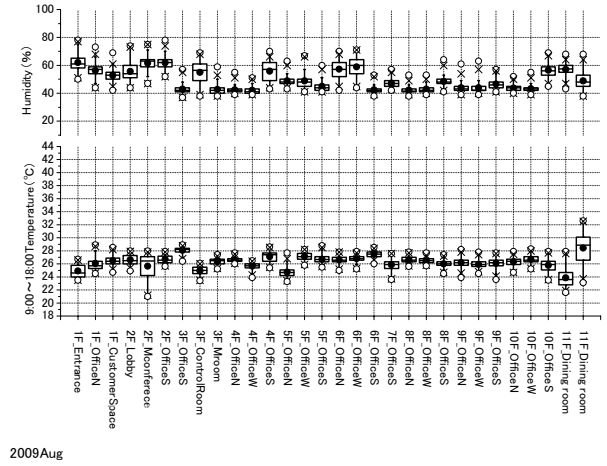


Fig 2 Indoor environment（2001.08）

Fig 3 Indoor environment(2009/08）

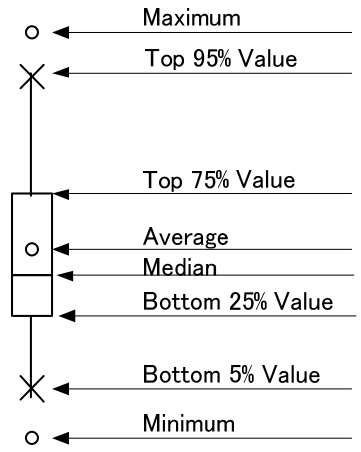


Fig 4 Legend of Fig 2～Fig 3

Table 3 The maximum electric power of 9 years after completion

Item	Date	（kWh）
Maximum electric power	2007.01.15	1,115(kW)
Daily maximum electric energy	2002.01.04	14,671
Daily maximum electric energy on maximum cooling load	2006.08.07	12,938
Daily maximum electric energy on maximum heating load	2003.01.06	8,392

4.2 Change of energy consumption in the overall building

Fig 5 shows the change in electric energy consumption for each month of the entire building after completion (9 years). Table 3 shows the maximum electric power and energy. Data in February and March of 2002 are missing due to instrument failure.
Whole building electric energy consumption after completion (9 years) has remained stable.

The electric energy consumption had increase with increasing heat source electric energy consumption in summer, and the maximum demand of electric power had occurred in winter.
Heat source system had stopped at startup in cooling mode by thermal storage system, but on the other hand, heat source system (R1, R2) had started at the same time on Monday 8:00 pm with light and the other general electric power, because thermal storage tank volume of heating mode is too small.
There are some disadvantages such as small storage tank and the primary circuit having heat exchanger.
But originally, we can ensure twice water-side temperature difference in heating mode comparing to cooling mode.
During the future renewal, we will avoid the heat source system driving at the start of heating mode by keeping doubled heating thermal storage tank capacity, adopting the heat exchanger designed to large temperature difference system.
Transition pattern of the outdoor air temperature which affects the cooling and heating load has become almost stable in each of nine years after completion.
In2006, the large amount of electric energy consumption in August attributes to R2 heat pump operation due to R1 failure.

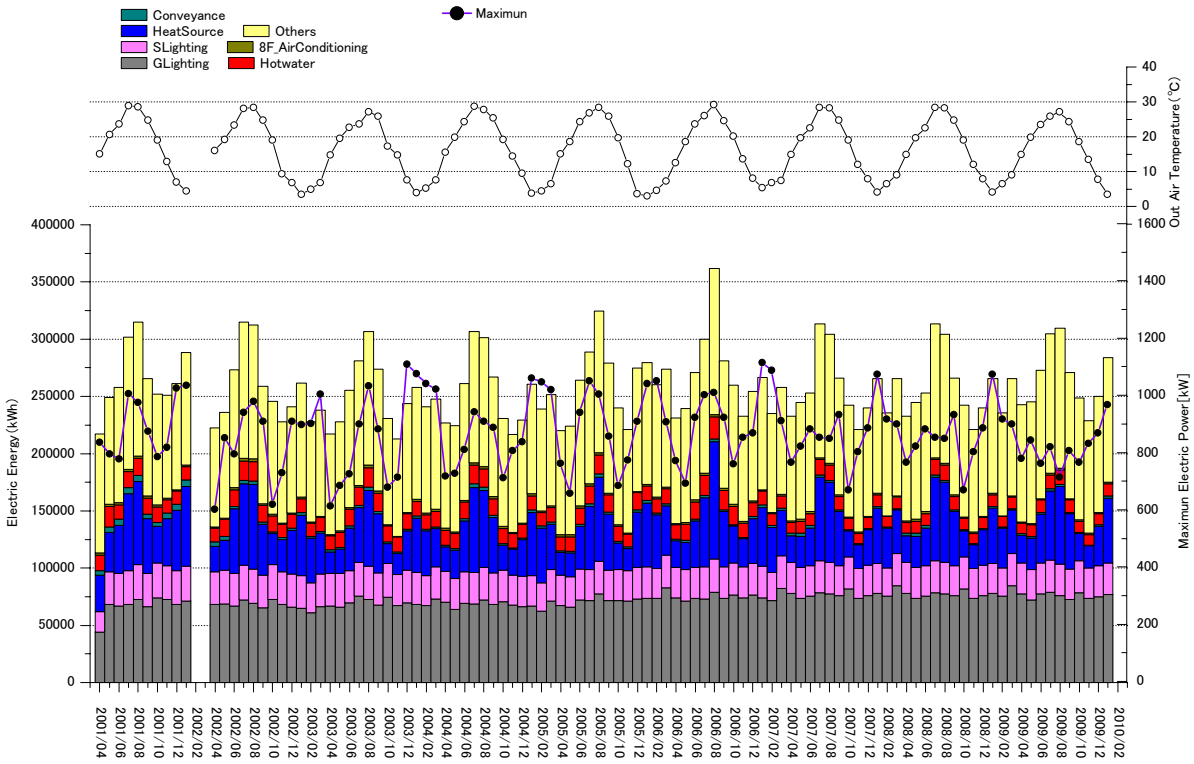


Fig 5 Monthly building Electric Energy consumption after Completion

4.3 Operation improvements in heat source system by thermal heat balance chart

Fig 6 and Fig 7 show thermal balance charts for operation improvement in heat source system.
We had dealt with cooling load by heat pump R1 on night-time charge mode, and daytime cooling mode by R1 and R2 after completion. But we can deal with whole daily cooling load by night-time charge of R2 working with R1 after improvement. And we had improved inefficient intermittent operation under keeping thermal storage volume.
In addition, secondary side water temperature which was moderately high at the end of air-conditioning time is also stable throughout the day after operation improvement.
It is effective for the monitoring of these improvements works, to show heat source system, secondary system, cooling and heating water temperature and status information including auxiliary machine into the same graph chart at once.

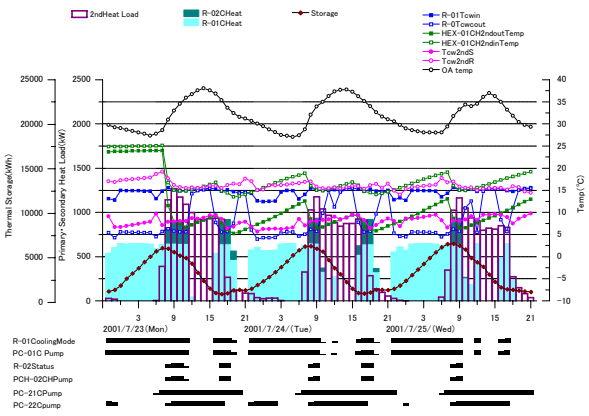


Fig 6 thermal heat balance of heat source after Completion

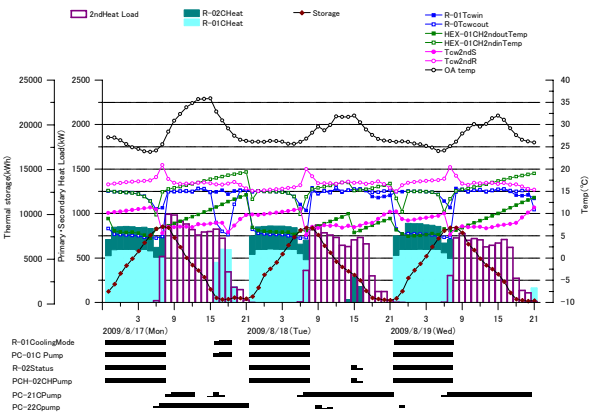


Fig 7 thermal heat balance of heat source after improvement.

4.4 Verification of the heat source system performance with COP evaluation

Fig 8 shows the manufacturers technical specifications along the COP performance curve, and measured data is 20% below the manufacturer specifications.
We always indicate measured values in a scatter plot in verification using a spread sheet chart. And cooling water temperature and heat source temperature in this case look like to be unstable by the scatter plot, but actually, you can see it is stable at approximately 20 ℃ by adding frequency distribution to it as Fig 8.
On the other hand, we cannot see COP degradation of air-source heat pump (R2) working supplementary , which holds nearly the same performance of manufacturers specifications（Fig 9).
We can understand that the heat pump in this building has been operated under conditions along the partial-load characteristics of the heat pump. And so we will be incorporated into the rational design of future Primary system renovation program（Fig 8・Fig 9）.

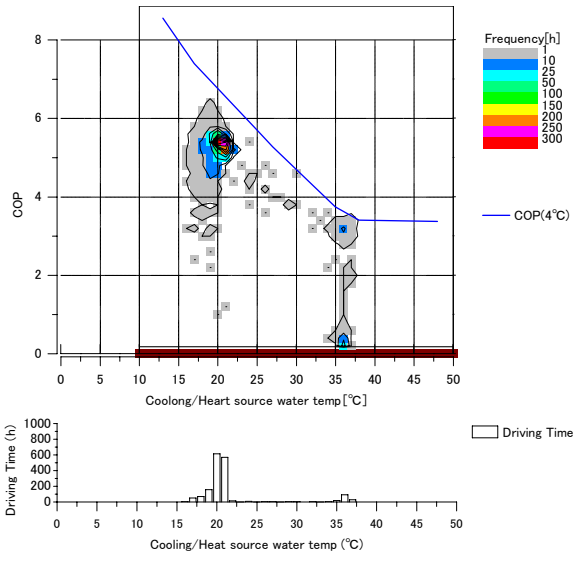


Fig 8The COP of Water-cooled chiller (R1) and the operating conditions (2009)

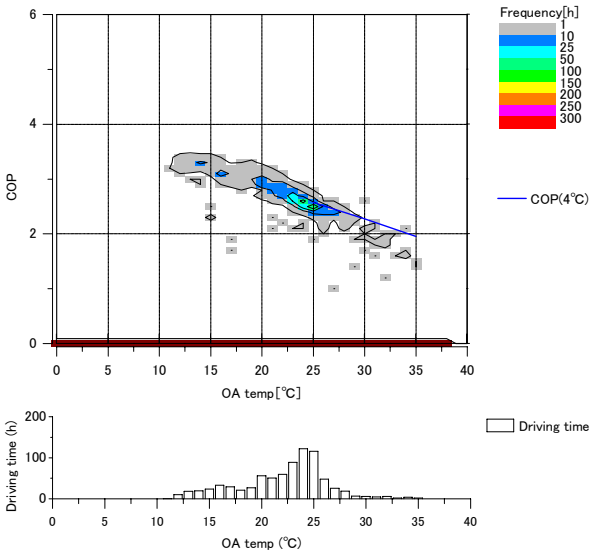


Fig 9 The COP of Air source heat pump chiller (R1) and the operating conditions (2009)

4.5 Adjustment of secondary chilled water pumps

Secondary chilled water pumps (PC-21, 22) between the secondary heat exchanger and air conditioner side are operated in the closed circuit system. We can see the chilled supply water volume was suitable. But actually, operating point shows instability by unadjusted

control in relationship among the number of pump, Cooling and heating load, and water temperature operating is following to the expected operating pipeline characteristic curves after adjusting in 2009.
In this case, we tend to carry out insufficient adjustment because we cannot obtain details of operating conditions from scatter plot graph on a conventional spreadsheet（Fig 10）.But we add the frequency distribution of each operating points to this graph, and we enable to adjust along expected operating pipeline curves （Fig 11）.

Incidentally, we are considering that electric power is proportional to the square of cooling and heating load in the expected operating characteristic curves from our experience of adjusting works.

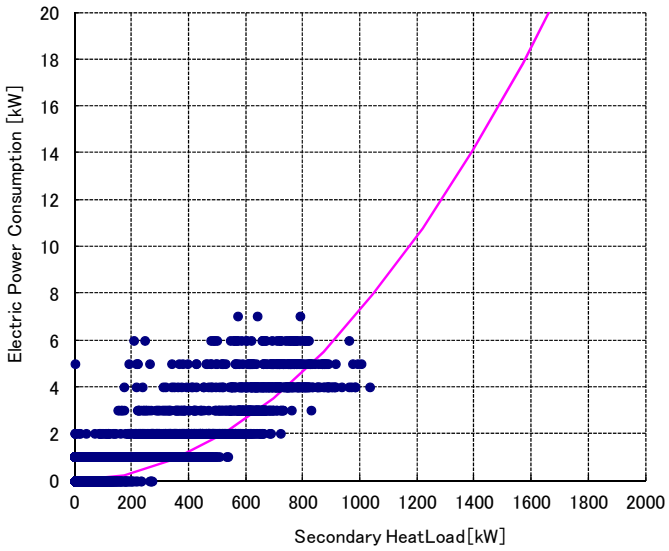


Fig 10 Operating conditions and evaluation of the secondary chilled water pumps

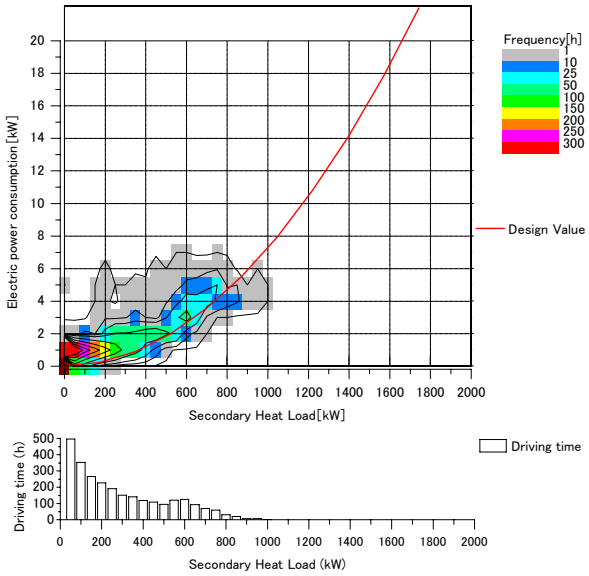


Fig 11 Operating conditions and evaluation of the secondary chilled water pumps

5 CONCLUSION

“Visualization” is to concentrate various necessary information on one graph, it helps detection of incomplete operation and investigation of the cause of error.
We have been challenging "smart visualization" for the construction of reasonable BEMS. As trying to applying our experience into the other facilities and consolidating other opinions, we are going to build up more practical BEMS for the real energy management.

REFERENCES[i]

SHASE Manual, 2005. Energy performance manual for building equipment, Society of Heating Air-cconditioning and Sanitary Engineering of Japan, SHASE-M 0007-2005