Research Article

DIVERSITY FACTOR ANALYSIS OF ENERGY CONSUMPTION FOR SCHOOL BUILDING

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ABSTRACT:
The energy conservation in Thailand is concerned and supported by Ministry of Energy and government policy. In the past, the energy consumption was obtained by energy audit or energy measurement from actual power of main systems. The ratio between the actual power (Pact) and the rated power (P_{max}) of systems defined as the diversity factor that was also used to analyze the energy consumption. In this study, the diversity factor was obtained by the actual power measured from the energy consumption behavior in the school building and maximum power. The energy consumption was simply evaluated by using 3 methods of diversity evaluation as the approximated diversity factor (D_a) with and without measurement and the measured diversity factor (D_m). In this study, the approximated diversity factor, D_a =0.80 was used and the average measured diversity factor, D_m =0.70 was obtained. As the results, 46.28%, 18.08% and 2.18% of energy consumption deviation were found from using the approximated diversity factor without measurement, the approximated diversity factor with measurement and the measured diversity factor, respectively. However the energy consumption analyzed by the approximated diversity factor did not measure from the actual power and the energy consumption behavior which showed the highest deviation from the actual value. The results showed that the energy consumption analyzed from the measured diversity factor with measurement could reflect the consumption behavior of the school building.

Keywords: *Diversity factor, energy conservation, school building*

1. INTRODUCTION

This present, the energy was consumed increasingly because of higher population. As the increase of population, the energy used in many sectors such as transport, industrial and building parts were also higher. In the building part, there are many sub-sectors such as hospital, school, office and department store which much energy consumption as shown in Table 1 [1]. In Thailand, school building was used the energy highly however the study of school building research was rarely found the energy consumption. As the previous study, energy consumption and energy saving used in dormitory was investigated [2]. The energy consumption such as lighting, air conditioning system measured and the specific energy consumption (SEC) in dormitory were shown as 10,978.09 kWh/Month and 6.41 kWh/m²/Month, respectively. In the past, the lighting tube brought the sunlight into the building was studied to apply instead of lighting and reduce energy consumption [3-5].

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Moreover, the energy consumption in school building was obtained by EnergyPlus program which could be evaluated for lighting and air conditioning systems. The energy consumption calculated from EnergyPlus program was different from measurement about 8.80% of error in air condition system. In the past, the energy consumption of school buildings were obtained by measurement with approximated diversity factor such 0.8 or 80% of actual power [6]. The diversity factor is the ratio between the actual power (P_{act}) and the maximum power (P_{max}) of systems [7-8]. Moreover, the diversity factor shows the ratio of actual power and also affects to energy consumption behavior from users. However, the diversity factor of school buildings was not really studied in the past. Thus, this study aims to find the diversity factor which shows the actual energy consumption and reflects the energy consumption behavior.

Table 1: Energy consumption in 5 building types

Building Types	Air condition (%)	Lighting (%)	Other (%)
Office	55	30	15
Department store	62	23	15
School	38	40	22
Hotel	65	18	17
Hospital	55	25	20

2. EXPERIMENTAL APPARATUS

The diversity factor was studied with energy consumption measured by Anemometer, Lux meter, Power logger and power meter shown in Figs.1-4. The anemometer was used to measure humidity, temperature and air flow for air condition system. Lux meter was used to measure illuminant in work place. The power logger and power meter were applied to obtain electrical voltage, current and power for three phase and single phase, respectively.

Fig. 1. Anemometer   **Fig. 2.** Lux meter   **Fig. 3.** Power logger   **Fig. 4.** Power meter

3. METHODOLOGY

The energy consumption in school building was measured in department of Mechanical Engineering to analyze the diversity factor. Firstly, the energy consumption from lighting, air conditioning and other systems were measured as P_{act} to compare with the energy consumption recorded from energy meter. The actual power, P_{act} was obtained from lighting system (P_L), air condition system (P_A) and other (P_O) systems as shown in Eq. (1). The maximum power, P_{max} was obtained from the rated power of lighting system (P_L), air condition system (P_A) and other (P_O) systems as shown in Eq. (2). The ratio between the actual power and the rated power (P_{max}) of systems defined as the diversity factor was also used to analyze the energy consumption. In this study, the approximated diversity factor, D_a =0.8 and the measured diversity factor, D_m obtained by the actual power (P_{act}) from the energy consumption behavior in school building and maximum power (P_{max}) as illustrated in Eq. (3). Then the energy consumption was obtained by Eq. (4). Anemometer, Lux meter, Power logger and power meter shown in Figs.1-4. The anemometer was used to measure humidity, temperature and air flow for air condition system. Lux meter was used to measure illuminant in work place. The power logger and power meter were applied to obtain electrical voltage, current and power for three phase and single phase, respectively.

$$\Sigma P_{max} = [P_L+P_A+P_O]_{measured\ load} \tag{1}$$

$$\Sigma P_{max} = [P_L+P_A+P_O]_{nameplate} \tag{2}$$

Diversity factor D_m:

$$D_m = \sum P_{act} / \sum P_{max} \tag{3}$$

Energy consumption:

$$E_{cons} = \sum P_{act} \times h \times D_m \tag{4}$$

P_L = Lighting load power
P_A = Air-conditioning load power
P_O = Other load power
D_a = Approximated diversity factor
D_m = Measured diversity factor
h = Consumption duration
E_{cons} = Energy consumption

4. RESULTS AND DISCUSSION

As the investigated school building, Department of Mechanical Engineering, the energy consumption was obtained from the digital meter about 136,512 kWh/year. This studied building consisted of academic staff room, laboratory, graduated students and meeting room. The energy consumption was obtained from air condition system, lighting system and other systems such as computer, laboratory equipment.

4.1 Energy consumption evaluated by the approximated diversity factor without measurement

Firstly, the energy consumption was evaluated by using the approximated diversity factor with rated power of load. This method was easy to evaluate the energy consumption by 80% load factor or diversity factor about 0.8. Normally, the energy consumption of school building was simply calculated as shown in Table 2. The 199,692 kWh/year of energy consumption was obtained with the approximated diversity. The obtained energy consumption was different about 46.3% compared to the actual energy consumption from digital meter.

Table 2: Energy consumption evaluated by the approximated diversity factor without rated power

Room	h (h/d)	$P_{\text{name plate}}$ (kW)	D_a	E_{cons} (kWh/year)
A01	8	10.09	0.80	23,238.00
A02	8	5.03	0.80	11,577.60
A03	8	0.92	0.80	2,120.40
A04	8	0.92	0.80	2,120.40
A05	8	14.36	0.80	33,073.20
A06	8	7.37	0.80	16,984.80
A07	8	6.89	0.80	15,865.20
A08	8	2.83	0.80	6,516.00
A09	20	14.58	0.80	83,959.20
A10	8	1.84	0.80	4,240.80
	Total			199,692.00

4.2 Energy consumption evaluated by the approximated diversity factor with measurement

Secondly, the energy consumption was evaluated by using the approximated diversity factor with actual load measured from main systems. This method was evaluated the energy consumption by 80% load factor or diversity factor about 0.8 with actual power. This evaluation of energy consumption was calculated as shown in Table 3. The 111,837.60 kWh/year of energy consumption was obtained from the approximated diversity and actual power. The obtained energy consumption was different about 18% compared to the actual energy consumption from digital meter.

Table 3: Energy consumption evaluated by the approximated diversity factor with actual power

Room	h (h/d)	P_{act} (kW)	D_a	E_{cons} (kWh/year)
A01	8	4.10	0.80	9,446.40
A02	8	1.71	0.80	3,939.84
A03	8	0.92	0.80	2,119.68
A04	8	0.92	0.80	2,119.68
A05	8	7.16	0.80	16,496.64
A06	8	6.83	0.80	15,736.32
A07	8	5.68	0.80	13,086.72
A08	8	1.73	0.80	3,985.92
A09	20	7.06	0.80	40,665.60
A10	8	1.84	0.80	4,239.36
	Total			111,837.60

4.3 Energy consumption evaluated by the measured diversity factor

Thirdly, the energy consumption was analyzed by using the measure diversity factor with actual load measured from main systems. This method was evaluated the energy consumption by measured diversity factor with actual power. This evaluation of energy consumption was calculated as shown in Table 4. The 139,487.90 kWh/year of energy consumption was obtained from the measured diversity and the actual power. The obtained energy consumption was slightly different about 2.18% compared to the actual energy consumption from digital meter. Moreover, the results showed the average diversity factor which evaluated the accuracy energy consumption for this studied school building was 0.7.

Table 4: Energy consumption evaluated by the measured diversity factor

Room	h (h/d)	P_{max} (kW)	D_m	E_{cons} (kWh/year)
A01	8	10.09	0.41	11,914.27
A02	8	5.03	0.34	4,925.38
A03	8	0.92	1.00	2,649.60
A04	8	0.92	1.00	2,649.60
A05	8	14.36	0.50	20,678.40
A06	8	7.37	0.93	19,739.81
A07	8	6.89	0.82	16,271.42
A08	8	2.83	0.61	4,971.74
A09	20	14.58	0.48	50,388.48
A10	8	1.84	1.00	5,299.20
	Total			139,487.90

5. CONCLUSION

This study was focused on the diversity factor analysis of school building. The ratio between the actual power (P_{act}) and the rated power (P_{max}) of systems defined as the diversity factor that was also used to analyze the energy consumption. In this study, the diversity factor was obtained by the actual power measured from the energy consumption behavior in the school building and maximum power. The energy consumption was simply evaluated by using 3 methods of diversity evaluation as the approximated diversity factor (D_a) with and without measurement and the measured diversity factor (D_m). In this study, the approximated diversity factor, D_a =0.8 and the average measured diversity factor, D_m were used. As the results, 46.3%, 18% and 2.18% of energy consumption deviation were found from using the approximated diversity factor without measurement, the approximated diversity factor with measurement and the measured diversity factor, respectively. The average diversity factor evaluated the accuracy energy consumption for this studied school building was 0.7. The obtained diversity showed that about 70% of rated power was used in the school building. The results showed that the energy consumption analyzed from the measured diversity factor with measurement could reflect the consumption behavior of the school building.

REFERENCES

[1]   Mungwititkul, W. Expense reduction process and technique for building and industry, The energy conservation center of Thailand, 2002, pp.66.

[2]   Kunchornrat, J. Study of energy consumption in dormitory of King Mongkut's University of Technology Thonburi, Mechanical Engineering of Network of Thailand, 2005.

[3]   Chirarattananont, S. Study of lighting duct used in building, Asian Institute of Technology, Thailand, 2005.

[4]   Kaewpradap A. and Namprakai P., Study specific energy consumption (SEC) in metal industry, E-NETT, Thailand, 2005.

[5]   Pulsin, U. Energy saving for non-designated building, Master thesis of King Mongkut's University of Technology Thonburi, 2003.

[6]   Katejanekarn, T. Simulation of energy saving in school building, Mechanical Engineering of Network of Thailand, 2007.

[7]   IEEE Standard 141(TM), IEEE Recommended Practice for Electric Power Distribution for Industrial Plants, Red Book, 1993.

[8]   Handbook for Electricity Metering, Edison Electric Institute, Tenth Edition.