The Optimal Energy Management of Hybrid Cooling System for Telephone Exchange in Thailand

Somkuan Rimsmutchai, Pornrapeepat Bhasaputra, Woraratana Pattaraprakorn, Natapongkorn Pawanawichien, Surasak Panjavaranont, Chaiyapat Kumpeerakupt, Kitti Tirawannavit, Wichit Krueasuk, and Kreingkrai Chongkhanpond

Abstract— *The existing cooling system of telephone exchange consumes more than 45% of overall energy consumption and generates the large amount of CO_2 that affect the global environment as well. Focusing on the energy conservation and expenditure, the hybrid cooling system using the air blowers integrated with the existing air conditioning system is proposed. The hybrid cooling system for telephone exchange in Thailand is proposed to enhance the energy management by integrating the conventional air conditioning system with air ventilation system. According to the complicated hybrid cooling system, the optimal energy management criteria are determined to minimize the energy consumption subject to security constraints for the different seasons. In additional, the energy consumption, life cycle costs, temperature and relative humidity profiles are compared with the conventional cooling system. The experiment demonstrated that the energy consumption of the cooling system decreased 91.54% and the overall energy consumption decreased 36.92% as compared to the convention cooling system. The annual cost of the proposed system can reduce up to 296,092 THB/Room with less than 1 year of return on investment. The proposed system can operate without any interruption under the temperature and relative humidity requirements. Finally, the report included important detail such as innovations, designs; preventive maintenance requirement and barriers of proposed system will be shown and described.*

Keywords— **Optimal, Energy, Hybrid, Exchange.**

1. INTRODUCTION

The telephone exchange is the back bone of the telecommunication system which consumes a significant amount of energy. However, the energy consumption of telephone exchange is concerned in term of significant operating cost. Figure 1 show proportions of energy consumption of telephone exchange, the proportions are 45% for air condition system, 40% for telephone equipments, 10% for lighting and 5% for the other.

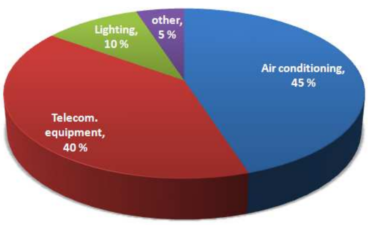

Fig. 1. Proportions of energy consumption of Telephone Exchange.

Somkuan Rimsmutchai (corresponding author), Pornrapeepat Bhasaputra, Natapongkorn Pawanawichien, Surasak Panjavaranont, Chaiyapat Kumpeerakupt, Kitti Tirawannavit, Wichit Krueasuk, and Kreingkrai Chongkhanpond are with Department of Electrical and Computer engineering, faculty of engineering, Thammasat University, 99 M18 Phaholyothin Road. Khlongluang, Pathumthani 12120, Thailand. E-mail address: somkuan_rim@hotmail.com.

Woraratana Pattaraprakorn is with Department of Chemical engineering, faculty of engineering, Thammasat University, 99 M18 Phaholyothin Road. Khlongluang, Pathumthani 12120, Thailand.

The traditional cooling system normally used the precision air condition for telephone exchange with many operation methods to enhance the energy management which is shown in Figure 2. Precision air-conditioning systems regulate temperature and relative humidity for sensitive and precisely purpose, the data centers and the telephone exchanges are typical principles used this kind of cooling system, its difference from air conditioning systen for resident which used in general household. In order to easy understand its can infer that the Precision air-conditioning systems have several special parts, the first part is the Heater Unit, both types included electric coils and hot refrigerant gas usually used for control room temperature within setting point, next part is Humidifier Unit, both types included infrared and electric coil usually used for controller room relative humidity within range, the last ones is Control Unit, it's improtant part used for controlled overall of air conditioning unit. Parts of conventional and precision air conditioning are shown in Figure 3. However, these types of air conditioning rather consume a lot of energy when comparing to air conditioning systen for resident.

This paper presents the optimal energy management of hybrid cooling system between precision air conditioning and air blowers to control the room environment for minimizing energy consumption and acceptable room conditions. Focusing on the energy conservation and expenditure, the hybrid cooling system using the air blowers integrated with the existing air conditioning system is proposed. Comparing the energy consumption, life cycle costs, temperature and relative humidity controls to the conventional cooling system control were done.

Fig. 2. Existing Cooling System of Telephone Exchange.

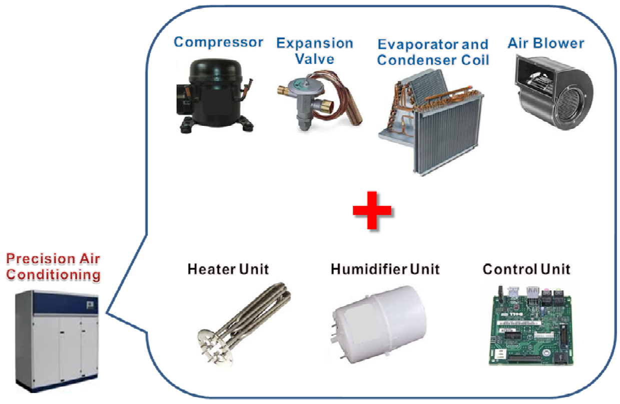

Fig. 3. Parts of conventional and precision air conditioning.

2. OPERATION STANDARD AND REGULATIONS OF COOLING SYSTEM FOR TELEPHONE EXCHANGE

Environmental Requirement

The basic environment requirements to operate the telephone exchange must meet three requirements including equipment operating temperature, relative humidity and air particle. Manufacturer's recommendation for environmental requirements of equipment is shown in Table 1.

Table 1. Equipment Environmental Requirement

Equipment	Environmental Requirements	
	Operating Temperature (°C)	Operating Humidity (%RH)
OSN-xxxx	0 - 45	10 - 90
DWDM-xxxx	0 - 45	10 - 90
NE-xx	0 - 45	10 - 90
MA-xxxx	0 - 45	10 - 90
NTU	0 - 40	10 - 90
PDH	0 - 45	5 - 95

Table 2 shows the average temperature and relative humidity of Bangkok, Thailand. The comparison of temperature and relative humidity in Table 1. and Table 2. seem that equipments will be able to operate without any control system, the telephone exchange can operate without the precision air conditioning system.

In fact, the generated heat from equipments may accumulate and increase the room temperature without the appropriate cooling system. The experimental results of various cases are illustrated in Figure 4, number two of graph: Inside room without air conditioning and ventilation, shows that the telephone exchange is need the ventilation system because temperature of telephone exchange without any ventilation system will be reached the upper limit in a short period.

Table 2. Average Temperature and Relative Humidity of Bangkok Thailand in 2010

Month	Temperature (oC)	Relative Humidity (%)
January 2010	32.00	86.65
Febuary 2010	33.53	90.32
March 2010	31.25	80.37
April 2010	33.38	63.70
May 2010	32.46	71.87
June 2010	32.99	76.60
July 2010	31.53	79.16
August 2010	31.20	79.39
September 2010	31.80	76.97
October 2010	31.57	71.71
November 2010	31.60	65.87
December 2010	30.07	61.49
Average	31.95	75.34

The various cases of relative humidity is recorded and shown in Figure 5. The relative humidity inside the room is lower than the outside. In addition, one blower may not maintain relative humidity of room; however three blowers cannot control relative humidity of room with significant additional controllability when compares with two blowers. According to experimental results, the optimal design of ventilation system is the hybrid two blowers with the existing precision air conditioning.

3. OPTIMAL ENERGY MANAGEMENT

Methodogy

From experimental results, only one blower can maintain the room temperature within the accepted range, however the room conditions are depend on many factors especially outside room temperature. The optimal design of ventilation system for temperature control is two criteria that are room temperature control by days and seasons.

Average temperature and relative humidity of Bangkok, Thailand, are shown in Table 2. which the out door ambient temperature is less than or equal 28.00^{o}C is 3,730 of 8,760 hours in a year or 43% of the whole year as shown in Figure 6. During this period, only one blower can maintain the room temperature within the recommendation with less of energy consumption. The rest 5,030 of 8,760 hours or 57% is important periods needs for optimal energy management.

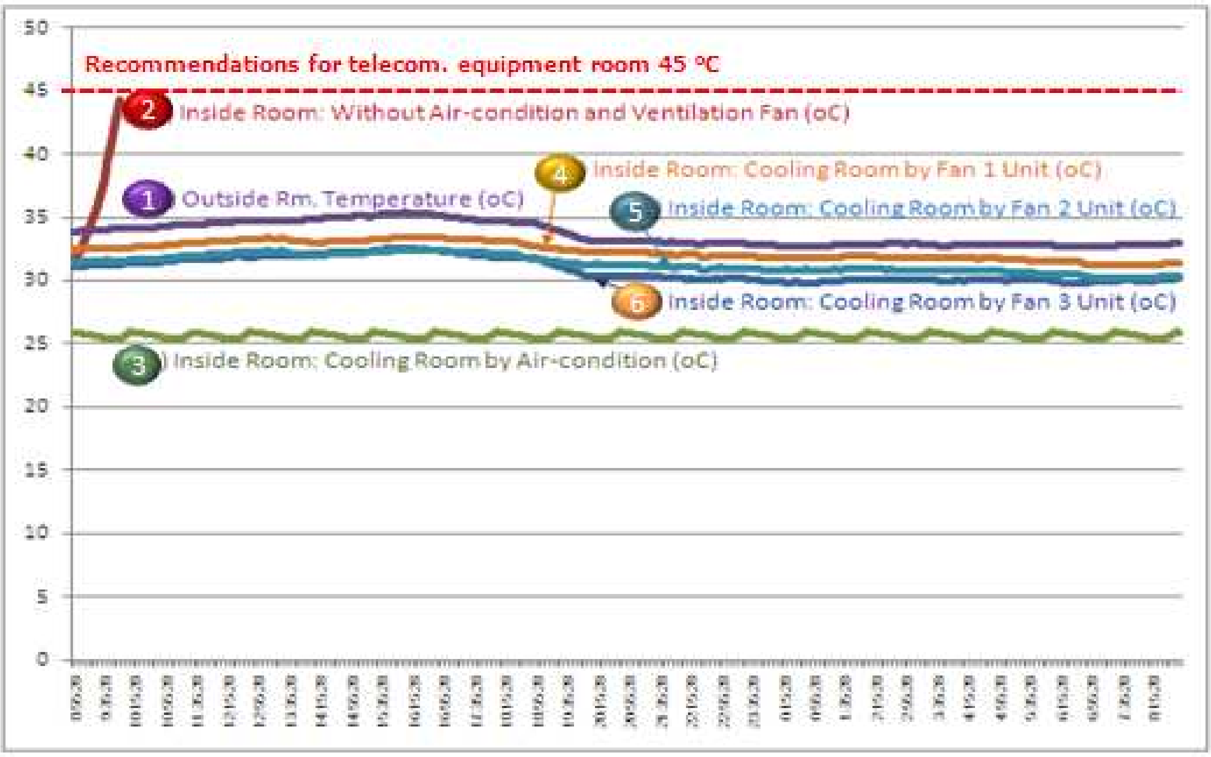

Fig.4. Comparison of Temperature with various cooling method and Recommendations for Telecommunication Equipment

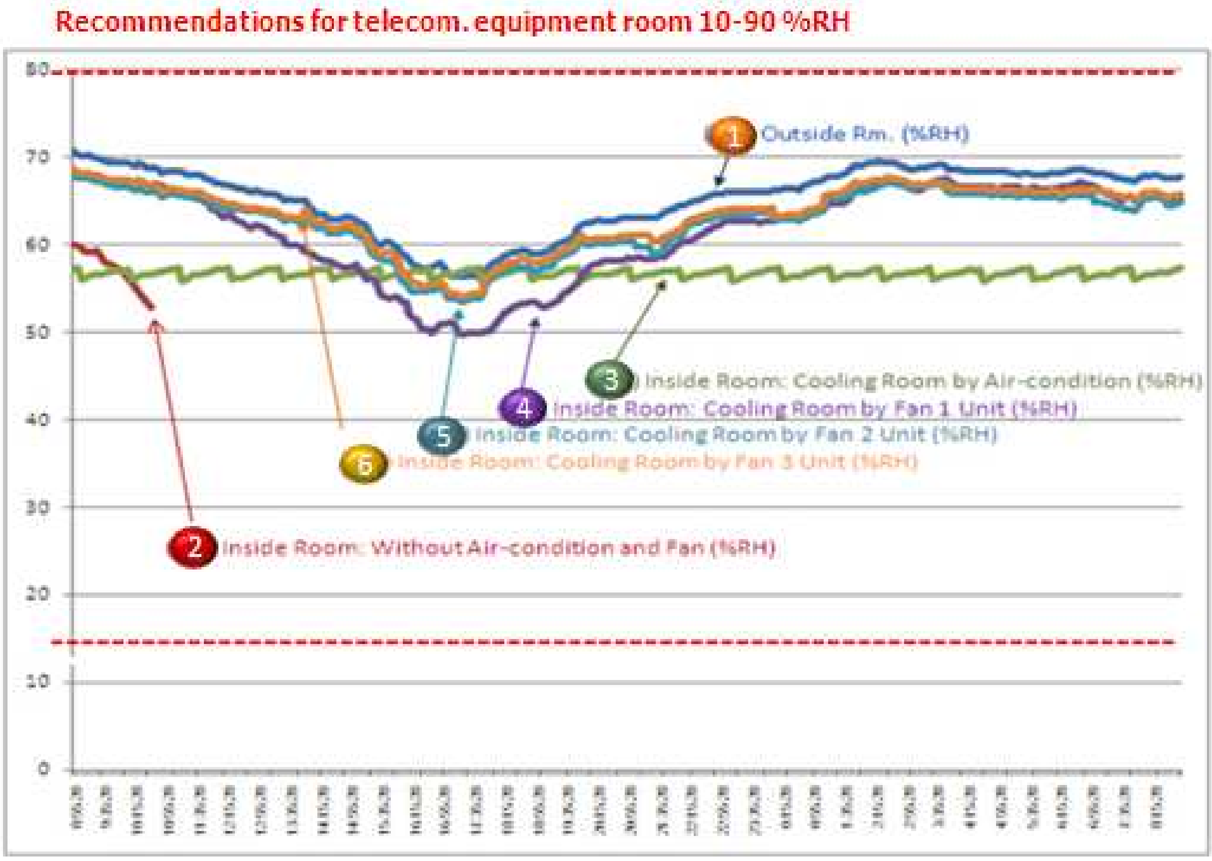

Fig.5. Comparison of Relative Humidity with various cooling method and Recommendations for Telecommunication Equipment.

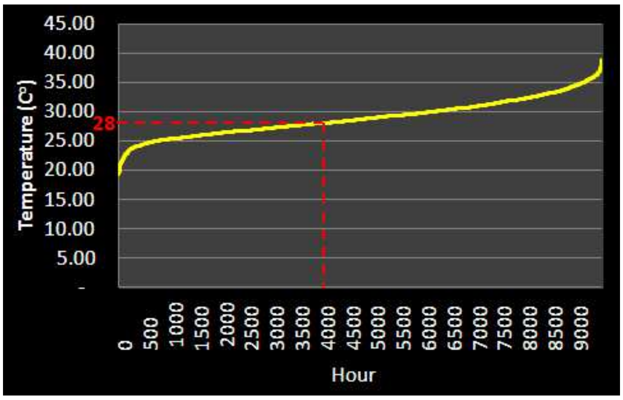

Fig.6. Temperature duration curve of Bangkok in 2010.

Design and Installations

The ventilation air volume is an important factor of generated heat for telecommunication equipment. If ventilation air volume is higher than generated heat the over need energy consumption is the waste of operating system. On the other hand, the ventilation air volume is under the standard may cause the damage of telecommunication equipment. The heat generated from telephone equipment is depending on many factors such as various ambient outside room temperature and load of telephone equipment operation. The first step of design and installations stage is data collection, this experiment used data logger to measures and records the room environment consists of temperature and relative humidity, both of inside and outside the room were done, details as shown in Figure 7.

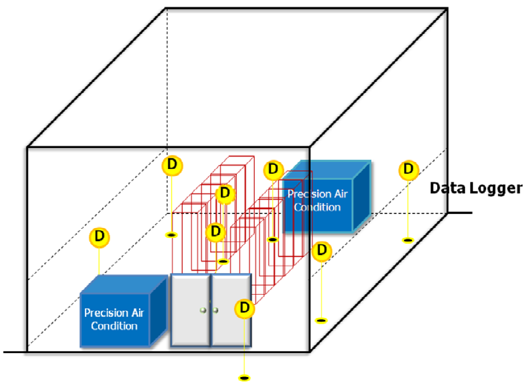

Fig. 7. Temperature and Relative Humidity Data Collection.

The airflow requirements are sometimes very difficult to evaluate for minimizing energy consumption. To avoid equipment shutdown caused by high temperature and to make sure that room temperature will be not excesses recommendation, the design of air flow rate and air change must be higher than normal design of ventilation system as shown in Eq.(1).

$$Q = Heat\ load \times \frac{(T_1 - T_2)}{1.108} \quad (1)$$

where:

Q air flow rate (ft^3/min),

T_1 the outdoor temperature (^OF),

T_2 the indoor temperature (^OF).

Air Changes

$$N = 60Q/V \quad (2)$$

where

N number of air changes per hour,

V volume of room (ft^3).

Air Change/h determined how many times of room volume would fill up with the air from the registers in one hour.

Installation

Three blowers with temperature sensor are installed as shown in Figure 8, the existing precision air conditioning and air blowers are used to control room conditions.

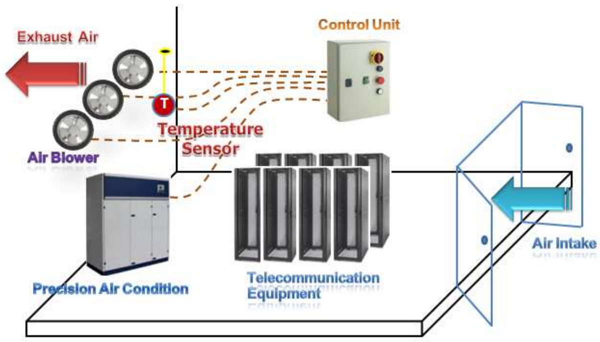

Fig. 8. Air Blowers, Temperature Sensor and Control Unit Installation.

Control Procedure

The temperature control procedures are shown in Figure 9, and operating procedures are as follow:

[a] When the room temperature is less than or equal 31 ^oC, one set of air blower is operated to control room temperature.

[b] When the room temperature is reached to 32 ^oC, two sets of air blower are operated to control room temperature.

[c] When the room temperature is reached to 33 ^oC, three sets of air blower are operated to control room temperature.

[d] When the room temperature is reached to 35 ^oC, the existing precision air conditioning is operated to control room temperature.

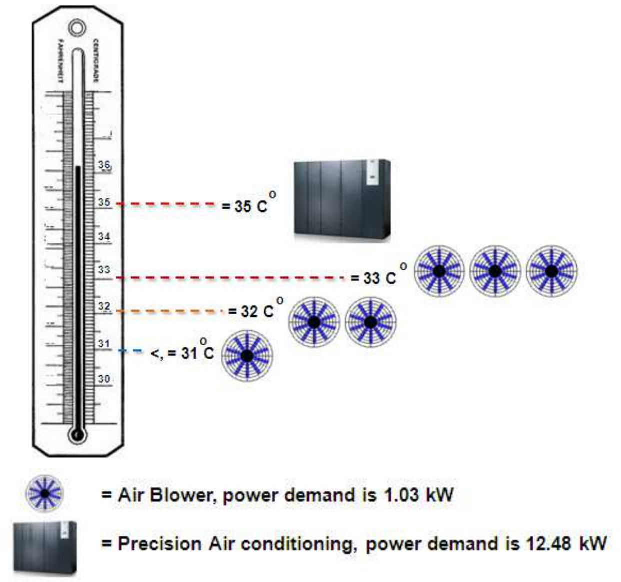

Fig. 9. Temperature Control Procedure.

Safety Preparations

However, a flexible working of controlled air blower by temperature is an optimum choice to maximize the energy saving. The design with automatic operate by use temperature sensor to control the number of blowers are required. This experiment utilized the existing doors for minimizing the installation cost. The fire rated steel doors of main entrance are used for air intakes to the room and in case of fire; function of the door is fire damper. Magnetic lock has been used to hold door to open, when normal situation and automatic relief door is to close in case of emergency situation.

In order to avoid accumulate of heat inside equipment rack, cover should be removed, the heat spread to room and remove to outside by ventilation system. The equipment rack is shown in Figure 10.

Fig. 10. Telephone equipment rack.

In addition, the safety design of fire detection system is need for safety and security conditions so the proposed system is redesigned the room conditions which gaseous suppression system to meet the recommended standard. Telephone exchanges must install fire detection and fire suppression system.

The automatic fire suppression system especially for the telephone exchange, is provided with total flooding gaseous system, as shown in Figure 11, when fire alarm persists, precision air conditioning and/or ventilation blowers have to shut off and every openings have to automatic close, each opening must equipped with fire resistance rated material with at least 2 hours. In case of fire and gaseous discharged the effective holding time to maintain the right concentration such as FM200 standard, at least 10 minute of holding time with 7% concentration is concerned.

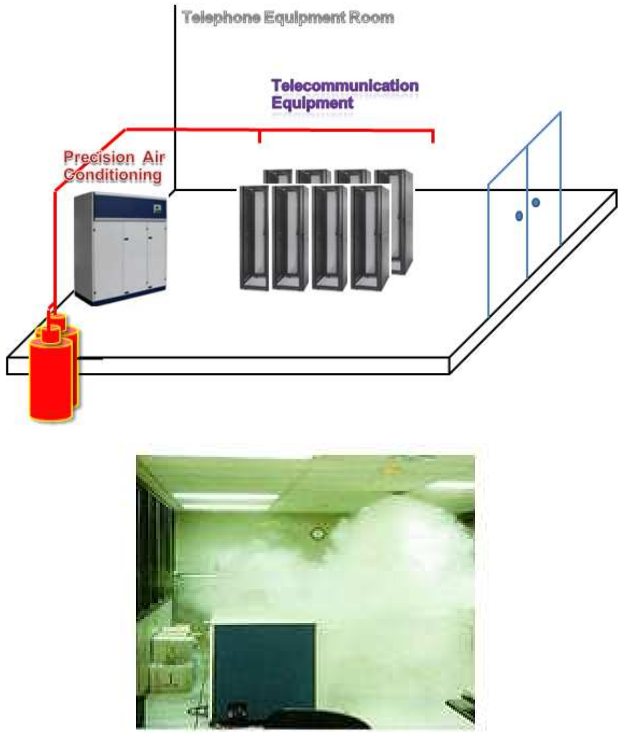

Fig. 11. Total flooding gaseous system in action.

Fig. 12. Fire damper electromagnetic locked type

In this design concept, when emergency situation and fire alarm persist, all of ventilation blowers shut off, fire damper with electromagnetic locked type is dropped to close the opening and magnetic lock at entrance door is relief, door automatic close to seal the room as shown in Figure 12 and Figure 13.

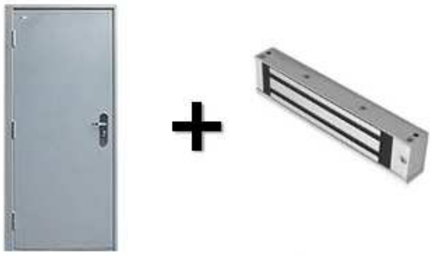

Fig.13. Door with magnetic lock.

This proposed experiment is not installed sensor to control relative humidity, during monitoring found that relative humidity of room is not over recommendation limit. The other control condition is air particle, the air filters are using to control air quality.

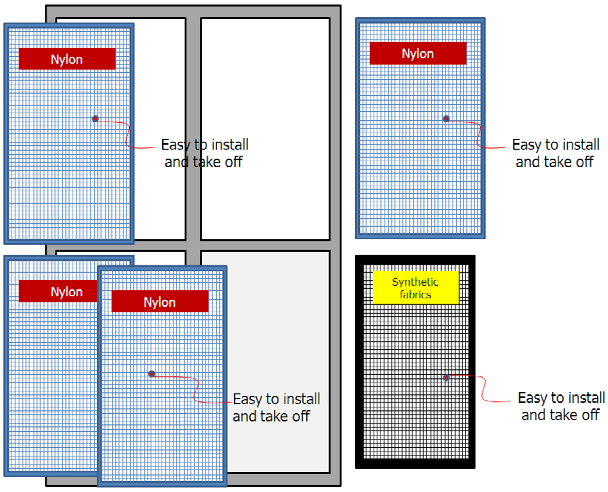

Fig. 14. Air Filter design for user friendly easy to take off.

Air filters are installed at air intakes point. The specification of air filter depends on volume of particle in the air, this experiment found that a lot of particle from outside air made air filter clog very quickly. The important issue is air flow, which is not only have to control air quality but also have to easy to preventive maintenance. Air filter shall be designed to easy to take off for cleaning and easy to install its back, quick lock basis are required. The double pre-filter is used two layers, first is nylon meshwork filter and second is polyester that normally used in air conditioning system as shown in Figure 14.

4. EXPERIMENTAL RESULTS

In this experiment, the details of designed ventilation blowers by using Eq. (1) and Eq. (2) are shown in Table 3, and selected air blower shown as Figure 15.

Financial Analysis

The Life Cycle Cost (LCC) of system is calculated by Eq. (3) that LCC of precision air conditioning system is 11,863,017 Baht. And LCC of the optimal energy management system is only 1,562,246 Baht. The proposed system can reduce LCC of environmental control system for telephone exchange up to 10,300,770 Baht or 7.6 times when compare with the conventional system.

Life Cycle Cost (LCC):

$$LCC = Cic+Cin+Ce+Co+Cm+Cd \qquad (3)$$

where:

Cic initial costs,
Cin installation and commissioning costs,
Ce energy costs,
Co operating costs,
Cm maintenance and repair costs,
Cd decommissioning/disposal costs.

Table 3. Air Blower Selected Specification

Normal air displacement at 0 mm. WG.	20,640 cfm.
Electrical system	1 phase 220 volts.
Motor current	4.48 amps.
Absorbed power	1,029 watt.
Fan speed	388 rpm.
Efficiency	20.1cfm/w.
Noise level	64 dBA at 7 m.

Fig. 15. Ventilation fan.

In addition, the life cycle cost of precision air conditioning and optimal energy management system consists of electrical expense, preventive and corrective maintenance costs, i.e., the details are shown in Table 4. The Present Value of cost saving of the optimal energy management system which calculated by the discount rate technique is calculated by Eq. (4) the details are shown in Table 5.

Present Value (PV):

$$\sum_{i=0}^{N} PVi \qquad (4)$$

where:

PV_i the present value of year *i*,
N the number of cycle year.

Furthermore, the proposed ventilation system with optimum design by the optimal energy management methods can enhance the energy efficiency for telephone exchange which can reduce the energy consumption up to 91.54% from existing precision air conditioning system. Figure 16 shows the energy consumption of proposed system and conventional cooling system.

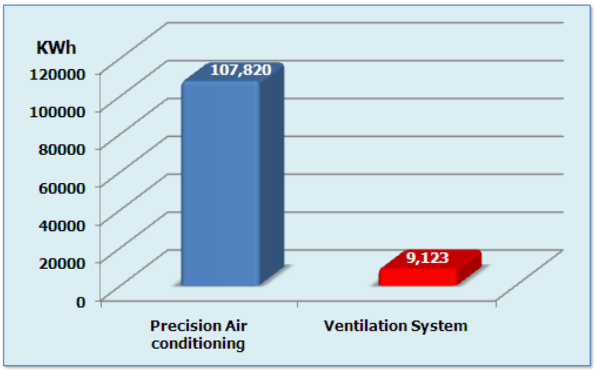

Fig. 16. Comparison of energy consumption with air conditioning and ventilation system.

The annual energy consumption for Precision Air conditioning system is 107,820 kWh/room and 9,123 kWh/room for conventional cooling system and proposed ventilation system respectively. The annual cost of the proposed system can reduce up to 296,092 THB/Room. The proposed optimal energy management of hybrid cooling system is able to greatly reduce energy consumption and operating cost, althoush, the cost saving depends on setting point of room temperature.

5. DISCUSSIONS

The results of experiment, during operated and monitored these hybrid cooling systems which using the air blowers integrated with the existing air conditioning system found that the system can be released heat that generated from equipments quite well and has ability to control temperature of telephone switching room within acceptable range with manufacturers recommend even though the raining day. The major concerned is air particle that come into the rooms and made air filter clog, obstruct the air flow and decreased volume of air intake to the room, rising of temperature which caused room high temperature. Some of air particle appeared on the wall, walk ways, some on the cabinets and switching board. At the first time, clean-up the air filter every 2 weeks, but it can't solved the room high temperature, so, in order to solve the problem its necessary to increase frequency of clean-up the air filter. At the next phase of experiment, additional air filter are required, two sets of air filter provided, twice day cleaned with alternate basis, under process to monitor the air particle.

Over one year operated didn't found damage of equipments which caused by heat or from collection of air particle. The factor affects to the proposed system should be mentioned as following, first of all, design and install the system should be considered of three requirements including equipment operating temperature, relative humidity and air particle. In addition, for flexibility and efficiency of operate and fixing the problems, the system shall be designed and installed with both automatic and manual mode basis, the watchdog system have to provide, alarm and warn when a trouble is brewing such as when ventilation fan is break down, the alarm should send to the responsible officer. Although the air ventilation system is the main system, the existing air conditioning system have to available for cooling the room for all time, especially need to be working automatically. Finally, from experiment results found that the hybrid cooling system by integrating the conventional air conditioning system with air ventilation system are suitably for reducing energy consumption for telephone exchange which installed equipment with circuit switch technology. IP base or package switch technology usually used in Data Center these devices generated high rate of heat and especially, its sensitive to heat can lead to unexpected problems with overheating, so, they might broke down. Until we have knowledge base about this system, advice that not to use with above-mentioned.

6. CONCLUSION

The proposed optimal energy management of hybrid cooling system for telephone exchange is redesigned the conventional system by considering equipment requirement, safety standard and energy management. From experimented results, the telephone exchange can operate without any effect but the energy consumption can reduce up to 91.54% and the overall energy consumption decreased 36.92% as compared to the convention cooling system. The annual cost of the proposed system can reduce up to 296,092 THB/Room with 1 year of return of investment. In additional, LCC of the optimal energy management system is only 13.47 % of conventional system, the proposed system can save up to 9,717,708 THB/Room, when compare with the conventional system. This hybrid cooling system have the potential for practical implementation, but, it's have to continued monitor and evaluated. Further study, when a fan driven by a fixed speed motor the airflow may sometimes be higher than it need to be, it is more efficient to regulate the airflow by regulating the speed of motor. Variable Speed Drives (VSD) with ventilation fan application is the way to enhance energy saving, it uses less energy than fixed speed mode of operations. The proposed temperature control method by used VSD application will be investigated in the future study.

Table 4. Comparison of Life Cycle of Air Conditioning and Ventilation System

LCC (life cycle cost)	Year												Total (Baht)
	1	3	5	7	9	10	11	13	15	17	19	20	
Precision Air condition 2 Unit													
Cic (initial costs/purchase price)	960,000	-	-	-	-	960,000	-	-	-	-	-	-	1,920,000
Cin (installation and commissioning costs)	720,000	-	-	-	-	720,000	-	-	-	-	-	-	1,440,000
Ce (energy costs)	327,953	327,953	327,953	327,953	327,953	327,953	344,350	379,646	327,953	327,953	327,953	327,953	6,822,039
Co (operating costs)	7,300	7,300	7,300	7,300	7,300	8,030	8,030	9,716	10,688	14,226	17,213	18,934	200,978
Cm (maintenance and repair costs)	30,000	40,000	120,000	40,000	40,000	30,000	30,000	40,000	30,000	40,000	40,000	120,000	1,080,000
Cs (downtime costs /loss of production)	-	-	-	-	-	-	-	-	-	-	-	-	-
Cenv (environmental costs)	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (decommissioning/disposal costs)	-	-	-	-	-	200,000	-	-	-	-	-	200,000	400,000
Total	**2,045,253**	**375,253**	**455,253**	**375,253**	**375,253**	**655,253**	**382,380**	**429,362**	**368,640**	**382,178**	**385,166**	**666,887**	**11,863,017**

LCC (life cycle cost)	Year												Total (Baht)
	1	3	5	7	9	10	11	13	15	17	19	20	
Air Blower 3 Unit													
Cic (initial costs/purchase price)	164,400	-	-	-	-	-	164,400	-	-	-	-	-	328,800
Cin (installation and commissioning costs)	109,600	-	-	-	-	-	109,600	-	-	-	-	-	219,200
Ce (energy costs)	27,747	27,747	27,747	27,747	27,747	27,747	27,747	27,747	27,747	27,747	27,747	27,747	554,946
Co (operating costs)	7,300	7,300	7,300	7,300	7,300	7,300	8,030	8,030	8,030	8,030	8,030	8,030	153,300
Cm (maintenance and repair costs)	3,000	3,000	19,500	3,000	3,000	19,500	3,000	3,000	3,000	3,000	3,000	19,500	126,000
Cs (downtime costs /loss of production)	-	-	-	-	-	-	-	-	-	-	-	-	-
Cenv (environmental costs)	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (decommissioning/disposal costs)	-	-	-	-	-	90,000	-	-	-	-	-	90,000	180,000
Total	**312,047**	**38,047**	**54,547**	**38,047**	**38,047**	**144,547**	**312,777**	**38,777**	**38,777**	**38,777**	**38,777**	**145,277**	**1,562,246**

Table 5. Present Value of Cost Saving which calculated by the Discount Rate Technique

Table 5. Present Value of Cost Saving of the Optimal Energy Management System which calculated by the Discount Rate Technique

Cost Saving	Year												Total (Baht)
	1	3	5	7	9	10	11	13	16	17	19	20	
LCC of Prec. Air cond. 2 Unit - LCC of Air Blower 3 Unit	1,733,205	337,205	400,705	337,205	337,205	510,705	69,603	390,585	2,012,108	343,401	346,388	521,610	**10,300,771**
Present Value calculate with Discount Rate (PV)	1,635,099	318,118	378,024	318,118	318,118	481,797	65,663	368,476	1,898,215	323,963	326,781	492,084	**9,717,708**
Net Present Value (NPV) in this design concept = 9,388,908 Baht.													

Remark: *r* is the rate of interate = 6%

REFERENCES

[1] Bearg, David W. (1993). Indoor Air Quality and HVAC Systems. CRC Press. pp. 64. ISBN 0-87371-574-8.

[2] Performance and Benefits of Zero Maintenance Air Induction Systems. Society of Automotive Engineers. Retrieved 2009-11-21.

[3] The Climate Group on behalf of the Global eSustainability Initiative (GeSI), SMART 2020: Enabling the low carbon economy in the information age.

[4] Arthur D. Little, Telecom & Media Viewpoint, "Cost Reduction in the Telecom Industry," Available: www.adl.com

[5] Peter F. Johnson, "Risk Assessment in Telephone Exchange," Faculty of the WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Master of Science in Fire Protection Engineering, July 1986.

[6] Rabie, N., Delport, G.J. "Energy management in a telecommunications environment with specie reference to HVAC," Centre for new Electricity Studies, University of Pretoria, South Africa, April 2001.

[7] Tietenberg, Tom. Environmental and Natural Resource Economics, Fifth edition. Massachusetts: Addison - Wesley. 2000. Chapter 4: p.74-75.

[8] World Bank. World Development Report : Development and the Environment . New York: Oxford University Press. 1992.

[9] Haifeng, L. *et al.*, "Estimating product lifecycle cost using a hybrid approach," in *Digital Information Management, 2007. ICDIM '07. 2nd International Conference on*, 2007, pp. 393-398.

[10] Church, E. A. and Hills, H. W. "Discount Rate for Present Wort Studies," *Power Apparatus and Systems, IEEE Transactions on*, vol. PAS-85, pp. 295-303, 1966.

[11] Pavlov, A. N. *et al.*, "Experimental installation for test of automatic fire gas explosion suppression system," in *Micro/ Nanotechnologies and Electron Devices, 2009. EDM 2009. International Conference and Seminar on*, 2009, pp. 332-334.

[12] Bin, Z. *et al.*, "Quality controls in scanning test rig for air filters," in *Electric Technology and Civil Engineering (ICETCE), 2011 International Conference on*, 2011, pp. 1412-1415.

[13] Dennis Bouley and Wendy Torell, *White Paper 163 Rev 1*, "Containerized Power and Cooling Modules for Data Centers," Available: *Data Center Science Center* DCSC@Schneider-Electric.com

[14] Tony Evans, *White Paper 59 Rev 2*, "The different Technologies for Cooling Data Centers,"