Electrical Energy Efficiency Improvement in Chiller Operation

Rifdian Indrianto Sudjoko*, Hartono, Kustori, Slamet Hariyadi, Fiqqih Faizah

Politeknik Penerbangan Surabaya, Jalan Jemur Andayani I No 73, Kota Surabaya, 60236
Corresponding Author. Email: rifdian.anto@gmail.com

ABSTRACT

The need for electrical energy to meet consumers is increasing which must be addressed immediately. Along with population growth and economic growth, this energy need will continue to increase. With the use of large amounts of electrical energy, it is necessary to increase efficiency in operating equipment. Airports are one of the largest users of electricity, especially when it comes to cooling systems. Therefore, it is necessary to save energy in airport operations. Airports are one of society's activities, so airports need to save energy. By optimizing power management and calculating the chiller coefficient of performance (COP) value, an airport can be built that saves energy on the HVAC system (especially chillers). Through analysis, it was found that COP increased to 0.584, and the value before optimization was 6.181. As COP increases, chiller performance will increase. The optimized electrical energy efficiency of the cooler is 138.82 kWh / day.

Keywords: coefficient of performanc(COP),energy management optimization,water chiller, electrical energy efficiency.

1. INTRODUCTION

Energy is a very important thing that is needed in large quantities. This is related to population growth and economic growth which changes every year. According to the National Population and Family Planning Agency (BKKBN), Indonesia's population growth rate is 1.49% or approximately four million per year [1]. One of the impacts of population and economic growth is causing an increase in energy demand. According to data from the US Energy Conservation Agency (2012), the increase in energy demand from 2009 to 2019 shows that economic growth with population growth also causes an increase in national energy demand, and makes energy use one of the main contributors to operating costs [2]. "Industrial" is one of the buildings that uses most of the electrical energy to run the air conditioning system. Electrical energy consumption used by industry can reach 30% of national electrical energy needs [3]. Therefore, optimizing the management of electrical energy in the "coolant" used in building cooling systems needs to be carried out.

Some buildings that require a lot of energy (especially electricity) are multi-storey buildings, factories, hospitals, office buildings and shopping centers [4]. Multi-storey buildings are an industry that falls into the category of shopping centers and require a lot of electricity. Nearly 50% of electricity in shopping centers is used to supply air conditioning (AC) systems [5]. In terms of energy conservation, a strategic step to support the maximum supply of electricity is to continue implementing national energy policies in accordance with Ministry of Energy and Mineral Resources regulations No. 13 (2012) [6]. One form of this work is to increase the energy consumption of certain buildings and other large buildings.

In this research, there were three coolers, each with a cooling capacity of 500TR. All three coolers operate at the same time to meet the cooling load requirements [7]. Meanwhile, in current conditions, industrial conditions are still relatively quiet due to limited access. Thus, the efficiency of using electrical energy is low. Therefore, it is necessary to save power by optimizing and managing energy in the cooler, which is expected to reduce peak operating costs due to low efficiency.

2. COOLING AND AIR CONDITIONING

Refrigeration and air conditioning are interrelated processes, but each process has a different scope. Cooling is the process of lowering the temperature and making the indoor temperature or indoor materials lower than the environmental temperature. In other words, the scope of refrigeration technology lies in the cooling process [8]. Refrigeration technology can not only cool the air, but also make the user feel comfortable (comfortable communication). According to the definition, air conditioning, temperature, humidity, flow rate and indoor air cleanliness must be adjusted at the same time. Interconnected components include: chiller, AHU, FCU, control valve, CHWP (cold water pump) and CWP (cooling water pump). The refrigeration or air conditioning cycle is shown in Figure 1

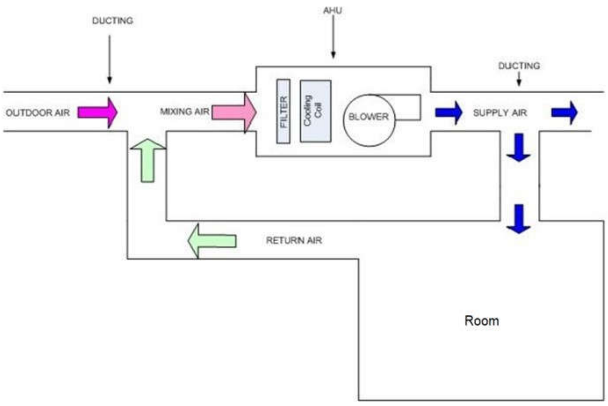
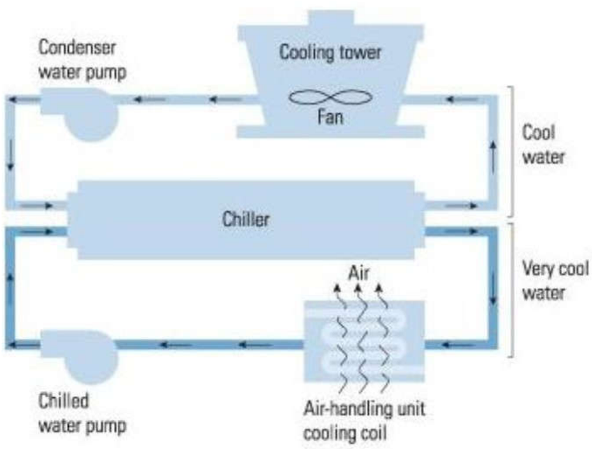


Figure 1. Refrigeration cycle

2.1. Chiller

Chiller is a tool for producing cold fluid (secondary refrigerant), used in cold water distribution systems [9]. large capacity chiller. The refrigeration cycle of a chiller system uses liquid propylene glycol, ethylene glycol, or other secondary refrigerants. In the cooler / evaporator, the liquid is cooled by a refrigerant which evaporates at a low temperature. After the liquid is cooled in the cooler, the liquid will enter the coil to cool the load. Thus, the temperature of the liquid will rise and return. to the cooler and circulate [10]. In a refrigerant system, refrigerant vapor is sucked into the compressor and the pressure is increased, so that the condensation temperature rises and it can be melted in the condenser.



In this process, the temperature of the condenser cooling medium (water or air) rises. Then, the liquid refrigerant flows to the cooler / evaporator through the refrigerant control device (expansion valve). In the expansion device, the refrigerant experiences a pressure drop. Thus, the boiling temperature decreases and is lower than the secondary refrigerant temperature [11].

2.2 Vapor Compression System

The compressed vapor refrigeration cycle is the most common type of refrigerator used today. Coolers consist of four main components, namely compressor, condenser, expansion valve and evaporator [12]. In this cycle, the low pressure refrigerant vapor will be compressed by the compressor into high pressure refrigerant vapor, then the high pressure refrigerant vapor will be condensed into high pressure refrigerant liquid in the condenser [13]. Then the high pressure refrigerant liquid passes through the expansion valve to reduce the pressure, so that the low pressure refrigerant liquid can evaporate back into the evaporator and become low pressure refrigerant vapor [14]. The vapor compression cycle is shown in Figure 3

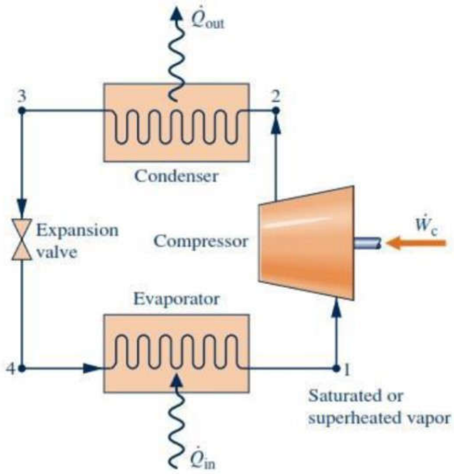


Figure 3. vapor compression cycle

2.3 Basic Performance Calculation

The basic basis for calculating cooling system performance includes the coefficient of performance (COP) and the electrical power consumed by the coolant.

2.3.1. Coefficient of Performace (COP)

COP can be formulated as

$$COP = \frac{E_R}{W_k} \tag{2.1}$$

Where : COP : coefiicient of performance
E_R = refrigeration effect

W_k = electrical power consumed by the chiller [7]

2.3.2. Chiller electrical power consumption

Electrical power input can be formulated as

$$Pi = \frac{\sqrt{3}V.I\cos\emptyset}{1000} \qquad (2.2)$$

Where :
Pi = chiller power input (kW)
V = voltage input (Volt)
I = current (A)
Cos ϕ= power factor (use 0.87 for chiller)

2.3.3. Chiller electrical energy consumption

Energy consumption can be formulated as

$$W = P\,x\,t \qquad (2.3)$$

Where :
W = chiller energy consumption (kWh)
P = electrical power used (Watt)
t = time duration (Hour)

2.3.4. Average electrical energy per day

Average energy consumption per day can be formulated as

$$\frac{kWh}{hari} = \frac{\sum P}{t} \qquad (2.4)$$

Where :
W = chiller energy consumption per day (kWh)
P = electrical power used (Watt)
t = time duration (Hour)

3. METHOD

Energy management is a comprehensive plan that can be planned and implemented systematically to use energy effectively and efficiently through planning, recording, monitoring and evaluating without interruption and without reducing the quality of production/services [15]. Energy management includes planning and operating units related to energy consumption and production. The goal of energy management is to save resources, protect the climate and save costs [16]. For consumers, energy management enables them to get the energy they need.

3.1 Chiller Electrical Energy Management Optimization Planning

Chiller power management optimization planning is carried out by changing the chiller start-up schedule from the existing operational schedule to the operational schedule during optimization. The initial operational schedule is shown in Table 1. Meanwhile, the operational schedule during optimization is shown in Table 2.

Table 1. Chiller Operational Schedule Before Optimization

Chiller No.	10	11	12	13	14	15	16	17	18	19	20	21	22
Chiller 1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chiller 2	1	1	1	1	1	1	1	1	1	1	1	1	1
Chiller 3	1	1	1	1	1	1	1	1	1	1	1	1	1
Chiller 4	1	1	1	1	1	1	1	1	1	1	1	1	1
Chiller 5	1	1	1	1	1	1	1	1	1	1	1	1	1

Table description :
Number 1 (on) and number 0 (off) indicate the running cooling indicator light. Based on the operation plan shown in Table 1, the chiller operating procedures on weekdays can be explained as follows:
- Chiller 1 operates from 10:00 to 22:00
- Chiller 2 operates from 10:00 to 22:00
- Chiller 3 operates from 10:00 to 22:00
- Chiller 4 operates from 10:00 to 22:00

Table 2. Chiller Optimization Schedule Operational Scheme During Weekdays

Chiller No.	10	11	12	13	14	15	16	17	18	19	20	21	22
Chiller 1	1	1	1	1	1	1	1	1	1	1	1	1	1
Chiller 2	1	1	1	1	1	1	1	1	1	1	1	1	1
Chiller 3	1	1	1	1	1	1	1	1	1	1	1	1	1
Chiller 4	1	1	1	1	1	1	1	1	1	1	1	1	1
Chiller 5	1	1	1	1	1	1	1	1	1	1	1	1	1

Table description :
Number 1 (on) and number 0 (off) indicate the running cooling indicator light. Based on the operation plan shown in Table 2, the chiller operating procedures on weekdays can be explained as follows:
- Chiller 1 operates from 10:00 to 22:00
- Chiller 2 operates from 10:00 to 22:00
- Chiller 3 operates from 10:00 to 22:00
- Chiller 4 operates from 10:00 to 22:00

There is no difference in conditions before optimization and during work, so it is necessary to recheck (calibrate) to make it more optimal.

3.2 Data Retrieval

Data obtained from the Chiller using an Avometer for the purposes of this research includes current, voltage and parameters used to calculate COP.

3.3 COP Data Parameter

For COP, the unit design is taken from the chiller name plate or chiller specifications on the chiller panel. After optimization, it will be calculated based on cooling capacity data and power input or the power needed to run the cooler. COP data before optimization is shown in Table 3. Meanwhile COP parameter data after optimization is shown in Table 4.

Table 3. Chiller Specification Data

No	Specification	Data
1	Tipe chiller	*Water Cooled Chiller*
2	*Cooling capacity*	1758 kW
3	Power input	284.4. kW
4	*COP*	6.181
5	Tipe *compressor*	*Centrifugal*
7	Jenis refrigeran	R-134a
8	Tegangan Supplay	3 Phase 380Volt / 50 Hz

Table 4. Chiller power consumption

	Power Consumption	
	Chiller 1,3,5	Chiller 2,4
Cooling Capacity	1758 kW	1758 kW
Power Consumption	271.40 kW	252.62 kW

4. RESULT AND DISCUSSION

4.1 Calculation Results of Chiller Electrical Energy Consumption Before and After Optimization

Optimizing cooling power consumption is with a start-up plan at 10.00 WIB and a power outage plan at 22.00 WIB. The optimized schedule is a delay in the start time of the chiller, namely 2 hours on weekdays and 2 hours on holidays. The results of optimizing power consumption can be seen in the current consumption of Chiller 1 to 5 on weekdays, which is shown in Figure 4, Figure 5, Figure 6, Figure 7, and Figure 8.

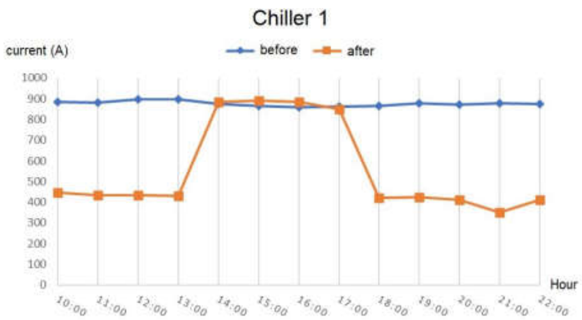


Figure 4. Current of Chiller 1

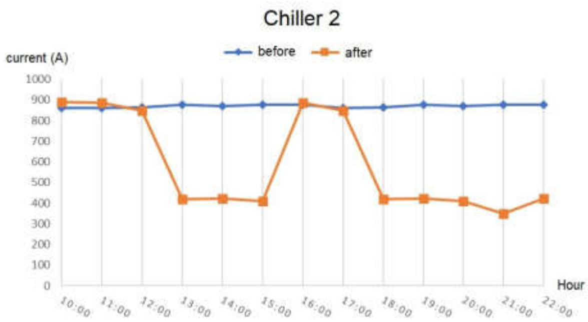


Figure 5. Current of Chiller 2

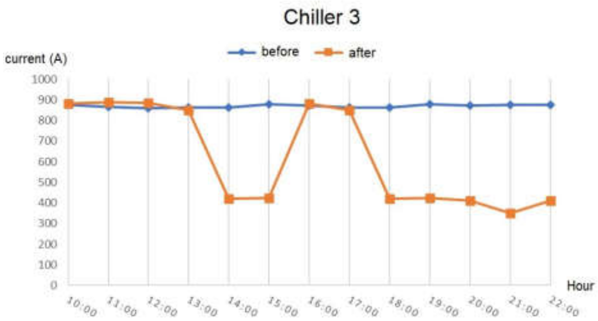


Figure 6. Current of Chiller 3

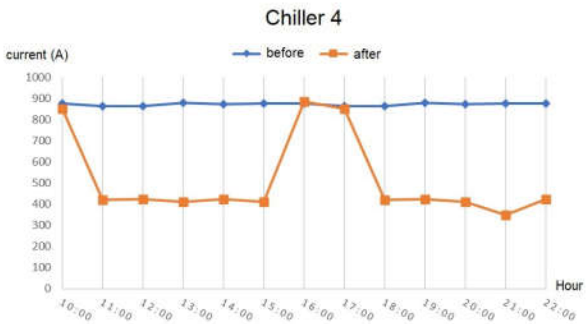


Figure 7. Current of Chiller 4

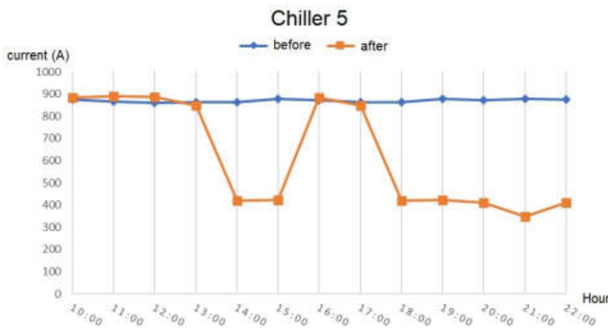


Figure 8. Current of Chiller 5

From Figure 4 to Figure 8, the average current consumption of chiller 1 to chiller 5 fluctuates. Current consumption fluctuations that occur cause fluctuations in power consumption because current and power are directly proportional [10]. Compared with conditions before optimization, the average current consumption after optimization is reduced by 34%. The average current and voltage values before optimization are 885A and 394 V, with cos φ = 0.87. To determine power consumption, formula 2.2 is used and the following results are obtained:

$$Pi = \frac{\sqrt{3}V.I\cos\emptyset}{1000} = \frac{\sqrt{3}.x394x885x0.87}{1000} = 524.81\ kW$$

4.2 COP Calculation Result

Using formula 2.1, the optimal COP value of chiller 1 to 5 is as following:

COP Chiller 1 :

Based on chiller 1 data in Table 4, the COP calculation results for chiller 1 are as follows

$$COP = \frac{E_R}{W_k} = \frac{1758}{271.4} = 6.478$$

COP Chiller 2 :

Based on chiller 2 data in Table 4, the COP calculation results for chiller 2 are as follows

$$COP = \frac{E_R}{W_k} = \frac{1758}{252.62} = 6.959$$

COP Chiller 3 :

Based on chiller 3 data in Table 4, the COP calculation results for chiller 3 are as follows

$$COP = \frac{E_R}{W_k} = \frac{1758}{271.4} = 6.478$$

COP Chiller 4 :

Based on chiller 4 data in Table 4, the COP calculation results for chiller 4 are as follows

$$COP = \frac{E_R}{W_k} = \frac{1758}{252.62} = 6.959$$

COP Chiller5 :

Based on chiller 5 data in Table 4, the COP calculation results for chiller 5 are as follows

$$COP = \frac{E_R}{W_k} = \frac{1758}{271.4} = 6.478$$

4.2 Average COP Calculation Result

Average COP value of chiller 1 to 5 is as following:

$$Average\ COP = \frac{\sum COP\ Chiller}{5}$$

$$= \frac{6.478 + 6.959 + 6.478 + 6.959 + 6.478}{5} = 6.718$$

Financial savings

The electricity price for power over 30,000 kVA is IDR 971.01 per kilowatt hour. The savings that can be generated are:

Financial Savings in one day are :

138.82 kWH x Rp. 971.01 x 12 = Rp. 1,627,547.29

Financial Savings in one month are :

Rp. 1,627,547.29 x 31 = Rp. 50,143,966.25

Financial Savings in one year are :

Rp. 50,143,996.25 x 12 = Rp. 601,727,955,-

4. CONCLUSION

From the results of the chiller power management optimization analysis in airport central AC planning, it can be concluded that the COP increased by 0.584, and the pre-optimization value was 6.181. When the COP value increases, engine performance will increase. By adding a COP cooler in the form of a peltier, power consumption can be saved. The electrical energy efficiency obtained after optimization was 138.82 kWh / day, while the initial value before optimization was 522.55 kWh / day. And the financial savings that can be generated by optimizing chiller power consumption in one day is IDR. 1,627,547.29, if in one month it is IDR 50,143,966.25, and if in one year it is IDR 601,727,955,-. Based on the calculation results above, the optimization method adopted is to change the cooler start-up schedule, thereby reducing power consumption and cooler operating costs.

AUTHORS' CONTRIBUTIONS

The proposed optimization of chiller operation can be applied to airports as centers of community activities

ACKNOWLEDGMENTS

Research can be carried out with funds from the research and community service center with SK no KP-Poltekbangsby 1343 Tahun 2023

REFERENCES

[1] M.E. Ahmad and S. Mekhilef, "Design and Implementation of a Multi Level Three-Phase Inverter with Less Switches and Low Output Voltage Distortation," Journal of Power Electronics, vol. 9, pp. 594-604, 2009.

[2] [2] Nugraha, Anggara Trisna, Alwy Muhammad Ravi, and Dadang Priyambodo. "Optimization of Targeting Rocket Launchers with Wheeled Robots." Journal of Electronics, Electromedical

Engineering, and Medical Informatics 3.1 (2021): 44-49

[3] E. I and O. Rivera, "Maximum Power Point Tracking using the Optimal Duty Ratio for DC-DC Converters and Load Matching in Photovoltaic Applications," IEEE, pp. 987-991, 2008

[4] Priyambodo, Dadang, and Anggara Trisna Nugraha. "Design and Build A Photovoltaic and Vertical Savonious Turbine Power Plant as an Alternative Power Supply to Help Save Energy in Skyscrapers." Journal of Electronics, Electromedical Engineering, and Medical Informatics 3.1 (2021): 57-63

[5] Hairul Nissah Zainudin Saad and Mekhilef," Comparison Study of Maximum Power Point Tracker Techniques for PV Systems", Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10), December 19-21, 2010, Paper ID 278

[6] Nugraha, A. T., and T. Agustinah. "Quadcopter Path Following Control Design Using Output Feedback with Command Generator Tracker LOS Based At Square Path." Journal of Physics: Conference Series. Vol. 947.No. 1. IOP Publishing, 2018

[7] Jiyong Li and Honghua. Wang,"A Novel Stand-alone PV Generation System Based on Variable Step Size INC MPPT and SVPWM Control", IPEMC 978-1-4244-3557-9-2009

[8] Priyambodo, Dadang, and Anggara Trisna Nugraha. "Design and Build A Photovoltaic and Vertical Savonious Turbine Power Plant as an Alternative Power Supply to Help Save Energy in Skyscrapers." Journal of Electronics, Electromedical Engineering, and Medical Informatics 3.1 (2021): 57-63

[9] Mei Shan Ngan and Chee Wei Tan,"A Study of Maximum Power Point Tracking Algorithms for Stand-alone Photovoltaic Systems", IEEE Applied power electronics colloquium (IAPEC), 2011

[10] Nugraha, Anggara Trisna, and Rahman Arifuddin. "O2 Gas Generating Prototype in Public Transportation." JEEMECS (Journal of Electrical Engineering, Mechatronic and Computer Science) 3.2 (2020): 187-192

[11] Huiying Zheng, Shuhui Li, Senior Member, IEEE, Ke Bao, and Dong Zhang,"Comparative Study of Maximum Power Point Tracking Control Strategies for Solar PV Systems", IEEE 978-1-4673-1935-5/12 ©2012.

[12] Nugraha, Anggara Trisna. "QUADCOPTER TRACKING USES A LOS-BASED TRACKER COMMAND GENERATOR WHEN THERE IS DISTURBANCE ON A SQUARE TRACK." SENIATI Proceedings (2018): 7-13..

[13] B. M Hasaneen, and Adel A. Elbaset Mohammed, “Design and simulation of DC/DC boost converter,” Power System Conf. Middle-East, pp. 335-340, 2008

[14] Ned Mohan, Tore M. Undeland, and Williams P. Robbins, Power Electronics: Converters, Applications, and Design, 3rd ed., John Wiley &Sons: USA, 2003, pp. 161

[15] Nugraha, Anggara Trisna. "Use of Interference and Observation Algorithms in Maximum Power Point Tracking Systems in Solar Cells Using DC-DC Photovoltaics Converters." Janitra Journal of Informatics and Information Systems 1.1 (2021): 10-19.

[16] W. Hart, Danil. (1997). Introduction to Power Electronics. Valparaiso University, Indiana: Prenice-Hall International, Inc.