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P W Sunu, D S Anakottapary, I W Suirya, I B Puspa Indra, I P G S Rahtika, D M R S Putra, I G S G Yusa, I M Wijayantara. "A brief comparative thermodynamics review of domestic air conditioning system with or without installed heat recovery", Journal of Physics: Conference Series, 2020

Journal of Physics: Conference Series PAPER • OPEN ACCESS On-site study the influences of load factor on power consumption and performance of air conditioning system for a commercial building To cite this article: I N Suamir et al 2020 J. Phys.: Conf. Ser. 1450 012101 View the article online for updates and enhancements. This content was downloaded from IP address 114.124.232.166 on 13/01/2021 at 04:08 On-site study the influences of load factor on power consumption and performance of air conditioning system for a commercial building I N Suamir1, M E Arsana1, Sudirman1, I W Temaja1, A Wibolo1 1 Department of Mechanical Engineering, Politeknik Negeri Bali, Kampus Bukit Jimbaran, Bali, Indonesia Email: nyomansuamir@pnb.ac.id Abstract. On-site study was held to investigate the influences of load factor on power consumption and energy performance of water-cooled air conditioning (WCAC) system. A comprehensive measurement has been conducted to a WCAC plant of a supermall building located in West Java, Indonesia. Hourly and daily power consumption and performance characteristics of the WCAC system at varied load factors for a period of one year were evaluated. Regression analyses were developed to evaluate the influences of load factor on the WCAC power consumption and performance. The WCAC system was found to operate with varied load factor ranging from 70 percent to 100 percent. Power consumption of the system was strongly influenced by the load factor. Power consumption boosted when the power factor increased. The increase of load factor was also found to significantly improve the cooling capacity but reduce the coefficient of performance (COP). The best potential performance of the investigated WCAC system could be obtained at load factor between 70 percent and 85 percent. 1. Introduction Commercial building sector, in Indonesia as a developing country, consumed about 5.3% of the country total energy use and the energy consumption increase of about 5.68% in a year [1]. This sector which includes shopping malls has energy saving potential ranging from 10% to 30% [2-5]. While in developed countries, energy consumption of both residential and commercial sectors could reach 20% up to 40% of total energy use [6]. Commercial buildings have been grouped into energy intensive buildings, where shopping mall buildings alone contributed energy use intensity from 500 to 1000 kWh/m2.y [7]. For shopping malls comprising food retail stores, the energy use intensity was in the range between 346 to 700 kWh/m2.y. Whereas for non-food retail stores could range from 146 up to 293 kWh/m2.y [8]. Further study on energy conservation strategies for food and non-food stores have been reported in [7,9-11]. The commercial building sector especially shopping mall in tropical countries such as Indonesia would require intensive use of air conditioning system and moreover the sector is rapidly growing, therefore studies on energy performance of air conditioning systems and factors that might affect for energy conservation evaluation seems to be appealing for researchers. In shopping mall buildings, the growth of energy use by air conditioning systems is remarkably significant. Energy consumption for air conditioning system could reach or even more than 50% of Content from building consumption [6,11]. Moreover, studies on shopping malls showed that air conditioning was the single largest electricity consuming service accounting for 47-54% of the total electricity consumption followed by electric lighting with energy consumption of 33-38% [12]. Air conditioning and electric lighting are very important for shopping malls because modern shopping arcades tend to have much larger lighting load, higher businesses density and, consequently, larger air conditioning demand. The increase of electrical energy consumption is one of the major issues that is raised by global use of air conditioning systems, which could be a drawback mainly due to its growth in developing countries [13]. Factors that may restrict the efforts to achieve energy saving were shortness of knowledge about critical-operation parameters such as evaporator and condenser approach temperatures and load factor. The increase of approach temperatures in the evaporator and condenser heat exchangers indicates that heat transfer has restricted. This might cause temperature lift and power consumption of the AC systems to increase [14]. Thermal efficiency of air conditioning systems could also be improved by optimizing the operating load (load factor) through switching the number of host capacity of parallel systems [15]. It was reported that the greater the difference of host capacity in the parallel system, the lower the energy consumption under full load. Studies on the air conditioning system at partial load operation ranging from 25-100% has reported that the partial load where the optimized performance reached the maximum value was obtained at partial load from 68-76% [16]. Other analysis result of annual performance according to the part load characteristics of water cooled air conditioning (WCAC) system showed that 70% of annual power consumption occurs at part load factor from 0 to 50%. Optimal performance of the WCAC could be reached at part load factor from about 40% up to 85% [17]. The paper presents result of on-site study the influences of load factor on power consumption and coefficient of performance (COP) of water cooled air conditioning (WCAC) system for a commercial building more specifically a shopping mall building. Results of performance characteristic which include regression analyses, correlations and influences of load factors on the WCAC system performance are presented and discussed. 2. Methodology On-site study and analyses were held for evaluation of the effects of load factors on the performance of water cooled air conditioning (WCAC) plant applied to provide cooling for a modern commercial building more specifically a supermall building located in West Java, Indonesia. The WCAC plant consists of 3 identical water cooled air conditioning systems namely WCAC 1, WCAC 2 and WCAC 3; cooling towers as the heat rejection system to the atmosphere; and air handling units (AHUs) as well as fan coil units (FCUs) as the loading system. The compressors of the WCAC systems are centrifugal compressors applied R-134A refrigerant. Each WCAC system is specified by manufacturer with overall efficiency 0.56 kW/TR and coefficient of performance (COP) 6.2. Operational data of the WCAC system were recorded hourly for about 10-12 hours per day and then then the data were analyzed daily for a period of one year. The data obtained directly from the building include power consumption, load factor, condensing and evaporating temperatures, evaporator-condenser approach temperatures, ambient temperature and flowrate of chilled and cooling water. The data also involve refrigerant pressure of the refrigeration system and pressures of chilled and cooling water and ambient temperature. Regression correlation analyses were established to evaluate relationship and effects of load factor on the energy performance (power consumption, cooling capacity and COP) of the WCAC system. Energy performance of each refrigeration system in the WCAC system stated as COP (Coefficient of Performance) is calculated from cooling capacity (Qe) and power consumption of the compressor (Wc) as expressed in Equation (1). COP = Qe (1) Wc Cooling capacity of the WCAC system is determined by using Eq. (2) which calculated from the water side of the evaporator which involves chilled water flow rate (VChW) in m3/s, temperature difference of the chilled water across evaporator (ΔTChW) in K, specific heat (Cp) and density (ρ) of the chilled water respectively in kJ/kg K and kg/m3. Qe =?.VChW.Cp.?TChW (2) Overall efficiency (OE) of the WCAC system in terms of full-load power consumption kW per ton of refrigeration (kW/TR) is determined by using Eq. (3). OE= Wc(inkW) (3) Qe(inTR) 3. Results and discussion 3.1. Load factor and WCAC performance Figure 1 shows daily presentation for a year operation time period of operating parameters incorporate ambient temperature (Tamb), condensation temperature (Tcon) and evaporation temperature (Teva). Condensation and evaporation temperatures of refrigerant of the refrigeration system are slightly oscillated throughout the year with annual average value of about 33 ºC and 5 ºC respectively. Even though ambient temperature is significantly varied. This indicates that condensation and evaporation temperatures are not directly influenced by the ambient temperature. Figure 1. Daily variation of condensation, evaporation and ambient temperatures. Figure 2 shows load factor (LF) or also known as part load ratio of the WCAC systems (WCAC 1, WCAC 2 and WCAC 3 of the plant) presented daily for a duration of one year. The figure clearly shows the load factor varies at a narrow range from 73-100% (for WCAC 1), 70-100% (for WCAC 2) and 72-97.8% (for WCAC 3) with annual average 88.3, 84.7 and 85.0% respectively for WCAC 1, 2 and 3. These results reveal that the investigated shopping mall building operates with fairly stable cooling demand throughout the year. The cooling demand is slightly lower in July, August and November. Figure 2. Daily load factor variation of the WCAC 1, 2 and 3 of the plant. Figure 3. (a) Power consumption, (b) cooling capacity and (c) coefficient of performance (COP) of the WCAC systems (WCAC 1, WCAC 2 and WCAC 3) evaluated for the period of one year. Figure 3(a) shows compressor power consumptions of the WCAC systems. It can be seen the instant power consumptions of WCAC 1, 2 and 3 respectively fluctuate in the range 0.51-0.71 MW, 0.49-0.71 MW and 0.51-0.69 MW. The power consumptions are relatively low in July, August and November. The cooling capacities of the WCAC systems show comparable variation to the compressor power consumptions as presented in Figure 3(b). Average cooling capacities of the WCAC systems are almost the same of about 3.4, 3.3 and 3.4 MW for WCAC 1, 2 and 3 respectively. Total instant cooling capacity of the WCAC plant is ranging from 5.9 MW to 7.6 MW (for the investigated plant, two WCAC systems simultaneously in operation and one of the three WCAC systems alternately in standby mood). The annual cooling capacity of the WCAC plant are 6.79 MW. From Figure 2, 3a and 3b can be recapped that power consumption and cooling capacity are following part load ratio. Figure 3c shows the COP of the WCAC systems. The graphs show small variation of COP occurs during the year of investigation. It specifies that the COPs are nearly constant throughout the year. The COPs vary in the range of 4.9-6.2, 4.9-6.4 and 5-6.5 respectively for WCAC 1, 2, and 3. The annual average COPs for the three WCACs could reach 5.6, 5.6 and 5.8. These COPs are equivalent to overall efficiencies of 0.63, 0.63 and 0.62 kW/TR. From Figures 2 and 3c, it can be summarized that the system COPs have weak relationships to load factors of the WCAC systems. 3.2. Regression analyses of load factor influences on energy performance Figures 4-6 present results of regression analyses evaluated daily for a year investigation. Correlations between the load factors and performance parameters, which contain compressor power consumption, cooling capacity and COP, have been established. Figures 4, 5 and 6 show the regression analysis results for WCAC 1, 2 and 3 respectively. Figure 4 shows the correlations between load factor (LF) and performance parameters comprise instant compressor power (Wc) (Figure 4(a)), cooling capacity (Qe) (Figure 4(b)) and COP (Figure 4(c)). The correlation equations of the parameters are also written on the graphs. Similar presentations are also shown for WCAC 2 (Figures 5(a), 5(b) and 5(c)) and WCAC 3 (Figures 6(a), 6(b) and 6(c)). Figure 4. WCAC 1: Regression analysis the effects of load factor (LF) on (a) power consumption, (b) cooling capacity, (c) coefficient of performance (COP). Figures 4(a), 5(a) and 6(a) present relationship between load factors and compressor power consumption of the three WCAC systems. It is found that load factor strongly influences compressor power consumption with determination coefficient (R2) of 1.0. This means load factor has very strong positive correlation with the power consumption of the compressors. The correlations signify that both correlated parameters move in the same direction. The power consumption steeply increases when the load factor increases. When the load factor raises from 70% to 100%, the power consumption steeply increases for about 43% from 492 to 705 kW. This tendency occurs in all three WCAC systems. Figures 4(b), 5(b) and 6(b) show regression analyses between load factor (LF) and the cooling capacity (Qe) of the WCAC systems. The correlation equations of the parameters are also written in the figure. It can be identified that between load factor and cooling capacity also have positive correlation but it is not as strong as the power consumption. The cooling capacity gently increases when the load factor raises. The cooling capacity increases of about 33.4% from 2.83 MW to 3.78 MW when the load factor raises from 70% to 100%. The correlations have coefficient of determination (R2) of 0.35, 0.34 and 0.34 respectively for WCAC 1, 2 and 3. The results of analyses indicate that load factor have medium correlation and moderately influences the cooling capacity. Figure 5. WCAC 2: Regression analysis the effects of load factor (LF) on (a) power consumption, (b) cooling capacity, (c) coefficient of performance (COP). Figure 6. WCAC 3: Regression analysis the effects of load factor (LF) on (a) power consumption, (b) cooling capacity, (c) coefficient of performance (COP). The regression analyses between load factor and the COP are shown in Figures 4(c), 5(c) and 6(c). Load factor shows a negative correlation to the COP. The COPs of the WCAC systems decrease when the load factors increase. The correlations have various coefficient of determination (R2) of 0.29, 0.42 and 0.11 respectively for WCAC 1, 2, and 3. The WCAC 1 and 2 show medium correlations but weak for WCAC 3. In average, load factor and the COP have medium correlation which indicates that the increase of load factor can moderately reduce the COP of the WCAC system. For an increase of load factor from 70% to 100% can reduce the COP of the WCAC system for about 22.6% from 6.36 down to 4.92. From the regression analyses of this study, it was found that WCAC system could perform closed to its specification when operated at load factor from 70% to 85%. 4. Conclusions Energy performance characteristics of water cooled air conditioning (WCAC) system for commercial building at different load factors have been established and regression analyses were also performed to evaluate the correlations and effects of the load factors on the WCAC system performances. The study can be concluded: (i) The investigated shopping mall building operated with fairly stable cooling demand throughout the year with load factor ranging from 70% to 100% and annual average load factor of 85%; (ii) The load factor has a very strong positive correlation to the power consumption of the WCAC system. When the load factor raises from 70% to 100%, the power consumption steeply increases for about 43%; (iii) The load factor and cooling capacity have positive correlation but it is not as strong as the power consumption. The cooling capacity increases of about 33.4% when the load factor raises from 70% to 100%; (iv) The load factor has shown a negative correlation to the COP of the WCAC system. The COP decreases when the load factor increases. When the load factor increases from 70% to 100%, the COP reduces for about 22.6% from 6.36 down to 4.92; (v) The investigated WCAC systems could perform closed to their specifications when operated at load factors ranging from 70% to

85%. 5. References

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