Comprehensive review on Energy and Efficiency performance of water chillers

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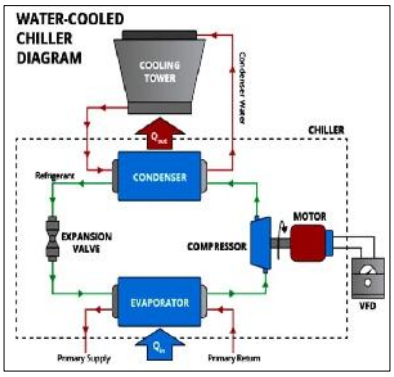
Abstract

Researchers Researchers are still focused on creating energy-efficient equipment and controlling methods because refrigeration and air conditioning systems like heating, ventilation, air-conditioning, and refrigeration (HVAC&R) water chiller systems, still consume a lot of energy in both commercial and residential buildings, and their operation is critical to ensuring the thermal comfort as well as other industrial purposes. The aim of the paper is to find out a technology to enhance chiller efficiency for energy management and energy savings in smart cities for chiller-based HVAC systems. HVAC&R equipment is a critical technology for minimizing building electrical energy usage. Few studies related to the overall system performance or the field experiments where some dynamic system characteristics might be lacking up to now. This paper provides a short overall review of enhancing the stability, efficiency, and reduction of electricity consumption of a water chiller refrigeration system employed in the industry and commercial buildings as well as in smart cities. If a system is a "closed loop" free of impurities, the water chiller will run more efficiently and last longer.

Keywords. Power consumption, Energy management, HVAC&R, Water chillers, Energy conservation, Smart city.

1. INTRODUCTION

A water chiller is a device that cools fluid below the surrounding air's temperature by removing heat from the water and transferring it to air through a heat exchange process using the basic components are a compressor, condenser, evaporator, and expansion devices with the mysteries of refrigeration cycles [1,2]. To achieve world-class manufacturing or reliability-centered maintenance in small, medium, and primarily large industries, the use of industry 4.0 technologies is critical [3]. The design of the water chiller for the industry level is customized by considering the client's requirements, and the appropriate product is recommended in smart



cities to increase energy efficiency and reduce repairs and increase reliability [4,5]. Refrigerant control is a successful instrument for increasing chiller efficiency as the effectiveness of a chiller can be impacted by contaminants in the refrigerant circuit because any leak allows air and moisture to enter the system and low-pressure chillers are more prone to contaminants[6,7]. The efficiency of the water chiller in HVAC systems decreases due to the loss of refrigerant via leaks. When technicians notice losses, they can able to find the leak if an appliance uses more refrigerant than recommended [8]. The cost of replacing refrigerants is reduced with prompt detection and correction, and chillers will continue to run as efficiently as possible improvements in efficiency[9]. Refrigerants can leak out of old chillers by 11-15% annually. Modern chillers with high-performance seals and specially designed pressure vessels can reduce annual loss to 0.1%[10]. An estimated 56.6% of a semiconductor factory SF's total electrical energy revenue goes toward powering the building's various facility systems in smart cities. About 27.2% of all electricity is used by the building's system [11]. Therefore, the government's energy-saving policy will center on research into ways to reduce energy consumption in smart cities' HVAC chiller systems, which is crucial work toward lowering the operating costs of SF[12].

2. KEY FINDINGS OF THE RESEARCHERS

Author: Type of Job	**Major issue present in Job**	**Techniques used by the researcher**
Rami Mansouri et al. (2022)[13] ; Energy performance and Environmental Impact	Global warming is caused by powerful greenhouse gases called refrigerants (CFCs, HCFCs, and HFCs). The carbon footprint concept is used to assess the environmental impact of food transport refrigeration systems on global warming.	TEWI values for various refrigerants were compared using the standardized technique created by AIRAH (Australian Institute of Refrigeration, Air conditioning, and Heating). We took into account the specifications of 240kW air-cooled vapor compression chillers that are commercially available.
Burky Anduv et al. (2021)[14] ; Energy efficiency	Finding defects is challenging based purely on visual inspection of maintenance employees.	Building automation systems (BASs) are frequently employed in contemporary construction. Developing trustworthy failure detection and diagnostic (FDD) techniques.
Yuying Sun et al. (2020) [15] ; Energy	Constant-speed air-cooled water chillers (CAWCs) are typically on-off operated with a fixed set	This article builds a general neural regression network (GRNN) model to reset two of a CAWC air conditioner (A/C) in real-time to

performance	point of chilled water return temperature, reducing their efficiency dramatically under part load conditions.	predict the best two values and achieve better control, developed by an optimal control method which can improve the indoor thermal environment and reduce the energy consumption of the air conditioning system by 11.0% during the cooling season.
Yijun Wang et al. (2019) [16] ; Energy conservation	The numerous chillers that are set up to produce chilled water for air conditioning account for a sizeable portion of their energy consumption.	Adding fresh load situations to the map periodically can enhance the performance in energy savings which is tested for eight weeks from August to September. During May to November the online chiller loading (OCL) indicates that the proposed strategy can achieve considerable energy saving. This is because the points on the near-optimal performance map guiding the proposed strategy have the chillers' best COP, and they can indicate near-optimal control for the chillers to save energy.
Yundan Liao et al. (2019) [17] ; Energy conservation	The stability of the system and additional cost brought by the sequencing activities are typically not taken into account in conventional chiller sequencing control. Operators turn off automated control mostly because of those quick or pointless sequencing activities.	By incorporating a cooling load forecast based on the ARX model into the standard chiller sequencing control logic that is based on the total cooling load. Study goal was to correctly limit the number of chiller switches in order to improve system stability and reduce operating costs. The duration of overcooling and under-cooling will lengthen as a result.
I Nyoman Suamir et al. (2018)[18] ; Energy consumption	The building chillers being studied are less energy-efficient and use more electricity.	Operation of chiller and energy conservation would benefit greatly from maintaining the quality and effectiveness of cooling towers. When a cooling tower with lower efficiency was used to operate the chiller, performance suffered.

F.J.S. Velasco (2018)[19] ; Energy efficiency	A 15% decrease in R450A's cooling capacity when compared to R134a. R1234ze (Cooling)'s capability has decreased by 25% compared to R134a.	The impact of compressor technology on this type of VCRS' overall performance. R513A is employed as a drop-in replacement for R134a.
Fu Wing Yu et al. (2016) [20] ; Energy performance	Constant-speed water-cooled centrifugal chillers' real working performance results in high power consumption, a low-performance coefficient, and high capital costs for commercial structures.	Replacing of water-cooled constant speed centrifugal chiller with a variable speed-controlled oil-free centrifugal chiller of the same capacity increased the average efficiency from 0.6 to 1 and the average system COP from 6.2 to 10.3. This reduced total power consumption by 9.6%.
A. Beghi et al. (2016)[21] ; Fault detection and diagnosis of HVAC water chillers by driven Data.	Less feedback datas are responsible malfunctioning operation is a significant obstacle in the development of effective Fault Detection and Diagnosis (FDD) procedures for HVAC installations. HVAC chiller system malfunctions can result in user discomfort, energy loss, system unreliability, and shortened equipment life.	For defect detection and isolation, a semi-supervised data-driven methodology is used. It uses Principal Component Analysis (PCA) to isolate factors associated with defects by separating anomalies from normal operating variability. The FDD algorithm uses data particularly gathered through laboratory tests to evaluate the performance of two types of systems: frictionless centrifugal and screw chiller systems.
Qi Jie Kwong et al. (2016)[22] ; Energy conservation	The advantages of radiant cooling systems in terms of energy efficiency and cost savings have been identified in numerous earlier studies. However, there may be a lack of statistics on the way to analyzing preliminary funding and preservation costs, especially for the slab-included model.	1. Radiant ground cooling is used in many buildings to maintain thermally acceptable conditions and some of the aforementioned research utilizing simulation and experimental approaches has acknowledged its efficiency in decreasing energy usage. 2. It also cuts the energy use in a tropical structure by 34%.

Leandro dos Santos Coelho et al. (2014)[23] ; Electrical energy conservation	If the chillers are handled incorrectly, the multi-chiller system's electrical energy consumption rises.	By utilizing the CSA (Cuckoo Search Algorithm), based on the infestation of certain cuckoo species chicks and their fighting behaviour, they can reduce power consumption. However, we can apply a more sophisticated technique called DCSA (Differential Cuckoo Search Algorithm),
Tzong-Shing Lee et al. (2012)[24] ; Energy Performance	VV-style finned tube condenser coils in large air-cooled water chillers are often designed with a top fan. This often results in uneven flow distribution and fluctuating wind speeds, lower than desirable heat transfer coefficients in the condenser, and impacts chiller energy and efficiency.	The impact of different condensing coil arrangements, such as variable fin configuration (VFC) or variable row configuration (VRC), on lessening airflow misdistribution across tiny air-cooled condensers. The VRC-designed condenser are analysis to optimize airflow distribution and improve heat transfer performance, increasing average wind speed and overall heat transfer coefficient by approximately 10.3% and 5.3%, respectively.
Kuei-Peng Lee et al. (2012)[25] ; Energy efficiency	Determining the ideal temperature settings and reducing chilled water system energy use for cooled and chilled water.	According to a model that employed a hybrid optimization technique that includes the Hooke-Jeeves and particle swarm optimization algorithms, the optimized settings lowered the entire energy required by the water chiller by 11.1% in the winter and 9.4% in the summer.

3. RESULT OF REVIEW

This paper takes a look at the water chillers, used in HVAC systems in smart cities that have been developed so far and are still being studied to improve further. Few reviews have been written regarding how to improve the chiller's effectiveness and how to use less energy. The refrigerant utilized in the chiller is also discussed. The review is on the numerous studies and experiments carried out by our researchers. The study also discovered that the chiller would operate at a higher condensing temperature as a result of the rise in cooling water temperature exiting the cooling

tower, which was a significant effect of connecting an inefficient cooling tower to the chiller. ARX model, GRNN model, FDD techniques and CSA algorithm, OCL strategies and many more algorithms-stragies and models can be used to increase stability, energy performance, and reduction of power consumption. We can also use R134a instead of R513a to increase cooling capacity.

4. CONCLUSION

After going through all the experimental paper that has been published by our researchers, we come to a conclusion that is as follows –

1. Stability of the system can be improved and also cost will reduce by adding a number of switches to the chiller.
2. The performance will increase if a higher-efficiency cooling tower will in use.
3. Energy can be saved by adding fresh load situations to the map periodically which also helps in enhancing the performance.
4. Cuckoo Search Algorithm is also a technique that can be used to reduce the electricity usage by the chillers.
5. The application of parallel processing to enhance simulation results without compromising accuracy is another area in need of attention from the growing research community.
6. ARX model can be used to incorporate robustness-adaptiveness and influence co-efficient estimation by sequencing control logic that can be used in standard chiller to increase the stability and reduced the operating cost.

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