A review of the future of district cooling systems (DCS) and its impact on smart city energy management

Ravindra Maanju*, Umesh Gurnani, Manish Jadoun, Rohitash Prajapati, Vijay dhayal , Shashank shekhar

Address: Department of Mechanical Engineering,

University of Engineering and Management, Jaipur

***Email: rmaanju@gmail.com**

Abstract

Research shows that the building sector uses 40% of all the energy that is made and contributes a lot to greenhouse gas emissions. The DCS system is a good method for managing energy and cooling in smart cities. The aim of this paper is to review the various technologies involved in this. Mid-class families in countries such as India cannot currently afford the refrigeration system; it is necessary to have the benefits of the DCS system to meet their needs, and it is very cost-effective. District cooling systems (DCS) are popular because they are cheap, save a lot of energy, and are more cost-effective than traditional cooling systems that use renewable energy .This review also looks at what DCS can do with renewable energy .The DCS system provides effective cooling with proper ventilation, and it is the cheapest technology, so you do not need to purchase a different air conditioner.

Keywords*:* Smart city, Energy Management, DCS, Chiller, ICS, ITS, Cooling system, Air conditioning

1. INTRODUCTION

District cooling is a cutting-edge and effective method for cooling large groups of buildings in urban areas and on college campuses. In a DC system, a central plant is home to sizable, extremely effective industrial grade equipment that creates chilled water for transmission to customer buildings through an underground network of insulated pipes [1]. In order to provide air conditioning, cold supply water enters the building and passes via a heat exchanger, absorbing heat from the building's interior [2]. District Cooling saves on capital expenditures associated with the installation of chillers and cooling towers are liberates precious rooftop and building space [3]. By combining the cooling requirements of various buildings, district cooling saves energy, water, and minimizes emissions. By using district cooling, can minimize costs and operating expenses related to huge individual chiller facilities 50% - 70% electricity demand in a building [4,5]. This paper gives a small review of the research on DCSs and how they can be used. DCS is explained in terms of its traits and problems.

The performance and progress of DCS systems that are integrated with sustainable energy technologies, such as systems that combine cooling, heating and thermal storage systems, are summed up [6]. The work done to improve the DCS is looked at and put into groups. It is well known that DC systems have the potential to help save a lot of energy, improve operational cooling ability, efficiency, flexibility, and reliability, and lower the cost and environmental impact of building air conditioning [7, 8].

2. Review Methodology

More than 102 papers that were relevant to the paper were examined from Scopus, Science Direct, Google Scholar, and the Web of Science. And to introduce several techniques for achieving the necessary cooling impact from the district cooling system, a summary sheet of the chosen research paper is created.

3. Literature Review

U.S. Choi et al. (1992) [9] Ice-water slurry, a friction-reducing additive, and the two-part combination have been compared in District Cooling Systems (DCS). The impact of the fluids on price and cooling capacity was examined individually for the new and the old DCS. Two criteria were used in each scenario to compare the fluids: constant pumping power, which offers the most advantage, and constant velocity, which is more practical. It has been demonstrated that utilising conventional district cooling technology would be highly expensive to enlarge the pipes in order to improve cooling capacity by the same amount as the ice-water slurry system. Keywords include cost-saving projections, district cooling systems, ice slurry, and a friction-reducing additive.

Wenjie Gang et al. (2015) [10] have noticed that DCS is simple to combine with renewable resources in the area in regions where heating is the primary focus. It’s important to investigate integration in both cooling-dominated and heating-required regions. A DCS can be cooled by water, ice, and PCMs. There is a need for better design and regulation of DCSs that incorporate heat storage devices. By increasing the difference in temperature between the return(hot) and supply(cold) water and reducing pipe resistance, the chilled water system's energy consumption can be reduced.

Xin Zhou et al. (2016) [11] study examines that impact of conventional air conditioning systems are responsible for energy consumption. But same time a district cooling systems in residential buildings used less energy. The system performance using simulations and field measurements in a residential building has determined in this study. Five separate AC use modes, ranging from mode A (the most frugal) to mode E (the least frugal), were categorised in a reduced-order and an AC-CP model that was created to represent conventional air conditioning systems consumption in the residential building area. This organisational strategy investigated the unpredictability of user composition. Some of the things he saw were the analysis of district cooling systems and the effect of various A.C. use modes on energy savings. According to the simulation results, there can be a 4.5-fold-variance in district cooling system(DCS) efficiencies depending on the AC use modes and user compositions. The performance of the district cooling system is impacted by the distributed cooling load requirements throughout houses and hours.

Luca Pampuri et al. (2016) [12] Even in moderate climates, space cooling is becoming an important and often overlooked energy need. Most of the time, electric appliances inside a building cool the space. This means that there will be a lot of problems in the summer when people use the most electricity. We need analytical methods for figuring out how much energy is used to cool spaces in cities or regions. This report is about research that was done in the southern part of Switzerland's Canton Ticino. It is based on real data from the local electricity company. The study looks at how much electricity big users use to find out if there is a big need for cooling, how this need affects electricity use, and if this need can be met by district cooling system (DCS).

Chengchu Yana et al. (2017) [13] have study effect of building load on DCS energy performance. The study indicated that when the Gini coefficient rises from 0.25 to 0.55, S-COP and COP-Plant decreased by 5.8% and 2.5%, respectively. Energy savings of up to 50% and 4% in total DCS energy consumption can be attained by carefully planning the grouping structure of secondary chilled water pumps. Chilled water distribution systems are more crucial in determining DCS energy performance than building cooling loads, according to the grouping coefficient, which has a greater impact on energy savings than the Gini coefficients of cooling loads.

G. Franchini et al. (2018) [14] have noticed that The two cooling plants studied use a single-stage absorption chiller with evacuated tube collectors and a two-stage absorption chiller with parabolic trough collectors (PTCs) (ETCs). To reduce costs and obtain a 0.7 annual solar fraction, an optimization technique determines the sizes off all major components. Over the course of a year, two plant layouts were simulated to assess energy performance under various operating situations. Efficiency and investment cost comparisons were made possible by the optimization based on component unit costs. This is because the two-stage absorption chiller has a greater efficiency (COP 1.39 vs. 0.723 at design circumstances) and the concentrated solar devices have access to a lot of direct normal irradiation (2296 kWh/m^2) (PTCs).

Abrar Inayata et al. (2019) [15] have noticed that Fossil fuel use damages the environment when trying to meet rising energy needs. There ought to be a way to stop using fossil fuels without sacrificing contemporary lifestyles. 40% of all energy used for dehumidification, heating, and cooling in a building. The majority of the world's greenhouse gas emissions come from buildings. Buildings receive central cooling from DCS. It's for networks in homes, businesses, and industries. Excellent energy economy, enhanced comfort and safety, lower operating and maintenance costs, and effective management and operation are all features of DCS. Using DCS with renewable energy is highly possible.

Valerie Eveloy et al. (2019) [16] gave A review on aiming on the requirements of cooling- subjugated regions, a small review of existing and emerging technologies of district-cooling system (DCS), operational factors, economic factors, and environmental factors, as well as analysis and optimization approaches, is offered. The incorporation of renewable energy sources with cooling/storage technologies, with a focus on heat-absorbing refrigeration, in a DCs design and analysis studies is examined. Published approaches for DC system analysis, modelling, and optimization are examined in terms of their goals, areas of application, sustainability-related standards, and major conclusions.

Maria Jangsten et al. (2020) [17] have analysis in 37 buildings and make a report of As the need for cooling in cities grows, Low delta-T, which is the difference in temperature between the water that goes in and the water that comes back out, often affects how well they work. The distribution system and the attached buildings' minimal temperature differences in DC systems with heat exchangers have not been extensively studied.

1. Operation on the primary side of the heat exchanger's saturation zone.
2. Secondary supply temperatures that aren't designed to meet the building's present cooling needs and/or when applied using secondary set points that don't take the outside temperature into consideration.
3. Low temperatures for the secondary return.

Kahramaa(2021) [18] (Qatar General Electricity and Water Corporation) According to Kahramaa, the district cooling system, the most energy-efficient way to cool a building, will reduce carbon emissions by roughly 10 million tonnes over the course of the next 15 years. The district cooling system covers 19% of the over-one-million-tonne cooling capacity. The DC plants power all of the FIFA World Cup Qatar 2022 stadiums. In Qatar, an air conditioning consumes 60 to 70 percent of total electricity, but district cooling can full fill same cooling requirement with using 40 percent less- energy compare to a conventional cooling methods. This results in significant financial savings. District cooling can help the economy, the environment, and society as a whole. Qatar saved 827 MW in electricity distribution capacity and 125 MW in electricity producing capacity between 2013 and 2019 by utilising district cooling. The research period saw a reduction in CO_2 equivalent emissions of 8,238 metric tonnes due to the usage of less fuel. District cooling (DC) is a method in which a central cooling plant distributes chilled water via a web of water pipes to multiple buildings.

Peipei Yu et al. (2021) [19] have noticed that important power constraint for the power reduction stage is ensured by a safe layer. Using a self-adaptive target technique, power rebound is minimised during the power recovery stage. During training, numerical calculations demonstrate that the DCS's operating power is consistently below the power cap, providing operating reserve "safety." Smooth recovery from a peak power rebound is possible for DCS operational power. The temperature variations in each building are kept to +_1°C for comfort. Usually, the skilled agent of the safe-DRL approach is able to treat DCS. If the physical system has changed, retrain the agent using the new system's historical data.

WeiZhang and WenpengHong (2022) [20] has suggested that one of the greatest cooling strategies for supplying a renewable, without dust or bacteria, and more effective cold water supply to cooling area is the aim of district cooling system (DCS). However, there is currently not enough research on the cooling control policy for each unit when the multiple cold sources in the DCS are pooled for cooling, especially when they are paired with ice thermal storage (ITS). This research provides a thorough out assessment of DCS and ITS performance in a sub-tropical zone and establishes suitable control parameters.

4. REVIEW RESULT

This paper gives an overview of the research and uses of DCS that have already been done. It is about how DCS can be used with different energy technologies, how design and operation can be optimized, and what else needs to be done. Combining DCS with the renewable energy and Integration with CCHP systems is most common in places where heating is the most important and needs to be studied in places where cooling is more important than heating. Most buildings in Asia that use DCSs are businesses and public buildings.

The work on designing the DCS is looked at from both a global and a subsystem point of view. The chilled water distribution system was the main focus of the subsystem design optimization. More research needs to be done on how to optimise the design of the parts of DCSs and multiple-stage construction in real-world applications. Over the coming decades, sustainable district cooling (DC) systems will become more crucial. This is because energy consumption in hot, humid areas is driven by economic expansion and population growth, while cooling loads are impacted by climate change. In this article, it examined that both current and future low-carbon energy-based sustainable space cooling systems that might be used in DC. In this article, challenges, existing situation, and future energy, environmental, and economic potential of DC in the GCC region, as well as the possibilities for modifying DC technology and controlling the market has discussed.

5. CONCLUSION AND FUTURE SCOPES

In terms of high-rise buildings, I don't see much of a challenge or change, but if you talk about smart cities or smart solutions, district cooling is something that is likely to grow in a big way. This has mostly to do with HVAC. We already have a plan in place in GIFT City, Gujarat. In many Middle Eastern and European countries, the idea is a common one. It involves a central cooling plant that sends chilled water to nearby buildings or whoever the customers are. The only heat transfer happens at the user end, where the chilled water is used for HVAC needs. Having a separate HVAC or chiller plant for each building is likely to become outdated in the future. Like with electricity, where each person has a metre that tracks how much they use, chilled water will also be metered in the future. Something like this hasn't caught on in India yet, but I think it will soon. In high-rise buildings, firefighting is the main problem, which is a big problem because the fire department isn't well-equipped to serve as expected because its equipment has limits on how high it can reach. For fire fighters to be able to put out any kind of fire, the fire detection and suppression systems inside a building have to be very strong.

6. REFERENCES

[1] P. A. stergaard et al., “The four generations of district cooling - A categorization of the development in district cooling from origin to future prospect,” Energy, vol. 253, p. 124098, Aug. 2022, doi: 10.1016/J.ENERGY.2022.124098.

[2] A. Anderson, B. Rezaie, and M. A. Rosen, “An innovative approach to enhance sustainability of a district cooling system by adjusting cold thermal storage and chiller operation,” Energy, vol. 214, p. 118949, 2021, doi: 10.1016/j.energy.2020.118949.

[3] A. Borodinecs, K. Lebedeva, N. Sidenko, and A. Prozuments, “Enhancement of Chiller Performance by Water Distribution on the Adiabatic Cooling Pad’s Mesh Surface,” Clean Technol., vol. 4, no. 3, pp. 714–732, 2022, doi: 10.3390/cleantechnol4030044.

[4] D. Mukherjee, S. Chakraborty, I. Sarkar, A. Ghosh, and S. Roy, “A detailed Study on Data Centre Energy Efficiency and Efficient Cooling Techniques,” Int. J. Adv. Trends Comput. Sci. Eng., vol. 9, no. 5, pp. 9221–9242, 2020, doi: 10.30534/ijatcse/2020/332952020.

[5] D. F. Dominković and G. Krajačić, “District cooling versus individual cooling in urban energy systems: The impact of district energy share in cities on the optimal storage sizing,” Energies, vol. 12, no. 3, 2019, doi: 10.3390/en12030407.

[6] O. Amer, R. Boukhanouf, and H. G. Ibrahim, “A Review of Evaporative Cooling Technologies,” Int. J. Environ. Sci. Dev., vol. 6, no. 2, pp. 111–117, 2015, doi: 10.7763/ijesd.2015.v6.571.

[7] S. Seyam, “Types of HVAC Systems,” HVAC Syst., 2018, doi:

10.5772/intechopen.78942.

[8] A. Afram and F. Janabi-Sharifi, “Theory and applications of HVAC control systems - A review of model predictive control (MPC),” Build. Environ., vol. 72, pp. 343–355, 2014, doi: 10.1016/j.buildenv.2013.11.016.

[9] S. U. S. Choi, D. M. France, and B. D. Knodel, “Impact of advanced fluids on costs of district cooling systems,” Argonne Natl. Lab., 1992.

[10] W. Gang, S. Wang, F. Xiao, and D. C. Gao, “District cooling systems: Technology integration, system optimization, challenges and opportunities for applications,” Renew. Sustain. Energy Rev., vol. 53, pp. 253–264, 2016, doi: 10.1016/j.rser.2015.08.051.

[11] X. Zhou, D. Yan, X. Feng, G. Deng, Y. Jian, and Y. Jiang, “Influence of household air-conditioning use modes on the energy performance of residential district cooling systems,” Build. Simul., vol. 9, no. 4, pp. 429–441, 2016, doi: 10.1007/s12273-016-0280-9.

[2] L. Pampuri, N. Cereghetti, D. Strepparava, and P. Caputo, “Analysis of the electricity consumptions: A first step to develop a district cooling system,” Sustain. Cities Soc., vol. 23, pp. 23–36, 2016, doi: 10.1016/j.scs.2016.02.015.

[13] T. T. Chow, K. F. Fong, A. L. S. Chan, R. Yau, W. H. Au, and V. Cheng, “Energy modelling of district cooling system for new urban development,” Energy Build., vol. 36, no. 11, pp. 1153–1162, 2004, doi: 10.1016/j.enbuild.2004.04.002.

[14] G. Franchini, G. Brumana, and A. Perdichizzi, “Performance prediction of a solar district cooling system in Riyadh, Saudi Arabia – A case study,” Energy Convers. Manag., vol. 166, no. January, pp. 372–384, 2018, doi: 10.1016/j.enconman.2018.04.048.

[15] A. Inayat and M. Raza, “District cooling system via renewable energy sources: A review,” Renewable and Sustainable Energy Reviews, vol. 107. Elsevier Ltd, pp. 360–373, Jun. 01, 2019. doi: 10.1016/j.rser.2019.03.023.

[16] V. Eveloy and D. S. Ayou, “Sustainable district cooling systems: Status, challenges, and future opportunities, with emphasis on cooling-dominated regions,” Energies, vol. 12, no. 2, 2019, doi: 10.3390/en12020235.

[17] M. Jangsten, T. Lindholm, and J. O. Dalenbäck, “Analysis of operational data from a district cooling system and its connected buildings,” Energy, vol. 203, 2020, doi: 10.1016/j.energy.2020.117844.

[18] D. K. B. T. AL THANI and D. K. M. AL-SHAFI, “District cooling to cut Qatar’s carbon emissions,” https://thepeninsulaqatar.com/, 2021, [Online]. Available: https://s.thepeninsula.qa/nf8921425

[19] P. Yu, H. Hui, H. Zhang, G. Chen, and Y. Song, “District Cooling System Control for Providing Operating Reserve based on Safe Deep Reinforcement Learning,” pp. 1–14, 2021, [Online]. Available: http://arxiv.org/abs/2112.10949

[20] W. Zhang, X. Jin, and W. Hong, “The application and development of district cooling system in China: A review,” J. Build. Eng., vol. 50, no. 104166, 2022, doi: https://doi.org/10.1016/j.jobe.2022.104166.