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Decision Support System in District Cooling System (DCS) Installation

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Abstract: District Cooling System (DCS) is consistent, profitable, and effective system intentionally used on district growth that encounters climate changes cause by nature loads and development. This study emphasizes on design consideration for existing building to install DCS focused on building capability, urban planning, and thermal prediction. Design consideration to install DCS and the characteristic required to install DCS in existing building area. Thematic analysis has been used in this study based on articles and pass research from year 2004 to 2021. The results conclude by the characteristic category DCS plant location, energy resources, economic city stage and type of building design compatibility. Result from the study shown that most DCS area located near to sea and the economic was in development phase area. Furthermore, the type of existing building needs to be Multi-Energy System (MES) to install the DCS system.

Keywords: District Cooling System (DCS), Air-Conditional (AC), Design Consideration

1. Introduction

Nowadays, it is important to save the environment and the normalizing the use of renewal energy has been implemented long time ago in Malaysia. Maintainable cities growth as meeting the necessities of the present without conceding the ability of future generations are important to balance environmental, living cost at the same time maximize profit by developing project system. DCS is an environmentally friendly technology for producing and distributing refrigeration using natural cooling resources. Generally, this research study describes the design of DCS that needed for existing building nowadays to installs DCS system. Thermal Energy Storage (TES) is a technology that store thermal energy in a storage medium so that it can be used later. TES shifts some of the electricity from the peak period to off-peak period (Mohd Hazzah Ahmad Siron,2015). DCS also applied this system which meet the requirements of air-conditioning in the future for building such as offices, hospital, hotel, campuses and residential.

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Tropical rainforest country such as Malaysia have average temperature 27 °C almost daily basis and the comfort providing by AC in these countries is practically essential for every building especially for big city areas where the temperature in normally high. In the other hand, Malaysia growth socioeconomic each year according to Socioeconomic Report 2019, the Malaysia economy raised at a modest rate of 4.3 per cent as equated to 4.8 per cent in the previous year. Energy sustainability should be limit in producing gas emission and prioritized natural energy that safer for the environment for next generation. Nevertheless, the increases of temperature are not obvious in current time but slowly rising in long term years effect. The solution into this problem are DCS that use natural and renewable resources such as lakes, seas and ground water. DCS centralize production of cold water and distributed by underground pipe network to the customer which is the surrounding buildings. Production can be constructed on various sources and technologies. Where excess cold is available from industrial processes, it can be used directly in the DCS and excess heat is available, absorption chillers can be used to produce cooling. Storage of cold water or ice can help increase energy efficiency and lower operation and maintenance cost. At the customer end of the system, the cooling is transferred to buildings in energy transfer substations (Gerardo L. et al., 2018). However, lack of study on design consideration of DCS to install in existing building cause slow practice of DCS in develop country.

2. Materials and Methods

This chapter was intended to describe appropriate methodology process to achieve the objective of this research study. Several methods have been using to conduct the study which divided into process of gathering information, process of analysis data and conclusion of the data. Figure 1 shows the Flow of Methodology process for the whole research study. This research study begins with searching for idea tittle for our research study. Problem statement gathered at first step. The problem facing divided into three. The first one was greenhouse gas emission that still contribute by existing building nowadays. Next, the high tariff of electricity and the increases of demand AC every year. Third is lack of design for existing building to install DCS.

DCS are system that use natural resources as cooling refrigerant and has been implemented in Malaysia for several places. Several methods use are thematic analysis and case study base on research study. Result will be categorized in table. The case study are online journal and research that study on the design on DCS. Several past studies shown the design categorized needed to intall DCS. This project consists on the implementation of DCS. It will go into detail about the current system of the building, with a subsequent analysis of the optimization of the system by the installation of a new water chiller system or district cooling system. This way, it will be finally analyzed the total costs of investment and an environmental study for those solutions. It must be said that the followed method is based in the handbook of district cooling and heating foundations carried out by the International Energy Agency. Starting by gather all the article, journal and document that related to the title and then base on the objective, the design criteria divided into 3 which is Central Cooling Plant, Distribution System and Energy Transfer System. After that data will be analyses and categorize base on objective two. If this answering both objectives continue to data analyses and lastly conclusion. After conclusion and finish the research study, this research comes to the end.

Table 1 shows the case study current building design DCS and data collection. This method used to answer the objective for this research study. This data collected from the field will be submitted to analyses using thematic analysis table. Assenting feature analysis will be used to recognize the dimension model and then followed by the structural equation model assessment. As a result, the beta amount between the variables will be established; therefore, the key determinants of criteria design for existing building can be identified.

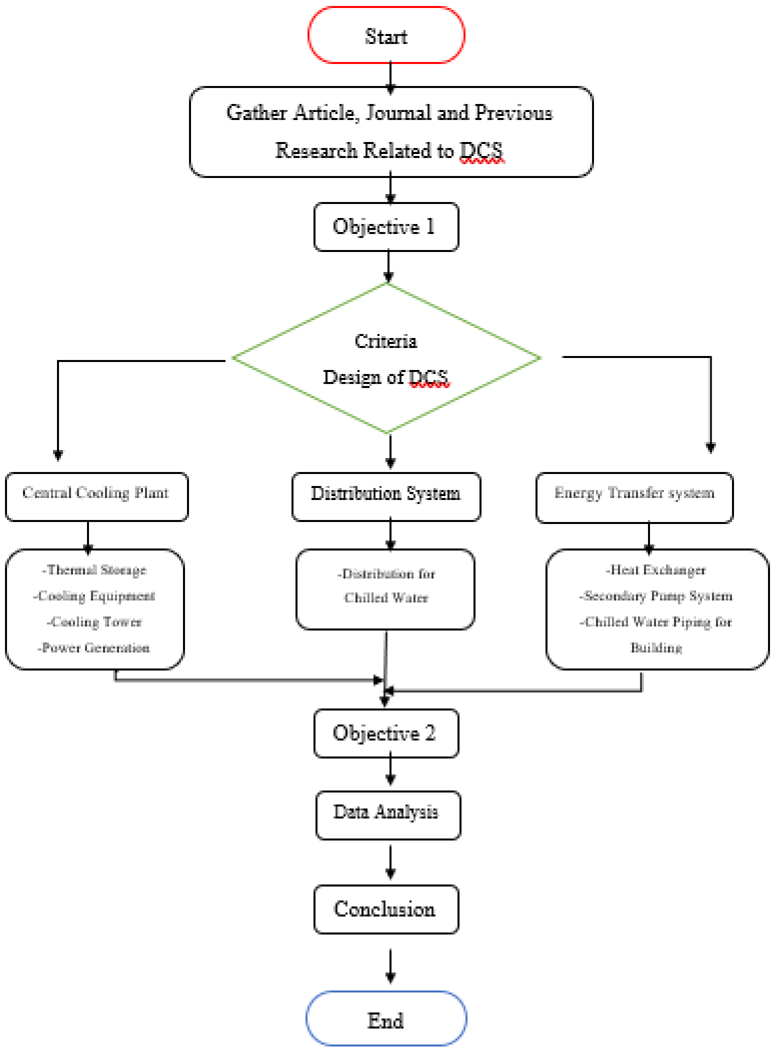

Figure 1: Flow of Methodology

Table 1: Data collection table

No.	**1**	**2**	**3**	**4**
Title	Electricity Cost Saving Comparison Due to Tariff Change and Ice Thermal Storage (Its) Usage Based on A Hybrid Centrifugal-Its System For Buildings: A University DCS Perspective 5 August 2013	DCS Using Central Tower Power Plant Solar PACES 2013	Identification of Design Criteria for DCS Network with Loop-Type System 22-25 August 2018, Hong Kong, China	Performance Analysis of a DCS Based on Operation Data

Author	Mohammad Omar Abdullaha, Lim Pai Yii A, Ervina Junaidi A, Ghazali Tambi A, Mohd Asrul Mustapha	C. Marugán-Cruza , S. Sánchez-Delgadoa , M.R. Rodríguez-Sáncheza , M. Venegasa	Gerardo L. Augusto	Xueqin Wua, Zhenqian Chena*
Problem	1. High ambient temperature of around 32–35 ◦C coupled with high humidity of near 85% during afternoon retro. 2. Total electricity charge is very high.	1. Some of the heliostats have to stop focusing at the central receiver, located at the top of the tower, because the maximum temperature that the receiver can withstand has been reached.	1. Piping system needs large initial investment cost; a thorough investigation would be required to properly design the network	DCS is recognized to be highly energy efficient compared to equivalent
Objective	A few DCS schemes are investigated to deliver "what-if analysis" and to minimize the overall electricity charges	To analyse possibility of exceeding heliostats to the receiver increasing the mass flow rate of the heat transfer fluid over the nominal value and using the extra heat as a source of an absorption chiller	Optimal design of DCS distribution network with loop-type system is needed determine the piping network design criteria that yields minimum overall cost.	Planning and operation for the plant at the next stage. On the other hand, the operation experience.
Method	Analysis Case study	Analysed the case	Exhaustive search method	Analyse
Result	Scenarios designed for the application of centrifugal with and without ice-thermal storage (its) systems on the buildings were investigated It was found that, due to the local	Chilled water would be used to cool buildings and offices, using a district cooling network. Using the extra heat of the solar power tower plant would greatly reduce the electricity usage	A district cooling distribution network model with loop-type system was investigated by calculating the system pressure drop, system volumetric flow rate and volumetric flow rate for each building Numerical results were also compared with traditional methods and have found some degree of similarities of pipe sizes except for pressure drop values exceeding 100 Pa/m	The lower value associated with the low occupancy ratio and lower temperature difference.

	tariff status, marginally saving can be achieved in the range of 0.08–3.13% if a new tariff is adopted			
Conclusion	Marginally exchangeable is mainly due to the local tariff conditions and lower local temperature range (t) which are less promising as compared with those reported in the literature elsewhere.	A circular field of heliostats focusing at a circular receiver, such as the case of Gem-solar plant. The quantified the thermal power that can be obtained from the unused heliostats, the cooling capacity of the absorption system as well as the heat losses through the insulated pipes that distribute the chilled water to the buildings of the network	The governing equations consisted of mass conservation, performance curve of variable primary flow pumping scheme, energy equations due to pipe friction and an equation that indicates the algebraic sum of head losses around any closed loop must be zero. Multivariable Newton-Raphson method was used to solve the system of nonlinear equations with the elements of solution vector determined using singular-value decomposition method.	The cold source production indicator for the whole cooling season was 28.93 W / m2, which was much lower

Table 1 shows the case study current building design DCS and data collection. The data will be using to categories and answer the objective for this research study. This data collected from the field will be submitted to analyses using thematic analysis table. Assenting feature analysis will be used to recognize the dimension model and then followed by the structural equation model assessment. As a result, the beta amount between the variables will be established; therefore, the key determinants of criteria design for existing building can be identified.

3. Result and Discussion

Table 2: Data Analysis

No.	Research Title; Author	Year	Description phrase	Category
1	Applying District-Cooling Technology in Hong Kong, T.T. Chow A, W.H. Au B, Raymond Yau B, Vincent Cheng B, Apple Chan A, K.F. Fong A.	2004	'Together with the convenience of bringing in **seawater**'	Environment
2	Energy Modelling of District Cooling System for New Urban	2004	District cooling technology is advantageous in warm and hot climatic regions, in that chilled water from a central refrigeration plant is. Delivered through a distribution network to	DCS Plant Location

	Development, T.T. Chowa, K.F. Fong A, A.L.S. Chan A, R. Yau B, W.H. Au B, V. Cheng B		groups of buildings. The technology is most **suitable for new urban development's system.** Design and construction receive much freedom.	
3	District Cooling, A Technology with Great Potential of Application, K. Papageorgiou, D. Anastaselos and A.M. Papadopoulos	2006	Contribution role of the **renewable energy sources** such seawater in this field˙ the decentralized production and distribution of thermal energy. It is remarkable that such units can **operate in combination with co-generation units,** where the surplus or the total of the thermal energy is converted into cooling energy.	Environment
4	District Cooling and Heating with Seawater as Heat Source and Sink in Dalian, China Li Zhend.M. Linhaiwen Shuhaiwen Shushow, Syingxin Zhuyingxin Zhu	2007	Study indicates that the use of **ocean thermal** energy in Dalian shows a promising prospect soon, which may be one of the most promising renewable energy resources that have great potential for development in China.	Energy Resources: Seawater
5	Optimal Size and Layout Planning for District Heating and Cooling Networks with Distributed Generation Options, Dr. Damiana Chinese	2008	**Consideration of plant location aspects developed cost minimization.** Nevertheless, minimizing pipe lengths and by reducing pipe diameters: thus, size reduction for capital cost optimization is common in water engineering systems design.	DCS Plant Location
6	Technological and Economic Evaluation of District Cooling With Absorption Cooling Systems in Gävle (Sweden) Elixabet Sarasketa Zabala	2009	The **plant room space requirement of the heat exchanger is much smaller than a chilled water plant for the building.** The interior space and penthouse area of the building can therefore be maximized, and neither will there be any need for installing a cooling tower or air-cooled condenser for heat rejection. No maintenance of the chiller plant, or about replacement of chiller plant upon the end of its service life. From a broader perspective, **DCS have the benefit of economic of scal**e and thus can reduce energy consumption and hence there will be less greenhouse gas emissions and atmospheric pollutants from power plants.	Economic City Stage
7	Study on The Decision-Making of District Cooling and Heating Systems by Means of Value Engineering, Haiwen Shu A, Lin	2010	Also implies that privileges of policy for renewable energy utilization system are necessary to help. Promote the energy-saving and environment-friendly scheme of **seawater source heat pump system**	Energy Resources: Seawater

	Duanmu, Chaohui Zhang, Yingxin Zhu			
8	District Cooling for Al Hamra Village in Ras Al Khaimah-United Arab Emirates (UAE), Withanage Chanaka Sameera Perera	2011	Typical Meteorological Year (TMY) weather file and oceanographic data for the site location is generated throughout the year. Among these **oceanographic data, sea water temperature has been found as playing the most important role for deciding the selection of system**	Energy Resources-Seawater
9	An Evaluation of District Energy Systems (DES) in North America: Lessons Learned from Four Heating Dominated Cities in The U.S. And Canada Lauren T. Cooper, University of Michigan Nicholas B. Rajkovich, University of Michigan	2012	The design, operation, and maintenance of **DES represents a new business opportunity for electric and gas utilities. Overall, the paper finds that local communities should emphasize DES because they are the direct beneficiaries of these systems.**	Economic City Stage
10	Feasibility Study for a District Energy System City of Courtenay, Stephen Salter P.Eng., Leep Ap.	2013	The economics of district energy for new buildings such as the planned Comox Valley **Hospital and the planned Mission Professional Buildings will be evident for existing buildings,** since the cost of boilers and dedicated utility spaces can be avoided for new buildings served by district energy.	Building Design Compatibility
11	Innovative Applications of O.R. Optimization Models for a Single-Plant District Cooling System Reem Khir Mohamed Haouari	2015	That explicitly capture the structural aspects as well as both Pressure- and temperature-related requirements, are developed and tested. The results of **computational experiments that demonstrate the practical effectiveness** of the proposed models are also presented.	Building Design Compatibility
12	Analysis of The Electricity Consumptions: A First Step to Develop A District Cooling System Luca Pampuri A, Nerio Cereghetti A, Davide Strepparavaa, Paola Caputo B	2015	Space cooling represents an increasingly and often understated important energy demand even in moderate climates. Usually **space cooling is provided at building level by electric driven appliances.**	Thermal storage estimation

13	Performance Assessment of District Cooling System Coupled with Different Energy Technologies in Subtropical Area Fu Xiao, Diance Gao	2015	In the **subtropical urban area with a high density of buildings, DCS is regarded as an efficient alternative to supply cooling to a group of buildings with high efficiency and low cost.**	Building Design Compatibility
14	The Rebound Effect in District Cooling Systems: Analysis Based on Case Studies and Surveys in China Siyue GUO, Da YAN, Shan HU,Xin ZHOU, Andong ZHU,	2016	It could be seen for **different district systems, the energy use, energy efficiency and cooling load can be quite different by usage mode, system design, pricing scheme, etc**. Most district systems, **people use more cooling, which makes higher energy use with higher EER**. systems when the occupants keep the operation mode of decentralized systems, the cooling usage may be not much higher, in some cases like that of decentralized systems, but the **system should be designed carefully to fit the low load rate.**	Building Design Compatibility
15	Technical and Economic Evaluation of District Cooling System as Low Carbon Alternative in Kuala Lumpur City Liu Wen Huia,B, Haslenda Hashima,, Lim Jeng Shiuna, Zarina Abdul Muisa,B, Liew Peng Yena, Ho Wai Shina,	2017	Buildings in Malaysia, most of them run on individual AC system which is less efficient. To meet a **minimum cooling load of 250 kw, a building needs 37 conventional electrically driven ac compressor system. As a result, individual AC has the highest electricity consumption about 1,600 MWH/Y.**	Thermal load estimation
16	Optimal Design of a District Cooling Grid: Structure, Technology Integration, and Operation, Fadi Al-Noaimireem Khirreem Khirmohamed Haouarimohamed Haouari	2018	The use of a technology mix that taps into the effectiveness of compression cooling and the environmental benefits of absorption cooling is considered. **A novel mixed-integer nonlinear programming model is developed to find the optimal structure**, layout, operating strategy, and mix of cooling technologies that minimize the total investment and operational cost	Building Design Compatibility
17	District Cooling System via Renewable Energy Sources: A Review Abrar Inayata, Mohsin Razab	2019	According to different studies, **building sector consumes around 40% of the total energy produced and it is and high energy efficiency**. DCS is a centralized system of supplying the thermal energy in form of chilled water for use in space cooling and	Building Design Compatibility

			dehumidification. In addition, DCS integrated with renewable energy is economically feasible when compared to conventional cooling systems.	
18	District Cooling Versus Individual Cooling in Urban Energy Systems: The Impact of District Energy Share in Cities on the Optimal Storage Sizing, Dominik Franjo Dominkovi´C 1, and Goran Kraja˘ci´	2019	Optimal DCS share was 30% of the total cooling energy demand for both developed scenarios, one that did not. In the scenario that **considered existing spatial constraints for installations, optimal capacities of methane and thermal energy storage types were much larger than capacities of grid battery storage, battery storage in vehicles and hydrogen storage.**	Building Design Compatibility
19	Gothenburg District Cooling System an Evaluation of the System Performance Based on Operational Data, Maria Jangsten	2020	Study of DCS and some of its **connected buildings and the DCS evaluation data base on its operation**.	Building Design Compatibility
20	Energy Flexibility as Additional Energy Source in Multi-Energy Systems with District Cooling Alice Mugnini, Gianluca Coccia, Fabio Polonara, and Alessia Arteconi	2021	The analyses carried out underline the importance of the **activation of building energy flexibility as an additional energy source in an MES** with district cooling. Indeed, its exploitation appears fundamental to making it possible for control to maximize energy performance. It should also be noted that, even if the MPC shows good performance for individual building optimization in the presence of an MES, this could lead to a deterioration in performance for other users when there is a constrained shared source	Building Design Compatibility
21	A Techno-Economic Assessment on the Adoption of Latent Heat Thermal Energy Storage Systems for District Cooling Optimal Dispatch and Operations Stefano M. A, Jia Y. S	2021	"The adoption of **Thermal Energy Storage System (TES) as part of a DCS** arrangement is Essential for ensuring optimal and efficient operations of the systems due to the chilled water temperature fluctuations	Thermal load estimation

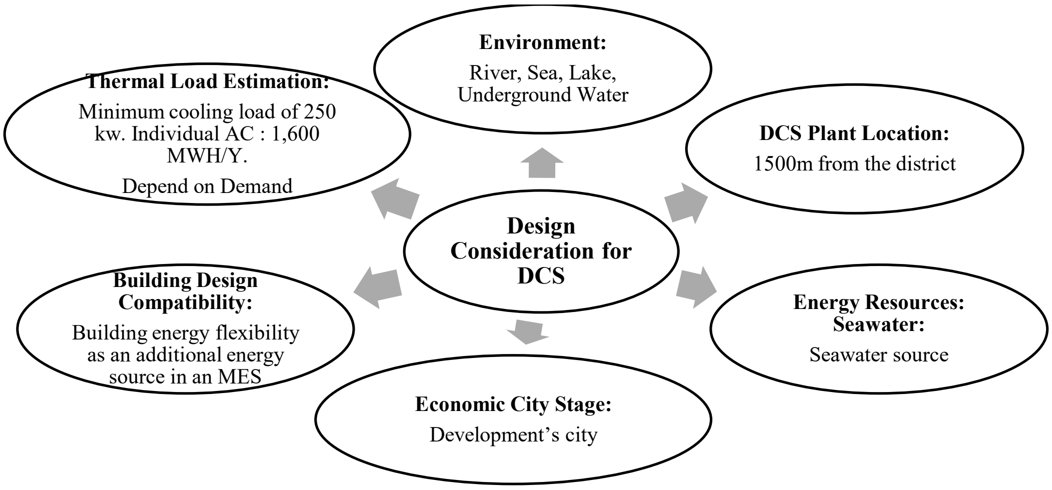

Figure 2: Design consideration of DCS system

From the Table 2 shows the studies data from year of 2004 to 2021. Most of case study shown that the location to install DCS closed to seawater as cooling refrigerant. Furthermore, DCS are large-scale production plant that convenience of bringing in seawater as a condenser cooling, the chiller plant is higher in efficiency than AC individual. As a recommendation, city that reached more than 500 MW of cooling load could be served by more than one DCS. From this study, despite of large investment cost, DCS not only can reduce electricity loads but also reduces carbon emission compared to other cooling systems. Besides, hot and humid weather in Malaysia due to development can optimized DCS using absorption cooling feasible as the technology are able to use the "free" and abundant waste heat or renewables as fuel, therefore it is more supportable and decreases the reliance on grid electricity. Resources most DCS system around the world use seawater as cooling or heating resources. The distance from sea water can be more than 1500 m from the district. This because of the plant produce noise leak. Load estimation is the foundation for designing a DCS.

Figure 2 show the design consideration of DCS system analyzed from Table 2. Design consideration for DCS location sea to district need to be consider depending on the cost, town planning and engineering plan. Economic city state most case study shown develop area that contain consumer building and high demand toward electrical and AC system. Building representation and planning needed to be consider in DCS design consideration as it affected the system operation costs even the system uses renewable energy. Though, before structure and implementation of DCS, it is significant to conduct more system limitations and optimizations that represents the real situation which can perform at its optimum operation conditions while diminishing the system cost and evade needless energy wastage. Environment consideration to install DCS needed multiple buildings where pipping network system can be installed. Study also shows that, DCS system can be maximize on existing building that support MES.

Table 2: Design consideration of DCS

Country	Hong Kong, China	Singapore	Malaysia	Dubai	Sweden
DCS plant	Kai Tak Development	Keppel DHCS Changi	DCS Megajana Cyberjaya	The Dubai Metro, Al Ringga DCS	Gothenburg Smart DCS
Population	86,000 people	5.45 million	140,000 people	10,279	579,281
Cooling Capacity	284 (MW)	37,500 (RT)	14,000 RT	10,000 TR	70 MW

Resources	Seawater Intake	Seawater intake	Seawater Intake	Underground water	River water
Area	1.7 million square metres	1 million sqm gross floor area, equivalent of 60 buildings.	48 buildings customers, 12 km underground network	0.6574 km²	447.8 Km, 30 km of piping
Economic stage	New development area	Growing, Manufacturing Sectors, Business and Ship, stage country	sustainable economic and smart city, development as a technological hub	Dubai Metro City Station (Mall, Oil and Gas, Hotels)	industries include motor vehicles, telecom, pharmaceuticals, machines, equipment, chemical goods,
Plant location	Public housing estate	entire business park	cities	Metro City	Cities
Energy resources	Chilled water	Chilled water	Chilled water	Chilled water	Chilled water
Economic city design	Hong Kong Airport area	High technology business, data and software enterprises, research and development divisions and knowledge intensive facilities.	48 buildings	Mall such as City Centre Deira, Dubai International Airport, Bur Dubai, BurJuman, the Dubai Mall and Mall of Emirates	large and different types of buildings
Building design capability	Support MES	Support MES	Support MES	Support MES	Support MES
AC Demand	35 percent average electric consumption	37,500 refrigeration tonnes (RT)	16,000 RT	30% to 50%	420 GWh

From the Table 3 above, show that the population start from 10,000 can install DCS. Besides, the cooling capacity minimum 10,000 TR support DCS with area within 0.6574 KM^2. For the economic stage, it's impossible to measure the real data of economic stage however, from the data, the cities must at least sustain economic, development area and consist of variety of industry. From the table above, the cooling resources made of seawater, underground water and river water. The cost of installation, built and starting operation of DCS are usually higher, however, the payback after period are much less economical.

4. Conclusion

As conclusion, the criteria for designing DCS provide the wide view on large population and high economic activity demand and commercial region to install. This provides beneficial to consultant centralize and large plant that distribute to few buildings at the same time. Accurately assessing cooling loads distresses, the design, operation, and cost-effectiveness of the DCS in many ways, as well as ensuring sufficient but not excessive plant and distribution capacity, providing the ability to cost-effectively meet the daily and periodic range of loads and providing a foundation for accurate profits projections. Investing in installing DCS into existing building needed further and extra inspect to optimize the model. Minimizing the operation costs such as the operational, pipeline and infrastructure purpose the importance on installing DCS. Besides reducing the heat rejection from existing building and maximize the use of natural cooling resources, design consideration needed solidity to achieve benefit impact of the system presently and in the future. From the research study, some recommendations are made for system supported DCS. The recommendation are as below:

I. Population: The population of the city that support DCS system minimum 10,000 people and above.
II. Cooling Capacity: Minimum cooling capacity DCS can produce can be 10,000 RT and above depending on the demand and costumer building.
III. Resources: The best resouces can be Seawater or River water.
IV. Area: Area for each city that can support DCS system are minimum 29.0 km^2 due to the initial cost and payback cost of the system.
V. Economic stage: The area must be developed area, consist of business, residential area, industries building and airport.
VI. Building design capability: Building capability must for existing buing must support MES system

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