Challenges of District Cooling System (DCS) Implementation in Hong Kong

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Abstract: The District Cooling System (DCS) is one of the most important green features to materialise the sustainability vision of HKSAR Government. Its application was found in the Kai Tak Development (KTD) and other planned new developments in Hong Kong. By applying the DCS, benefits can be realised through cooling load sharing amongst the diversified cooling requirements, reduced standby capacity and spatial requirements. Apart from reducing the overall plant space, the operational cost, maintenance cost and energy efficiency can also be improved substantially and therefore be more cost-effective throughout the building life-cycle. Yet, there are many challenges on implementing the system. Issues on land use, planning, design, environmental, institutional and regulatory arrangement are substantial. This paper will discuss some of these challenges and the possible solutions for the DCS installed in Hong Kong

District Cooling; District Energy; Energy Efficiency; Air-Conditioning; Sustainable Design; Low Carbon Planning

Introduction
The use of electricity for air-conditioning system in Hong Kong contributes 29% of our total electricity consumption [1]. Nowadays, providing comfortable indoor environmental conditions for the occupants of offices and other public spaces is a basic requirement. Energy efficiency of our air-conditioning system is therefore imperative on achieving the energy saving target of the society as a whole. Energy codes on controlling the design of air-conditioning and other building services systems are now in place in Hong Kong.

Amongst different energy-efficient systems, DCS is the most sustainable solution for the planning of a new district, in which chilled water can be distributed through a network of underground pipes from a large scale centralized chiller plant to multiple buildings. It is particularly suitable for developments with high-density or clusters of buildings, which minimizes the infrastructure required for the distribution of chilled water to buildings of different uses.

A successful DCS has to be planned and designed with enhanced system performance and economics in mind. This is done by optimizing the design of chilled water production and the associated distribution network, therefore enhancing the energy efficiency and financial viability. Based on the most recent experience of DCS systems in Kai Tak Development (KTD), it has a potential to save 20% to 35% energy as compared with traditional air-cooled
air-conditioning systems and water-cooled air-conditioning system. The users can also enjoy a better quality and reliability of services.

In addition to a better energy efficiency, there are other environmental and planning benefits by adopting DCS, such as:-

- Reduced water consumption
- Reduced carbon footprint
- Minimised noise and vibration impact
- Flexibility in building design
- Saving in plantroom space
- Reduced operating redundancy
- Enhanced system reliability

When developing the implementation strategy of a DCS, it is necessary to consider the business environments and constraints of providing cooling services to the district. In particular, the viability of the DCS service is highly susceptible to the specific project constraints including the urban and utility planning requirements, development programme and potential users and provider(s) etc. Cost model and financial analysis are essential to evaluate the potential of the DCS as a business in the market to compete with alternative cooling technology — i.e., that potential customers will connect to the DCS if it promises to be not more expensive than installing alternative cooling.

**DCS systems at Kai Tak District**

The KTD DCS is the first of its kind innovative cooling method to be implemented in Hong Kong. It is one of the key initiatives of the 2008-09 Policy Address when the Government planned to implement the DCS to promote energy efficiency and conservation. KTD is a mixed development with a GFA of over 1.7 million m² of non-domestic air-conditioned area in the old Kai Tak Airport area. The development includes commercial offices & retail, government offices of various departments, transport infrastructure, community buildings, hotels and both public and private housings. The DCS will serve all the buildings of KTD, with the exception of domestic developments. The feasibility study, system design and implementation were commenced from year 2000 to realise this innovative and energy efficient system. By using seawater for heat rejection, there is further energy saving and also have more open spaces released to the public through removal of cooling towers. Figure 1 shows the masterplan of KTD DCS.
The KTD DCS comprises two separate plants and associated chilled water distribution network and customer substations. The south DCS plant room, named South Plant is situated underground at the previous flight runway at Kai Tak serving the South Apron and Runway Boulevard of KTD. The plant adopts variable primary flow chilled water system with direct seawater cooled heat rejection method.

The north DCS plant room, named North Plant is situated at the northern end of Kai Shing Street and adjacent to Kwun Tong Bypass in KTD serving the North Apron. Same as the South plant, the chiller system is a variable primary flow with direct seawater cooled heat rejection arrangement. The main distribution chilled water pipe is a 3-pipe ring circuit direct buried underground.

The DCS project is funded by The Government of the Hong Kong Special Administrative Region and is being implemented in three phases (Figure 2). Phase I works are mainly on pipe laying and Phase II works on construction of chiller plant rooms, seawater pump house, and other associated facilities were started in February and March 2011 respectively. Works in
these two phases are scheduled to tie in with the earliest development in KTD, including the Kai Tak Cruise Terminal and public housing estate. To serve the remaining developments of KTD, Phase III works on installation of additional electrical and mechanical equipment and extension of pipes commenced on July 2013.

The South Plant commenced operation in February 2013, serving Kai Tak Cruise Terminal. And the North Plant also commenced operation in May 2013, serving the new developments at the North Apron area.

With a design capacity of 284MW, the KTD DCS will reduce electricity consumption by approximately 35% compared to conventional air-cooled system. The maximum annual saving of electricity is expected to be about 85 million kWh, equivalent to a reduction of 59,500 tonnes of carbon dioxide emissions from the development.

**Challenges on DCS Implementation**

Despite the advantages of DCS experienced in KTD, full implementation of DCS in Hong Kong faces many challenges and makes it difficult to reach its full potential.

**Site planning and interfacing issues**

The sites for the construction of DCS plants and pipeworks are extensive and the construction will generally be carried out in phases extending over a long period. Inevitably there will be interfaces with other infrastructure, especially at the chilled water and condensing water pipeworks. Lot of interfacing issues is common and may happen even in green field site. An integrated planning approach is required to minimize its complication on construction and therefore the potential escalation on cost.

Whenever an interfacing issue is identified, coordination has to be conducted with concerned parties to deal with the constraints and to resolve the conflicts, preferably during the early scheme design stage.
Discharge of condensing water

Direct seawater cooling method was adopted by the KTD DCS, implying that seawater will be drawn from the Victoria Harbour and discharge back to it for heat reject. An exercise for the approval of Environmental Impact Assessment (EIA) has conducted in the early planning stage. The water quality criteria (for temperature, biocides and residual chlorine) for cooling water discharges have been agreed with Environmental Protection Department (EPD). The Near field and far field numerical models were then be used to assess impacts of seawater intake for cooling and thermal effluent (seawater) discharge. Typically for cooling water discharges, a water temperature of 2°C above ambient should be achieved at the edge of the mixing zone. To prevent short-circuiting of the intake and discharge locations, intake water temperature should be less than 0.5°C above ambient.

The CORMIX model developed by USEPA was used for predicting near field thermal plume behaviour. The Cormix model provides information on the spread (plume width), dilution and trajectory of the thermal plume. Where necessary the boundary conditions of the near-field will be extracted from the far-field model. Different tidal conditions would also be taken into considerations. Far field modelling was carried out using the Delft3D suite of models. Detailed models for the Victoria Harbour, the Eastern Buffer, and Western Buffer Water Control Zones have been set up, calibrated, verified, were discussed and agreed with EPD.

Compliance with Water Quality Objectives has also been assessed based on the water quality modelling results. Statistical analyses of water quality, temperature changes, biocide concentration, residual chlorine etc, were conducted at representative indicator points in the zones of interest. Some of the indicator points were located at the same EPD routine monitoring stations to check for consistence with historical data. Based on modelling results, the distance separation needed between the intake and discharge locations were determined so as to prevent short-circuiting by cooling water discharge.
Figure 5: Thermal model and water quality model for planning of seater intake and outfall location along the Victoria Harbour.

Construction challenges

For the pipe-laying works, both open trench method and trenchless excavation method were adopted. Trenchless excavation method was applied in some sections, where existing site constraints are prohibitively high for constructing any trench. This method can minimize the disturbance to the public.

Trenchless method by means of Tunnel Boring Machine (TBM) was used. It has the advantages of giving limited disturbance to the surroundings and producing a smooth tunnel surface. However, in using the TBM for constructing the DCS pipes, there are limitations on curve radius and generally the maximum tuning angle of bored tunnel is 5 degrees. There is also a requirement of a minimum site area for the jacking pit and receiving pit which depend on the size of drill head. In addition, sufficient working space for sediment/slurry treatment tank and TBM operation and control room should also be required.

Pipe Insulation

As the DCS pipework involved an extensive network of underground pipework, the amount of heat gain in the pipework has a significant impact to the energy efficiency and cost effective of the system. The heat gain of the underground pipework system depends on the type, thickness and thermal properties of insulation, pipe diameter, chilled water temperature and ambient condition. In order to obtain an optimum thickness of the insulation, the heat gain calculation against the cost with different thickness of insulation has been carried out and concluded that factory-prefabricated insulation by using polyurethane with 65mm thickness has been adopted. All necessary components are prefabricated at the factory which can not only control the workmanship and quality, but also minimize the installation time at the site.
Leakage Detection System

As most of the pipeworks are direct buried, monitoring system is therefore required to check the pipework performance and allowed early warning if it has any leakage. Water leakage detection system installed to monitor the DCS distribution network so that the DCS service provider will carry out remedial action once leakage is found along the pipeline. This can provide early warning to the service provider and also provide systematic monitoring to the pipework performance. The leakage detection system is addressable so that it can identify the leakage within a certain length and leak detection sensitivity level must be able to be adjusted at site to suit the condition. Sensing cables shall be installed in factory together with pre-insulated pipework to maintain good quality.

Testing and Commissioning

For the system as complicated as the DCS, Testing and Commissioning (T&C) plays a pivotal role on its normal operation and energy saving in long-term. Systematic approach is required to ensure all the components are function at its designed performance and the entire system at its maximum efficiency. Three level of checking were proposed for the T&C plan:-

1) **Components and Plant Level** - Specifications for sub-system components specifies quality requirements, performance requirements and life time requirements, which allows for review of fabrication and factory testing of components. Typically, a plant was inspected and tested after installation on site in order to secure that no damage has occurred during transport. For major equipment such as chiller, FAT test was carried out before delivery to ensure the performance is satisfactory.

2) **Sub-systems & DCS Pipework Level** - After delivery / installation of components and subsystems, such as chiller, pump, pipework etc, close supervision was enforced by experienced engineer and subsequently tested for joint functionality in accordance with specifications.

*Figure 7: Non-destructive Test for field welds on DCS pipework*
3) **Overall System Level** – This is the functional Testing of the entire DCS System. The tests shall demonstrate the compliance of the Contractor’s works with the design requirements. The test demonstrates the ability of the DCS System to operate at the optimum efficiency. Verification of system redundancy including failure of equipment and burst of sectional pipeline shall be included.

![Figure 9: Functional test of DCS system (a)Embedded water leakage detection cable in direct laying DCS pipework; b) Hydraulic pressure Test of DCS Pipework](image)

**Conclusion**

DCS delivers significant benefits both in terms of environmental, comfort, operational efficiency, energy conservation, flexibility in planning and superior system reliability. The recent KTD DCS has demonstrated the commitment of the Government on implementing the concept in Hong Kong. Yet, the entire planning, design, construction and operation process are not without difficulties. Integrated designs as well as innovation in construction technology of DCS are the key to success. In long run, DCS (if widely adopted in Hong Kong) could play an essential role in de-carbonizing Hong Kong and promoting more innovations to our construction industry.

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