De-carbonizing Hong Kong-What energy strategies are effective?

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Abstract. Buildings account for 67% of carbon emission and up to 90% of electricity consumption of Hong Kong. One third of our electricity is used on air-conditioning, which naturally become a key to decarbonization of the City. District Cooling System (DCS) is one of the most important sustainable infrastructures as stipulated in the Hong Kong’s Climate Action Plan 2030+. As one of the key initiatives to increase the awareness of energy efficiency concept to the community, the HKSAR Government has promoted the adoption of DCS in the Kai Tak Development (KTD) and other planned New Development Areas (NDA). By applying the DCS, the cooling load could be shared amongst the diversified cooling requirements of various building types in the same district, thus the benefits including the improvement of energy efficiency, reduction of standby capacity and spatial requirements can be enjoyed. In recent years, Hong Kong has amassed many experiences on DCS. Successful implementation of DCS at KTD has provided many valuable know-hows on its design, construction and operation. Many challenges on the implementing DCS including the land matter, design, planning, environmental and regulatory arrangements have been resolved and paved the way for the wider application in other NDAs such as the Tung Chung New Town Extension (East) and Kwu Tung North. For each of these NDAs, many site-specific constraints are required to be investigated and addressed. This paper will discuss the DCS implementation issues, highlighting the lessons learnt and the possible solutions for wider adoption of DCS in Hong Kong.

1. Introduction

Hong Kong has acceded to the Paris Agreement and will follow its reporting timeline. In its Climate Action Plan 2030+ paper, the HKSAR Government seeks to make Hong Kong a better and smarter place to live and work. It is targeted to reduce its carbon intensity by 65% to 70% using 2005 as the base [1]. Recently, a public consultation exercise was conducted to set a target beyond 2030. Sector-wise, buildings account for 90% electricity consumption and 60% carbon emission in Hong Kong according to Hong Kong Energy End-Use Data 2016 issued by Electrical and Mechanical Services Department (EMSD) of HKSAR Government [2] (Figure 1). Among the various electricity uses in buildings, air-conditioning is the largest portion (about 30%) of consumption, energy efficiency for air conditioning becomes imperative on achieving our target on carbon emission reduction.
DCS has been adopted in many countries and was found to be a sustainable infrastructures and energy efficient systems for the planning of air conditioning system in a large new district. With the aid of underground chilled water pipes to form a distribution network, chilled water can be distributed from the centralized chiller plants to the DCS consumer buildings. Since 2000, Hong Kong has been investigating its implementation in the territory. It is particularly suitable for Hong Kong where the developments are with high density or clusters of buildings, such that the infrastructure required for the distribution of chilled water to the buildings of different uses can be minimized. The design of the chilled water production shall be optimized such that the system performance can be enhanced. DCS centralizes the source of cooling energy to serve consumer buildings, thus high tonnage chiller shall be adopted so that better coefficient of performance (COP) can be achieved. This arrangement can also enhance the reliability of services of cooling energy provision to the end users. According to the experience of DCS in KTD, approximately 20% and 35% of energy can be saved compared with traditional air-cooled air conditioning system and water-cooled air conditioning system respectively [3], [4], [5] &[6].

Apart from energy saving, DCS would also be beneficial to the DCS consumers in terms of environmental and planning concerns:

1. More flexible building designs for consumer buildings because they need not install their own chillers and the associated electrical equipment in their buildings; Also, elimination of the heat rejection equipment (eg. cooling tower) at roof of consumer buildings can save outdoor space for the greenery.
2. By adoption of seawater as heat rejection media, cooling tower installation at the centralized chiller plant can also be omitted. Thus the heat island effect can be eliminated.
3. Reduction of the capital cost by approximately 5% to 10% of the total building cost due to the elimination of the chiller plants and the respective builder’s works
4. Minimization of noise and vibration impact arising from the operation of chillers to the DCS consumer buildings, as the chillers are located in the DCS plant which is away from the consumer buildings.
2. Kai Tak District Cooling System

KTD is a huge development project spanning a total area of over 320 hectares (Figure 2). The planned total non-domestic air-conditioned area is 1.73 million m² comprising of mixed building types including hospitals, hotels, schools, commercial buildings, sport facilities, etc. Since high cooling demand and diversity of cooling load profiles were anticipated, the feasibility study and system design were commenced from year 2000 to implement this innovative and energy efficient system. The DCS project is funded by The Government of the Hong Kong Special Administrative Region and is being implemented in phases. Phase I and Phase II works were completed in 2012. Figure 2 shows the masterplan of KTDCS and chilled water distribution pipe arrangement in KTD. Some key lessons learnt are discussed as follows:-

Figure 2: Masterplan of KTDCS and DCS Distribution Network Arrangement

2.1. Market Solution

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. Tariff is one of the critical parameters to identify if adoption of DCS is financially viable. A fare tariff should consider the risk of investor and provide the incentive for the DCS consumer to save the energy use. In KTDCS, the proposed tariff aims to achieve full recovery of DCS investment over its project life in 30 years. The cost comparison with the adoption of conventional water cooled air conditioning per unit of cooling energy system is considered in order to attract the potential DCS consumer to use DCS, such that the uptake rate of DCS in KTD could be escalated to operate DCS in a more energy efficient way.

2.2. Reliability

To enhance reliability of the DCS service, a bank of chillers in each plant was designed with a range of cooling capacities such that breakdown of any one chiller will not cause adverse effect on the operation of DCS. The main distribution chilled water pipe, with total pipe length of about 40 kilometres, is a 3-pipe ring circuit direct buried underground. Two out of 3 pipes are used during normal operation (i.e. supply / return pipe). To further enhance system reliability, besides the adoption of ring circuit, 3rd pipe was installed as standby purpose. With respect to electrical provision, the power serving DCS plants are fed from two supply sources such that if any one source fails, the supply will be automatically switched over to another source and ensure 100% power supply can be maintained.
2.3. Energy efficiency and management

The operation for DCS plant commenced in 2013 to serve the DCS consumer buildings in KTD. With a design cooling capacity of 284MW, the KTDCS will reduce electricity consumption by approximately 35% compared to conventional air-cooled system upon completion of the project in 2022. 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. The implementation of DCS at KTD to provide more energy efficient air-conditioning services for all non-domestic buildings is the first of its kind in Hong Kong. The system performances of DCS in KTD are monitored by an automatic computerized system, namely the District Cooling Instrumentation, Control and Communication Systems (DCICCS). DCICCS consists of the optical fibre network for data transmission and the automatic computerized monitoring system for central-control and remote-monitoring. Figure 8: North DCS Plant Control room and DCICCS Interface

3. Conclusion

DCS can deliver benefits to the operation efficiency and energy conservation, as well as increase the flexibility in planning and superior system reliability. The recent KTDCS has demonstrated the commitment of the Government on implementing this sustainable infrastructure concept in Hong Kong for combating climate change. Integrated designs as well as innovation in construction technology of DCS are the key to success. Thus DCS could play an essential role in de-carbonizing Hong Kong if this can be adopted appropriately. In view of the foreseeable huge energy saving, the HKSAR Government is exploring the feasibility of DCS implementation in a number of new development areas in Hong Kong to further foster low-carbon development, including the NDA at Tung Chung New Town Extension (East) and Kwu Tung North etc. The potential saving in energy on air conditioning will be enormous for Hong Kong when the DCS is realised in the coming years.

References

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