# Engineering Design for Power Supply to District Cooling System at Kai Tak Development

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**Abstract** — The Kai Tak Development (KTD) will generate substantial new demand for air-conditioning. The Government is grasping this opportunity to promote energy efficiency in the provision of air-conditioning in this area by implementing a District Cooling System (DCS) for public and private non-domestic developments.

The DCS is a large scale centralized air-conditioning system which produces chilled water at the central chiller plants and distributes the chilled water to user building for air-conditioning purpose. The DCS is an energy-efficient air-conditioning system as it consumes 35% and 20% less electricity as compared with traditional air-cooled air-conditioning systems and individual water cooled air-conditioning systems using cooling towers respectively.

With this new central cooling network, the need for chiller plants and cooling towers on top of each building in future will be taken away. Apart from the reduction of upfront capital cost for chiller plants at the buildings, this also allows more flexible building designs and be so beneficial to the designers. Moreover, the DCS is more adaptable to the varying demand for air-conditioning than individual air-conditioning.

To meet the high expectation and requisite of reliability for a district cooling system, there is a genuine need for a dual feed supply from Power Company to enhance the power relaibility for the southern and northern DCS Plants cum seawater pump house. And, resilience design is adopted for the engineering design of the landlord 11kV and LV power supply distribution.

## I. INTRODUCTION

A District Cooling System (DCS) is a large scale centralized air-conditioning system to produce chilled water at its central chiller plants and distributes the chilled water to user buildings of various air-conditioning loads. The DCS is an energy-efficient air-conditioning system as it consumes 35% and 20% less electricity as compared with traditional air-cooled air-conditioning systems and individual water-cooled air-conditioning systems using cooling towers respectively. The technology has been widely adopted around the world.

From the perspective of individual users, the DCS would bring about the following benefits:

(a) reduction in upfront capital cost for installing chiller plants at their buildings, the reduction is estimated to be about 5 – 10% of the total building cost;
(b) user buildings do not need to install their own chillers and the associated electrical equipment thus allowing more flexible building designs;
(c) noise and vibration arising from the operation of heat rejection equipment and chillers of air-conditioning plants in buildings can be reduced as there will not be any need for such equipment for buildings subscribing to DCS; and
(d) the DCS is more adaptable than individual air-conditioning system to the varying demand for air-conditioning.

KTD, with a planned total of about 1.7 million square metres ($m^2$) in public and private non-domestic air-conditioned floor areas requiring about 284 megawatt (MW) cooling capacity, presents a unique opportunity for implementation of a DCS in Hong Kong. As announced in the 2008-09 Policy Address, the Government plans to implement a DCS at KTD to promote energy efficiency and conservation.

The DCS project can bring about significant environmental benefits. By implementing the project, the maximum annual saving in electricity consumption will be up to 85 million kilowatt-hour, equivalent to a reduction of 59,500 tonnes of carbon dioxide emission per annum.

The project is to construct a large scale centralized air-conditioning system which produces chilled water at its central chiller plants and distributes the chilled water to user buildings in KTD through an underground water piping network. The scope of works comprises (a) construction of a northern chiller plant; (b) construction of southern underground chiller plant cum underground seawater pumphouse and above-ground operational facilities; (c) laying of seawater intake and discharge pipelines; (d) laying of chilled water distribution pipe networks; and (e) provision of connection facilities including heat exchangers at user buildings.

The project is currently implemented in three phases to match with the development schedule of KTD. The Phase I and II works include the construction of core facilities comprised of the northern and southern plant rooms and pipelines to the first package users, such as Cruise Terminal Building. The contracts for Phase I and Phase II have been started in February 2011. The Phase III works, which is mainly the pipe laying and installation of chillers, are under planning and will be implemented in accordance with the development schedule of KTD. A conceptual layout plan of the proposed DCS is shown in Figure 1.

The DCS is for public and private non-domestic developments at the KTD. All public developments in the region will connect to the DCS provided that their implementation programme can match the development schedule of the DCS. With a view to increasing the subscription rate and maximizing environmental benefit of the project, the Government has actively explored the feasibility of the suggestion of mandatory connection of private non-domestic projects in KTD to the DCS by prescribing such requirements in the land lease conditions.

To meet the high expectation of reliability for a DCS serving the whole area of KTD, the electrical supply and distribution system is a key factor to the secure and continuous operation of the plant.

## II. Electrical Installation

### Reliability of District Cooling Plant

According to District Cooling Best Practice Guide published by International District Energy Association, DCS shall achieve a reliability exceeding 99.94%.

In view of this, the power supply design to the DCS in both HV power supply from power company and customer distribution transformers side are also targeted to achieve this criterion.

The DCS will be taken to have a robust commercial arrangement of 3-legged cable supply from power company. This arrangement offers 99.99% reliability level such that each of the cable carries 50% of the required electrical load, therefore failure of any one of the cable will result in no reduction in the power supply condition.

### 11kV Incoming Power Supply from Power Company

To secure power supply reliability for DCS, 11kV power supply fed from two supply sources is adopted such that when one source fails, the power supply will be automatically switched over to the other source.

The 11kV switchboards inside the power company zone substation should be of double busbar arrangement. With the closed ring circuit system, there will be no power interruption in case of fault of any one cable or during installation of additional customer substation.

### Power Company Zone Substations for DCS

The DCS requires both HV (11kV) and LV (380V) electrical supply to Southern Plant (underground seawater pump house & underground southern DCS plant) and Northern Plant (northern DCS plant) as shown in Figure 1.

Southern Plant and Northern Plant will be supplied from separate zone substations in order to further minimize the interruption to the DCS in case of power supply failure.

The power for Southern Plant will be supplied by the zone substation at Cruise Terminal. In the meanwhile, the Northern Plant will be supplied by the power company zone substation at Eastern Road which is currently under construction and will be commissioned by the first quarter of 2012.

In view of the long distance cables run and minimization of energy loss in power transmission, HV (11kV) supply taken from the power company substation will be adopted.

The step down from 11kV to 380V for equipment will be accomplished by landlord distribution transformers inside the two Plants. Cast-resin dry type transformers are to be provided with the following advantages: -

- insulated with an epoxy resin/quartz powder mixture, an environmentally friendly material, that makes the windings maintenance-free, moisture resistant, flame-retardant and self-extinguishing;
- no gas inclusions in the epoxy resin casting process;
- more compact; and
- as quiet as oil-immersed types.

### HV Power Supply to DCS by Landlord

Apart from the 11kV/380V transformers and switchgears, 11kV landlord supply to HV chillers is also required due to large capacity of chillers. Thus, HV distribution system with vacuum circuit breakers is adopted for power supply to the HV chillers to provide longer design life, less maintenance but higher reliability.

Electronic protection relays are applied in view of its advanced features and technical advantages over conventional relays such as continuous self monitoring and self diagnostic features, sophisticated relay characteristics, fast protection time, ability to capture system fault information, remote communication, built-in control and metering functions, etc.

### Resilience Design of Power Supply to DCS

As to achieve resilient and reliability of the power system and eliminate single point of failure in both 11kV and 380V electrical distribution, the following arrangements will be adopted: -

(a) In the 11kV side, every two 11kV supply feeder will be paired-up to work as a group to achieve 100% redundancy in terms of power supply capacity. It means that one feeder takes up 50% of the total load supply for the reason as stated before. Each pair of 11kV 7MVA supply feeders will be arranged form two different sources (namely source A & B) so that in case of failure of source A 11kV feeders, source B 11kV feeders will take up 100% of the connected loads by closing the tie section breaker. (Figure 2)

(b) In the LV side, customer transformers are grouped together in groups of three (3) customer transformers. Each transformer group will be normally loaded to maximum at 80% - 20% - 80% respectively for optimization of resilient design by offering minimal spare capacity of the transformers and to ensure no interruption to the loads in case of breakdown of any one of the transformers within the group. In case of failure of a transformer, another transformer can take up 100% of the connected loads by closing the tie section breaker. In addition, the supply source to the three transformers will be arranged in “Source A – Source B – Source A” or “Source B – Source A – Source B” so that supply to LV switchboards will be maintained even the changeover mechanism from source A to B (or source B to A) if the HV side failed. (Figure 3)

(c) To achieve higher utilization of the 20% loaded transformer in the “80% - 20% - 80%” arrangement, standby plant equipment including chillers, associated chiller pumps and cooling towers, etc. will be connected to the 20% loaded transformer with changeover mechanism to other 20% loaded transformer. (Figure 4)

Practically, standby plant equipment remaining idle for long time may deteriorate or result in dysfunction when put into operation even with regular checking during routine maintenance. To avoid this, N+1 arrangement of equipment is to be adopted on rotation basis. Each equipment will have to operate as duty one according to the programmed sequence. As such, each of the equipment group will operate continually and the 20% loaded transformer will be loaded more in accordance with the operation sequence.

## III. Total Power Demand

### Total Power Demand of Entire District Cooling System at ultimate phase

A total of about 90 MVA power supply will be required for the entire DCS, which demands for 28 nos. 7MVA 11kV supply feeders. The 28 nos. 11kV supply feeders will then distribute to HV chillers and 32 nos. 2,000kVA dry-type customer transformers.

### HV Tariff Metering

Utilities meters and its associated metering panels will be provided and located in the 11kV switchrooms of the power company. Summation metering will be applied.

During DCS operation, record of on-site electricity consumption will be taken through the District Cooling Instrumentation, Control and Communication Systems ( DCICCSs).

## IV. Transient Over-voltages and Harmonics

Apart from the reliability of power supply to DCS, concerns on surges (transient over-voltages) shall also be considered as it may cause disastrous consequences due to power interruption incurred.

### Lightning Strikes and Switching

Lasting from microseconds to milliseconds large transient over-voltages can be caused by the secondary effects of lightning by electromagnetic pick-up (inductive coupling) or differences in potential between two connected earths (resistive coupling). Moreover, intentional or unintentional switching operation (earth faults or short-circuits) can cause surges too.

To mitigate the surges, surge protection devices (or referred to as arresters) are to be installed at mains power supplies to divert transient surges and to limit impulse currents.

### Motor Starting

Motor starting methodology of large capacity motors (in the order of several hundred kW) is taken into consideration in mitigating the high inrush current and voltage sag during start-up. In this regards, variable speed drive (VSD) will be used for starting of water pumps.

The VSD shall protect itself against the following: -

- phase unbalance at the supply port;
- earth fault at the output terminals;
- over current;
- over temperature;
- over voltage;
- under voltage; and
- loss of control.

The VSD shall protect the motor against the following: -

- short circuit;
- overload;
- over temperature;
- phase unbalance and single phasing; and
- earth fault.

### Harmonics

The impacts of harmonics to mains power supply and electrical installation is commonly known and aware nowadays. DCS uses large amount of non-linear equipment like VSD, switching mode power supplies, electronic devices that may cause adverse effects. Harmonic filters shall be provided for all VSDs and major non-linear loads to achieve the requirements specified in COP for the Energy Efficiency of Electrical Installation.

## V. Conclusion

To ascertain the deliverable benefits of DCS – convenience, flexibility, reliability, maintainability and energy efficiency, the design of power supply and distribution to DCS plant equipment plays a crucial role. The design engineers are continuously working closely with the power utility company, contractors and DCS operator so that a sophisticated and comprehensive electrical installation can be accomplished in a complete-solution approach throughout the whole project including procurement, construction, and commissioning of a high-efficiency DCS plant.

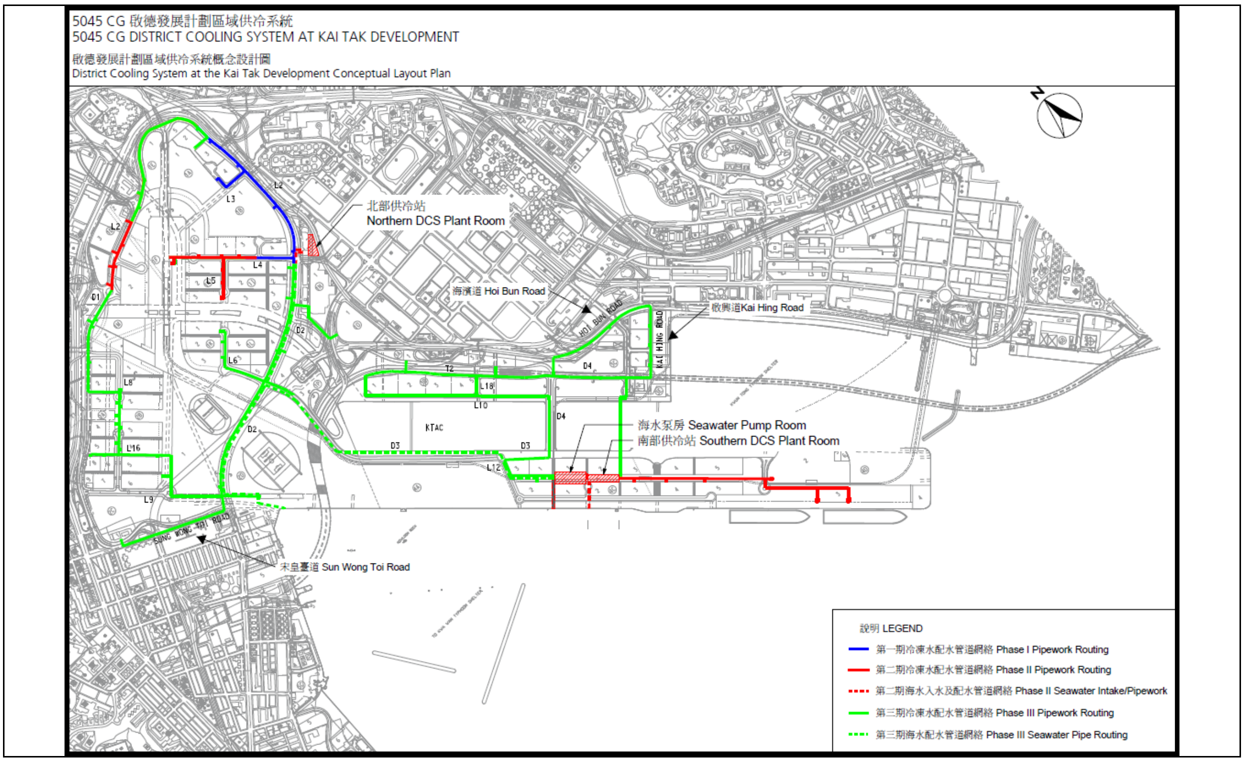


Figure 1: Conceptual Layout Plan of DCS

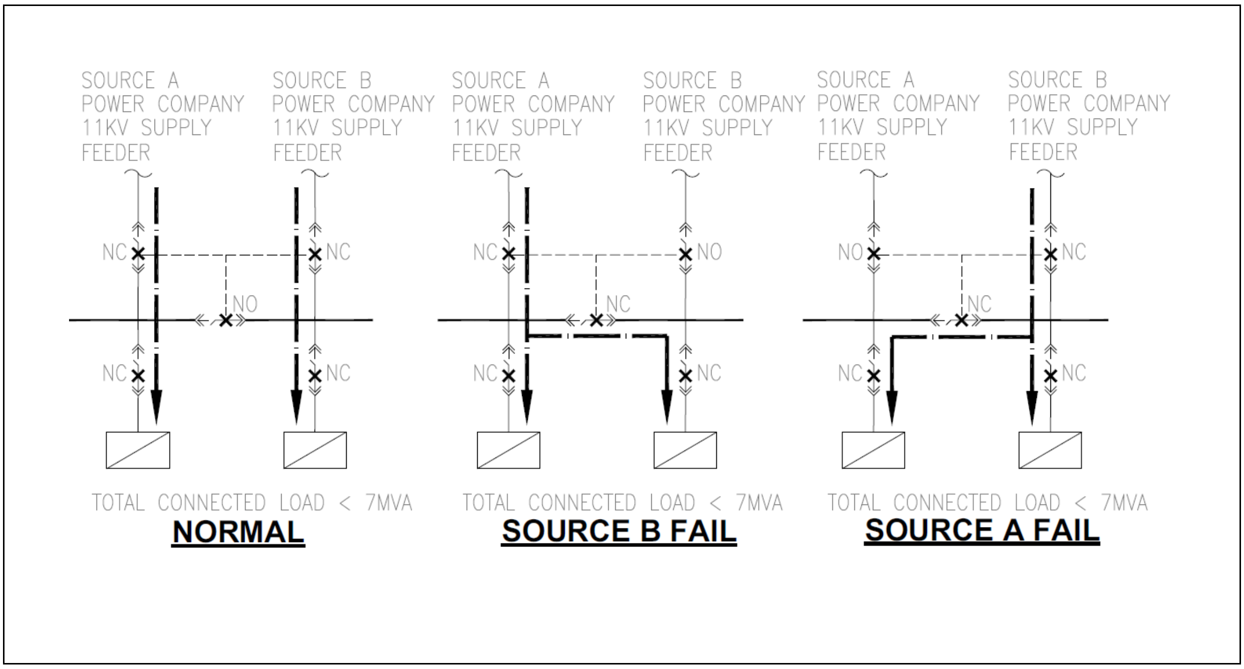


Figure 2: Power Company 11kV Supply Arrangement

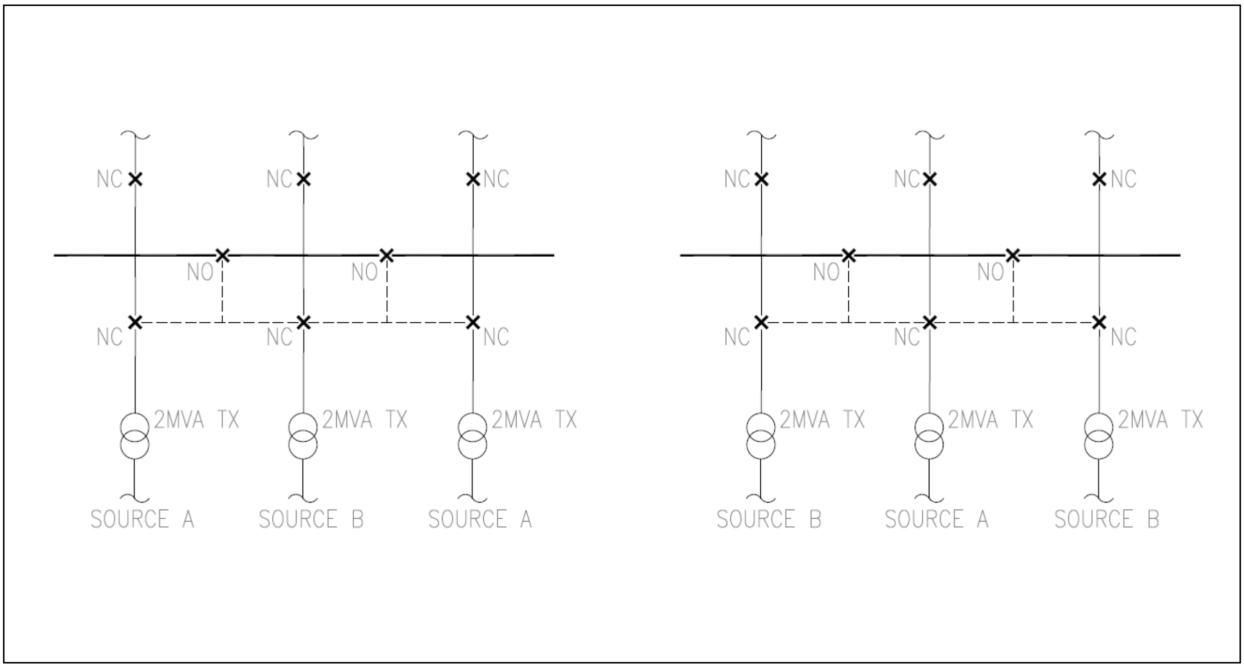


Figure 3: Transformers and LV Supply Arrangement

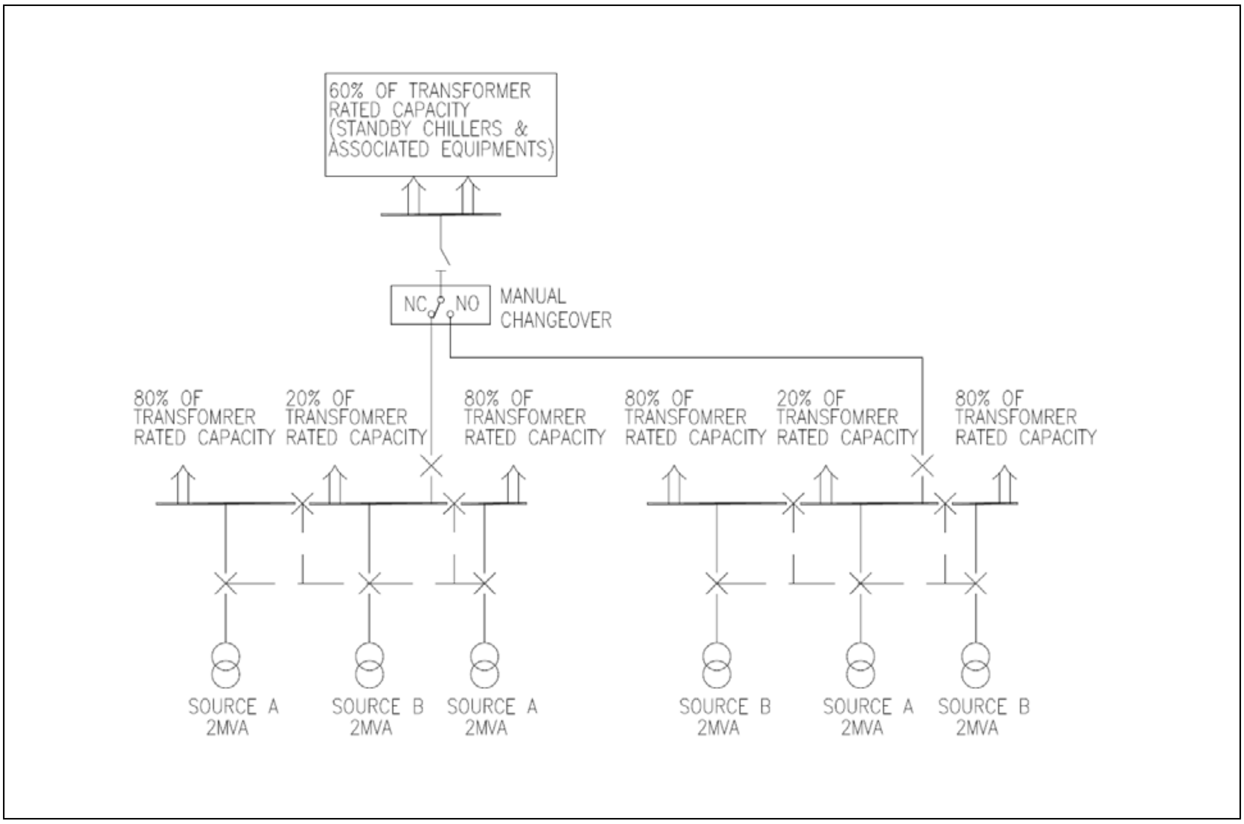


Figure 4: Arrangement to Achieve Higher Utilization of the 20% Loaded Transformer