International Journal of Engineering Research and General Science Volume 3, Issue 4, July-August, 2015
ISSN 2091-2730

District Cooling Conversion System: A Case Study

Ms. Gagan kaushik [#1], Mr. Sachchida Nand [*2]

Jagannath University, Jaipur

India

Abstract—This paper presents the study and implementation of district cooling system. In a district cooling approach cooling is served for group of buildings. This study is aimed to show the DCS conversion suitability of the existing buildings in India by the case study. In existing infrastructure there is no requirement for load calculation, and also we know the actual load profile for each building. It is observed that sometimes buildings are designed with excess tonnage of refrigeration that could not be fully utilized. To take advantages of above known factors, existing HVAC system is modified with sharing of loads.

Different organizations have different load profile during a day. The two different buildings are chosen for the study. This analysis is completed to model a DCS for these two organizations. Most of the time both buildings run at their part load. It allows to design a centralized chiller plant for lesser load than the cumulative load by opting a lesser value of diversity factor.

Keywords— Centralized chiller plant, District Cooling, Diversity Factor, HVAC, Load profile, Part Load, Ton of refrigeration .

1. INTRODUCTION

Chilled water plant serves to meet the large cooling demand of an organization. Industrialization and modernization led to the drastic increase in the use of air conditioning system for cooling the buildings as well as such large consumers of HVAC Come Closer To Each Other. All around the World. The Last Two Decade Has Witnessed A Severe Energy Crisis In Developing Countries Especially During Summer Season Primarily Due To Cooling Load Requirements Of Buildings. An Organization Has To Pay A Big Amount For The Installation And Further Maintenance Of Central Air Conditioning System. It Is Also Responsible For The Increasing Consumption Of Energy Which Led To Environmental Pollution Resulting In Global Warming And Ozone Layer Depletion.

District Cooling System Eliminates The Need To Establish The Individual Chiller Plant. The Idea Of Centralized Cooling Is Similar To District Heating In European Countries Except To Supply Chilled Water Than Heated. Ahmadabad In India Is Also Planning To Use The District Cooling System For Its GIFT city in Gujarat.

In centralized cooling system chilled water is distributed in pipes from a central cooling plant to buildings for space cooling and process cooling. It contains three major elements, the cooling source, a distribution system, and customer installations, also referred to as energy transfer stations (ETS) or consumer substation.

Chilled water is typically generated at the central cooling plant by compressor driven chillers. District cooling systems typically vary the chilled water supply temperature based on the outside ambient temperature. Chilled water is distributed from the cooling source to the customers through supply pipes and is returned after extracting heat from the building's secondary chilled water systems. Pumps distribute the chilled water by creating a pressure differential (DP) between the supply and return line.

2. DCS CONVERSION MODELING

To make centralized cooling system by combining individual chiller plants, first prerequisite is to collect data regarding

- Cooling load for each buildings

- Diversity factor in their designing
- Load profile
- Design value of δ T
- Different arrangements of components and their size.

After getting all these details about the organizations under consideration, centralized chiller plant is modeled in successive way by designing of its components.

2.1 Designing of Chillers

Depending upon the use different chillers are used. But in chilled water system most commonly used is water cooled chiller. The main focus in designing of chillers is to discretize the net load for DCS in such a way so that load variation requirements can be meet for each building. Another important parameter is operating δt for chilled water. With varying δt, flow rate $per\ TR$ also varied and hence it changes the quantity of chilled water supply. So to avoid low δt syndrome, for DCS high δt more than or equal to 14°F is used.

Not only follow the variation in load even efficiency of the plant can be increased by VFD and dual compressor chillers; those are more efficient on part load than full load.

It may be necessary to lower the supply water temperature to balance the chiller LMTD with the coil LMTD.

CHW ΔT	10	12	14	16	18
Suggested CHW T(°F)	44	44	42	42	40

Table:1

2.2 Designing of Distribution Lines:

Unlike to any chilled water plant on site, in dcs distributing lines offer a great head to overcome. For district cooling distributing lines are either open to atmosphere or buried ground. But in hot climate zones it is necessary to use underground buried pipe lines. Another designing parameter for distributing lines is velocity of flow. The main obstacle is to decide the velocity of pipe flow to balance between the pipe size and pipe head loss. As the distributing lines are so long, so in addition to cost and ease of installation, toughness strength, availability with preinsulation, thermal expansion/contraction and corrosion resistance are also important characteristics. Welded steel, ductile iron and high density polythene (HDPE) materials are commonly used in distribution system in district cooling. But all the material poses different property, so the selection of the material is done on the basis of available environmental conditions and parameters.

2.3 Designing of Pumps

Chilled water from central plant to consumer buildings is circulated with chilled water pumps, primary and secondary while the continuous flow of condenser water through the chillers is made with the help of condenser pumps. All these pumps are designed for different head with the help of performance curve at their rated speed. Rated speed is different for 60 htz and 50 htz power supply. Generally for 60 htz , speed is 3500rpm & 1750rpm while for power supply at 50 htz rated speed is 2900rpm & 1450 rpm. To design the pump system we need two parameters, flow rate and head available

Primary pumps are designed to provide head so that flow can take place from chiller to secondary pumps. Generally it varies from 14-15 m for primary –secondary variable flow.

The most important in pumping system is to design the secondary pumps. These are provided as per the no. Of consumer buildings. Secondary pumps serve the chilled water to the remotely placed buildings. So the head depends upon the head loss occurred in distributing pipe lines.

Another pump to design in case of chilled water system with water cooled chiller is condenser pump. It involves the head required for the flow of condenser water from chiller to cooling tower. Generally in case of simple chilled water plant on site, cooling tower is placed on the roof while the chiller plant is at the basement, but in case of DCS cooling tower is located at the same level, so the head required is less than is individual chiller system.

2.4 Design of ETS (Energy Transfer Station)

It forms the interface connection between the chilled water plant and the individual buildings. It is also called as customer. There are two ways to connect chilled water plant to building system, indirect and direct connection.

3. Case Study And Implementation

To model the concept of district cooling for existing buildings in India, two buildings named Ansal plaza and Ansal IT park located in Greater Noida city of Uttar Pradesh state in India are taken for further study and analysis. Specifications of the buildings are given in Table 2.

Ansal plaza is a three storey building with two basements. Ansal plaza provides the space for different shopping centers, restaurants, shops and a cinema hall. It is situated in a crowded place. It is observed that space is occupied by the persons during the whole period of working, but at the evening load rises more.

Ansal ITpark is basically a office purpose space that runs its own HVAC from 9:00 am to 5:00 pm. So in case of Ansal ITpark, load is zero after 5:00 pm in a day, while for Ansal plaza it is the time for raised load. So the requirement can be met by increasing the supply of chilled water to the Ansal plaza.

Building specifications									
Building	Cooling load TR	Diversity factor	$design\ \Delta T$(°F)		Pumps			Building height	Working hours(in summer)
			Chilled water	Cooling water	Primary pumps hp	Secondary pumps hp	Condenser pumps hp		
Ansal plaza	2400TR ($600TR \times 4$)	80%	10 °F	7 °F	25(5)	40(5)	60(5)	37.5 m	11-12 hrs/day
Ansal IT park	400 TR ($200TR \times 2$)	80%	10 °F	7 °F	15(2)	15(2)	20(2)	15 m	7- 8 hrs /day

Table: 2

3.1 Modeling of chillers

By allowing a lower diversity ratio selection as 75 % we determine the district cooling system with the required cooling capacity of 2625 TR on the base of design capacity of 3500TR. It is surveyed that most of the time single chiller with 600 TR is run while for may to august it is required to run two chillers i.e. 1200 TR. While in Ansal IT Park generally single chiller is made to run with 200 TR but for very hot days both chillers are needed to run. To accommodate the load variation, whole load is divided into three chillers with unequal sizing.

With $\Delta T = 18$ °F and 1.33 gpm/TR, (nominal speed of 1450 rpm at 50 htz.)	
CH1	1600 TR with dual compressor
CH2	800 TR with VFD
CH3	225 TR

Table: 3

3.2 Modeling of Distribution Lines

To supply chilled water from central plant to consumer buildings distribution lines plays a vital role. Parameter to be considered in designing of distribution system are pipe material and equivalent length apart of these, reynold`s no. For pipe flow, frictional head loss are also important terms to specify the system. For both the building distribution line is different with different parameters. Both buildings are at 4 kms apart, DCS is supposed to establish at the mid distance. But by considering 5% increment in length of distributing pipe on account of bends, the equivalent length for each consumer becomes 2.1 kms. For each pipe line considering the material ductile iron with HDPE encasing to avoid leakage and heat loss.

Building	Maximum Design flow rate (1.33gpm/TR)	Velocity of flow	Diameter of pipe	Reynold`s no.	Friction factor	$\frac{\Delta \text{ HFP}}{L}$ $\left(\frac{ft\ of\ fluid}{100\ ft\ of\ pipe}\right)$	Head loss
Ansal plaza	3192 gpm	8 fps	13 inches	7.13×10^5	0..014	1.285	88.56 feet(27 m)
Ansal ITpark	532 gpm		5.5 inches	3.02×10^5	0.016	3.47	239.24 feet(73 m)

Table: 4

One important parameter in distributing pipe line designing is velocity for pipe flow. A balanced value of 8 fps is selected to decide the pipe size and head loss. Different parameters under consideration for each distributing line are summarized in Table 4.

3.3 Modeling of Pumping System

Secondary pumps					
Pump	Model	Head	Dia. Mm	Hp	H
S1	250× 200 − 315	27m	336	87 hp	82%
S2	125× 100 − 500	73m	454	58 hp	55%

Table 5(b)

Primary pumps with head of 14 m(46 feet)				
Pump	Model	Dia. Mm	Hp	H
P1	200× 150 − 315	302	40 Hp	61%
P2	150× 125 − 250	243	15 hp	81%
P3	100× 65 − 200	220	5 hp	77%

Table 5(a)

Selection of pump depends upon the flow rate required and the head against which pump has to do work. Here we consider the dedicated pumping system i.e. For each chiller there will be one primary and one condenser pump but secondary pump will be two for whole system to supply water to each connected building. Designing of any pump system require determining the pump horse power, impeller diameter and required efficiency at the rated speed. All the chiller compressor and pumps run at same nominal speed of 1450 rpm at 50 htz. Sizing of pump is done with the help of manufacturer`s catalogue of 50 htz performance curves. Data determined by using selection chart and performance curves of each pump is listed above in Table 5(a), (b) and (c).

Condenser pumps with **3 gpm /TR with 24 m head**				
Pump	Model	Dia. Mm	Hp	H
C1	$250 \times 200 - 315$	360	93 Hp	73%
C2	$250 \times 200 - 315$	308	59 hp	77%
C3	$125 \times 100 - 315$	302	18 hp	75%

Table 5(c)

3.4 Modeling of Cooling Tower

For water cooled chillers cooling towers are provided. Required specifications regarding the DCS modeled are approach and range. As in India, atmosphere is hot & humid so the ambient air wet bulb temperature selected is 78 °F with approach of 7°F and range of 10°F. Design condenser water temperature / cooling tower set point = ambient wet bulb temperature + design approach temperature = 78°F + 7°F = 85°F . For district cooling, cooling tower size varies with the range and approach specified for it.

3.5 Modeling of Energy Transfer Station:

As DCS under consideration is limited to serve for two buildings and both buildings are supposed to agree with sharing of load, direct connection of ETS is suggested to minimize the cost.

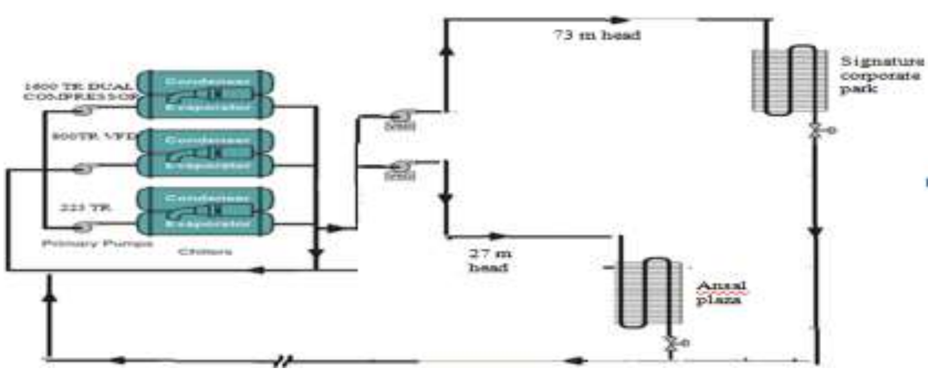

Figure 1

4. RESULTS & COMPARISONS

On the basis of design data, energy saving and other conclusions derived by the conversion into DCS, are discussed in this section.

4.1 Energy Saving

It is concluded that in comparison to individual cooling system (ICS) DCS offers a great saving in pumping energy. Saving in energy by the comparative study of DCS and ICS system is plotted on bar graph.

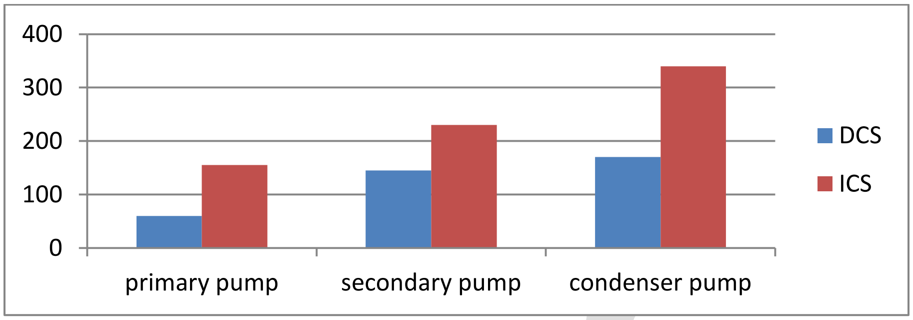

Figure 2

4.2 Cost Saving

Despite of establishing individual chiller system on site, serving district cooling, consumer organization can achieve cost savings along with energy saving. In any chiller plant the most money consuming part is chiller, but DCS limits the over sizing of chillers so cost. Cost saving in chillers is directly relate to the change in diversity adopted in conversion from ICS to DCS. Another cost saving is in terms of land consumption.

5. CONCLUSION

An assessment method and approach is proposed to model different parts of district cooling system. The detailed analysis and study concluded that

- DCS shows high energy saving potential all the year.
- DCS works effectively for partial loading, as VFD and dual compressor Chillers can work with high efficiency at part load.
- Chillers are the main subsystem that consumes a great part of overall initial cost. DCS also offers a great saving in cost in comparison to ICS.

REFERENCES:

[1] International district energy association, District Cooling Best Practice guide, First edition

[2] Bard Skagestad and Peter Mildenstein, International energy agency, IEA district heating and cooling connection handbook

[3] David Rulff (2011), Modeling satellite district heating and cooling networks.

[4] Graham Ross (August 2008) 'A Set of guidelines for a preliminary investigation into using District Heating and Cooling together with Sustainable Buildings in Glasgow'.

[5] Antoni Carreras Betran (August 2013) ,Energy system and economic analysis of district cooling in the city hall of Gävle.

[6] Fluide design ,frictional head loss calculations.

[7] Southerncross Pentair, ISO pump performance_data_50 hz

[8] Daikin,Chiller plant design –application guide, AG 31-003.

[9] District energy, Best practice IEA district heating and cooling connection handbook.

[10] Energy saver cogeneration feasibility guide.

[11] International district cooling conference(2007), district cooling best practices piping systems.

[12] Roy s. Hubbard, Energy Impacts of Chilled Water Piping Configuration, Johnson control Inc.