Operational Management System In District Cooling Plant Company

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Abstract - *This study aimed to determine the operational management systems in the District Cooling Plant company in Qatar. Specifically, it described the firmographic profile of the district cooling plant companies in terms of type of customers, number of years in operation, cooling demand, cooling plant capacity, total plant energy produced, KPI requirement met, electricity consumption, plant HVAC and energy delivered to customers.; analyzed the operational management system in terms of strength, weaknesses, opportunities and threats in cooling plan company; identified the operational challenges encountered and come up with an Action Plan to address the operational challenges encountered to improve the Operational Management System of the District Cooling Companies in Qatar. Descriptive qualitative research was used. Participants were selected from different district cooling companies based on their direct involvement in the District Cooling Plant with Plant Engineer level with at least 10 experience in the field that have direct access to all desired data needed for this study. Based on the results, it was found out that district cooling plant challenges are: Low delta T syndrome or so low chilled water return from customer ETS, Plant Equipment design challenges. Extreme ambient whether condition during summer was not considered while designing or sizing the equipment. In addition to this, equipment redundancy also not thoroughly considered to improve plant reliability. Manpower selection process and Operations and maintenance program implementation were also highlighted in this study. Recommendations to improve district cooling plant operation performance in terms of plant efficiency, reliability and therefore profitability of the district cooling companies and to ensure success of the DCP business operations were formulated.*

Keywords: District Cooling Plants, Operations and Maintenance, Management System

INTRODUCTION

Climate change is growing concern all over the world, steady ambient temperature rise is happening globally year after year as highlighted by various individuals and organizations. In addition to this, world economy is also progressing thus, utility demand of electricity, water, telecommunications, and cooling were following the trend to cope up with business growth worldwide.

Operations management plays an important role in the administration and growth of the business. The practices of the company create a system that concerns the highest level of efficiency within an organization, the conversion of materials and labor into goods and services as efficiently as possible to maximize the profit of an organization. This includes resources utilization of materials, staff, equipment, and technology while Operations managers always look to develop, and deliver products to clients based on client needs and the capabilities of the company.

District cooling has its roots in the early 1800s when proposals were made to distribute clean, cold air to buildings through underground pipes[1]. The Colorado Automatic Refrigerator Company was established in Denver in 1889. In the 1930s large cooling systems were built in the Rockefeller Centre in New York City and the United States Capitol buildings. In 1960s, the first commercial district cooling systems were installed in the USA in commercial areas near cities. In 1967 Europe obtained its first district cooling system. Climadef began supplying district heating and cooling to the La Défense office complex in Paris. In 1989 Scandinavia obtained its first district cooling system in Baerum outside Oslo.

In November 2003, Qatar’s United Development Company (UDC) and UAE’s National District Cooling Company (Tabreed), along with some local Qatari investors, founded the Qatar District Cooling Company as a joint venture with the intention of providing district-cooling services to the public, commercial and industrial sectors of Qatar. Currently, Qatar Cool is the leading commercial provider of district cooling services in Qatar [2].

In the district cooling plant sector there is comprehensive tactical concerns, including determining capacity of the plants by implementing equipment design optimization, project management methods study the operational gap in the operational management of the district cooling plant that uses huge amount of water and electricity for the plant operations.

With this report, researcher would like to highlight the existing annual plant actual electrical and water performances from the data gathered from engineers that are currently working from different district cooling companies who could provide the latest available operational data to support this study. The author field involvement in the district cooling business within the Gulf countries and have been observed actual progressive growth of the industry drives to perform this research that will provide company managements additional instruments to be used to evaluate their utility performances and improved their respective profits. As the company grows respective employee benefits and compensation will follow and the financial stability of the company will define the tenure of each employee within the organization on that specific aspect.

While preparing the report, District Cooling Plant Operational challenges had been noted. Root causes of this challenges has been pinpointed and corresponding strategies has been formulated. Responsible persons for each strategies were also identified. The first and foremost is: Low chilled return temperature coming from customers resulting district cooling plants poor electrical performance and the reason for not meeting the desired specific electrical performance or key performance indicators.

Second: Plant Design issues: Cooling tower design to address summer extreme weather condition within the region. During summer, humidity is reaching above 31.1 degree Centigrade wherein this is just current design criteria considered by most of the engineers doing the design. Equipment redundancy is also part of design issues that aims to provide additional standby equipment is also neglected as highlighted by one of the respondent. Another challenge encountered was the water treatment program being implemented by DCP operators that needs to be evaluated continuously to avoid two main concerns such as scaling and corrosion of the system that was discussed in the latter part this report. Operations and Maintenance strategies implemented is also another challenge for the plant owners which needs an annual review to measure the effectiveness of the system and to evaluate the equipment life cycle. Based on this review, management may decide for possible equipment upgradation considering latest available technologies in the market. These challenges are the prime considerations of the author in selecting the title of the thesis. In addition to this, the author possessed considerable years of hands on experienced in the district cooling plant operations business gained from well-known companies in State of Qatar and United Arab Emirates.

OBJECTIVES OF THE STUDY

This study aimed to determine the production management systems in the District Cooling Plant company in Qatar and address the challenges encountered in its operations.

Specifically, it describe the firmographic profile of the district cooling plant company in terms of type of customers, number of years in operation, cooling demand, cooling plant capacity, total plant energy produced, KPI requirement met, electricity consumption, plant HVAC and energy delivered to customers.; analyzed the operational management system in terms of strength, weaknesses, opportunities and threats in cooling plan company; identified the operational challenges encountered and come up with an Action Plant to address the operational challenges encountered to improve the Operational Management System of the District Cooling Companies in Qatar.

MATERIALS AND METHODS

Research Design

This study used the descriptive qualitative research. The goal of descriptive research was to describe a phenomenon and its characteristics. This research is more concerned with what rather than how or why something has happened. Therefore, observation and survey tools are often used to gather data [3]- [5] Qualitative research, however, is more holistic and often involves a rich collection of data from various sources to gain a deeper understanding of individual participants, including their opinions, perspectives, and attitudes. Qualitative research collects data qualitatively, and the method of analysis is also primarily qualitative. This often involves an inductive exploration of the data to identify recurring themes, patterns, or concepts and then describing and interpreting those categories. This happens when the researcher first examines the qualitative data thoroughly to find the relevant themes and ideas and then converts them into numerical data for further comparison and evaluation.

Participants of the Study

Participants were selected from different district cooling companies based on their direct involvement in the District Cooling Plant at Plant Engineer level that have direct access to all data needed for this study. Plant Engineers selected as respondents have minimum 10 years of experience in the district cooling plant operations and maintenance. Based on their tenure in the industry, the researcher considered them as experts on this specific line of business thus their response will be highly valuable in conducting this study.

They are well trained and experienced not only from plant operations and maintenance. They are also exposed to project construction and commissioning phase. Most of them attended the factory acceptance test "FAT" for various equipment conducted in product country of origin factories. They have witnessed the actual equipment performance testing and certified "passed" each equipment that will be installed later their district cooling plant premises.

Data Gathering Instrument

The researcher used tailored fit questionnaire to meet the researcher objectives. Part 1 is about the firmographic profile of the company which asked about the type of customers, number of years in operation, cooling demand, cooling plant capacity, total plant energy produced, KPI requirement met, electricity consumption, plant HVAC and energy delivered to customers. Part 2 is an open-ended question regarding the strength, weaknesses, opportunities and threats of the company and Part 3 is also an open-ended question regarding the operational challenges encountered in the operations of the district cooling plant.

Data Gathering Procedure

Data were gathered after the approval of the objectives of the study. A tailored fit questionnaire was validated and proceeded with the survey and focused group discussions were conducted using the guide questionnaire. With the permission of their management, actual plant operating data within a certain period were gathered. Actual data shared by them were evaluated and analyzed. Interviews with DCP Plant Engineers were also done to get most accurate data within their specific fields. Other information that was not covered the questionnaires were also gathered through physical interviews. Their feedbacks were also included in this report.

Other relevant information was also taken from the related literatures, district cooling conferences presentation materials used by well-known personnel within the district cooling business across the globe. The author personally attended some of these highly important events like Euro heat conference, International District Cooling and Heating Conferences that were once held in Doha Qatar in year 2017. Those important and highly accurate details from specific district cooling personalities were considered and part of this study that serves as additional references.

Data Analysis

The results were analyzed in qualitative approach. This often involves an inductive exploration of the data to identify recurring themes, patterns, or concepts and then describing and interpreting those categories. Since it is qualitative research, the data collected qualitatively can also be analyzed quantitatively. This also used frequency distribution in determining the recurrence of the event especially in tallying the firmographic profile of the district cooling plant. Ranking was also used in the interpretation of data.

Ethical Considerations

Ethical considerations have been practiced by the researcher in the conduct of the study to ensure that every information that will be gathered will be used for research purposes only to maintain the quality and integrity of the research. It also ensured the confidentiality and anonymity of the respondents by not seeking their names as they're answering the questionnaires. The researcher also ensured that the respondents voluntarily answer the questionnaires according to their will. Lastly, it also ensured that none of the respondents of the study will be hurt or harmed and their safety and security is of top priority.

RESULTS AND DISCUSSION

Table 1 represents the firmographic profile of the firm such as type of customers, number of years in operation, cooling demand, cooling plant capacity, total plant energy produced, KPI requirement met, electricity consumption, plant HVAC and energy delivered to customers. There are three district cooling

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companies that participated in this study that provides data that were all based in the middle East of Asia specifically from Qatar and UAE.

Respondent	**Type of Customers served**	**RANK**
Company A	Government	
Company B	Government	
Company C	Commercial & Residential	
Respondent	**No. of Years in Operation**	
Company A	14	1
Company B	1	3
Company C	8	2
Respondent	**Cooling Demand**	
Company A	25,000 TR	3
Company B	29,338 TR	2
Company C	37,600 TR	1
Respondent	**Cooling Plant Capacity**	
Company A	25,000 TR	3
Company B	40000 TR	1
Company C	37,600TR	2
Respondent	**Plant Energy Produced**	
Company A	48,547,937 TR-Hrs.	2
Company B	12,025,300 TR-Hrs.	3
Company C	49,614,816	1
Respondent	**KPI Requirement Met**	
Company A	NO	2
Company B	NO	3
Company C	YES	1
Respondent	**Plant Electricity Consumption**	
Company A	45,126,098 kW-Hrs.	2
Company B	12,952,232 kW-Hrs.	3
Company C	48,376,240 kW-Hrs.	1
Respondent	**Plant HVAC consumption**	
Company A	150,000 TR-Hrs.	3
Company B	731,150 TR-Hrs.	1
Company C	191,960 TR-Hrs.	2
Respondent	**Energy delivered to customers**	
Company A	48,547,937 TR-Hrs.	2
Company B	8,661,035 TR-Hrs.	3
Company C	49,422,856 TR-Hrs.	1

These three companies from two different countries are now well established and etched their names in the utility business across the region. Two of them are operating and maintaining their owned district cooling plant, while last one is categorized as plant operator.

As to the type of customers with respect to respondent's profile given, in first line of table 1, Company A, B are all serving government building facilities while Company C is serving commercial and residential buildings.

As to the number of years in operation, Company A has been in the business for the past 14 years, Company B is just more than a year since it has been commissioned. Company B total delivered cooling to customers has the least among the three because at this point not all customers are not yet ready, or buildings connected to the DCP are not yet fully occupied. Company C is on their 9th year since commissioning in year 2011. All the district cooling plants capacity has more than 10,000 tons of refrigeration which are considered large plant capacity. Only one of them is having thermal energy storage "TES" tank. Having TES has great advantage compare to other plant that don't have. This is well justified by their electrical performance for the whole year when compared to two plants that don't have TES tank.

With respect to electricity key performance indicator criteria, Only Company C able to meet electrical performance KPI, however, it was the opposite in water performance criteria. Water KPI was met by the three respondents. The main reason of not meeting the electrical performance KPI is due to un-availability of energy transfer station to plant automated communication system. "Not knowing what is happening in the field un-able things to be manageable. Another reason is un-commissioned energy transfer. If ETS left un-commissioned, it will end up continuous excessive chilled water supply flow which is un-efficient situation. These two reasons are leading as to the most common challenge in DCP operations known as Low Delta T syndrome.

As to plant capacity, Company B is the biggest among the three with total of 40,000 TR capacity while Company A and C have 25,000 and 37,800 TR respectively. However, Company B has the least demand since it is just newly commissioned as stated above. Furthermore, it is justified in the total energy delivered to customer within the year. Total cooling delivered to the customer represents the load availability from within. It is always best to district cooling plants to have maximum load during peak season and close to corresponding part load conditions between off peak and peak season.

As to the Plant Energy Produced, Company C produced the most even though it has lesser than plant capacity than company B. This primarily due to number of customers connected to this plant and occupancy rate of customers compared to company A and B. As to the Plant HVAC consumption, Company B, provides the highest. This is because of the building size of the plant. As general heat load calculation logic, the bigger the building area, the higher the cooling load will get.

Table 2.District Cooling Company Strength, Weaknesses, Opportunities and Threats Analysis

Strengths	**Weaknesses**
• Provides lower investment cost to clients. • Availability of open spaces in lieu of chillers place. • Much lower power consumption gas emission to environment will also be minimized. • Lesser contribution to ozone layer depletion. • Zero operations and maintenance cost for client, developer that will lead to better management. • Electricity peak requirement within the grid will be decreased during summer season. • More reliable source or supply of cooling system.	• High investment cost for the district cooling companies. • Concept is applicable only to high density populated area. • Utilities are available within the development location • Implementing guideline in operating district cooling plants is not yet established in some countries hence tariff is not properly regulated.
Opportunities	**Threats**
• Huge market growth of the business that could be capitalized. • General public environmental awareness will be improved • Utilization of Treated Sewage "TSE" Effluent water in the district cooling that reduced potable water consumption • Reverse osmosis plant and components manufacturers will be benefited.	• Customer buildings completion delay and low occupancy rate. • Absence of chilled water leak detection system within the chilled water pipelines. • Un-commissioned energy transfer stations. • Building heat load calculations overdesign. • Lack of energy transfer station communication system to plant PLC and SCADA system. • Resulted to low return temperature or the low delta T syndrome.

Table 2 presents the District Cooling Company Strength, Weaknesses, Opportunities and Threats Analysis. As to its strengths, the top identified is that through this district cooling facility, it will provide lower investment cost to the clients. Considering that the building owners do not have put up their own chiller plant. Chillers and other equipment procurement cost will be saved by the customers because all the above cost are shouldered by the district cooling plant owner. Customers or clients will be focusing more on the building HVAC system. This is simply because above statements are the main concepts of the district cooling business. DCP provides cooling services to the customers hence, customers need not to purchase their own chillers for their building cooling system. Just like in electricity, since power providers are selling electricity through power transmission lines, private and public sectors are just buying it instead of putting up their own power generating unit or so-called power generators. "A large part of the customer experience for utility companies is helping customers lower their bills and increase their energy efficiency" [6]. The higher the supply availability in the market the better for the customer - supply and demand principle. In this set up, cooling utility cost will be a lot cheaper compare to conventional cooling.

Building space provided for the chillers and auxiliaries can used for other purposes is another strength identified. Thus, it will provide savings or maybe earning opportunity for the building owner. Manpower cost for the chiller plant will be avoided by the building owners as well since they are just buying the cooling from cooling provider. In the long run utilizing DCP will be both beneficial for the plant and building owner due to better coefficient of performance DCP that could provide compared to conventional cooling or electric chiller. Absorption chiller efficiency ratio" EER" is usually ranging from 15 to 25, while electric chiller EER is usually ranging from 5 to 15 only.

Another advantage from a cooling perspective is that the primary energy and carbon dioxide emissions are the most relevant indicator since renewable energy is already considered in non-renewable primary energy factors [7]-8]. On the other hand, Introduction of thermal energy storage tank to the district cooling plant concept will trim down the electrical peak load requirement within the grid during summer since

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cooling peak demand will be met by chilled water stored in the thermal energy storage tank that was produce during nighttime. Around 20% of electrical consumption peak will be shave if the plant has TES. [9]. Thermal energy storage is like a battery for a building's air-conditioning system. It uses standard cooling equipment, plus an energy storage tank to shift all or a portion of a building's cooling needs to off-peak, nighttime hours. During off-peak hours, chilled water is made and stored inside thermal energy storage tanks. The stored chilled water is then used to cool the building occupants the next day. In some country, electricity tariff at night is cheaper than daytime. Due to this, TES charging is being done during nighttime while electricity cost is lower compare at daytime hence cooling generating cost will be lower in producing same quantity of chilled water. [10]

District Cooling System provides more reliable cooling system source since plant was designed with standby units. When one chiller goes off, there's available standby unit to take the current cooling demand unlike in conventional cooling like for example in our respective home when our air conditioning unit went off, most of us do not have spare unit therefore our cooling comfort will be disturbed until air conditioning unit was repaired.

As to its weaknesses, Investment cost is huge in the part of district cooling plant owner. The primary reason is that they have built district cooling plant building, procure all the equipment, and build the underground insulated chilled water networks. There's a study by Berbari, in 2016 that a minimum of 15,000 TR demand load shall be consider in doing direct chilled water connection in high rise buildings otherwise it will jeopardize the overall plant performance. High rise buildings usually have their own chilled water pumping system utilized to bring the chilled water up the highest point of use. The set-up is called secondary chilled water loop. If direct chilled water connection is exercised for high rise building, then all the pumping energy will be shouldered by the DCP's which in turn additional power loss to the DCP owners. Another possible loss for the DCP's will be chilled water leaks. Any chilled water leaks occurrences in the building means loss of water, chemical and energy to the DCP's.

Lower than specified demand cooling load will result to longer rate of return of investment. Like in electricity, power provider wishes to increase the monthly consumptions to generate more revenues. The higher the revenue the better ROI results for the DCP'

DCP concept is applicable to high density populated area and if electricity and water source to support the district cooling requirement is available within the development location. Where there is populated area and economic growth, there is cooling demand especially in the hot countries like middle east. The primary prime mover of the district cooling plant are electricity and water hence availability of said utilities are highly essential in putting DCP.

Another drawback is, since DCP concept is adapted by few countries and regions only, some countries legal legislations were not yet adapted therefore regulations are not yet defined. This concerned will lead tariff disagreement between DCP and building owners. Prior to DCP operations government must release the mandated cooling tariff as baseline of DCP owners and customers while processing or drafting their service contract agreement wherein cooling tariff is one the main agenda and basis of corresponding calculation of due fees. DCP owners usually charge their customers based on cooling demand capacity charge, connection charge, and consumption charge. All these charges were based on unit cost or cooling tariff that should be mandated by the government otherwise disagreement will arise between DCP owners and customers.

As to opportunities, In the bright side, research result saying that DCP has great business opportunity in the future. This is due to increasing population and economic growth within the Gulf Cooperation Council "GCC". Berabari, [11] confirmed that the new market research study, the District Cooling market is expected to reach US$ 29 Billion by 2020 at a CGAR of 11.4% within the Middle East. Since DCP utilization is more efficient than conventional cooling electricity consumption will be lower thus carbon footprint to the environment will be lesser. Valerie et.al proposed the possible utilization of the renewal energy to be used in district cooling plants in 2016. In this concepts, wide range of research involving the public is being considered hence public environment awareness will be enhancing.

Qatar is one of dry countries with very limited water resources, yet the demand on water is great due to its vast industry and continuous increase in population. It is one of the most dry and arid regions in the world which is facing inconceivable challenges in protecting fresh water for domestic, agriculture and industrial uses. Thus, reusing treated sewage effluent (TSE) will

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be essential to overcome the water scarcity in this country. Although the reuse of TSE is vital to save water and sustain the environment, it may adversely affect the environment if the treatment process is inadequate. Nowadays TSE utilization in new DCP's has been mandated by government of Qatar. This legislation aims to cut the potable water consumption that will ultimately help the environment and will provide lower water consumption operating cost since TSE is recycled water coming from sewage water treatment plant that has way lowered unit cost compared to potable water. In Qatar, potable water unit cost is 8.6 QAR/cubic meter while TSE is around 0.5 to 1.5 QAR per cubic meter depending on location and pumping station provider

Because TSE water can't be directly used for chiller applications, proper water treatment is needed. To ensure that TSE that water can be used for the chillers, water treatment companies designed a complete packaged solution with Ultrafiltration (UF) and Brackish Water Reverse Osmosis (RO). "The mall needs to reduce Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) to make the water suitable for their chiller application to avoid damage to piping and chiller tubes due to corrosiveness in nature of TSE water. Therefore, RO treatment plant manufacturing business were also boosted by this occurrence.

As to threats, delay means different things to different parties. From the outset of a project, therefore, it is important to identify the problems that the risk of delay creates for the different parties involved. If a building cannot be used when intended, all manner of problems are potentially created for the client. "Realization of an income from the asset may be postponed, alternative accommodation costs may be incurred, financing costs may increase, and depending upon how risk is allocated in the contract and the nature of the delay events, the client may be faced with claims from the contractor" "For a contractor, a delay means an increase in overheads, potential liabilities to the supply chain and a liability for delay damages to the client if such a provision has been included in the contract". "A risk of insolvency may also be created by cash flow problems resulting from a tie up of resources and delayed recovery of payments" [12]. All the treats associated shall be dealt with through project contracts management.

"The over-specification and over-design of building service systems often results from the cumulative addition of various design margins. It is quite possible that sometimes margins are added as a matter of habit. With no real thought as to whether they are applicable to a particular situation, calling into question the issue of design" [13].

Internal leak detection systems "LDS" are one of the most common technologies used to detect a leak. Common pipeline leak detection technologies use point sensors to track flow rates, as well as apply mathematical and statistical computations to monitor flow rates, pressures, temperatures, and product characteristics. Although these systems are useful in identifying leaks, they lack in sensitivity. Leaks take longer to detect, and small leaks may go completely undetected. A system without LDS is like a shopping mall shops exit doors without alarm protection system against burglars.

Table 3 presents the Operational challenges encountered in the district cooling plant. Based on the information gathered from the respondents' operational challenges in table 3, that were grouped as follows such as, low delta T syndrome due to lack of energy transfer station" ETS" to plant PLC integration and customer ETS not commissioned. Absence of automation and communication system between plant SCADA system and customers ETS resulting to low chilled water return temperature or the so-called low delta T syndrome. As ultimate result, district cooling plant keep on supplying un-necessary chilled water flow to customers without any control thus it provides losses to the district cooling companies. "For complete control of the building, a proper SCADA implementation and the optimization strategy has to be built. For better communication and efficiency, a proper channel between the Communication protocol and SCADA has to be designed" [14]

Cooling tower design, this must be addressed during the design stage of the plant. Careful equipment selection shall be exercise by the EPC. "A steady-state model is developed to investigate the effect of the chilled water supply temperature and the inlet condenser water temperature on the performance of the centralized chiller system" [15].

Water treatment system for condenser and chilled water system was not properly selected. Suitable water treatment program shall be adapted to protect the equipment from corrosion and to meet the local

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government legislations applicable to plant water discharge to the environment. The program shall be continuously monitored by water treatment service provider in weekly basis. Basic parameters like conductivity and Calcium shall be one of them. Hardness in water in the form of magnesium and carbonate could be measure in the form conductivity. Importance of doing this is to eliminate pipe scaling that will reduce the plant performance. Parameter's deviations shall be immediately corrected.

Redundant equipment. There's no more standby equipment available that could be operated to respond in peak season load demand. Plant equipment redundancy was not designed properly. Reliability of the plant has been compromised during peak load season. This is a critical judgement in the part of the engineering team who designed the plant capacity. It was highlighted by company C that this is one of their great challenge especially during summer season when the load is at its peak. Any equipment breakdown within the season posed a great risk to the operations that will lead to catastrophic customer dissatisfaction and complaints.

"Redundancy system is very useful to enhance the performance and reliability of the power generation system of a cogeneration plant or any Utility Generating Plant. However, the associated operating cost of redundancy system is very high. The common redundancies used in a cogeneration power plant are public utility and generator set. To select the best redundancy options which incurs minimum operating cost, it is required to evaluate the cost of different redundancy options." [16].

As discussed in the previous paragraphs, redundancy involves increased capital and operating costs but will ensure higher system availability. On the

Table 3. District Cooling Plant Operational Challenges

1	Energy Transfer Station differential temperature. Improper water treatment program and water balancing that includes poor preventive maintenance program to secondary chilled water network.
2	High humidity resulting for inefficient cooling towers effecting overall water and electrical performance.
3	Rapid evolving of technology transcending for higher CAPEX to upgrade obsolete equipment.
4	Major equipment installed e.i chiller, pumps and cooling towers don't have an option for variable loading in times of part load demand.
5	Stable utilities supply such as Electrical and Water. Often this was a challenge to operate plant efficiently due to restrictions of power and water supplies.
6	Contractor compliance to deliver the plant in full Auto Operation and with stable data acquisition log. Most often contractor failed to fine tune the control logic resulting to erratic behavior of pumps and valves.
7	High Ambient Temperature and Relative Humidity in Summer - Operating the cooling towers in full speed, poor cooling tower performances, MV/LV transformer reaching its critical temperature, and operating the plant without stand-by equipment.
8	Maintaining the water quality of condenser loop - Ineffective water treatment will lead to corrosion and scale formation in heat exchangers and cooling towers. The approach temperatures significantly affect the plant performance.
9	Controlling the delta T from customer - Instead of comfort cooling, most of the Arabs prefer to have the room temperature below 20 degrees. DCP has no control over this unless certain agreement has been established.
10	Part-load demand due to incomplete or improper commissioning of ETS controls.
11	Chilled Water Flow Less issue to the building Energy Transfer Station (ETS) and since the ETS is located a top of the buildings which compromise the plant operating in high secondary pump speed which lead to low return water temperature occurrence during winter season. And due to unfinished commissioning, there without proper instrument metering of flow, temperature, pressure send to plant SCADA system
12	High Ambient/Dry and Wet bulb temperature as well as Cooling Tower Makeup water temperature were extremely high during summer season resulting to chiller lift pressure and other operating parameters in high that could lead to poor performance of the whole DC system. However, those challenges could be resolve by replacing the Cooling tower Fills (as per life span) and periodic cleaning of the Cooling Tower, Condenser Tubes and proper monitoring of water quality and chemical treatment use.
13	Chilled Water Network Water leakage some places are still unidentified.
14	Lack of redundancy/standby equipment during summer season, need to establish additional equipment (Chiller, Cooling Tower, and auxiliary pumps) to cope the demand load during summer season.
15	Insufficient air flow around the location of the cooling tower area due to enclosed building walls.

other hand, one query that must be raised is: Is there potential for a common failure? Can a failure occur that will affect both A and B machine or equipment? In this case all the cost and effort of duplicate equipment would be worthless by [17]. The last but not the least, proper plant operation and maintenance. A systematic approach in designing plant preventive maintenance program shall be carefully adapted. "It needs to upkeep the equipment performance to prolong its value and life cycle" [20]. Implementation of previous experiences and original equipment manufacturers "OEM" recommendation shall be collectively outlined and applied to have optimized plant performance. Program should undergo continuous evaluation and improvement every year that should be led by the technical management team. (ISO 9001:2015).

Maintenance was an area that was often thought of an area that did not need much attention. However, with the greater focus on fields of safety, environment, energy efficiency and profitability Maintenance has now become an area where there is renewed attention. Maintenance in the past was thought in terms of Breakdown and Preventive Maintenance. Starting from the late eighties and early nineties there have major developments in Maintenance. The advent of Predictive and Condition Based Maintenance resulted in major improvement to equipment life and consequently to the overall reliability of equipment. The wider appeal of strategies like Total Productive Maintenance (TPM), World Class Manufacturing (WCM) and Six-Sigma also saw an increased focus on Plant Maintenance.

In addition to Plant Maintenance, Reliability Management has been included in the talks and gained popularity, wherein the attention has been to not just attending to plant and machinery, but to manage equipment as an integrated system under a larger family of Asset Management. The emergence of Reliability Centered Maintenance (RCM) in the Airline Industry and the demonstrated improvement in the reliability of the assets has resulted in a closer focus on Reliability Management. Currently, Plant Maintenance and Reliability Management go together and are thought of as not two separate streams but as one integrated method [18].

Another alternative approach is that of Maintenance optimization. This has been elaborated in detail by [19]-[24] Maintenance optimization is an exercise that uses mathematical models to assist with the decision-making process for maintenance implementation. These models combine reliability with economics by quantifying costs, benefits, and various constraints, and integrating the factors into basic economic methods. These models are particularly helpful for comparing the cost-effectiveness of different maintenance policies, determining efficient inspection and maintenance frequencies, and incorporating numerous constraints into the decision-making process [25]. The traditional optimization model provides a simple, easy to understand example of how optimization models work. While the most useful models will optimize for multiple criteria, the traditional model only optimizes for one variable – cost [26].

Table 4 Action Plan Addressing the Operational Challenges to Improve its Operation Management System

Key Results Area	Strategies	Persons Involved
Low differential temperature.	• All customer connected will be advised to fully commission their programmable logic controller. • Then ETS to plant communication will be established to hardwire communication cabling going to DCP PLC. • DCP SCADA system integration with ETS. • Inclusion of metering devices in the plant and ETS in the plant design.	Customer Service Customers Engineering O&M/Customers
Preventive maintenance program of secondary chilled water network.	• Secondary chilled water treatment analysis report will be required to provide from each customer. • Analysis of the water treatment reports. • Customer's facility management team "FM" training on system optimization	O&M/Customers
Design and Maintenance of cooling towers	• Consideration of high humidity season while designing cooling tower. • Cooling tower wall enclosure design shall have air louvers.	Engineering Engineering

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	• Cooling tower fan motors variable frequency drive inclusion in the design. • Effective implementation of cooling tower maintenance. • Continuous implementation, review of water treatment program. • Cooling tower structure life cycle evaluations. • Cooling tower yearly efficiency evaluations.	O&M
Equipment upgrade	• Equipment life cycle evaluation at specified period. • Annual review of equipment history cards. • Equipment performance annual evaluations. • Implementation of equipment upgradation.	Management, O&M
Options for variable loading	• To be considered in the DCP design stage concept. • Primary and distribution pumps to be equip by variable frequency drives.	Engineering
Stable utilities supply (Electrical and Water)	• Multiple options of water supply should be established. • Additional standby power supply source from different grid shall be available.	Engineering team
Plant Equipment redundancy	• Additional sets of equipment to be considered during design stage of the project. • Spare parts inventory management	Engineering O&M Manager
Absence of chilled water leak detection system "LDS".	• LDS addition during design stage of the project. • Plant operator's awareness on how to observe chilled water leak even though there's no LDS system installed.	Engineering O&M

CONCLUSION AND RECOMMENDATION

Three district cooling plant served both the government and residential customers within Qatar and the UAE. Company A and C were both considered known for the business since they both served the customers in considerable years already. Respective plant operational statistics has been tabulated. It is noted that only one out of three company meet the electrical performance KPI. The SWOT Analysis is conducted, providing low investment for customers but with long term benefits for both DCP owner and customers as considered most notable strength. Good district cooling business opportunity is on the way due to bright economic future within the region. During initial operation stage of DCP, un-commissioned ETS, heat load over design, low delta syndrome are the noted threats. While high investment cost for DCP owner was noted as top weakness. All the district cooling companies highlighted the low delta T syndrome, cooling tower design, ETS to plant PLC integration, building heat load calculations over design, proper water treatment program selection and plant equipment design or selection. An action Plan addressing the Operational Challenges encountered in district cooling companies to improve the operation management system of the companies was formulated.

DCP owner shall enforce to customer complete commissioning of their energy transfer station prior to chilled water supply connection request to DCP. This is to establish immediate ETS to plant integration/communication. This is a straightforward approach to address the most common challenge in the DCP which is low delta T syndrome. During conceptual design stage of the DCP, extreme humidity condition should be considered in sizing cooling towers. Adding redundant equipment or additional units will improve the plant reliability during peak load season.

Stringent employee selection process. Putting the right person for the specific job description creates big difference in the Operations and Maintenance Department. Operations and Maintenance program annual review shall be exercise by the technical committee that includes, equipment performance, equipment life cycle, preventive maintenance effectiveness and manpower annual performance review. Equipment upgrade and employee training are also highly recommended whenever possible.

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