شرکت آتیه پردازان شریف

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World Applied Sciences Journal 12 (7): 988-998, 2011
ISSN 1818-4952

An Economical Comparative Study of Different Methods for Decrease Cooling Towers Makeup Cost in Oil Refineries

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Abstract: This article reviews the cases of Water and energy loses in cooling towers of oil refineries. Cooling towers are the equipment to set the temperature cooling water service of integrated oil, gas and petrochemical used. In this equipment, heat and mass transfer occur simultaneously to cool water in the vicinity of air. Hence, the significant transfer of air and water to create moist air from the process cycle casualties is removed. The main goal of this research is to reduce water cost of cooling water system of the oil refinery. Economic principles in order to review the definition of an objective function for a Trade-off between construction cost, installation and operation dry cooling tower and reduce the cost of wet cooling tower make-up water is more. Results obtained from studies in the sample case study objective function, the Tabriz refinery cooling towers were selected, expresses that: There is no economic justification for replacement method, also saving cost in series hybrid method is 171,600.00 US$ per year and in split method is 212,400.00 US US$ per year. Presenting the proposed method based on dry bubble temperature variations during the year can be a combination of two methods used to determine the best route in the cold months of the year (December, January and February) split method and the rest months use series method to the cost saving result is expressed 281,100.00 US$ per year.

Key words: Dry bulb temperature · Cooling tower · Makeup water cost · Series method · Split method

INTRODUCTION

Nowadays water and energy are two main requirements of oil, gas, petrochemical and chemical processes. Many processes need large amounts of hot water or cooled. On the other hand, some processes may also require specific water quality and temperature that specific functions. It is also important that water enters the process with the required temperature. Therefore, under such conditions, the quality and the amount of energy required for heating or cooling water are considered. After the energy crisis in the seventies decades last minimization of energy consumption become a major problem for industries, water was considered the most important source of industries requirement, after energy. Industrial processes use a lot of water for cooling purposes. Cooling water is used to extract unusable heat from process streams. Cooling water used in the industries is of two types, raw water and treated water.

Raw water is directly drawn by pumps from natural water sources like rivers, lakes, etc. or is lifted from deep tube-wells. Treated water is obtained from a water treatment plant in which the raw water is freed from its hardness and dissolved substances. The problem of fouling and corrosion of the heat exchanger surfaces can be minimized if the treated water is used for cooling purposes. The hot water from on ‘once through cooling’ system cannot always be discharged into lake, river, canal, etc. Discharge of hot water causes thermal pollution and can severely affect the aquatic creatures and algae in natural water. Conversation of water in a plant is done by cooling the warm water from heat exchangers, reactors, etc. and reusing it. Only a small quantity of makeup water is necessary to compensate for the losses during use. The losses are mainly due to evaporative cooling. Cooling of warm water is done by direct contact with air in cooling towers. Water is fed at the top of a cooling tower and air is drawn at the bottom or through the side walls. Evaporative with air cooling of water occurs in the tower,

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the latent heat of vaporization being supplied mostly by the water itself. To solve the problem of makeup water cost of waste water in cooling towers, dry cooling towers are used instead of wet cooling towers. Dry cooling towers are the equipments where the water flows in pipes by having the blade, had no direct contact with air. This paper investigates the economic alternative dry cooling tower in some parts of the year. Different methods are studied for reducing the cost of makeup water by hybrid cooling system vs. dry cooling system. In this research, Tabriz oil refinery cooling system is used as a case study.

Cooling Towers: Cooling towers play an important role in the cool-end system of power plant and its cooling capacity can affect the total power generation capacity directly [1]. The cooling towers are the equipments which cooling operation involves "simultaneous transfer of heat and mass" [2]. Cooling tower is a relatively inexpensive and dependable heat rejection device and used for dissipating heat from water-cooled refrigeration, air-conditioning, power plants and other industrial process systems [3]. Cooling towers are one of the most widely equipment units used in cooling systems, which also consist of a network of heat exchangers in closed circuit that consume water only to make up for the inherent losses in the process [4].

Basically, there are two types of cooling towers, namely, direct contact or open cooling tower which exposes the water directly to the atmosphere and transfers source heat load directly to the air. The other type called closed circuit cooling tower which maintains an indirect contact between the fluid and the atmosphere [5]. In water cooling, for instance, the air flowing through the cooling tower is 'unsaturated'. Evaporation of water occurs and the water vapor is transported to the bulk of the air thereby increasing its humidity. The water temperature decreases and some amount of heat transfer from the warm liquid to the gas occurs. The rate of transfer of water vapor (generally to air) depends upon the vapor pressure of the water and the moisture concentration in air. Two types of temperature the 'dry-bulb' and the 'wet-bulb' temperature are defined in connection with air-water contacting. Dry-bulb temperature is the temperature of air measured by a thermometer that's 'bulb is dry', i.e. not in touch with water or any other liquid. This is the true temperature of the air. Wet-bulb temperature is the temperature attained by a small amount of evaporating water in a manner such that the sensible heat transferred from the air to the liquid is equal to the latent heat required for the evaporation. The wet-bulb temperature is measured by passing air over the bulb of a thermometer which is covered with a cloth-wick saturated with water [6].

Considering the fact that in dry cooling towers circulatory cooling water temperature lower than the temperature of the bubble is not possible; with recognizing losses in water systems, cooling tower replacement conditions dry instead of wet cooling tower more general, or at least part of the year will examine. Economical method to determine the replacement cost, which includes replacement (the cost of construction, installation and commissioning of dry cooling tower, pumps and related pump and fan electricity costs) cost of water is decreased due to compensatory replacement of whole or part year and compared in terms of replacement cost less than compensatory cost savings by water, the alternative methods will used [7].

Three Types of Wastes Occur in Wet Cooling Towers:

Evaporation lost (W_e): Circulatory water per unit time that evaporates in a cooling tower.

Drift and Windage Lost (W_d): Fine water droplets which leave with air from above the tower.

Blowdown (W_b): deliberate discharge of a water of wet cooling tower due to increased concentration of solids in the water circulatory.

The summation total of waste waters called 'Makeup Water'.[8]

$$Makeup\ Water = W_e + W_d + W_b \qquad (1)$$

Economic principles in order to review the definition of an objective function for a Trade-off between construction cost, installation and operation dry cooling tower and reduce the cost of wet cooling tower make-up water is more.

Objective Function = (Makeup Water Cost) - [(Dry Cooling tower Cost) + (Pump Cost) + (Fan Cost)

In the replacement study of dry cooling tower instead of wet cooling tower, the most important factor is determining the area needed for a certain amount of water in the dry cooling tower. By determining the required area and calculate the overall cost of the dry cooling tower in comparison with the makeup water level decreased due to compensatory hybridization can be economical in the project be evaluated and discussed.

To calculate the cost of dry cooling tower, following costs should be calculated:

- Required Area (A)
- Axial fan motor shaft power (F.P.)
- Dry cooling towers construction, installation and commissioning costs (I.C.)

Case Study: In this paper, the cooling water system of Tabriz refinery is used as a case study. For this purpose data collected from weather Meteorological Organization and process cooling water system of the refinery in a one-year period were collected. Methods In this paper, study the conditions of dry cooling tower replacement instead of wet rather than a general or conditions and different scenarios, with analysis advantages and disadvantages of each mode and compare the technical and economic methods to achieve an optimal state of proposed economic and will.

Number of Days Allowed for the Replacement of Dry Cooling Tower Instead of Wet: First, the highest monthly mean air temperature charts of Tabriz vs. months of the year to be draw. Physical limitations restrict cooling towers operations with approach temperature less than 3°C [7]. According to Equation 2 by considering approach temperature equal 3°C output water temperature from cooling tower will be calculated. By consider approach temperature equal to 3°C then moving the size of chart before 3°C we achieve a minimum water temperature output from the tower in the average monthly temperatures reach. Based on data of Tabriz Refinery output water temperature required by the cooling tower is 28°C. Now if we draw a line under temperature 28°C months in parallel to the axis.

Approach temperature = output water temperature – Dry bulb temperature (2)

In this case in the days since that low place crosses the line and put the chart are alone dry cooling tower can be used. Number these days is about 245 days (Fig. 1).

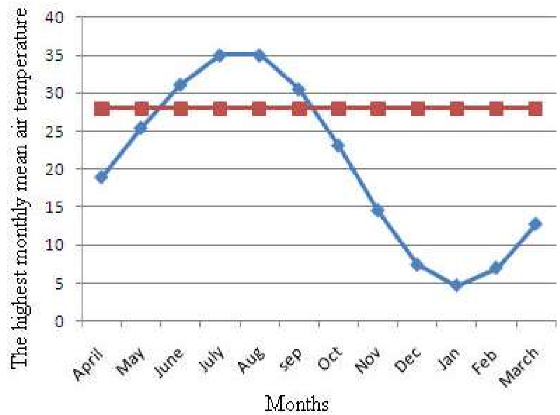

Fig. 1: Estimated days per year which dry cooling tower can be used alone

According to the data of the Tabriz oil refinery; current cooling tower makeup water volume is 762.5 (m^3/hr), which is injected to the system in two parts:

- Raw makeup water rate of approximately 11% of the total makeup water price 0.086 US$/$m^3$.
- Treated makeup water rate of approximately 89% of the total makeup water price

0.154 US$/$m^3$

Thus the total cost of monthly makeup water of Tabriz oil Refinery is 80,400 US$/month.

Dry Cooling Tower Design Calculations

Design Information and Assumptions: Average circulating water temperature 49°C, environment air temperature (Dry Bubble) 23.3°C, refineries altitude of main sea level is 1362 m. forced draft dry cooling tower with two fan and fin pipe with 25.4 mm outer diameter, 15.9 mm blade height, BWG=12, 64 mm tube pitch, Triangular pipe design bundle, 18.28 m pipe length, 4 row tube and 7 pass tube, carbon steel pipe material, extruded aluminum fin material (0.4 fin number/mm).

Construction, Installation and Commissioning Costs of Various Equipments: For determining the equipment costs regarding to their capacity can use the following equation [9]:

$$C_E = C_B\left(\frac{Q}{QB}\right)^M \quad (3)$$

For updating the annular costs of different years can use the following equation:

$$\frac{C_1}{C_2} = \frac{INDEX1}{INDEX2} \quad (4)$$

Materials used in the structure of equipment, operating pressure and temperature of a specific effect on the main equation will cost the correction coefficients related to each of these cases should be in order. Thus following formula will be used:

$$C_E = C_B(\frac{Q}{QB})^M f_m f_p f_t \quad (5)$$

The overall cost processes, services and workers can be multiplied by a factor in the cost of installation and equipment intended by the following formula is obtained the expression:

$$C_F = \sum_i f_i C_{E,i} \quad (6)$$

Thus total cost of construction, installation and commissioning of equations is equal to:

$$C_F = \sum_i [f_m f_p f_t (1 + f_{PIP})]_i C_{E,i} f + (f_{ER} + f_{INST} + f_{ELEC} + f_{UTIL} + f_{OS} + f_{BULD} + f_{SP} + f_{DEC} + f_{CON} + fws) \sum_i C_{E,i} \quad (7)$$

Calculated costs from the formula, construction, installation and commissioning of equipment based on CCF if the cost as per dollar per year multiplied by the years and dividing this amount by 12 monthly cost of installing dry cooling tower. Considering the volumetric flow rate of water pump inlet, pump flow from the vertical axis should use the following formula, which will cost only a function of pumping input water flow [10].

$$C = 0.02(gpm)^{0.78} kUS\$, \; 1000 < gpm < 13000 \quad (8)$$

According to the above formula, construction, installation and commissioning costs of pump is equal to: Select pipes made from carbon steel, equal to the input pressure 1.2 bar and finding related information from tables. To calculate break kilowatt station using the following formula [11]:

$$bkw = \frac{Q.\Delta P}{3600 \times e} \quad (9)$$

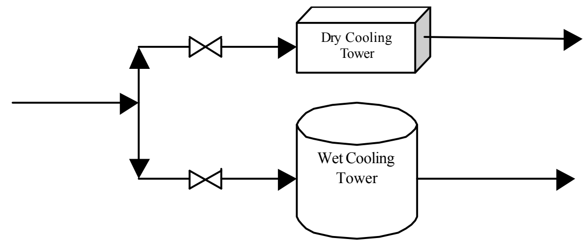

Fig. 2: Global aspect of replacing dry cooling instead of wet

Calculating the real power pumps and electric power fan motor monthly electricity costs can be equal to Power×25.2 US$/month can be calculated. Cooling tower operates in all hours of day and night in rest of the year so cooling system operating time is equal to 720 hours/month.

Monthly Cost of Construction, Installation and Commissioning of Dry Cooling Tower: Calculated cost from equation is dry cooling tower's installed cost and if multiply it to CCF with unit of (1/year) we earn yearly and monthly cost [9].

$$CCF = \left[\frac{(i+1)^n \times i}{(i+1)^n - 1}\right]$$

Where;
i= industrial interest rate (17%)
n= useful Operating life of system (15 years)
In result CCF= 0.187822
Dry cooling tower monthly cost = $CCF(\frac{1}{Year}) \times C_F(Rls) \times (\frac{Year}{12month})$

Study on Replacing Dry Cooling Tower Instead of Wet in 67% Days of a Year: General index of replacement method has been show in Fig. 2:

In this study, according to the presented objective function there is an economical balance between decreasing makeup water cost of current wet cooling tower and increasing installation cost of dry cooling tower with attentive to explained methods in compare with decreasing makeup water cost. Replacement method for dry cooling tower instead of wet in 245 days of year is suitable and economical.

Calculation of Replacing Dry Cooling Water Instead of Wet in 245 Days of Year: In table1 operation parameters and estimate of dry cooling tower installed cost has been shown.

Table 1: Dry cooling tower cost in replacing method in terms of US$/month

Temperature Range	[°C]	28
Heat capacity of dry cooling tower	[Mw]	373.34
Required area for heat transfer	[m^2]	61,300
Motor shaft power of fan in Temperature range	[kw]	6,360
Construction, installation and commissioning cost	[US$]	1,310,000
Dry cooling tower cost	[US$/month]	2,095,000

Table 2: Total replacing cost comparison with saved makeup water cost (US$/8 month)

Dry cooling tower cost	[US$/8month]	2,095,000
Fan electrical cost	[US$/8month]	1,309,000
Pump electrical cost	[US$/8month]	86,800
Pump cost	[US$/8month]	82,100
Total replacing cost	[US$/8month]	3,573,000
Wet cooling tower water cost	[US$/8month]	643,200

Manufacturing, Installation and Commissioning Cost in Replacing Method: By using the following relations we can calculate the related costs for pump and fan with electrical power of 412.8kw [6].

$$C=0.02(50,600)^{0.78}\ \&\ C_F=5.5C$$

Because in replacement method, dry cooling tower works just in 8 month of year so increase 33% (approximately 5 years) to the useful life of the dry cooling tower

$$CCF=0.17769(1/8\ month)\ x\ C_F$$

In table 2 total cost of replacing has been compared with saved makeup water cost.

By comparing the total replacement cost of dry cooling tower water by annual makeup cost we find this method is not economically efficient. However the described problems related to the cooling system to review hybridization method in this system.

Hybridization of Tabriz Refinery's Cooling System: There is tow suggestion method for current wet cooling tower hybridization:

Series Method of Current Wet Cooling Tower with a Dry Cooling Tower: In this method, firstly the rest of returned process hot water entered to dry cooling tower and cold water to determine temperature. Then this water entered second stage to the wet cooling tower to reach the required temperature. Overview of this method is as Fig. 3.

Split Method: In this method, some hot water entered to dry cooling tower and the rest of the water sent to wet cooling tower. The water which a few degrees drop in temperature and then sent to dry cooling tower to reaches required temperature. Splint method in two directions is achieved (Fig 4).

Split Method, Path A: In this path, the amount of water which lost its temperature in dry cooling tower will be mix with the remaining water which has not yet miss temperature before entering to wet cooling tower then all amount of water entering to wet cooling tower. In ‘A’ branch volumetric flow of 11,500 m^3/hr and 56°C temperature divided to ‘B’ and ‘C’ branches. Branch ‘B’ with optimized volumetric flow and temperature, which will be calculated, go to dry cooling tower. The exiting water from dry cooling tower in branch ‘D’ which is heat missed and achieved to optimize temperature will mixed branch ‘C’ and with total volumetric flow (11,500 m^3/hr) and equilibrium temperature of mixing branches ‘B’ and ‘C’ with the branch which is ‘E’ strew to wet cooling tower. In wet cooling tower, total water in branch ‘E’ achieved 28°C temperature and has been use in refinery. Equilibrium temperature in branch E is calculated as follows:

$$m□_D\ (56-T_{equ}) = m□_C\ (T_{equ}-T_{C\ opt}) \quad (11)$$

Where; T_{equ}= equilibrium temperature in branch E

$T_{C\ opt}$= optimize output temperature from dry cooling in branch C

Split Method, Path B: In this path, the exiting water from dry cooling tower is directly strewing wet cooling tower to achieve to refinery required temperature.

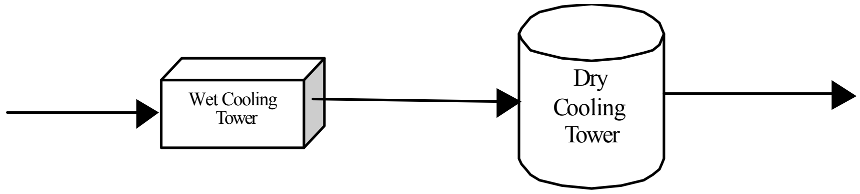

Fig. 3: Global index of series method of hybridization split method

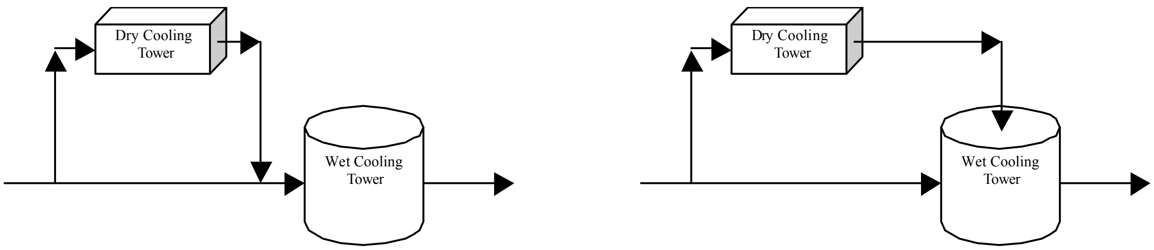

Fig. 4: Global aspect of split method of hybridization system

Table 3: Dry cooling tower cost in series method with current wet cooling tower (US$/month)

Temperature Range	[°C]	4	6	8	10	12	14
Heat capacity of dry cooling tower	[Mw]	53.33	80.00	106.60	133.33	160.00	186.67
Required area for heat transfer	[m^2]	4,950	7,410	9,880	12,400	14,800	17,300
Motor shaft power of fan in Temp. range	[kw]	679	1,020	1,360	1,700	2,030	2,370
Pressure drop	[kPa]	106.5	107.8	108.9	110.0	111.0	111.9
construction, installation and commissioning cost	[US$]	173	258	344	431	516	602
Dry cooling tower cost	[US$/month]	24,400	36,300	48,400	60,700	72,700	84,800

Table 4: Electrical power cost of fan (US$/month)

Temperature Range	[°C]	4	6	8	10	12	14
Motor shaft power of fan in Temp. range	[kw]	679	1,020	1,360	1,700	2,030	2,370
Fan cost	[US$/month]	17,000	25,000	34,000	43,000	51,000	60,000

Table 5: Electrical power cost of pump (US$/month)

Temperature Range	[°C]	4	6	8	10	12	14
Motor power of pump in Temp. range	[kw]	378.0	382.6	386.5	390.4	394.0	397.0
Pump cost	[US$/month]	9,500	9,600	9,700	9,800	9,900	10,000

In this method, the circumstance of carrying the process is similar to path ‘A’ with this difference which the water in branches ‘C’ and ‘D’ entered to wet cooling tower directly. By Evaluating amount of decreasing makeup water in tow lines ‘A’ and ‘B’ and comparing this two quantity conclude that the amount of makeup water in this two paths are equal, So by the following reasons path ‘B’ is chosen.

- Not created back mixing phenomenon
- Decreasing temperature of exciting water from dry cooling tower in direction to arrive to wet cooling tower.
- Decrease in piping costs

Hybridization Method of Series Wet and Dries Cooling Towers

Construction, Installation and Commissioning Cost of Dry Cooling Tower, Pump and Fan in Series Method: In this study, construction, installation and commissioning cost of dry cooling tower in constant volumetric flow rate 11,500 m3/hr at the different temperature ranges of 4, 6, 8, 10, 12, 14°C are calculated. Tables 3, 4 and 5 represents the cost of dry cooling tower, pump and fan in mentioned temperature range in series method. Table 6 shows total hybridization cost in series method.

Table 6: Total hybridization cost in series method (US$/month)

Temperature Range	[°C]	4	6	8	10	12	14
Total hybridization cost in series method	[US$/month]	58,100	78,100	99,300	120,7000	140,800	162,000

Table 7: New makeup water cost in series hybridization Method (US$/month)

Temperature Range	[°C]	4	6	8	10	12	14
New makeup water volume	[m^3]	378.0	382.6	386.5	390.4	394.0	397.0
New makeup water volume	[US$/month]	69	63.4	58.1	52.5	46.9	41.3

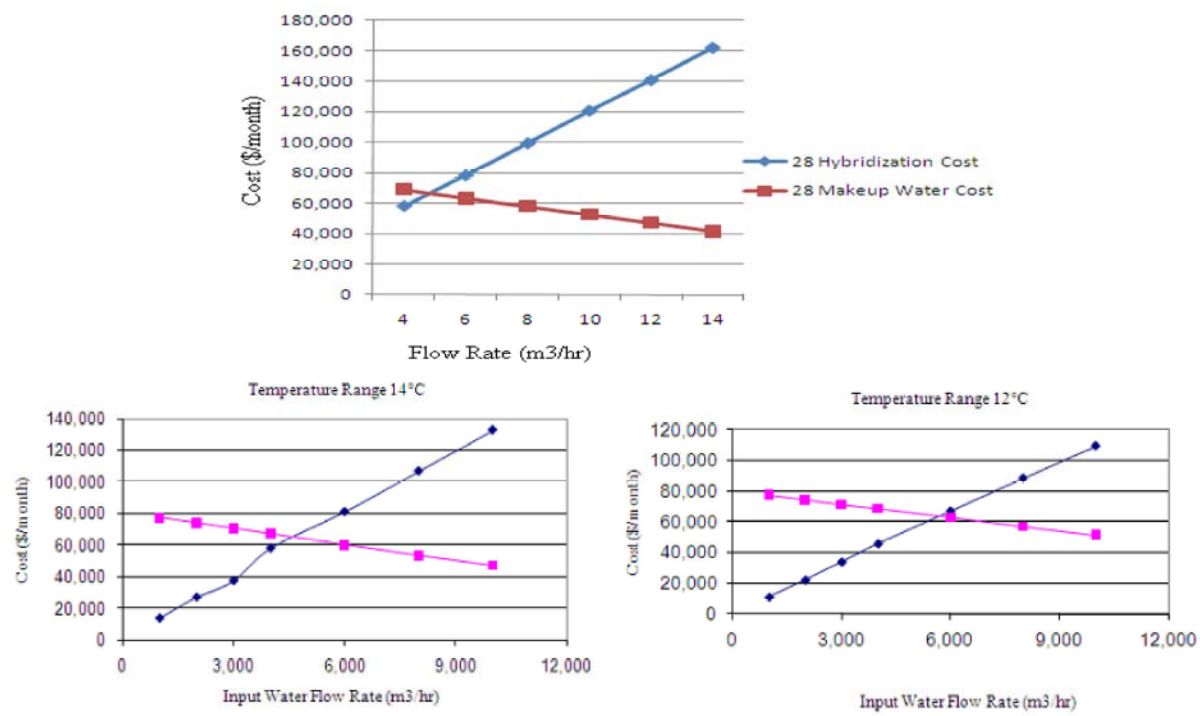

Fig. 5: Hybridization cost with series method

Also by using previous equations, Construction, installation and commissioning cost of pump in series method is 7,200 US$/month. Table 7 have been shown total makeup cost for series method.

Economical Study on Series Method: In Fig 5 total series hybridization draw in terms of mentioned ranges and calculation to conjoin it with new makeup cost graph in different ranges.

The Best Condition in Series Hybridization at 32.3°c Dry Bulb Temperature: In this case, total volume of hot water in dry cooling tower being cold approximately 4.5°C, function of annual saved cost for cooling system is equal to:

Saved Cost = Current wet cooling towers makeup cost - Hybridization cost.

This cost is 14,300 US$/month or 176,100 US$/year.

Hybridization by Using Split Method

Construction, Installation and Commissioning Cost of Dry Cooling Tower in Split Method: In this study, Construction, Installation and commissioning cost of dry cooling tower of different volumes (1,000, 2,000, 3,000, 4,000, 6,000, 8,000 and 10,000 cubic meters) and in temperature ranges of 8, 10, 12 and 14°C is calculated.

Economical Study on Split Method: In this study, conjoin total split hybridization cost graph in different volume flow with makeup cost graph in different ranges coordinates of conjunction place of costs line in different range temperature has been shown in Fig. 6 and Table 8.

The Best Condition in Split Hybridization in 32.3°c Dry Bulb Temperature: If 7,134 m^3/hr of water cooled by dry cooling tower, from 56 reduced to 46°C, the amount of annual saved cost for Tabriz refineries cooling system is 17,700 US$/month or equivalent to 212,400 US$/year.

Table 8: Hybridization cost of split method in different temperature ranges (US$/month)

Temperature Range	[°C]	8	10	12	14
Input water flow to the dry cooling tower	[m^3/hr]	8,760	7,130	5,705	4,800
Hybridization cost of split method	[US$/month]	63,000	62,700	63,400	63,900

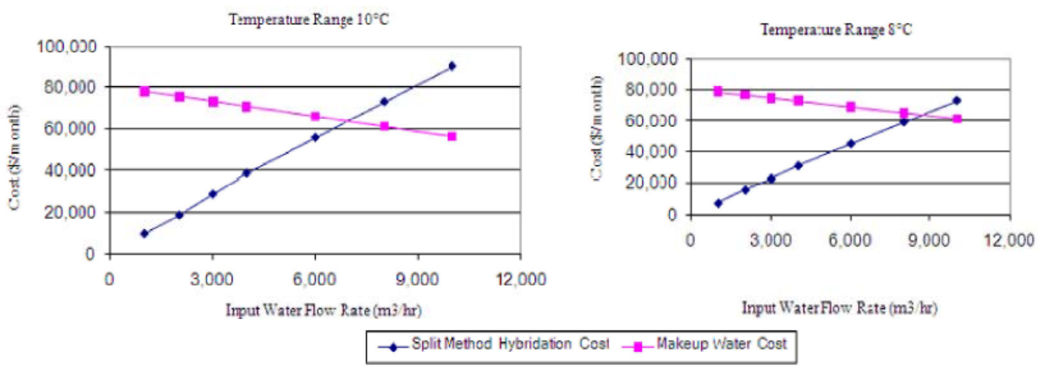

Fig. 6: Hybridization graph of split method in different temperature ranges

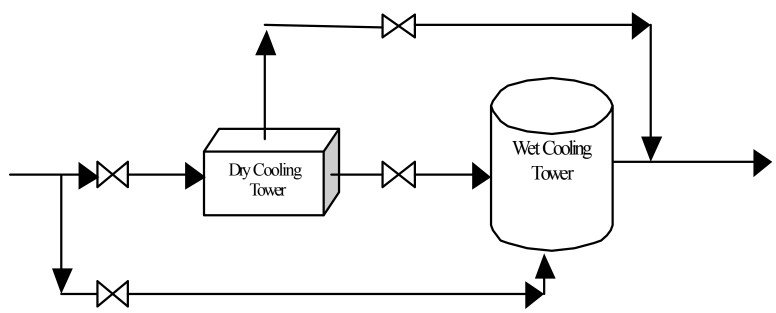

Fig. 7: Global index of proposed method

Proposed Method: In this method, can determined water flow directions by using valves with proposed of 3 systems; wet, dry and hybrid (series and split) systems in different month of years. Outline of the method in Fig. 7 is shown.

The circumstances of changing proposed method to dry, wet and hybrid systems.

Wet Systems: valve number 2 is opened and the other valves are closed.

Dry Systems: valve number 1 and 4 are opened and the other valves are closed.

Hybrid System:

- Series method: valves number 1 and 3 are opened and the other valves are closed.
- Split method: valves number 1, 2 and 3 are opened and valve number 4 is closed.

Determining Optimize Case in Proposed Method: In the proposed method to determine the optimal mode in the proposed system, based on months in dry bubble temperature in Tabriz (air temperature and environment) are divided into three categories:

- Cold months (Dec, Jan, Feb)
- Moderate months (March, April, May, Sep., Oct. and Nov.)
- Warm months (June, July, Aug)

Series Method with Dry Bulb Temperature of 4, 18 and 31°C: Calculate the construction, installation and commissioning cost of dry cooling tower and pump and calculate electrical cost of pump and fan and makeup cost in dry bulb temperature (4, 18, 31°C) and then drew total hybridization cost in terms of ranges in constant volume flow and conjoin it with new makeup cost graph in different ranges.

Table 9: Saved cost of all kinds of hybridization methods in different dry bulb temperature Comparison

Method	Season	Dry Bulb Temperature (°C)	Saved Cost (US$/x Month)	Total Annual Saved Cost (US$/year)
Series	-	32.3	-	171,600
Split	-	32.3	-	212,400
Proposed (Series)	Cold months (x=3)	4, 18, 31	77,700	272,700
	Moderate months (x=6)	4, 18, 31	142,800	
	Warm months (x=3)	4, 18, 31	52,200	
Proposed (Split)	Cold months (x=3)	4, 18, 31	86,100	268,500
	Moderate months (x=6)	4, 18, 31	133,200	
	Warm months (x=3)	4, 18, 31	49,200	

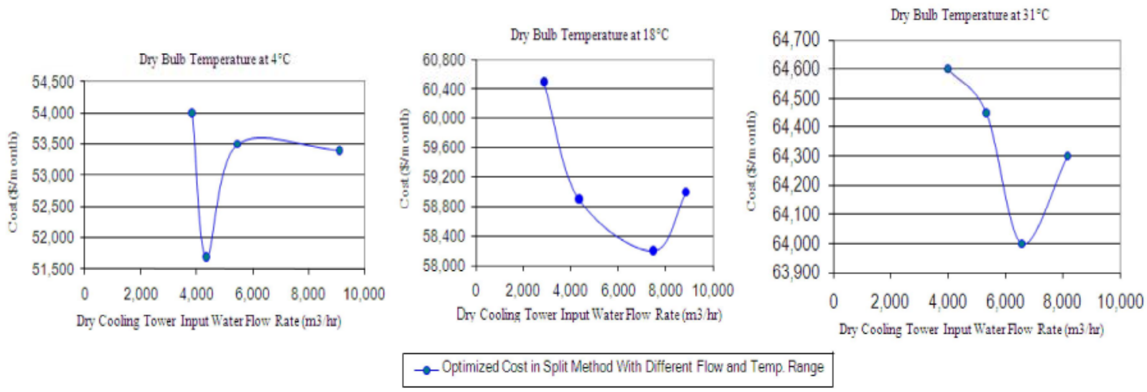

Fig. 8: Hybridization optimized method in split method

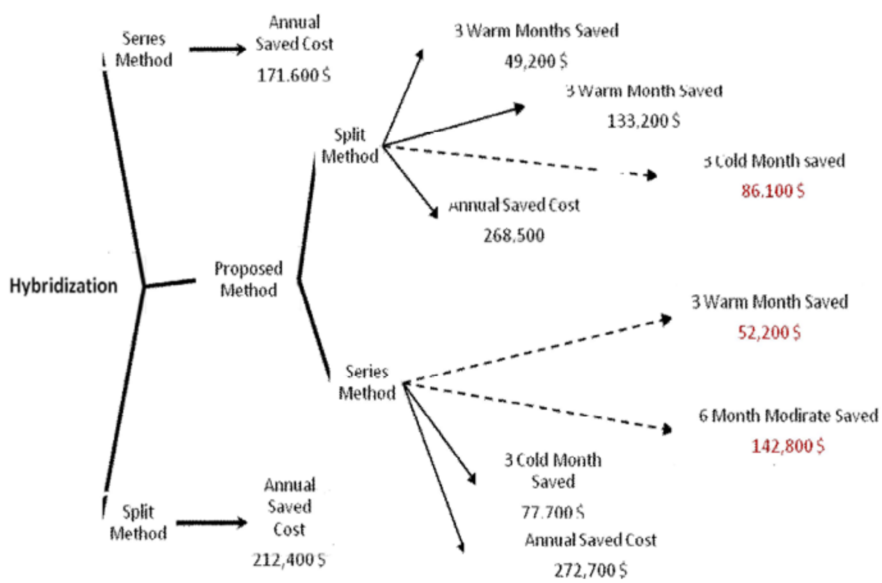

Fig. 9: Saved cost of all kinds of hybridization methods in different dry bulb temperature

Split Hybridization in Dry Bulb Temperature of 4, 18 and 31°C: Calculate the construction, installation and commissioning cost of dry cooling tower and pump and calculate electrical cost of pump and fan in temperature range of 12, 20, 24 and 28°C and makeup cost in 4, 18 and 31°C dry bulb temperature and then draw total hybridization coast graph in terms of 10, 12 and 14°C ranges in mentioned volumetric flows and conjoin that with new makeup cost graph.

Determine Optimize Condition in Dry Bulb Temperature of 4, 18 and 31°C: If in 3 cold months decrease temperature of 4,334 m^3/hr of warm water in dry cooling tower from 56°C reduced to 32°C and in 6 moderate months decrease temperature of 7,477 m^3/hr of warm water in dry cooling tower from 56°C to 44°C and in 3 warm months decrease temperature of warm water in dry cooling tower from 56 reduced to 46°C and draw graph of optimize hybridization cost (Fig. 8) we can optimized saved cost for cooling system and it shown in Table 9.

CONCLUSION

Comparison of Saved Cost for Kinds of Hybridization Methods in Different Dry Bulb Temperatures: In table 9 saved cost of all kinds of hybridization methods in different dry bulb temperature are compared.

In Fig. 9 saved cost of all kinds of hybridization methods in different dry bulb temperature are compared.

According to Fig. 9 the condition is optimize which have the most saved cost for cooling system (red in graph) with comparing graph quantity economical way is as following:

- In 3 warm month with average 31°C dry bulb temperature:

Using proposed system and split method if we cool 4,334 m^3/hr of warm water in dry cooling tower amount of 24°C, the saved cost of three 3 months is equal to 86,100 US$.

- In 6 moderate months with average 18°C dry bulb temperature:

With the proposed system and series method if total warm water is cooled in dry cooling tower amount of 7.7°C, save cost of the 6 months is equal to 142,800 US$.
3- In 3 cold month with average 4°C dry bulb temperature:

Using proposed system and series method if we cool the warm water amount of 6°C by cooling tower, save cost in this 3 months is equal to 52,200 US$.
Therefore; total annual save cost is equal to 281,800 US$.

ACKNOWLEDGMENT

The authors would like to thank Islamic Azad University, Amol and Mahshahr branch and R&D department of Tabriz Refining Company for all their supports.

Nomenclature

A	surface area per unit volume,m²	f_{ELEC}	Electrical (installed)
C	Pump purchasing cost in terms of 1,000 US$	f_{ER}	equipment erection
C_1	equipment cost in first year, US$	f_{INST}	instrumentation & controls (installed)
C_2	equipment cost in second year, US$	f_{PIP}	piping (installed)
C_B	basic cost for equipment,US$	f_{SP}	site preparation
C_E	equipments cost according to capacities, US$	f_{UTIL}	utilities
Q	equipment capacity, m^3/h	f_{WC}	working capital (15% of total capital cost)
C_F	total cost for a complete system, US$	gpm	input water flow, m^3/h
CCF	installed cost coefficient	I.C.	installation costs, US$
E_{equ}	optimize output temperature,°C	Index1	cost index in first year
F.P.	axial fan motor shaft power, Kw	Index2	cost index in second year
e	mechanical efficient	M	constant according to kinds of equipment
f_f	correction factor for design pressure	n	useful operating life of system, year
f_i	installation and commissioning factor	ΔP	pressure drop of pipe side KPa
f_m	correction factor for used material	T_{equ}	equilibrium temperature,°C
f_t	correction factor for design temperature	T_{opt}	optimize output temperature,°C
f_{BUILD}	Buildings (including services)	W_e	water flow rate lost by evaporation, m3/h
f_{CONT}	contingency (about 10% of fixed capital cost)	W_b	water flow rate lost by deliberate discharge m^3/h
f_{DEC}	design, engineering and construction	W_d	water flow rate lost by entrainment, m3/h

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