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Optimizing the Geometric Properties of dry Cooling towers (Heller tower)

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ABSTRACT
Regarding the cooling tower of Heller with natural draft, due to its function type, the environmental conditions influence it more than other types of cooling systems do. The intensity of these influences is sometimes such that it changes the unit generation power up to more than 10 percent of the nominal value in the cold and warm seasons. This paper, studies and investigates the influence of geometric properties which include: the method based on geometric properties of the tower (increasing the height of the tower, increasing the lower diameter of the tower), methods based on cooling elements geometric properties and the combined method (simultaneous change of deltas and increasing the height of delta and etc...),and in the end of the paper, two methods will be proposed to increase the efficiency of the Heller towers (of course, the selection of each of the above methods, requires the evaluation of administrative expenses and problems), and in this case, the temperature of the condenser will be reduced by about 2(°C).Since the Heller towers in our country have been built by EGI Company of Hungary, therefore all the calculations performed, are extracted from this company's documents and then, an application is designed to carry out the calculation tasks for the Heller tower. All the graphs in this paper have been produced by this application.
Keywords: *Dry cooling towers, increasing the efficiency, the geometry of the Heller tower, thermal power plant, heat exchanger*

INTRODUCTION

Cooling systems in power plants, proportional to the condensation of steam coming out of the turbine, can function directly or indirectly by water or air. The use of dry natural flow cooling towers under certain conditions including the insufficiency of water and the existence of problems such as water loss prevention, is of high importance. Given the water shortage in areas away from rivers, lakes and natural water sources, the necessity of using dry cooling towers, becomes more evident. In terms of possessing rivers and natural water sources, Iran is one of the dry countries. For that reason, the necessity of using dry cooling towers becomes more evident, particularly because the plan to change wet cooling towers to dry ones for some plants is being investigated. Given the above issues, the study and investigation of cooling towers performance and factors influencing it is important in plant designs. Different methods to enhance the performance of indirect dry cooling towers (Heller) exist, and each of these methods, have their own cons and pros. An accurate evaluation of these methods will help identify the effective method. Most of the researches are about the investigation of the Heller tower's environmental factors and provision of suggestions to reduce the influence of environmental factors on the efficiency of the Heller tower. [1] [2]

THE METHODS USED

Increasing the tower height

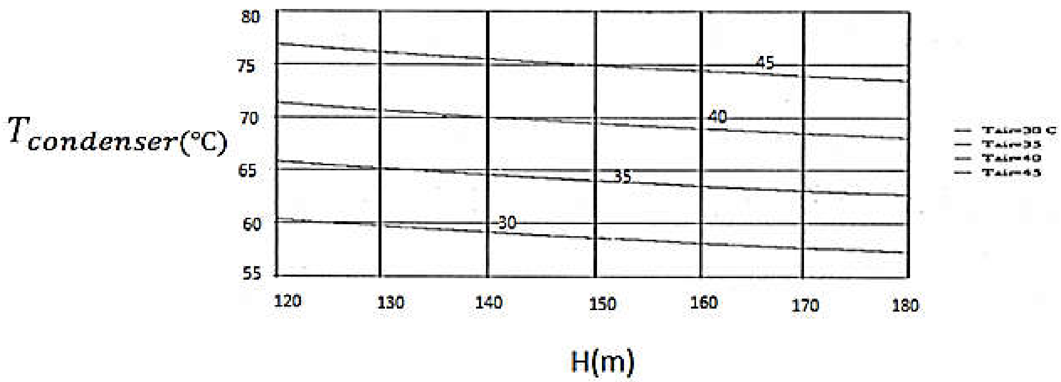
1- By increasing the tower height, the effective height of the tower is increased and it in turn, increases the natural draft of the tower. This increase in the natural draft is about 0.4 Kg per square meter for every 10 meters.
2- By increasing the tower draft, the mass flow rate and the speed of the air passing through the deltas is increased.
3- Due to increase in the air passing over the heat exchanger, air-side heat transfer coefficient is increased.
4- By increasing delta level, air pressure drop in deltas increases. As a result, the probability of the formation of deposits on heat exchanger pipes and the reduction of heat transfer coefficient increases.

5- By increasing the air-side heat transfer coefficient, the total heat transfer coefficient will also increase. Therefore, by increasing the total heat transfer coefficient, the amount of the heat exchanged in the tower will increase. Therefore, the temperature of the condenser and ITD will also increase. Approximately, for each 10 meter increase in the tower height, the temperature of the condenser and the value of ITD, will be reduced by 0.6 Celsius degrees. As a result, the temperature will increase from 30 to 31 Celsius degrees, the condenser temperature will increase about 1.1 Celsius degrees and the value of ITD will also increase by less than 0.1 Celsius degrees. Therefore, in order to reduce ITD, an increase of about 10 meters in tower height seems enough, whereas in order to reduce the condenser temperature, the tower height should be increased by 15 meters which is not that reasonable. However, it should be noted that there's a possibility to increase air temperature to higher values.
Given the concept of ITD that means the difference between the warm water of the tower entrance and the ambient air,it can be calculated through the below equations [3]:

$$ITD = \frac{Q_{0,D}}{Q_{1,D}} \qquad (°C)\ (1)$$

In this equation $Q_{d,o}$(lcal/ h) is the amount of heat that each thermal column exchanges. And (lcal/ h ,c)$Q_{d,l}$ is the heat capacity of each thermal column of a delta. Given that the condenser temperature is actually the sum of the temperatures of environment, water entering the tower and the terminal temperature difference "TTD" between condenser(in the spray condenser, it's the temperature difference between the steam entering the condenser and the water exiting the condenser), the condenser temperature can be calculated through the equation below [2]:

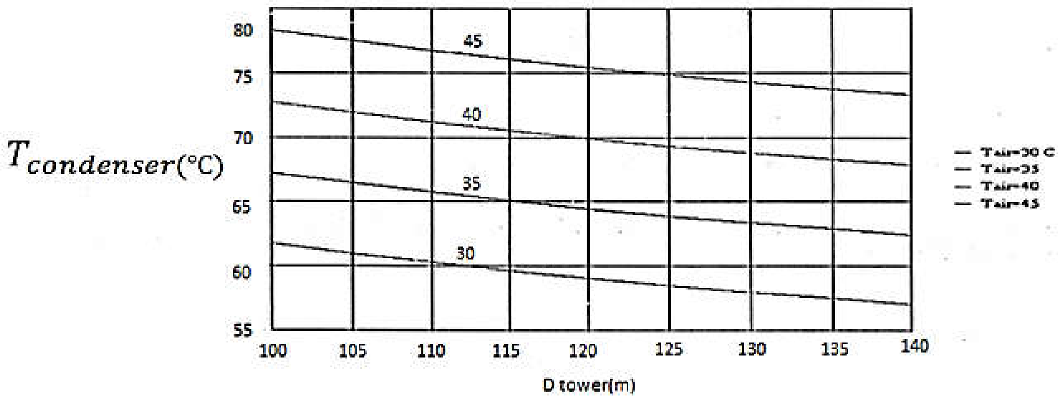
$$TTD \quad T_{condenser}=ITD+T_{ambient}+ \ (°C(2))$$



Graph (1) – Condenser outlet temperature changes based on the tower height

Increasing the lower diameter of the tower
Increasing the lower diameter of the tower will lead to the following results:
Due to the increase in the lower diameter of the tower, the internal tower volume increases and it reduces the density difference between tower inlet and outlet air. As a result of density reduction, the pressure difference between the inside and outside of the tower will also be reduced, and in the end, the tower draft will also be reduced. For example, for every 5 meter increase in tower diameter, we will have 2 percent reduction in the draft. With decreased tower draft, the speed andflow rate transmitting through the tower will be reduced.
With decreased deltas air inlet speed, pressure drop in the deltas will be reduced. Also, more deposits will be formed on the thermal exchanger pipes. And this will result in the increase of air-side heat transfer coefficient, to increase a little.
With decreased air speed transmitting through the thermal exchanges, heat transfer coefficient will also be decreased. With decreased air-side heat transfer, the total heat transfer coefficient will also be reduced.
By increasing the lower diameter of the tower, the number of inside tower deltas can be increased. Therefore, the heat transfer level in the tower will be increased. As it's observed, in this method, we are dealing with two contradicting effects, on the one hand, heat transfer level is increased and on the other hand, the total heat transfer coefficient is reduced. But in the end, the effect of increased temperature transfer level, will be higher on the heat exchange rate in the tower. And this will reduce the condenser temperature and the ITD.

In this method, if the tower diameter is increased by 5 meters, the condenser temperature and ITD will be reduced by about 0.6°C.therefore, when the ambient temperatures reduced by 1°C, then in order to reduce the condenser temperature and ITD to more than 1°C, the tower diameter should be increased up to about 10 meters. Therefore the influence of this method on condenser temperature and ITD, is very little



Graph (2) - Condenser outlet temperature changes based on lower diameter of the tower

Delta angle reduction

As we know, each delta is comprised of two vertical thermal columns. The angle between these two thermal columns is called delta. The change in this angle, will lead to the following results:

With decreased delta angle, the cross section of air transmission path will be reduced and air flow rate transmitting over the tower will be reduced. Also, the pressure drop on the deltas will be reduced.

With decreased air flow rate, the density difference between the tower inlet and outlet air will be reduced.

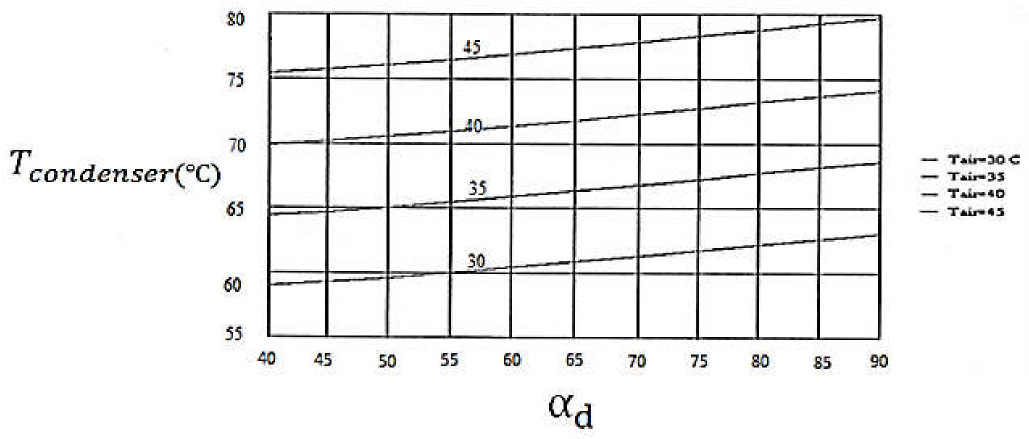
With decreased density difference between the tower inlet and outlet air, the natural draft of the tower will be reduced.

With reduced air speed passing over thermal columns exchangers, the air-side heat transmission coefficient will be reduced. With reduced air-side heat transmission coefficient, the total heat transmission coefficient will also be reduced.

As it's observed, reduction in the delta angle, will have a negative influence on the total heat transmission coefficient. But with reduced delta angles, the number of the deltas in the tower can be increased. As a result, the heat transmission level will be increased and the heat transmission rate in the tower will be increased.

And in the end, delta angle reductions, will reduce the condenser temperature and ITD value (with the condition that their number will be increased).This temperature reduction can be small.

With 1°C increase in ambient temperature, the value of ITD will be increased by 0.1°C and the condenser temperature will also be increased by 1.1°C. In this case, in order to deal with the negative effects of temperature increase, the deltas' angles should be reduced by 47°. In this case, 24 more deltas should be installed in the tower.



Graph (3) –condenser outlet temperature changes based on deltas angles changes

Increasing deltas height

With increased delta height, the effective tower height will be reduced. Therefore, the natural draft of the tower will be reduced. Due to the reduction in the tower draft, the flow rate and consequently, the air speed passing through the deltas will be reduced.

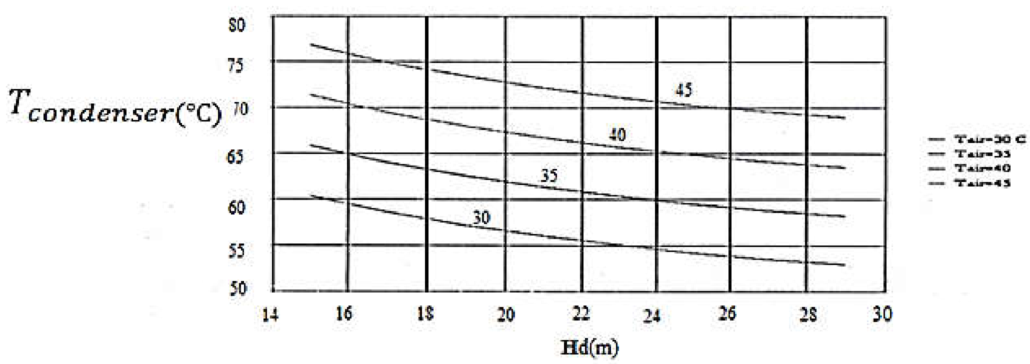
With reduced air speed passing over the deltas, the air-side heat transmission coefficient will be reduced. Due to the reduction in the air-side heat transmission coefficient, the total heat transmission coefficient will also be reduced.

With increased deltas' height, the tower heat transmission level will be increased.

With increased deltas inlet air flow rate, the pressure drop in the deltas and also the tower inlet and outlet density difference will be reduced.

As it's observed in this method, although, with increased deltas height, the total heat transmission coefficient is reduced, but due to the increase in the level of heat transmission in the deltas, the heat transmission in the tower, will be effectively increased. For example, if the height of the deltas increases from 15m to 20m, the condenser temperature and ITD will be increased by almost 4°C.

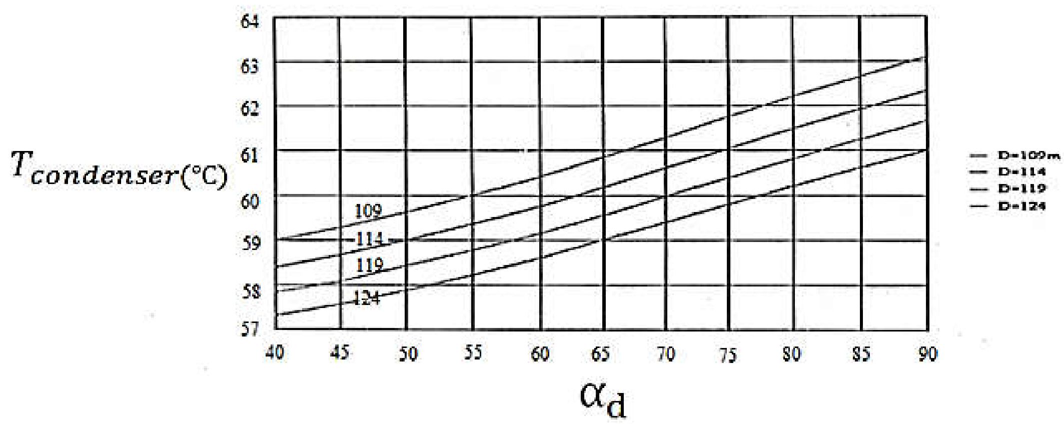
When the temperature rises by about 4°C, if we increase the height of the deltas from 15m to 20m, the condenser temperature and ITD will be increased by almost 4°C. And this shows the effectiveness of the method for increasing the deltas height.



Graph 4- condenser outlet temperature changes based on deltas height changes

The method for increasing the lower diameter of the tower and reducing the deltas angles

In fact, in this method, by increasing the tower diameter and reducing deltas angles, more deltas can be installed inside the tower. Therefore, the heat transmission level will be increased and the tower efficiency will be enhanced. For example, if the deltas angle is considered as 50° and the tower diameter as 119m, 30 additional deltas can be installed in the tower and in that case, the amount of ITD and condenser temperature will be reduced by about2°C.

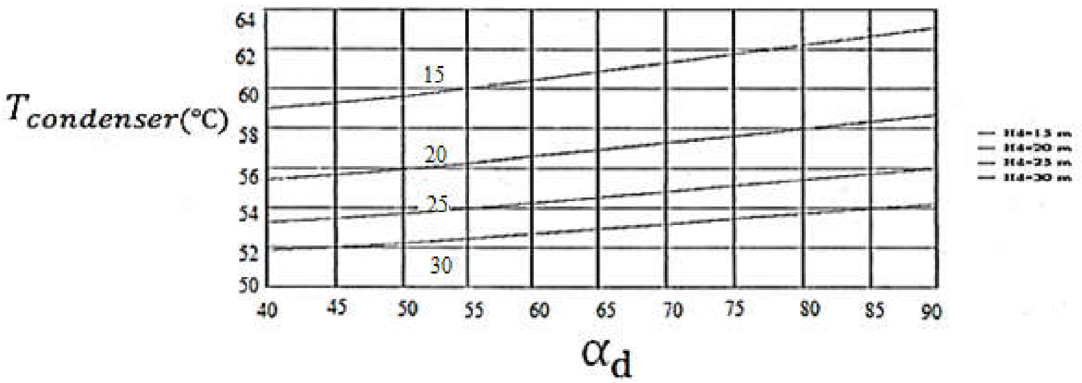


Graph 5- condenser outlet temperature changes based on tower diameter and deltas angles changes.

The method for increasing deltas height and reducing deltas angles

Given that increasing deltas angles, has a great effect on reducing the amount of ITD and therefore condenser temperature, its combination with the deltas angle reduction method, will be highly effective.

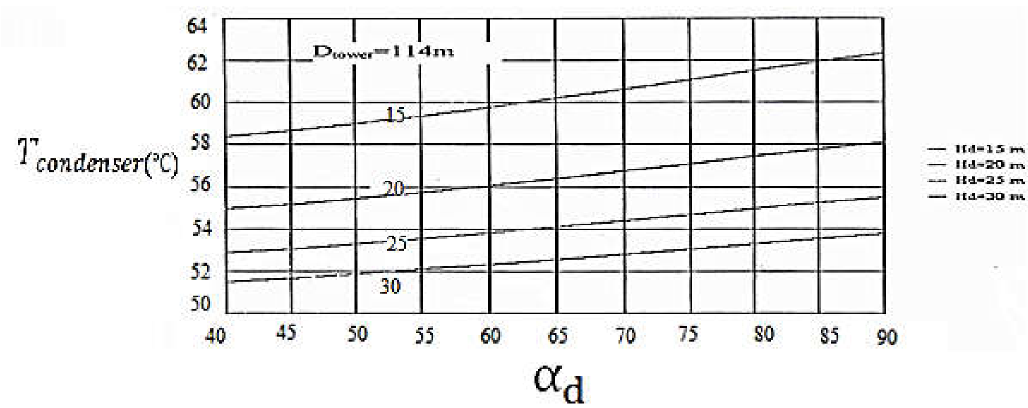
For example, if a 20 meter delta is used instead of a 15 meter delta, and the delta angles is selected as 50° instead of 60°, the amount of ITD will be reduced by 4.6(°C) and the condenser temperature will be reduced by 4.5(°C).



Graph 6- condenser outlet temperature changes based on height and deltas angles changes

The method for increasing the lower diameter of the tower and increasing the height and reducing the deltas angles

In this method, we are facing a remarkable increase in heat transfer level. Therefore, we will experience much influence on ITD and condenser temperature. Of course, it should be noticed that the administrative charges and problems of this method is high. Also, we should be cautious to keep the ITD in the allowed limit by the EGI Company ((°C)<ITD<33 (°C)). For example, if the height of the deltas is selected as 20m, the tower diameter as 114m, and the deltas angles as 50 degrees, the condenser temperature changes can be observed in graph 7.



Graph 7- condenser outlet temperature changes based on height and deltas angles changes

Investigating the methods used

The method for increasing the tower height

This method is based on increasing the ITD and condenser temperature by 0.6(°C) for every 10 meter increase in the tower height, and given the problems of undertaking this method, this amount is very little. Also, changing the height of the built tower is really hard, and it's not correct to do it in terms of security and economic matters. Therefore, this method for increasing the tower height is not appropriate.

The method for increasing the lower diameter of the tower

The mere increasing of the lower diameter of the tower, will not increase the efficiency of the Heller tower, and even decreases its efficiency a little, because it reduces the tower draft. But in case we increase the deltas inside the tower by increasing the lower diameter of the tower, the heat transmission level will be increased and that will increase the tower efficiency and consequently reduce ITD and condenser temperature. The influence of this method on the ITD and condenser temperature will be about 1.2 °C for every 10 meter increase in lower tower diameter. The sole use of this method is not explainable in administrative or economic terms. But this method can be used in combination with other methods.

Reducing deltas angles

By reducing the delta angels, more deltas can be installed inside the tower. And this will result in increasing the level of heat transfer. By adding 18 additional deltas in the Heller tower of Esfahan Shahid

Montazei power plant's tower, the condenser and ITD temperature will be reduced by 0.8°C.The adoption of this method is proper in terms of administrative and economic issues,and that is if the deltas angle is chosen properly.Also, with the use of this method, the peak coolers can be removed.

Increasing the height of the deltas

One of the most effective ways to increase tower efficiency, is to increase its deltas height. Even though this method will reduce tower draft, but due to the increase in the level of heat transfer, the ITD and condenser temperature will be significantly reduced.

Of course the use of this method, entails high costs and many administrative problems. This method can also be used in plants whose tower stokehole is of metal (e.g. Power plant of Shahid Rajayi in Ghazvin). But in plants such as the Esfahan's Shahid Montazeri plant, this method cannot be applied due to the concrete construct of the tower stokehole.

The combined methods

The method of increasing the base diameter of the tower and simultaneous reduction of deltas angles, had the greatest influence in reducing ITD and condenser temperature. But it should be noted that there are lots of administrative problems in this method.Therefore it's best to use one of the two methods of increasing the deltas height and reducing deltas angles and or increasing the lower diameter of the tower and reducing the deltas angle.

Table (1) – Changes in the number of deltas and condenser temperature in the method of increasing the height and reducing deltas angles

Delta height (M)	Delta angle	Number of deltas added	Condenser temperature changes (°C)
15(m)	60	0	0
	55	8	-0.4
	50	18	-0.8
	45	29	-1.1
20(m)	60	0	-3.8
	55	8	-4.3
	50	18	-4.5
	45	29	-4.8
25(m)	60	0	-6.2
	55	8	-6.5
	50	18	-6.7
	45	29	-7

Table 2 - Changes in the number of deltas and condenser temperature in the method of increasing the lower diameter of the tower and reducing deltas angles

The lower diameter of the tower	Delta angles	The number of added deltas	Condenser temperature changes °C
109(m)	60	0	0
	55	8	-0.4
	50	18	-0.8
	45	29	-1.1
114(m)	60	5	-0.7
	55	14	-1.1
	50	24	-1.4
	45	36	-1.8
119(m)	60	1	-1.3
	55	20	-1.6
	50	30	-2
	45	43	-2.3
124(m)	60	16	-1.8
	55	26	-2.2
	50	37	-2.5
	45	50	-2.9

The above table is drawn for the following reference conditions: ($T_{condenser}$=30(°C),Relative Humidity=10%, α_d=60, D_{tower}=106(m)).

As it's seen in table 1, if deltas with heights above 25m are used, the temperatures in the condensers will have the maximum reduction. But then this problem will arise that due to an increase of 10m in deltas height, the circulating water pump (cw pump) function will change, and it will use more power and will decrease the efficiency of the plant, also the administrative cost of this method is high. Therefore, an optimum condition shall be selected. And according to table 1, it seems that the best condition, is to use the 20 meter delta and 55 degree delta angles. In this case, by increasing the air temperature to above 34℃, we will experience negative effect on the condenser temperature. Although, we may experience cw pump function point,but sincethe efficiency of the cooling tower will be increased, and consequently the generation power of the plant will be increased, and also because the peak coolers can be removed from the circuit, then this method is suitable. But regarding towers with concrete structures without the possibility to increase the delta height, it's best to use the second combined method. In the method of increasing the lower diameter of the tower and reducing the deltas angles of table (2), in the optimal condition, a diameter of 114m and delta angle of 45 degrees or a diameter of 119m and delta angle of 50 degrees, shall be used. In this case, with the increase in the air temperature up to more than 32℃, we will not experience any negative effect on the condenser temperature, and the peak coolers can be removed from the circuit. Of course, due to the increase in the number of the deltas, the function point of the cw pump will change a little.

Table 3 –Comparison between various methods of increasing the efficiency of the Heller tower

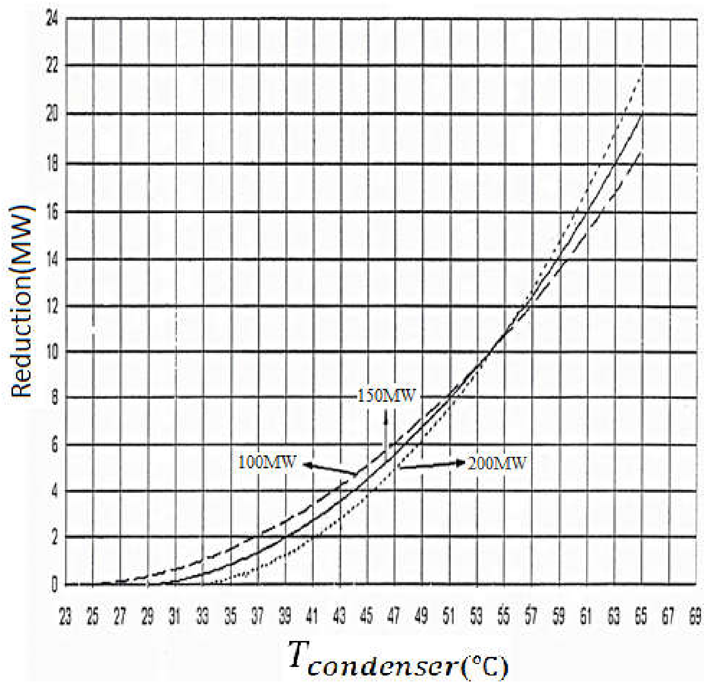
Proposed method	Execution cost	Condenser temperature reduction	ITD reduction	Result
Increasing tower height	Much	little	little	Improper
Increasing lower tower diameter	Proper	little	little	Relative good
Reducing delta angles	Proper	Relative good	Relatively good	Relative good
Increasing deltas height	Good	good	good	Relative good
Increasing deltas height and reducing delta angles	Proper	good	good	Relative good
Increasing lower tower diameter and reducing delta angle	Proper	good	good	Proper
Increasing tower diameter and deltas and reducing deltas angle	Very much	Very good	Very good	improper

CONCLUSIONS

Investigating the influence of the selected method on the generation power of the Shahid Montazeri plant

According to what's been said, the method of increasing the lower diameter of the tower and reducing the deltas angles is identified as proper, and as it was observed, the optimal condition is that the following properties be used: 114m diameter and deltas angle of 45 and or 119m diameter and deltas angle of 50 degrees. (Of course the selection of each of the above methods requires the investigation of the costs and the administrative problems). In this case, the condenser temperature will be reduced by about 2℃. Therefore, up to the temperature of 32℃, there is no need to use the peak coolers and if the ambient temperature is increased again, the peak coolers can be used in the dry mode. As we know, the increase in the ambient temperature, will increase the condenser temperature and the pressure inside the condenser. With the increase of the condenser pressure, the turbine outlet power will be reduced.

In graph 8, the relation between the condenser temperature and reduction of the turbine power, in loads of 100, 150 and 200 MW, related to the plant of Shahid Montazeri plant are illustrated. For example, if each unit of this plant, is placed in the generation peak (200 MW), and the condenser temperature is reduced from 61℃ to 59℃, then the turbine outlet power, will increase by 2 MW, and in total, the total plant generation power will increase by about 8MW.



Graph 8 –Reduction of turbine outlet power compared to the condenser temperature [2]

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