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Mathematical Modeling of Hybrid Cooling Tower for Steam Power Plant

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ABSTRACT

An economical and environmental requirements of hybrid cooling tower in steam power plant are represented by decreasing of outlet water temperature, reducing of water and energy consumption, and working without mist formation. The present work is devoted to study and determine the best contact method of dry and wet tower to build hybrid cooling tower.A three suggested models differs in contacting method of air and water are studied. Analysis of these models are dependent on the basic principles of thermodynamics ,mass and heat transfer with considering of initial and boundary conditions. The best model must be giving accepted values in economical and environmental requirements. A Computer program by Matlab is used for solving the governing equations and determining the suitable mathematical model. The results are indicated that the third model (air in series and water in parallel) is the best in contacting method which satisfied the economic and environment requirements .The results are recorded and represented by graphs.

Keywords: Cooling Towers, Steam Power Plants, Energy.

النمذجة الرياضية لبرج التبريد المزدوج في المحطة البخارية

الخلاصة

إن المتطلبات الاقتصادية والبيئية لبرج التبريد المزدوج للمحطة البخارية تتمثل في تخفيض درجة حرارة المياه الخارجة منه والتقليل من استهلاك المياه والطاقة وتوفير حالة عمل للمحطة بدون تكون الضباب تجنبا لمضاره السلبية . يختص هدا البحث بدراسة وتحديد الطريقة الأفضل لربط الجزء الجاف مع الجزء الرطب لبناء برج تبريد مزدوج للمحطة البخارية . تم اقتراح وتصميم ثلاثة نماذج مختلفة الاحتمالات في الربط لتياري الماء والهواء لغرض دراستها والمقارنة بينها لاختيار النموذج الأفضل اقتصاديا وبيئيا. بنيت أسس تقويم النماذج المقترحة التي أجريت عليها الدراسة على القواعد الأساسية والثرموديناميكية لانتقال الحرارة والمادة آخذين بعين الاعتبار الظروف المناخية . تم استخدام برنامج Matlab لحل المعادلات الحاكمة وتم تحديد النموذج الرياضي الفيزيائي لحسابات البرج المزدوج. تم تحديد التصميم الأمثل في طريقة ربط الجزء الجاف والرطب معا وفق الشروط الحدية لكل نموذج . أعطت نتائج هده الدراسة بان النموذج الثالث(ربط الهواء على التوالي والماء على التوازي) هو الأفضل اقتصاديا وبيئيا حيث أنتج أقل فقد في المياه وأعطى اقل درجة حرارة خارجة من البرج وكذلك أعطى اقل استهلاك في الطاقة وحالة عمل للمحطة بدون تكون الضباب الغير مرغوب فيه.النتائج سجلت وتم تمثيلها بيانيا.

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List of symbols

Symbol	Description	Units
A	surface area of heat exchange	(m^2)
A_a	surface area of heat transfer	(m^2)
A_s	surface area of mass transfer	(m^2)
C_{pa}	heat capacity of dry air	$(kJ/kg.K)$
C_{PV}	heat capacity of vapor	$(kJ/kg.K)$
C_w	heat capacity of water	$(kJ/kg.K)$
h	specific enthalpy	(kJ/kg)
Δh_v	difference enthalpy evaporation	(kJ/kg)
K	total heat coefficient	$(W/m^2.K)$
K_V	Vapor number	-
$L_a=\dot{m}_{aW}/\dot{m}_a$	ratio of air mass flow rate of dry tower	-
$L_w=\dot{m}_{wW}/\dot{m}_w$	ratio of water mass flow rate of wet tower	-
L_o	ratio of air to water	-
$\dot{m}_a$	total mass flow rate of air	(kg/s)
$\dot{m}_w$	total mass flow rate of water	(kg/s)
$\dot{m}_{wv}$	mass flow rate of water evaporation	(kg/s)
n	Coefficient –n (partial load)	-
t_m	temperature of wet air	C^o
P	pressure	(P_a)
V	volume	(m^3)
V_a	volume of heat transfer by convection	(m^3)
V_s	volume of mass transfer by evaporation	(m^3)
X_a	air humidity	(g/kg)

Greek symbol

$\Phi+$	Cooling tower efficiency	-
h_c	Condenser efficiency	-
a	heat transfer coefficient by convection	$(W/m^2.K)$
s	rate of mass transfer	(m/s)
s_o	coefficient of mass transfer	(m/s)
j	humidity ratio	(%)

Abbreviations

Symbol	Definition
DCT	Dry cooling tower
HCT	Hybrid cooling tower
WCT	Wet cooling tower
t_{wD1}	inlet water temperature to dry tower
t_{aD1}	inlet air temperature to dry tower
$\dot{m}_{aD1}$	mass of air to dry tower
$\dot{m}_{aW1}$	mass of air to wet tower
X_{aD1}	air humidity at entrance of dry tower
X_{aW1}	air humidity coefficient at entrance of wet tower
t_{wD2}	outlet water temperature to dry tower
t_{aD2}	outlet air temperature to dry tower
t_{wW2}	outlet water temperature to wet tower

INTRODUCTION

The theory of cooling water coming from condensation process, i.e. incoming or outgoing from the condenser is based on exposing to air or more accurately exposing the surface of water to the air only. This process would cool the air, however, slowly, and this is similar to the cooling of water available on the pool and swamps surfaces. There is a faster way made by spraying water in the air. Both ways include exposing the water surface to air[1].Cooling towers are used with condensers cooled by water to decrease the temperature of the water used as a medium of condensation when it acquires the thermal power lost from the condenser. Pump the hot water outgoing from the condenser to enter to the cooling tower from the upside, then distributed equally in drops form, and it contacts the air incoming to the tower as shown in the figure (1). Cooling process is performed inside the tower as a result of evaporating a portion of water while contacting the air heat transfer by load process, carrying the steam ejected to outside the tower, and thus leads to high air humidity. In addition to that, a portion of the sensed heat transfers from air to air, and therefore, the temperature of the air outgoing from the tower increases. The efficiency of the cooling tower depends significantly on the humid temperature of the air incoming to the tower, and whenever the temperature of the wet air while coming inside is low, the efficiency of the tower will be increased. [2,3]. The average of the heat transfer in the tower depends on the degree of the wet temperature of the incoming air. Reasons of using the cooling towers: in huge cooling and condensation units, such as the power stations and central air conditioning, where it is necessary to have huge amounts of water to cool the cooling liquid. If the temperature of the water coming inside the condenser is relatively high, then we need huge amount of water whether the cooling unit is medium or large. The efficiency of the cooling tower depends on the following: the wet temperature of the air while coming inside the tower, the area of the water surface exposed to air, period of exposure and the speed of air flow in the tower and the direction of the air flow compared to the falling water (parallel , contrast or crossing) [4] .The wet type is more common in large cooling towers, such as in electrical power generation. It is a direct contact heat exchanger, in which hot water from the condenser and cooling air come into direct contact. The water flows in either open circuit or closed circuit. In open circuit, cooling water is pumped into a system of pipes, nozzles, and sprayers within the tower. Air from the atmosphere enters the tower from the bottom of the tower and flows upward through the falling water [5]. The water is collected at the bottom of the tower and then re circulated to remove more heat from the condenser. The temperature of the cold water entering the condenser will determine the steam condensate temperature and, hence, the backpressure, which impacts the efficiency of the whole power generation system [6]**.**

The mist is considered as a basic factor in the wet cooling tower as a result of evaporating low rate of water while cooling, and this leads to form mist. This has the following negative impacts: complaints and protests from the local residence. It creates corrosion and ice in the adjacent areas. Problems appear in the adjacent areas from traffic roads (roads and railways) in case of huge cooling towers [7]. Figure (3) illustrates the thermal representation of the psychometric drawing of the hybrid tower as shown in the figure (2).

The external air enters to the wet portion represented at point 1. Air comes out from the wet portion at point 2 upon cooling water. We notice mist formation (outside saturation curve) . Hot air leaves the dry portion of the thermal exchanger at point 3 after cooling water at fixed humidity level, and then mixes with air outgoing from the wet portion. Mixed air currents leave from the dry and wet parts represented at the point 4 outside the tower. We notice that the mixing line (1-4) (resulted from mixing the surrounding air with the ejection air) if not crossed with the saturation curve (humidity = 100%) then there will not be condensed outgoing water, and therefore, not mist will appear [9,10].

Mathematical model of the hybrid cooling tower (HCT)

This model consists of three elements:-

Mathematical model for wet cooling tower operation (WCT)

Mathematical model for dry cooling tower operation (DCT).

Determination of xa2, ta2, tw2 when coming out from the tower, i.e. two temperatures when water and air currents are outgoing with the humidity content of the air upon leaving (xa2).

In order to facilitate the calculations of the hybrid cooling tower, take into consideration the following : the tower is considered as adiabatic system with the surrounding atmosphere, in case of steady state of the tower related , distribute regularly air and water amounts to the tower profile surface .

Mathematical model of wet cooling tower (WCT)

The mathematical model of the wet cooling tower operation shall be studied according to Merkal relations [3]. The wet tower effectiveness might be expressed as : -

$$h_c = (t_{w1} - t_{w2})/(t_{w1} - t_{m1}) \qquad \ldots (1)$$

In order to determine the evaporation number Kv, we may start from the thermodynamic basic of heat and mass transfer and to equalize water and air state . Figure (4) explains the cycle of air and water in cooling tower for steam power plant.

From equations of water equilibrium and energy balance[3] :-

$$m_a . dX_a = dm_w \qquad \ldots .(2)$$

$$\dot{m}_a . dh_a = \dot{m}_w . dh_w + h_w . dh_w + h_w . d\dot{m}_w \qquad \ldots .(3)$$

$$d\dot{m}_w = s\,(X_g - X_a)\,dA_s \qquad \ldots .(4)$$

$$dQ_a = a\,(X_g - X_a)\,dA_a \qquad \ldots .(5)$$

$$\dot{m}_a\, dh_a = dQ_a + dH \qquad \ldots .(6)$$

$$dH = h_{vg} . d\dot{m}_w \qquad \ldots .(7)$$

$$= dQ_a + h_{vg}\, d\dot{m}_w - h_w\, d\dot{m}_w \qquad \text{....(8)}$$

$$= dQ_a + (h_{vg} - h_w)\, d\dot{m}_w \qquad \text{....(9)}$$

$$\dot{m}_w . dh_w = a\,(t_g - t_a)\, dA_a + s\,(X_g - X_a).(h_{vg} - h_w)\, dA_s \qquad \text{....(10)}$$

$$K_v = \int \frac{s\ .dA}{\dot{m}_W} \qquad \text{....(11)}$$

$$A_a = A_s = A \qquad \text{....(12)}$$

$$\frac{dA}{\dot{m}_w} = \frac{dh_w}{a\,(t_g - t_a) + s\,(X_g - X_a)(h_{vg} - h_w)} \qquad \text{....(13)}$$

$$K_v = \int \frac{C_w . dt_w}{\frac{a}{s\ C_{pa}} . C_{pa}(t_g - t_a) + (h_{vg} - h_w)}$$

$$Z = \frac{a}{s\ c_{pa}} \qquad \text{....(14)}$$

$$) \qquad \text{...(15)}$$

$$K_v = \int \frac{dh_w}{(h_g - h_a) + (\frac{a}{s\ .c_{pa}} - 1)} . \frac{1}{((h_g - h_a - (X_g - X_a)h''_{wg})) + (X_g - X_a)h'_{wg}} \qquad \text{...(16)}$$

$$K_v = \int \frac{s\ .dA}{\dot{m}_w} = \int \frac{dh_w}{h_g - h_a} \qquad \text{....(17)}$$

Mathematical model of dry cooling tower (DCT)

The model of the dry cooling tower operation shall be studied according to nature of flow heat exchange. The dry tower effectiveness might be expressed as per the following relations [13,14]:

$$\Phi = \frac{t_{w1} - t_{w2}}{t_{w1} - t_{a1}}$$

(18)

$$\Phi = \frac{\dot{m}_a . C_{pa}}{\dot{m}_w . C_w}\{1 - \exp((\frac{-\dot{m}_w C_w}{\dot{m}_a C_{pa}}).1 - \exp(\frac{-K.A}{\dot{m}_w . C_w}))\}$$

(19)

$$\Phi = \frac{1 - \exp((\frac{KA}{\dot{m}_w C_w}).(1 - \frac{\dot{m}_w . C_w}{\dot{m}_a . C_{pa}}))}{1 - \frac{\dot{m}_w . C_w}{\dot{m}_a . C_{pa}} \exp((\frac{K.A}{\dot{m}_w C_w})(1 - \frac{\dot{m}_w . C_w}{\dot{m}_a . C_{pa}}))}$$

(20)

$$\Phi = \frac{K.A}{\dot{m}_w . C_w} / (\frac{\frac{K.A}{\dot{m}_w C_w}}{1 - \exp(\frac{K.A}{\dot{m}_w C_w})} + \frac{\frac{K.A}{\dot{m}_a C_{pa}}}{1 - \exp(\frac{K.A}{\dot{m}_a C_{pa}})})$$

(21)

The dry and wet tower contacting depends on type of hybrid cooling tower and on the calculation of the main parameters and according to basic of physics, mathematical relations and boundary conditions[15,16,17] .

Dry part calculation

a- saturation state

$$X_{aD2} \geq X_s(t_{aD2})$$

$$h_{aD2} = C_{pa} . t_{aD2} + X_{s(taD2)} .((C_{PV} . t_{aD2} + \Delta h_V) - (X_{aD2} - X_{s(taD2)})) . C_w . t_{aD2}$$

….(22)

b- without saturation $X_{aD2} \leq X_s(t_{aD2})$

$$h_{aD2} = C_{pa} . t_{aD2} + X_{aD2} .(C_{PV} . t_{aD2} + \Delta h_V)$$

(23)

$$\dot{m}_a . X_{a2} = L_a \dot{m}_a X_{aw2} + (1 - L_a) \dot{m}_a . h_{aD2}$$

Wet part calculation

$$\dot{m}_a . h_{aD2} = L_a \, \dot{m}_a \, h_{aw2} + (1 - L_a) \, \dot{m}_a . h_{aD2}$$

$$\dot{m}_{w_v} = \Delta \dot{m}_w = \dot{m}_{w1} - \dot{m}_{w2} = \dot{m}_a (X_{a2} - X_{a1}) \qquad (26)$$

Suggested models

There are several methods for contacting of air and water flow . In this work we shall test three models to find the best that give the economical and environmental requirements. Figure (5) explains the schematic diagram of hybrid cooling tower contact with thermal station

Boundary conditions of suggested models

Model 1

$t_{wD1} = t_{w1},\ t_{wW1} = t_{wD2},\ t_{w2} = t_{wW2}$

$t_{aD1} = t_{aW1} = t_{a1}$

$t_{a2} = t_{a2}(L_a, t_{aW2}, t_{aD2}, X_{aW2}, X_{a1})$

$X_{aW1} = X_{aD1} = X_{aD2} = X_{a1}$

$X_{a2} = X_{a2}(X_{aW2}, X_{a1}, L_a)$

$\dot{m}_{wW1} = \dot{m}_{wD2},\ \dot{m}_{wD1} = \dot{m}_{W1}$

$\dot{m}_{aW} = L_a . \dot{m}_a \ ,\ \dot{m}_{aD} = (1 - L_a)\dot{m}_a$

Model 2

$t_{wD1} = t_{w1}, t_{wW1} = t_{wD2}, t_{w2} = t_{wW2}$

$t_{aW1} = t_{a1}, t_{aD1} = t_{aw1}, t_{a2} = t_{aD2}$

$X_{aW1} = X_{a1}, X_{a2} = X_{aD2} = X_{aD1} = X_{aW2}$

$\dot{m}_{wW1} = \dot{m}_{wD2} ,\ \dot{m}_{wD1} = \dot{m}_{w1}$

$\dot{m}_{aD} = \dot{m}_{aW} = \dot{m}_a$

Model 3

$t_{wW1} = t_{wD1} = t_{w1}$

$t_{w2} = t_{w2}(\dot{m}_{wD2}, t_{wD1}, t_{wW2}, \dot{m}_{wW2})$

$t_{aW1} = t_{a1}, t_{aD1} = t_{aW2}, t_{a2} = t_{aD2}$

$X_{aW1} = X_{a1}, X_{a2} = X_{aD2} = X_{aD1} = X_{aW2}$

$\dot{m}_{wW1} = L_W . \dot{m}_{w1}, \dot{m}_{wD1} = \dot{m}_{wD2} = (1 - L_W)\dot{m}_{w1}$

$\dot{m}_{aD} = \dot{m}_{aW} = \dot{m}_a$

Working conditions

$\dot{m}_w = 83 kg/s$, $t_{w1} = 50 \ C^{o}$, Computer program

The governing equations are solved by Mat lab language which is used the psychometric diagram with applied the boundary and working conditions. Figure (9) shows the flow chart of a computer program steps of solution:

RESULTS AND DISCUSSION

Figure (10) explain the outlet temperature tw2 as function of Xa2 . It shows a comparison of tw2 for models 1, 2 and 3, the model 3 is the best model because it gives a lower water outlet temperature tw2 than others models Tables (1) and (2) show the comparison of thermal parameters between model 1 and model 3.Model 1 gives outlet water temperature tw2=36.5 at Xa2 =19.292 while for model 3 at Xa2= 19.292 gives tw2= 35.55 . Table (3) shows the results of model 3 which are ,outlet water temperature, evaporation losses and evaporation rate at different air humidity. From the above comparison, we take model 3 is the best, because tw2 is a lower, so that model 3 has to studied in deep since it is shown to be the best in achieving of an economical and environmental requirements .

Figure (11) shows the working state for model 3 parameter load n = (0.4 - 0.8) . There is no effect of n on the outlet water temperature when Lw = 1, but there is an effect at small value of Lw

Figure (12) represents the effect of partial load state for wet tower on cooling water temperature and evaporation rate for model 1. Also there is no effect at La=1. The comparison at the same conditions between curves of models 1and 3, show that model 3 give best working conditions than model 1 according to cooling water temperature as shown in figures (11and12) Figure (13) represents the evaporation losses for model 1and 2 .Model 1 give evaporation losses lower than model 3 when water temperatures are equal and tw2 increase slowly at decreases La Figures (14 and 15) represent a comparison of evaporation losses rate for model 3 with different temperatures ta1=25 C and ta1=30C ,it is notice that, the evaporation losses rate not exceeds 1.67% which equal to evaporation losses rate for model 1 The effects of partial load parameter for wet tower on outlet water temperature are given through the index (n) by following relation [12] :-

$$K_V = K_V^G (l_o / l_o^G)^n \qquad (27)$$

Table (4) shows the effect of Kv on outlet water temperature for wet tower to comparison with dry tower so that, It can be seen that tw2 decreased at Kv increasing (Kv = 0.36 leads to tw2 =45 C while when Kv =2.0 , tw2 = 25 C). Figure(16) explain the comparison results of model 3 and 1 with increasing of Kv, while leads to tw2 always lower for model 3 than model 1. Model 3 is better since tw2 more decreasing with increasing of kv than for model 1. This produce high effectives for model 3 than model 1 . $t_{a1} = 20C^{o}$, $j_1 = 0.7$**)** t_{a1}, j_1

Table (1) results of model 1 of thermal parameters

L_a	t_{wD2} (C^{0})	t_{aD2} (C^{0})	t_{aW2} (C^{o})	X_{aW2} (kg/s)	t_{w2} (C^{0})	t_{a2} (C^{0})	X_{a2} $(\frac{g_w}{kg_a})$
0.30	44.5	43	35.90	39.2	36.5	39.42	19.292
0.60	46.20	47.40	33.53	34.43	31.30	38.21	25.535
0.70	47.23	48.71	33.19	33.46	30.17	36.20	27.511
0.80	48.22	49.63	32.56	32.662	29.33	34.62	28.355
0.90	48.52	49.94	32.45	32.734	28.56	33.53	29.249
0.95	49.32	50.00	32.66	32.290	27.72	32.49	30.196
0.95	49.55	50.00	32.12	32.029	27.95	31.82	31.345

Table (2) results of model 3 of thermal parameters (t_{a1}, j_1)

$t_{a1} = 20C^{o}$, $j_1 = 0.7$

L_W	t_{wD2} (C^{0})	t_{aD2} (C^{0})	t_{wW2} (C^{0})	t_{w2} (C^{0})	t_{a2} (C^{0})	X_{a2} $(\frac{g_w}{kg_a})$	$\dot{m}_{wv}$ (kg/s)
0.30	42.14	24.33	18.55	35.55	39.03	19.292	4.018
0.60	39.62	27.86	23.18	30.07	38.52	25.596	6.655
0.70	37.77	29.86	24.43	28.55	37.84	27.376	7.567
0.80	35.78	30.76	25.39	28.25	36.55	28.360	8.453
0.90	34.54	30.89	26.33	27.77	35.53	29.729	8.615
0.95	33.16	31.29	26.55	27.47	34.10	30.471	9.058
0.95	32.56	31.68	27.33	27.21	32.23	31.166	9.252

Table (3) results of model 3 outlet water temperature, evaporation losses and evaporation rate.

$t_{a1} = 20C^{o}$, $j_1 = 0.4$

L_a	t_{wD2} (C^{o})	t_{aD2} (C^{o})	t_{aW2} (C^{o})	X_{aW2} (kg/s)	t_{w2} (C^{o})	t_{a2} (C^{o})	X_{a2} $(\frac{g_w}{kg_a})$
0.50	45.57	45.74	33.40	33.116	31.35	38.64	20.493
0.60	46.16	47.43	32.33	32.017	29.69	37.63	22.498
0.70	46.90	49.55	32.17	31.029	28.62	36.20	24.412
0.80	47.99	49.77	31.66	30.194	27.77	34.63	26.392
0.90	48.55	49.95	31.20	29.894	26.95	33.32	26.790
0.95	48.99	50.00	31.04	29.630	26.69	32.25	27.654
0.95	49.44	51.00	30.81	29.493	26.13	31.16	28.217

$t_{a1} = 20C^{o}$, $j_1 = 1.0$

L_a	t_{wD2} (C^{o})	t_{aD2} (C^{o})	t_{aW2} (C^{o})	X_{aW2} (kg/s)	t_{w2} (C^{o})	t_{a2} (C^{o})	X_{a2} $(\frac{g_w}{kg_a})$
0.50	44.91	45.66	34.88	38.150	33.22	38.13	26.516
0.60	45.91	46.98	34.20	37.484	32.01	37.16	28.683
0.70	46.55	48.38	33.85	36.424	31.07	35.81	30.352
0.80	47.76	49.66	33.58	35.669	30.30	34.34	32.231
0.90	48.23	49.94	33.44	35.338	29.91	33.43	32.569
0.95	48.99	50.00	33.37	35.134	29.55	32.88	33.109
0.95	49.55	50.00	33.18	34.656	29.24	33.34	34.152

$t_{a1} = 30\,C^{o}\ ,\ \Phi_1 = 1.0$

L_W	t_{w2} (C^{0})	$\dot{m}_{w_V}$ (kg/s)	$\frac{\dot{m}_{W_V}}{\dot{m}_W}\%$
0.70	43.00	2.590	0.86
0.80	42.80	2.80	0.93
0.85	42.60	2.90	0.97
1.00	41.90	3.27	1.00

$t_{a1} = 30\,C^{o}\ ,\ j_1 = 0.2$

L_W	t_{w2} (C^{0})	$\dot{m}_{w_V}$ (kg/s)	$\frac{\dot{m}_{W_V}}{\dot{m}_W}\%$
0.70	37.00	5.700	1.40
0.80	36.10	6.700	2.00
0.85	35.50	6.272	2.21
1.00	34.10	7.260	2.42

$t_{a1} = 25\,C^{o}\ ,\ j_1 = 1.0$

L_W	t_{w2} (C^{0})	$\dot{m}_{w_V}$ (kg/s)	$\frac{\dot{m}_{W_V}}{\dot{m}_W}\%$
0.30	36.00	2.550	0.85
0.40	35.80	2.640	0.89
0.50	35.70	2.730	0.91
0.60	35.40	2.950	0.95
0.70	35.10	3.020	1.00
0.80	34.80	3.189	1.06
0.85	34.40	3.330	1.11
0.90	34.20	3.470	1.15
0.95	33.90	3.600	1.2
1.00	33.60	3.750	1.26

$$t_{a1} = 25C^{o} \ , \ j_1 = 0.7$$

L_W	t_{w2} (C^{0})	$\dot{m}_{w_V}$ (kg/s)	$\frac{\dot{m}_{W_V}}{\dot{m}_W}\%$
0.30	37.62	1.908	0.63
0.40	37.52	1.980	0.66
0.50	37.38	2.01	0.67
0.60	37.28	2.16	0.72
0.70	36.95	2.253	0.75
0.80	36.82	2.37	0.79
0.85	36.52	2.44	0.81
0.90	36.31	2.55	0.85
0.95	36.13	2.66	0.89
1.00	35.92	2.79	0.94

Table (4) calculated wet part parameters to comparison.

$t_{W1}\ c^{o}$	$t_{W2}\ c^{0}$	$t_{m1}\ c^{o}$	$t_{a1}\ c^{o}$	L_{o}^{G}	K_V^G
45	35	10	15	1.5	0.363
38	24	12	15	1.3	1.27
45	25	18	20	1.5	1.898
35	25	25	22	1.0	2.036

CONCLUSIONS

Results of this study indicated that, the contacting method of air in series and water in parallel for hybrid cooling tower give outlet water temperature lower than others of contacting methods, this leads to choose model 3 is the best model, since it satisfied the ecumenical and environmental requirements. Also the contact of air in series and water in parallel for hybrid cooling tower decreased the energy consumption (low of co2 gases) and working conditions without mist formation. So that we can know there is mist or not by determination of this is a very important requirement in steam power plant. There is no effect of the partial load coefficient (n) on the outlet water temperature when Lw = 1, but there is an effect at small value of Lw . Finally, there is no effect of (n) in state of working wet cooling tower. .

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Figure (1) Condenser and cooling tower contact in steam power plant (Didacta- Italia).

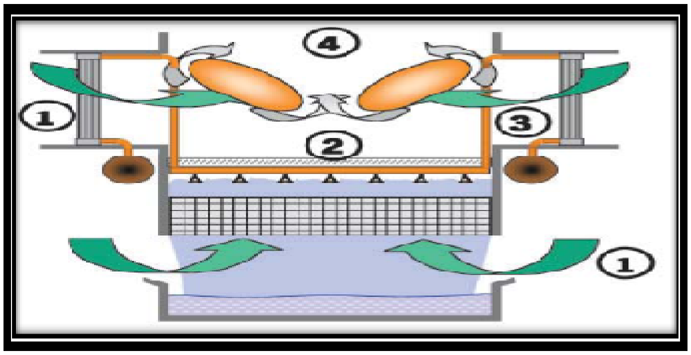

Figure (2) Hybrid cooling tower.

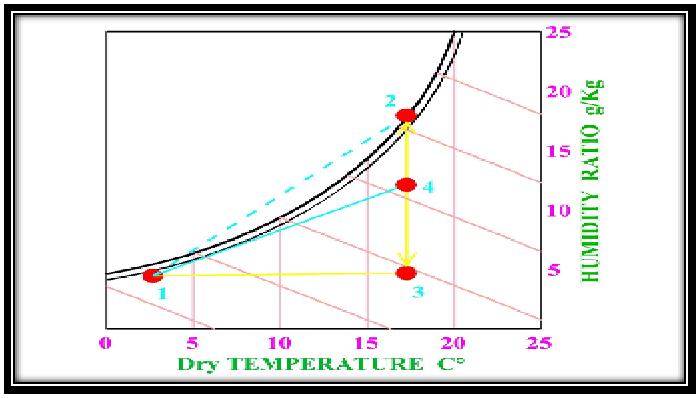

Figure (3) Thermal cycle of hybrid cooling tower on the psychometric diagram.

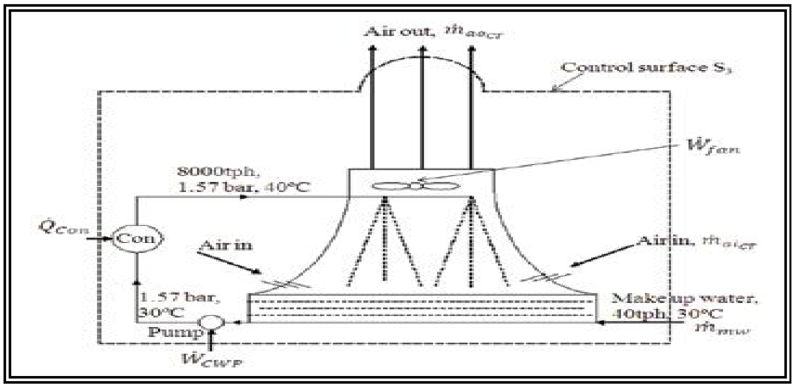

Figure (4) The schematic diagram of the cooling tower subsystem for the steam power plant.

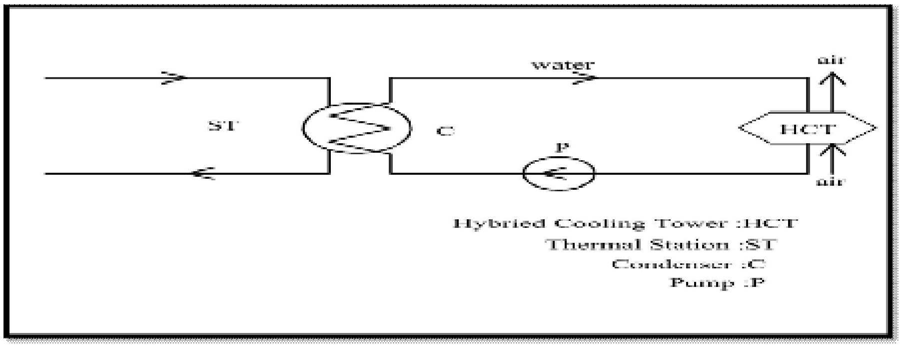

Figure (5) Schematic diagram of hybrid cooling tower contact with thermal station.

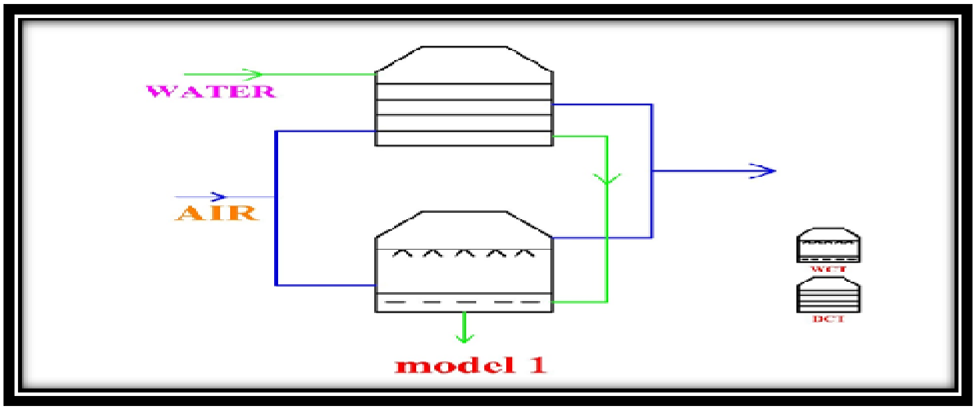

Figure (6) Model 1 for hybrid cooling tower (air in parallel and water in series).

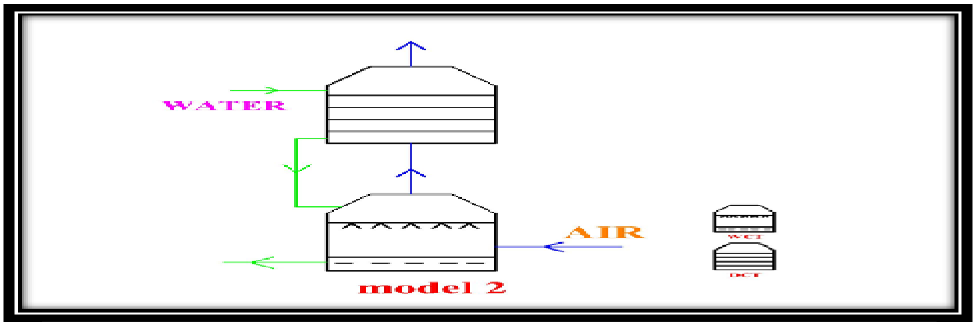

Figure (7) Model 2 for hybrid cooling tower (air and water in series).

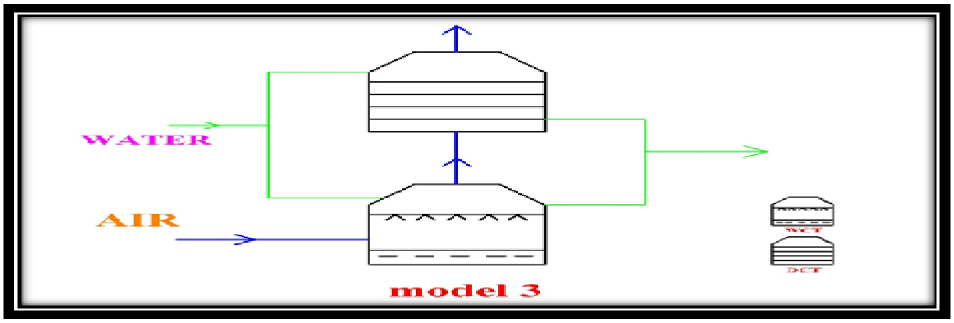

Figure (8) Model 3 for hybrid cooling tower

(air in series and water in parallel).

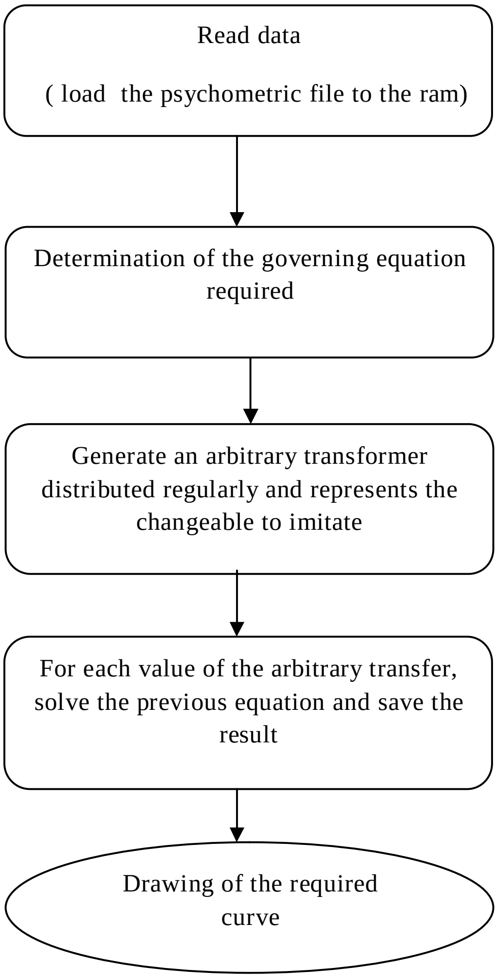

Figure (9) Shows the flow chart of Solution steps.

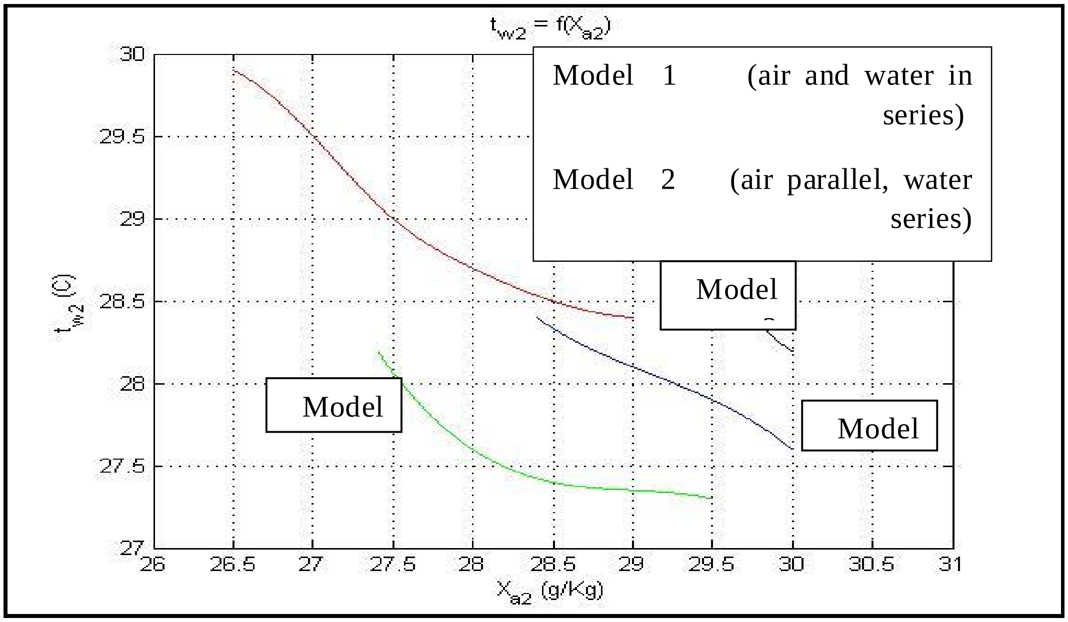

Figure (10) Comparison of outlet water temperature for models 1, 2 and 3.

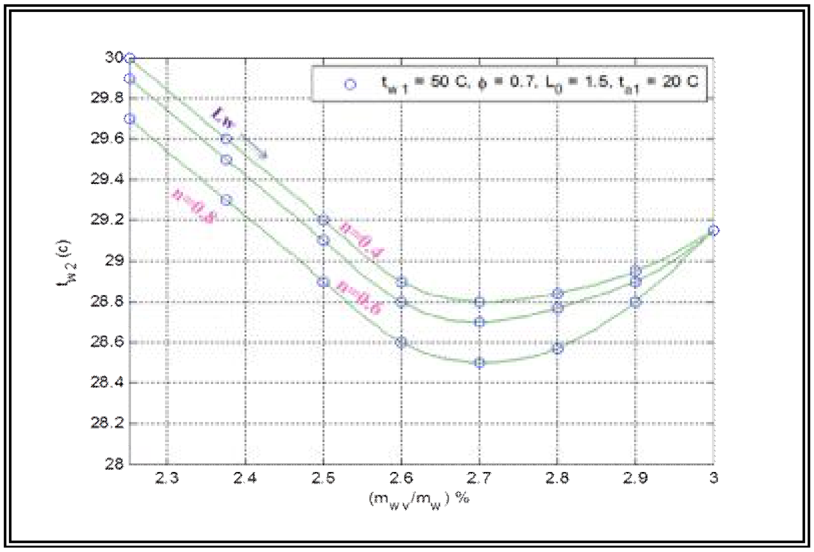

Figure (11) working state at partial load for model 1.

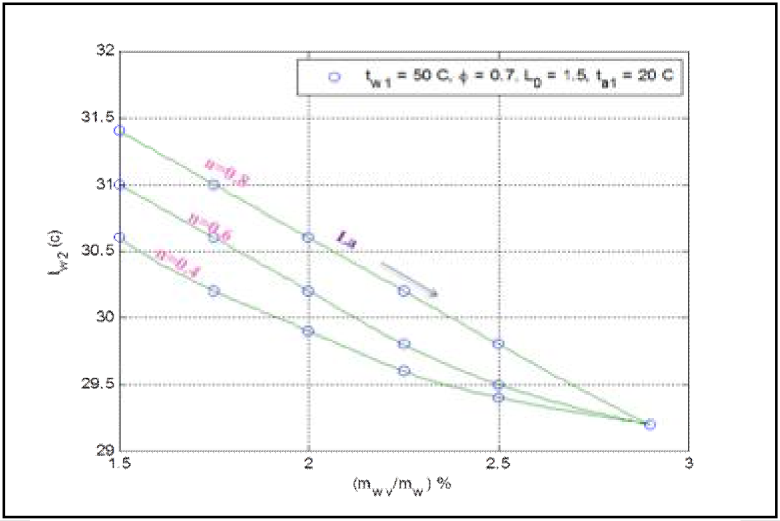

Figure (12) working state at partial load for model 3.

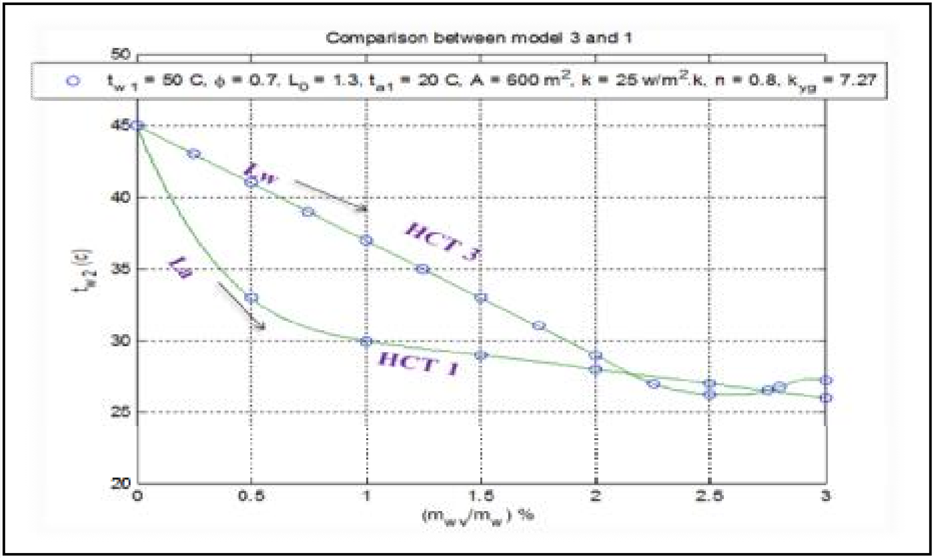

Figure (13) Comparison of evaporation losses for model 1and 3.

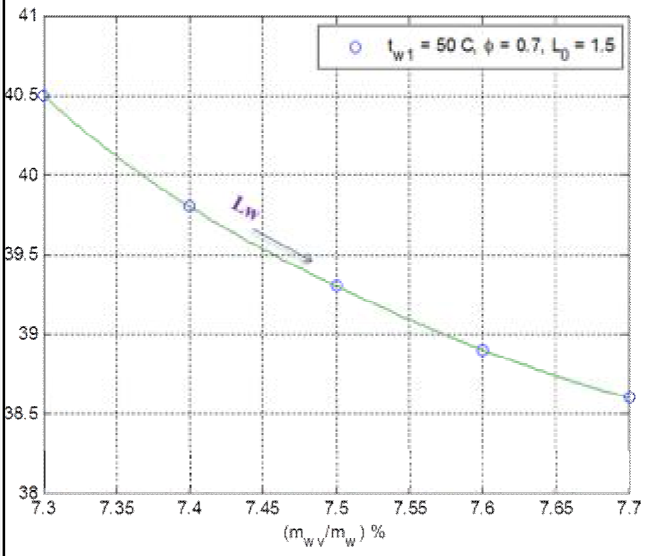

Figure (14) Outlet water temperature with evaporation rate at $t_{a1} = 25C^{\circ}$ for model 3.

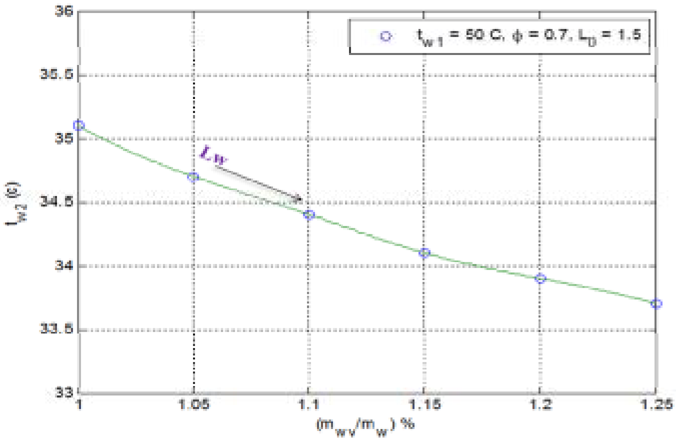

Figure (15) outlet water temperature with evaporation rate at $t_{a1} = 30C^{\circ}$ for model 3.

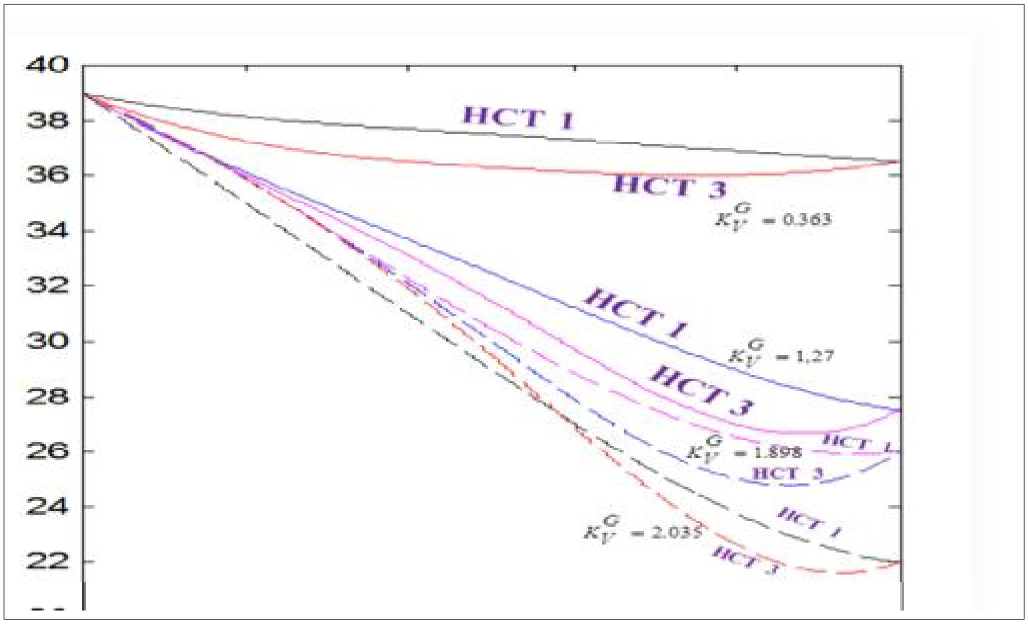

Figure (16) Effect of wet part on cooling water temperature for models 1 and 3.