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Consumption Optimization of a Commercial Building, Considering the Performance of Air & Water Cool Chiller

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Abstract: In this paper, performance analysis has done to save energy consumption in between ACCH & WCCH at Godrej BKC Kurla (West) in Maharashtra. There are both ACCH & WCCH of 400TR (506KW) & 600TR (360KW) capacity respectively. Firstly, both chillers (ACCH & WCCH) theoretically Ikw has calculated and then same has cross checked at different loads during running condition, found both ACCH & WCCH'S Ikw is near about the theoretical value. Now, based on Ikw both ACCH & WCCH'S (excluding pumps & CT-fans) 15min electrical consumption theoretically calculated & then same was cross checked with the help of energy metre reading, found all the experimental values are near about to theoretical values. On the basis of these experiments, an empirical relation has been developed that shows the performance of both chillers as well as its cost effectivity. ACCH is the best to run till 100TR, beyond it there is a loss of 6units/hr (per 10TR) to run ACCH & minimum Rs.4,48,750 p.a. can be saved by running WCCH. If WCCH is run at 400TR (i.e. at ACCH's full load) then around 72576 units can be saved yearly & in terms of cost Rs. 9,65,268 p.a. can be saved.
Keywords: ACCH, WCCH, performance, consumption saving, comparison between ACCH & WCCH, commercial building.

I. INTRODUCTION

As we all know that, population is being increased & energy consumption is directily proportionl to it. People to stay, to work, to their entertainment and to get them medical facilities hospital, residential & commercial buildings, Hotels & Malls etc. are constructed and such buildings consumes huge amount of energy.

Light, inverters, computers, fans, lifts, TV, heater, gyser, ovens, HVAC system etc are such equipments where energy is used. From the previous research, it was found that HVAC system consumes huge amount of energy. Around 40-50% of total energy consumed by it. This paper is concerned with HVAC system. In this paper, a performance analysis has been done between ACCH & WCCH as per the availability & arrangements of chillers in this site.

Different researchers have given different concepts to optimise the overall energy consumption, which will be discussed in literature review.

II. LITERATURE REVIEW

Nur Najihah Abu Bakar et al. [1], this paper presents evaluation on class shifting strategy in term of its ability in reducing energy consumption.

The study was conducted on selected building in faculty of electrical engineering UTM by using energy efficiency index reading as a baseline in determining waste and saved energy. It can minimize electricity usage by simply shifting occupants into an appropriate room which is design nearly for that amount of capacity. The result from the application of shifting method showed a significant number of energy saving that can be made.

Ahmad Sukri Ahmad et al. [2], this paper presents the energy management program carried out at faculty of electrical engineering UTM. Various energy saving activities were initiated since 2010 and the EEI is used as an indicator of building's energy consumption performance during the energy management programme. This programme has shown encouraging results with a 14% reduction in the electricity bill.

Takefumi Hatanaka et al.[3], In this paper a case study has been performed for the supermizer to control the speed of 3phase ac induction motor, to reduce the energy consumption. Controlling parameter are frequency, speed, load, power factor, current, voltage. As we all know that 3 phase induction motor plays a vital role in HVAC system. AHU, secondary pump, blower everywhere it is used.

Muhammad Fairuz Abdul Hamid et al.[4], In this paper a study was done to analyze the energy performance of a commercial building in North Peninsular Malaysia in terms of BEI & annual cooling energy. This paper ensures that in a commercial building around 42% of overall building energy consumption is due to HVAC.

From the analysis, researcher concluded that around 52.82% & 36.44% of energy respectively can be saved in terms of BEI & annual cooling energy.

Rajesh Tilwani et al.[5], A case study has been performed & found that the office buildings located in India especially in southern region may consume about 55-60% of total energy for air conditioning system alone.

Different energy saving proposal was performed to minimize the energy consumption of an office building in which detailed energy audit was carried out, found annual energy saving potential of 231656 KWH, in terms of cost saving, it would be Rs.16.2 Lakh. In order to achieve this benefit, it requires one time investment of Rs.27.5 Lakh, resulting the payback period of 1.7years.

Lijie et al.[6], CWS system has been used to enhance the performance of ACCH, moreover in the full storage system the calculated energy consumption of the chiller has been found to be 4% lower than the conventional system. CWS operating with full storage strategy is the optimal choice for the Kuwait climate.

Since, both peak power & energy consumption of the chiller can be reduced.

Madhur Behl et al.[7], power consumption of a chiller is highly affected by its COP, which is optimal when the chiller is operated at or near full load.

COP is the ratio of total heat removed by the plant to its power consumption. COP varies with load, it will be higher at full load. For a chiller plant, its overall COP can be optimized by utilizing a TES & switching its operation between COP – optimal charging and discharging mode.

This paper concluded that green scheduling approach has the potential to reduce the total monthly electricity bill by almost 17% compared to system without TES.

Jun Zhang et al.[8], In this paper Tabu search algorithm has been applied to solve the optimal load distribution strategy problem for the cooling system constituted by multiple chiller water units. Chiller was run at different load by keeping the concept of Cop. In this concept single chiller run to meet the 40% load of entire building.

Zhang Xiaoming et al.[9], COP of ACCH varies, it is high in evening & low in a day time. High COP makes high chilled water with less electricity consumption & vice versa. When ambient air temp gets high, condenser isn't able to work efficiently. So, chilled water produced by chiller will be reduced. In order to maintain chilled water leaving temperature, ACCH's compressor will have to work harder to raise the pressure of refrigerant , which causes more electricity consumption & lower COP performance.

G. P. Maheshwari et al.[10], This paper concluded that WCCH performs more efficiently than ACCH. Daily energy consumption of WCCH is 32% less than that of ACCH.

A. Abbreviation

1) ACCH – Air cooled chiller
2) WCCH – Water cooled chiller
3) IKW – Input KW
4) BEI – Building energy index
5) W.r.t. – With respect to
6) CT – Cooling Tower
7) TR – Tone Ratio
8) KW – Kilo watt
9) HVAC – Heat ventilation & air conditioning
10) AHU – Air handling unit
11) CWS – Chilled water storage
12) COP – Coefficient of performance
13) TES – Thermal energy storage

B. Methodology

There is a common secondary ckt for both chillers (ACCH & WCCH) in this site. On that basis theoretical & experimental analysis has been done.

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1) *Theoretical Analysis:* As we have already discussed about the chiller capacity & KW. On this basis, we are going to calculate the Ikw of both ACCH & WCCH.

Ikw - KW is required to run singleTR.

S.NO.	PARAMETER	WCCH	ACCH
1	Unit Model	YKEEESQ75EOG	RTAC400H
2	Capacity	600 TR	400 TR
3	KW	360 KW	506 KW
4	Compressor Type	Centrifugal	Rotary
5	No. of compressors	1	4
6	Refrigerant Type	R-134a	R-134a
7	Refrigerant Kg	1ckt x 506Kg	2ckt x 209Kg
8	No. of ckt	Single	Double
9	Primary Pump (HP)	30HP	20HP
10	Condenser Pump (HP)	40HP	Not Required
11	CT Fan 1 & 2	2x20 = 40HP	Not Required

Table 1 : Details of WCCH & ACCH

Ikw of ACCH (Ikw)ACCH = 1.265 ....(1)

Ikw of WCCH (Ikw)WCCH = 0.6 ....(2)

2) *Experimental Analysis*

a) Now, Ikw of both ACCH &WCCH (excluding pumps & C.T.) was noticed during running condition at different loads.

Load (%)	TR	Ampere	Voltage	KW	IKW
15	60	114	424	75.34616	1.25576928
30	120	232	418	151.1662	1.25971824
35	140	277	424	183.0779	1.307699589
40	160	309	425	204.7094	1.279433813
45	180	354	421	232.3142	1.29063444
50	200	394	416	255.4936	1.277467776
55	220	425	419	277.5833	1.261742318
60	240	464	415	300.1625	1.2506772
65	260	498	413	320.6046	1.233094735
75	300	581	416	376.7557	1.255852416
80	320	621	409	395.9181	1.237243916
85	340	635	411	406.8234	1.196539465
90	360	699	407	443.4677	1.23185469
95	380	738	405	465.9097	1.226078242
97	388	754	410	481.8874	1.241977918
100	400	776	420	508.0441	1.27011024

Table 2 : Various parameters of ACCH at different load (experimental Data).

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Load (%)	TR	Ampere	Voltage	KW	IKW
40	240	243	409	118	0.491666667
60	360	355	420	209	0.580555556
65	390	383	418	230	0.58974359
70	420	415	415	251	0.597619048
75	450	449	412	274	0.608888889
85	510	505	413	312	0.611764706
95	570	561	409	345	0.605263158
100	600	591	402	359	0.598333333

Table 3 : Various parameters of WCCH at different load (experimental Data).

b) Again, the performance of both ACCH & WCCH were cross checked with energy meter reading. Theoretically 15 min consumption (in KWH) of both chillers has calculated at different load & same was correlated with the energy meter readings.

Load	Theoretical Value				Experimental Value			% increament w.r.t. Theoretical Value (KWH)
	TR	IKW	KW	KWH	Initial Reading	Final Reading	Consumption (KWH)	
0.6	240	1.265	303.6	75.9	599.105	599.1891	84.1	10.80368906
0.67	268	1.265	339.02	84.755	593.3645	593.4521	87.58	3.333136688
0.67	268	1.265	339.02	84.755	603.26	603.3486	88.61	4.548404224
0.72	288	1.265	364.32	91.08	603.9059	603.9982	92.36	1.405357927
0.82	328	1.265	414.92	103.73	593.5182	593.6244	106.16	2.342620264
0.82	328	1.265	414.92	103.73	588.7344	588.8413	106.89	3.046370385
0.96	384	1.265	485.76	121.44	645.9374	646.0573	119.88	-1.28458498

Table 4 : Comparison of ACCH energy meter reading of 15min with Theoretical value.

Load	Theoretical Value				Experimental Value			% increament w.r.t. Theoretical Value (KWH)
	TR	IKW	KW	KWH	Initial Reading	Final Reading	Consumption (KWH)	
0.56	336	0.6	201.6	50.4	769.8901	769.939	48.91	-2.956349206
0.68	408	0.6	244.8	61.2	758.3161	758.3788	62.68	2.418300654
0.7	420	0.6	252	63	755.076	755.1423	66.34	5.301587302
0.75	450	0.6	270	67.5	754.2816	754.353	71.38	5.748148148
0.82	492	0.6	295.2	73.8	760.7328	760.8088	76.01	2.994579946
0.84	504	0.6	302.4	75.6	753.8707	753.95	79.21	4.775132275
1	600	0.6	360	90	787.7366	787.8279	91.34	1.488888889

Table 5 : Comparison of WCCH energy meter reading of 15min with Theoretical value.

PARAMETER	WCCH (KW)	ACCH (KW)
Chiller	360	506
Primary Pump	22.38	14.92
Condenser Pump	29.86	Not Required
CT Fan 1	14.92	Not Required
CT Fan 2	14.92	Not Required

KW constant

Table 6: Details of equipment's power consumption

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3) Emperical relations to calculate KW of both ACCH & WCCH to get single TR cooling.

(KW)ACCH = TR x (IKW)ACCH + (KWconstant)ACCH ....(3)

(KW)WCCH = TR x (IKW)WCCH + (KWconstant)WCCH ....(4)

TR	(KW)ACCH	(KW)WCCH	Unit Price	Electricty Consumption Price for an hour		Percentage Saving of WCCH w.r.t. ACCH	
				ACCH	WCCH	Unit	Price
1	16.185	82.68	13.3	215.2605	1099.644	-66.495	-884.3835
10	27.57	88.08	13.3	366.681	1171.464	-60.51	-804.783
20	40.22	94.08	13.3	534.926	1251.264	-53.86	-716.338
30	52.87	100.08	13.3	703.171	1331.064	-47.21	-627.893
40	65.52	106.08	13.3	871.416	1410.864	-40.56	-539.448
50	78.17	112.08	13.3	1039.661	1490.664	-33.91	-451.003
60	90.82	118.08	13.3	1207.906	1570.464	-27.26	-362.558
70	103.47	124.08	13.3	1376.151	1650.264	-20.61	-274.113
80	116.12	130.08	13.3	1544.396	1730.064	-13.96	-185.668
90	128.77	136.08	13.3	1712.641	1809.864	-7.31	-97.223
100	141.42	142.08	13.3	1880.886	1889.664	-0.66	-8.778
110	154.07	148.08	13.3	2049.131	1969.464	5.99	79.667
120	166.72	154.08	13.3	2217.376	2049.264	12.64	168.112
130	179.37	160.08	13.3	2385.621	2129.064	19.29	256.557
140	192.02	166.08	13.3	2553.866	2208.864	25.94	345.002
150	204.67	172.08	13.3	2722.111	2288.664	32.59	433.447
160	217.32	178.08	13.3	2890.356	2368.464	39.24	521.892
170	229.97	184.08	13.3	3058.601	2448.264	45.89	610.337
180	242.62	190.08	13.3	3226.846	2528.064	52.54	698.782
190	255.27	196.08	13.3	3395.091	2607.864	59.19	787.227
200	267.92	202.08	13.3	3563.336	2687.664	65.84	875.672
210	280.57	208.08	13.3	3731.581	2767.464	72.49	964.117
220	293.22	214.08	13.3	3899.826	2847.264	79.14	1052.562
230	305.87	220.08	13.3	4068.071	2927.064	85.79	1141.007
240	318.52	226.08	13.3	4236.316	3006.864	92.44	1229.452
250	331.17	232.08	13.3	4404.561	3086.664	99.09	1317.897
260	343.82	238.08	13.3	4572.806	3166.464	105.74	1406.342
270	356.47	244.08	13.3	4741.051	3246.264	112.39	1494.787
280	369.12	250.08	13.3	4909.296	3326.064	119.04	1583.232
290	381.77	256.08	13.3	5077.541	3405.864	125.69	1671.677
300	394.42	262.08	13.3	5245.786	3485.664	132.34	1760.122
310	407.07	268.08	13.3	5414.031	3565.464	138.99	1848.567
320	419.72	274.08	13.3	5582.276	3645.264	145.64	1937.012
330	432.37	280.08	13.3	5750.521	3725.064	152.29	2025.457
340	445.02	286.08	13.3	5918.766	3804.864	158.94	2113.902
350	457.67	292.08	13.3	6087.011	3884.664	165.59	2202.347
360	470.32	298.08	13.3	6255.256	3964.464	172.24	2290.792
370	482.97	304.08	13.3	6423.501	4044.264	178.89	2379.237
380	495.62	310.08	13.3	6591.746	4124.064	185.54	2467.682
390	508.27	316.08	13.3	6759.991	4203.864	192.19	2556.127
400	520.92	322.08	13.3	6928.236	4283.664	198.84	2644.572

Table 7 : Comparison between air & water cooled chiller at different load.

III. RESULT

From the table 2, it has been concluded that (Ikw)ACCH varies from 1.196 at 85% - 1.307 at 35%.
From the table 3, it has been concluded that (Ikw)WCCH varies from 0.491 at 40% - 0.611 at 85%.
From the table 4, a comparison of ACCH energy meter reading of 15min (in KWH) with experimental value has been done, found 10.803% max & -1.284% min w.r.t. experimental value. From the table 5, a comparison of WCCH energy meter reading of 15min (in KWH) with experimental value has been done, found 5.748% max & -2.956% min w.r.t. experimental value.

IV. DISCUSSION

From the tables 2,3,4&5, it has been noticed that the experimental values are near about theoretical values. So, by keeping this in mind, it has found from the equation 3&4 and Table 7 that there is a loss to run WCCH upto 100TR (for this particular site) & as load increases beyond 100TR, there is around 6units/hr can be saved (w.r.t. to ACCH at every 10TR) by running WCCH. But since there is a single compressor in 600TR WCCH in this particular site, it is quite not possible to run WCCH below 40% load(i.e. 240TR). So, if there is a load below 240TR of entire building then we will have to run ACCH which will led 92.44units/hr more than WCCH & hence there is a loss of Rs1229.45/hr.

V. CONCLUSION

ACCH & WCCH both plays a vital in their respective applications. ACCH is mostly preferred where there is a shortage of water (specially in Gulf) otherwise WCCH is the best option to save energy. Instead of running ACCH at full load WCCH should be run that can save 198.84units/hr & Rs 2644.572/hr.

	PARMETERS	Units/Hr	Rs/Unit	Total consumption that can be saved
At Load 400TR (Full Load)	Daily	198.84	13.3	Rs 2,644.572
	Monthly	5965.2	13.3	Rs 79,337.16
	Yearly	72576.6	13.3	Rs 9,65,268.78
At Load 240TR (Minimum)	Daily	92.44	13.3	Rs 1,229.452
	Monthly	2773.2	13.3	Rs 36,883.56
	Yearly	33740.6	13.3	Rs 4,48,749.98

Table 8 : Lookout for an yearly electricity consumption that can be saved to run WCCH instead of ACCH at different load.

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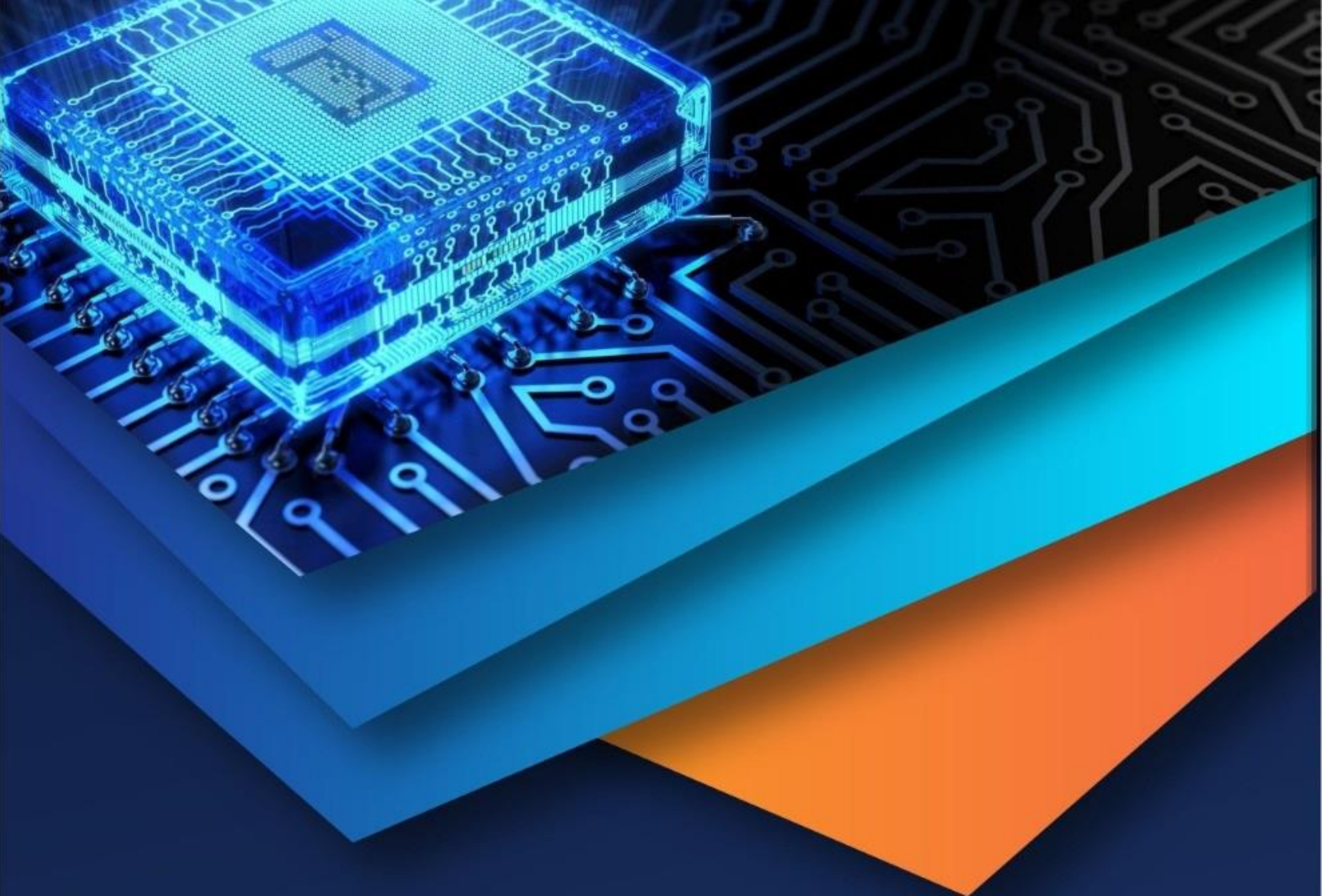

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