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Air Cooled Chiller Efficiency Optimization

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Abstract - *This research paper focuses on Energy Optimization of Air cooled chillers for Data centers . As these air cooled chillers run on VCRC , it demands huge energy. Hence the study deals with findings of how the ambient temperature can be exploited to cool the hot return water temperature from the data or air handling units and thus improve the efficiency of chiller. The following study will show the 600 TR chiller for a application like data center will make use of ambient air rather than compressors to reduce the energy consumption and ultimately improve the overall efficiency of chiller*

Key Words: Efficiency , VCRC , COP , Free Cooling , Compressor , Heat Exchanger , Chiller , Data Center.

1. INTRODUCTION

Air cooled chiller work on VCRC (Vapor Compression Refrigeration Cycle). The components of the VCRC are Evaporator, Compressor, Condenser, Expansion Valve.

All the components operate coherently to achieve the desired cooling performance. As the compressor is energy intensive, this study focus majorly on reduction in power consumption.

1.1 Air Cooled Chiller Design

The chiller has the capacity of 2088 kW and the entering water temperature from the AHU's is 39 °C and the leaving water temperature is 29°C. The outside ambient temperature is 45 °C. The location is Mumbai. The 45 °C is the design ambient temperature.



Fig -1: Air Cooled Screw Chiller

1.2 Standard Vapor Compression Refrigeration Cycle

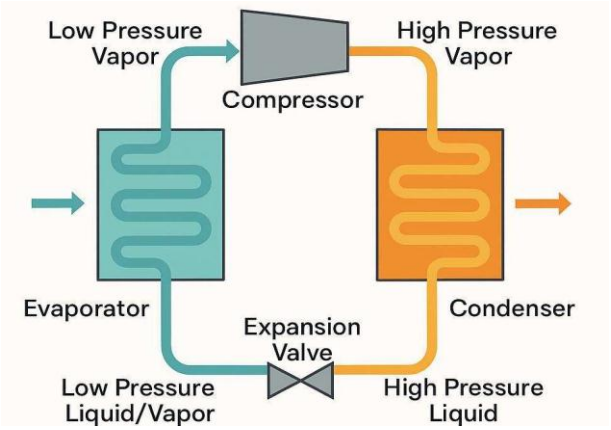


Fig -2: Vapor Compression Refrigeration Cycle

The standard cycle consists of four components-

1. Evaporator
2. Compressor
3. Condenser
4. Expansion Valve

These are the four main function components of a standard air cooled chiller.

The Heat Rejection takes place in the evaporator . The warm return water from the Data center exchanges heat with the evaporating refrigerant, probably R134a or R1234ze. The quantity of the refrigerant charge depends on the total cooling capacity desired to be removed.

The evaporator is usually DX type or Flooded type.

It varies from manufacturer to manufacturer .Each has it's own advantages and disadvantages.

Now, the compressor increases the pressure and temperature of the refrigerant gas by compressing it.

Probably, screw compressor which is a positive displacement compressor. This increases the condensing temperature and accordingly pressure.

The condenser aids in the heat rejection process . The total heat to be rejected by the condenser is equal to the heat absorbed by the refrigerant in the evaporator and the heat gain in the compressor through the work of compression.

By rejecting the heat through fans and ambient air , the gas is condensed into liquid form. The manufacturers in general design subcooling of 5-8 K to gain more refrigerating effect per Kg. The pressure of the refrigerant remains constant in this process.

The Expansion Valve , usually Thermostatic Expansion valve or Electronic Expansion valve reduced the pressure of the gas enabling it to absorb the heat from the warm water . The expansion process is a isenthalpic expansion process, that is , the enthalpy remains constant during this process.

1.2 Power Consumption

The air cooled chiller for the cooling capacity of 2088 kW

Which is 593 TR consumes 480 kW power. The COP comes as 4.35 according to this.

COP = Cooling Capacity Power Consumption

1 TR = 3.517 kW

2. ANNUAL POWER CONSUMPTION

Considering the City Mumbai for which chiller is designed, the annualized power consumption at 100% load is 0.48 kW/TR . This is when the chiller runs completely on the DX mode (i.e., the compressors are ON). However, the compressor usage can be minimized by exploiting the colder ambient conditions during various times of the year . As all over the year it is not going to be 45 °C. The 45 °C design condition is considering the worst case scenario. Below table summarizes the kW/TR for the chiller at 100% and 75% of loading in standard chiller (VFD Operated)

Table -1: Operating Parameters for Standard Chiller

Loading	%	100%	75%
CW In	°C	39	36.5
CW Out	°C	29	29
Amb	°C	45	45
Capacity	kW	2088	1566
Total Capacity	kWhr	18,290,880	13,719,036
Total power Consumption	kWhr	2,502,799	1,690,564
EER	kW/kW	7.31	8.12
EER	kW/TR	0.48	0.43

As we can see in the above table, the power consumption at 100% & 75% of loading is 0.48 and 0.43 respectively. The capacity requirement at 100% of Chiller Loading is 182 lakh kWh and the power consumed is 25 lakh kWh. This results into the Energy Efficiency Ratio of 7.31.

The below chart summarizes the kW/TR at 4 Point Part Load i.e., 100% loading , 75% , 50% and 25% of Chiller Loading . Now we will see how we can reduce this kW/TR power consumption by use of free cooling .

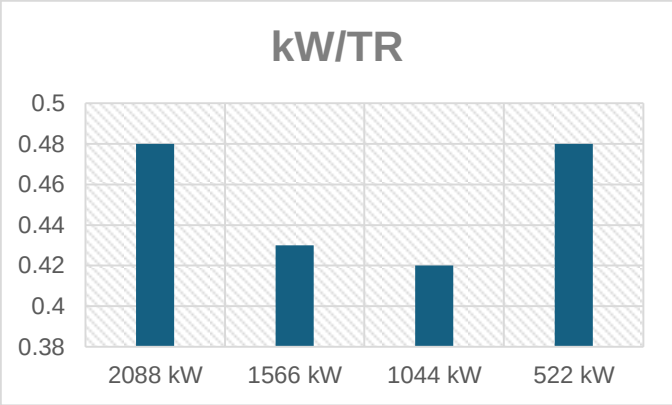


Chart -1: Efficiency of Standard VFD Screw Air cooled chiller

The Free Cooling coils are installed parallel to the DX refrigeration coils. The hot return water coming from the Data Center is bypassed provided the free cooling conditions are satisfied. The free cooling logic will be explained further in this paper. This method of bypassing the warm water into the free cooling coils in order to achieve partial or full free cooling surely does reduce the power consumption of a air cooled chiller. Now, how much power does this method actually reduce. Lets see and dive further into this topic.



Fig -3: Air Cooled Screw Chiller with Free Cooling Coil

The free cooling performance totally depends on the ambient conditions and the respective location. Suppose for a location like Delhi, there are more colder hours which contribute more towards free cooling hours.

The name Free Cooling Implies the cooling is done without or minimal usage of Energy/Power. The compressor operates at part load conditions or the compressor is bypassed provided all the conditions are satisfied.

Full Free cooling model saves enormous amounts of Energy. However, it depends on the ambient conditions.

Table -2: Free Cooling Performance at 100% & 75% Load

Loading	%	100%	75%
CW In	°C	39	36.5
CW Out	°C	29	29
Amb	°C	45	45
Capacity	kW	2047	1549
Total Capacity	kWhr	17,931,106	13,572,280
Capacity-Free Cooling	kWhr	8,045,382	7,321,490
Capacity-Free Cooling	%	45%	54%
Total power Consumption	kWhr	2,075,954	1,553,685
EER	kW/kW	8.64	8.74
EER	kW/TR	0.41	0.40

Above table shows the free cooling performance at 100% and 75% of chiller loading , their power consumption and Energy Efficiency Ratio.

As we can see in the table above ,the total free cooling possible at 100% cooling load is 45% of total cooling capacity required.

Also , if you can see or compare table 1 and table 2 , we can notice that there is 14.5% savings in terms of kW/TR of cooling over standard chiller.

The COP(Coefficient of Performance) has also increased from 7.31 to 8.64 due to Free Cooling

3. Free Cooling Logic

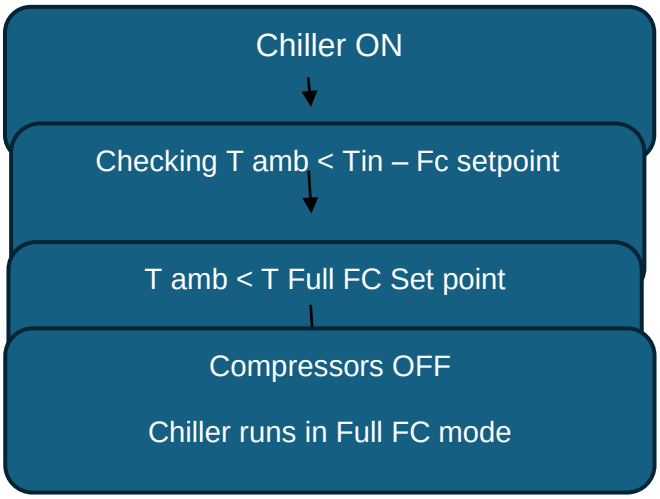


Chart -2:- Free Cooling Operation Logic

4. Free Cooling Modes

There are in principle three modes of operation with regards to free cooling chiller

4.1 DX Mode
4.2 Mixed Mode (DX + Free Cooling)
4.3 Full Free Cooling Mode

4.1 DX mode

In DX mode, as discussed in section 1.2 of Standard Vapor Compression refrigeration cycle ,the chiller operates exclusively through all 4 functional components (Compressor, Condenser , Expansion Valve , Evaporator)

4.2 Mixed Mode (DX + Free Cooling)

In this Free Cooling Chiller, as per the operating logic incorporated, the free cooling will get activated when the ambient temperature is 2 deg C colder than the warm return water temperature from the DC (Data Center).

However, the free cooling capacity varies with Delta T between the cold ambient temperature and the return water temperature

Free Cooling Capacity = function (return water temperature – ambient temperature)

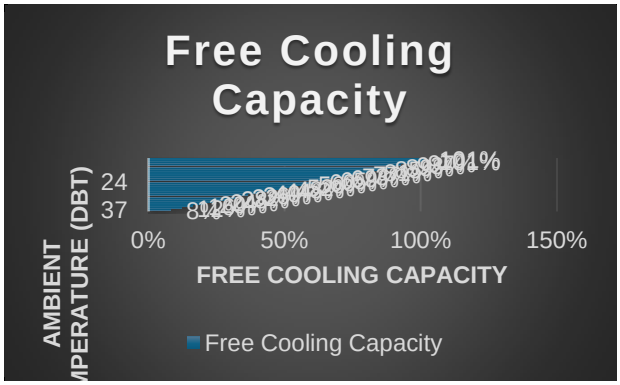


Chart-3: Ambient Temperature Vs Free Cooling Capacity

As you can see explicitly in the above chart, the free cooling capacity increases almost linearly with the decreasing ambient temperature.

The free cooling capacity at the 37 deg C ambient, that is , dry bulb temperature is 8% And at 14 deg C dry bulb temperature, the free cooling capacity is 2047 kW as minimum.

4.3 Full Free Cooling Mode

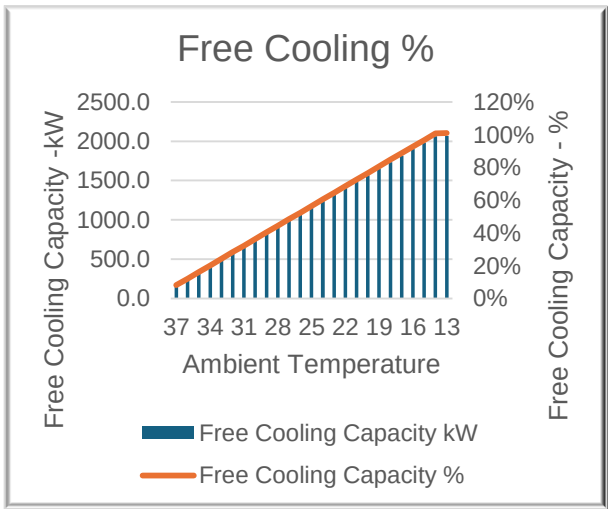


Chart-4: Ambient Temperature Vs Free Cooling Capacity increase %

So, as discussed earlier the free cooling percentage increases with increase in the delta between warm return water temperature and the ambient temperature. For this chiller, at around 25 deg C of delta T, we achieve full FC capacity i.e., the compressors are fully shut off and the water is cooled by means of cold ambient air. Thus, increasing the efficiency of chiller dramatically.

The delta for free cooling also depends on the coil surface area and the heat transfer coefficient.

Also, as the return water temperature increases, the total percentage of cooling capacity increases.

Maybe from increasing the chilled water to 42 from 39 deg C , we may achieve 50% of free cooling capacity at 100% cooling load of chiller.

5. Operating Cost

The total power consumption at 100% loading for standard chiller is 25 lakh kWh, while the free cooling chiller consumes 20 lakh kWh.

Hence, as per the 8 rs/kWh. The total cost of operation for standard chiller will be 20000000 rs.

On the other hand, the free cooling chiller has consumption of 16000000 rs .

Therefore, with the operation of chiller in free cooling mode the savings are 4000000 rs.

6. CONCLUSIONS

This Study concludes that the while the free cooling chillers may look heavy on capex , however the savings on OPEX are noteworthy.
Free Cooling Chillers save significant amount of Energy Consumption. The Energy savings in this study at 100% cooling capacity load operating is about 14 % approximately.

BIOGRAPHIES:-



Mr. Sahil Bavdhankar Mechanical Engineer (2+ years of Experience in Data Center and HVAC Industry)