Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 08, pp.19010-19017, August, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

PERFORMANCE EVALUATION OF HEAT PUMP USING SIMULATION TECHNIQUES FOR REPLACING ELECTRIC WATER HEATING SYSTEM TO ACHIEVE ENERGY CONSERVATION AND IMPROVE IEQ IN AN PROCESS INDUSTRY

*Jadhav, G. B., Nalawade, S. N., Shinde N. N. and Doshi, S. A.

Department of Technology, Shivaji University, Kolhapur, Maharashtra, India

ARTICLE INFO

Article History:
Received 24th May, 2015
Received in revised form
26th June, 2015
Accepted 16th July, 2015
Published online 21st August, 2015

Key words:

Heat pump, Simulation, IEQ, Energy conservation, Electric heater.

ABSTRACT

In a process industry heat pump can be used for water heating application for an energy conservation application. The theoretical design for heat pump is designed from the point of view replacing electrical heaters. This paper presents simulation results of designed heat pump for water heating in a process industry. The paper also shows the results of indoor environmental quality improvement by heat pump around its surroundings. The compressor consumption analysis has done for electrical heater and heat pump also simulated results for compressor is shows in this paper. Electricity consumption has been reduced by designing and simulating heat pump process.

Citation: Jadhav G. B., Nalawade S. N., Shinde N. N. and S. A. Doshi, 2015. "Performance evaluation of heat pump using simulation techniques for replacing electric water heating system to achieve energy conservation and improve IEQ in an process industry, ", *International Journal of Current Research*, 7, (8), 19010-19017.

INTRODUCTION

Heat pumps use electricity to transfer heat from one place to another to provide heating or cooling. The basic components of heat pumps include a compressor, condenser, expansion valve, and evaporator. The importance of energy conservation has been highlighted by in EC ACT- 2001 by Govt. of India. The total potential of energy conservation by Energy Management and Energy Efficiency Improvement Program is estimated to 25000 MW. There is a potential of saving 25-30% of energy in various designated agencies of MSME. In manufacturing and process industries, the process designs are based on the type of machine installed at the time of machine erection and commissioning. However, with the time and technological development they become obsolete and the efficiency of the machine and process goes down. Under the circumstances to improve the efficiency of the system, it is necessary to integrate the new technologies under Energy Efficiency Improvement Program.

***Corresponding author: Jadhav, G. B.**
Department of Technology, Shivaji University, Kolhapur, Maharashtra, India.

I. Design of Heat pump technology

1.Heat Capacity

$Q = m * C_p * \Delta t$

2.Theoretical COP of the system

$COP_{(th)}$ = refrigeration effect/ compressor work

Refrigeration effect = $h_1 - h_6$

Compressor work = $h_2 - h_1$

3. Refrigerant mass flow rate

Heat added to cold water = Heat rejected from condenser

$$Q = m_r * \Delta h_r$$

4. Compressor work and selection

$$W_C = m_r * (h_2 - h_1)$$

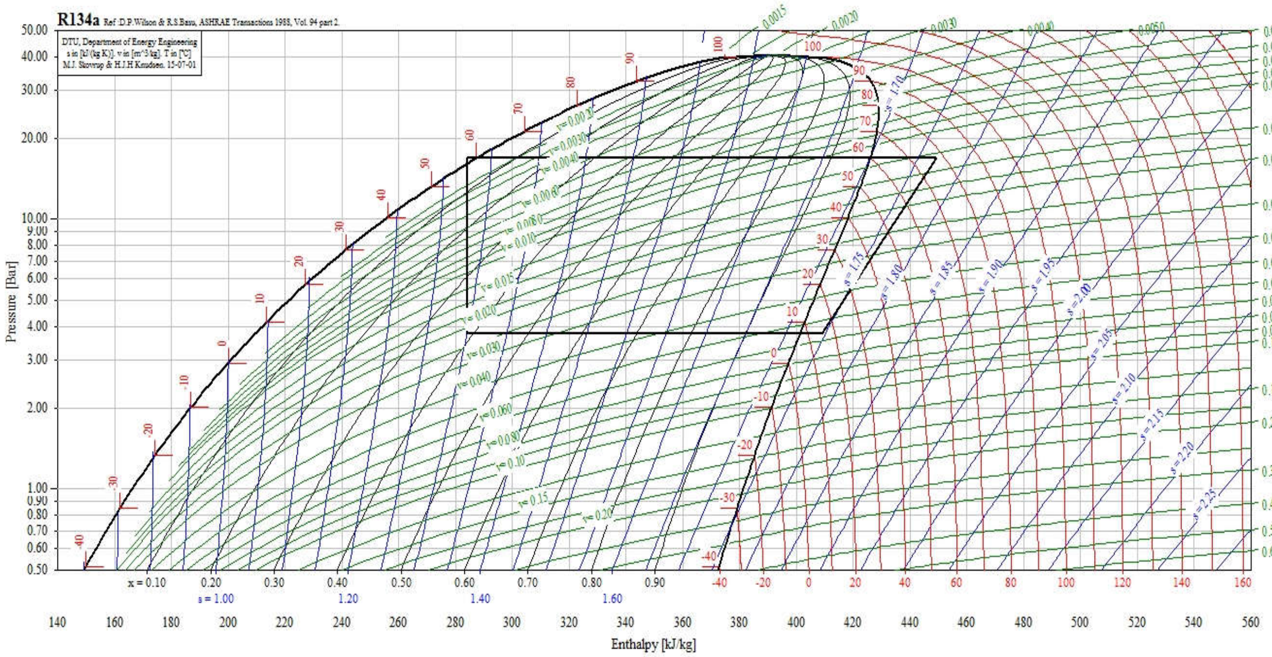

Figure 1. Prssure- enthalpy chart

5. Effective Performance Ratio (EPR)

5.1 Ideal (Carnot cycle assumption)

$$EPR = T_2 / (T_2 - T_1)$$
$$EPR = Q_{rejected} / W$$

Isentropic work done by compressor $W = Q_{rejected} / EPR$
Isentropic efficiency by compressor = Isentropic Work / Actual Work

5.2 Actual EPR

$$EPR = Q\ rejected / W_{act}$$
$$EPR = COP + 1$$
$$COP = EPR + 1$$

6. Design Procedure of shell and tube condenser

6.1 Mean temperature evaluation

Cold fluid inlet temperature = T_{Cin}
Cold fluid outlet temperature = T_{Cout}
Hot fluid inlet temperature = T_{hin}
Hot fluid outlet temperature = T_{hout}
Hot fluid mean temperature= T_{hmean}
Cold fluid mean temperature= T_{cmean}

6.2 LMTD

$$\Delta T_{LMTD} = \frac{(T_{hin} - T_{cout}) - (T_{hout} - T_{cin})}{\ln\left[\frac{(T_{hin} - T_{cout})}{(T_{hout} - T_{cin})}\right]}$$

6.3 Area of tube

$$A = \frac{\mathbf{Q*1000}}{\mathbf{LMTD*\ Uassume}}$$

6.4 No of tubes

$$N_t = A / (\pi * d_0 * L)$$

6.5 Tube pitch

$$P_t = 1.25\ d_o$$

6.6 Bundle diameter

$$D_b = d_o (N_t / K_1)^{1/n_1}$$

6.7 Shell diameter

$$D_s = D_b + BDC$$

6.8 Baffle spacing

$$B_s = 0.5 D_s$$

6.9 No.of tubes per passes

$$N_{tpp} = N_t / \text{number of pass}$$

6.10 Tube side mass velocity

$$G_m = \text{Tube side flow rate} / [N_{tpp} * (\pi * d_i^2/4)]$$

6.11 Tube side velocity

$$u = G_m / \rho$$

6.12 Reynolds number

$R_e = \rho ud/\mu$

6.13 Prandle number

$P_r = \mu C_p / k$

6.14 Nusselt number

$Nu = Re^{0.8} * 0.023 * P_r^{0.4}$

6.15 Heat transfer coefficient inside tube

$H_i = N_u * k / d_i$

6.16 Shell side area

$$A_s = \frac{[(tube\ pitch - OD) * D_s * baffle\ spacing]}{tube\ pitch}$$

6.17 Shell side mass velocity

G_s=Mass flow of refrigerant/A_s

6.17 Equivalent diameter of shell

$D_e = 4[P_t^2 - (\pi * d_0^2)] / [\pi * d_0]$

6.18 Shell side Reynolds number

$R_e = D_e * G_s / \mu$

6.19 Shell side Prandtl number

$P_r = \mu C_p / k$

6.20 Heat transfer coefficient of shell side

$H_0 = 0.36(k/d_e) * R_e^{0.55} * Pr^{0.33} * (\frac{\mu}{\mu w})^{0.14}$

6.21 Overall heat transfer

$$U_{actual} = \frac{1}{\frac{1}{hi} + \frac{1}{h0} * \left(\frac{di}{do}\right)}$$

6.22 % of overdesign

$= (U_{actual} - U_{assumed} / U_{actual}) * 100$

6.23 Pressure drop calculation

Shell side pressure drop = $8 * j_f * (Ds/D_e) * (L/B_s) * (\rho * u^2/2) * (\mu/\mu_w)^{-0.14}$

Tube side pressure drop = $2 * j_f * G_S^2 * D_S * (N_B + 1) / \rho * D_e * (\mu/\mu_w)^{-0.14}$

7. Expansion valve selection

Calculation of nominal capacity

$Q_n = Q \times K_{dp} \times K_t$

Where,

Q =Heating load
K_{dp}= Correction factor for pressure differential
K_t = Correction factor for liquid and evaporating temperatures

8. Evaporator design

8.1 Heat absorbed in evaporator

$H_{absorbed} = m_r * (h_1 - h_4)$

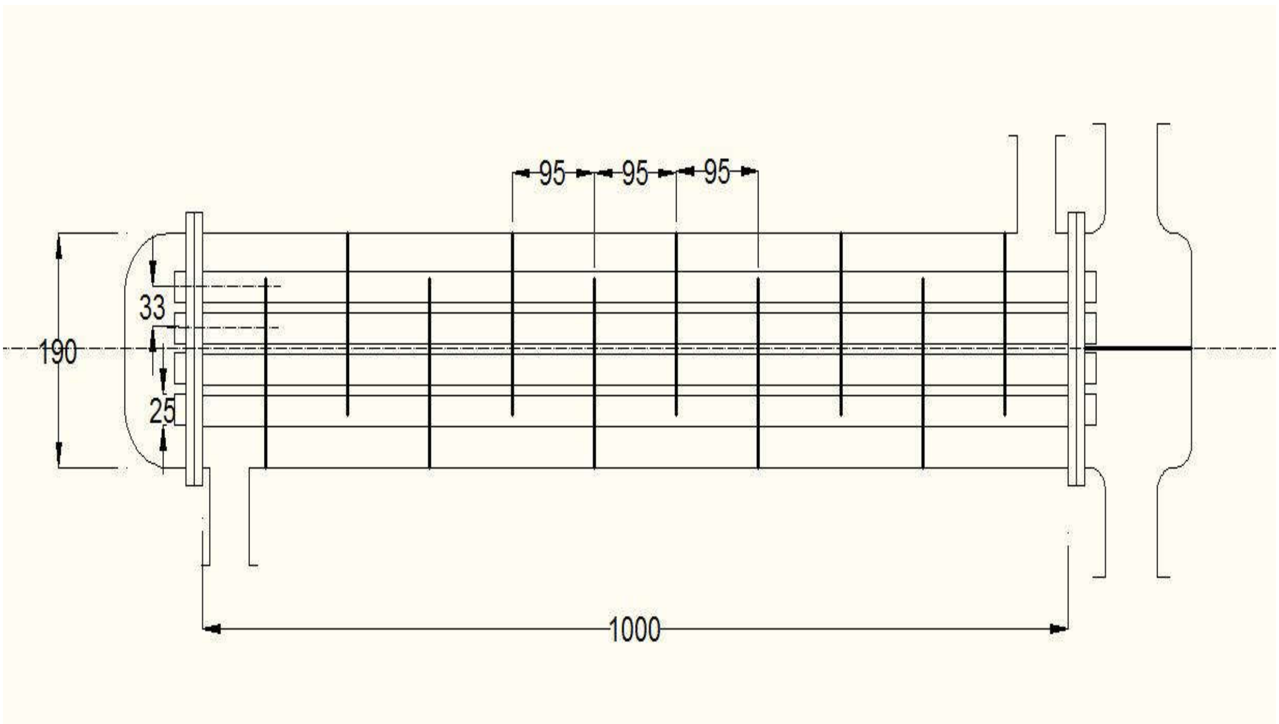

Figure 2. Designed condenser diagram

8.2 Air mass flow rate

$$Q = m*c_p*(T_{ambient} - Tair)$$

8.3 Mass velocity

$$G = m/ A_{min}$$

8.4 Reynolds number

$$R_e=G*d_h/ \mu$$

8.5 Number of tubes

$$N_t= m_r/ \rho Au$$

8.5 Area of tube

$$A_t = \pi*d^2/ 4$$

8.6 Total width = 2* fin width

8.7 Total cooling from evaporator

$$Q = h*A*(T_{AIR} - T_{DP})$$

The designed condenser, compressor, evaporator and expansion valve are to be shown in above figure. The process is same as vapor compression system. This system is connected to washing tank replacing electric heater

II. Energy Consumption Simulation Analysis Over The Time In Pack Calculation Pro Software

Pack Calculation is an application for comparing the yearly energy consumption of refrigeration systems and heat pumps. Among other features, trans critical CO_2 systems can be compared with traditional systems. The application compares different systems based on a geographical location. Traditionally, refrigeration systems (and heat pumps) are dimensioned based on a single operating point (normally somewhere around the point where the load is highest). This approach ensures that the system will deliver the cooling (or heating) required. Recently, standards for measuring seasonal performance of both refrigeration systems and heat pumps, have appeared. Pack Calculation Pro provides a more detailed simulation of the yearly energy consumption than the standards offer.

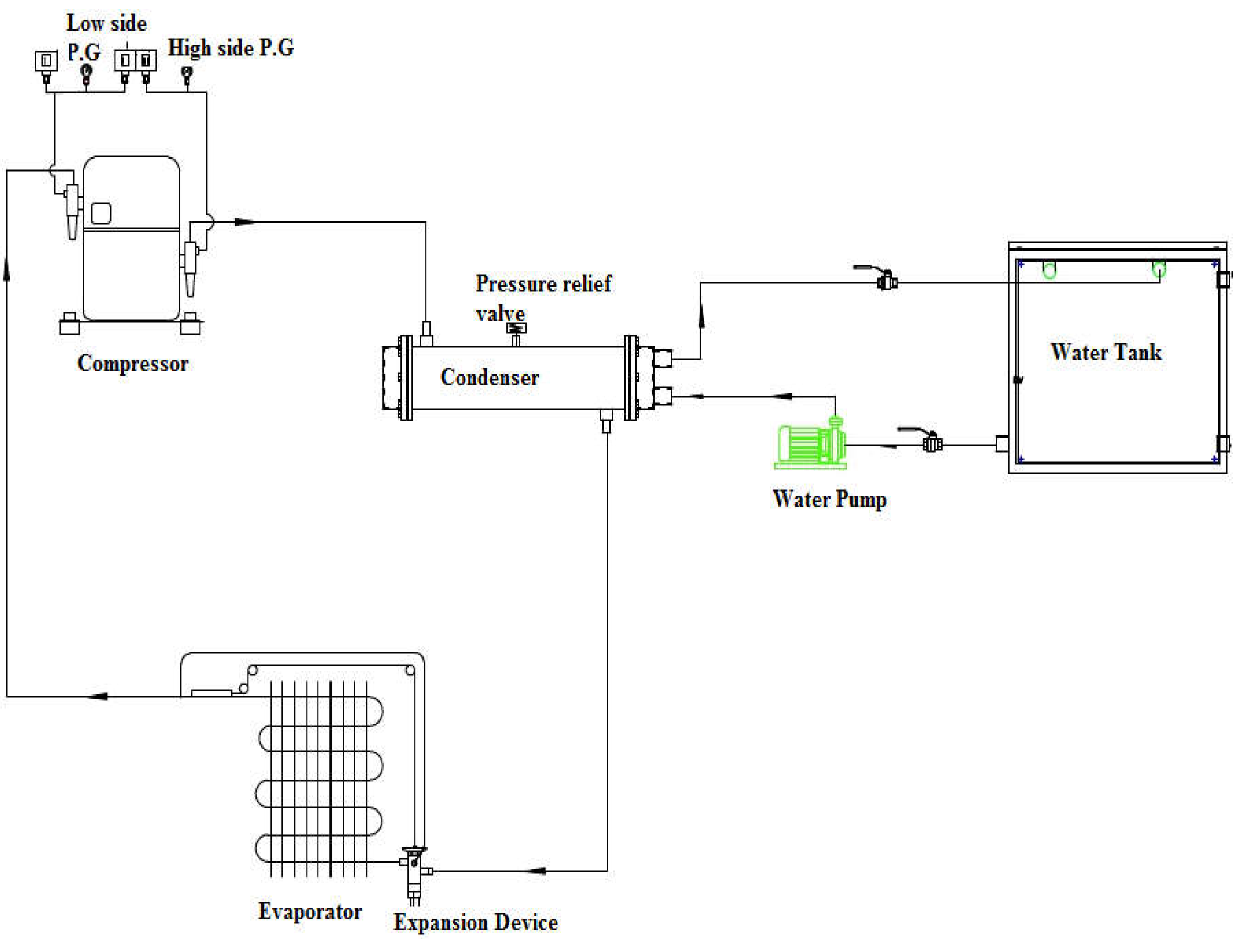

Figure 3. Designed heat pump system

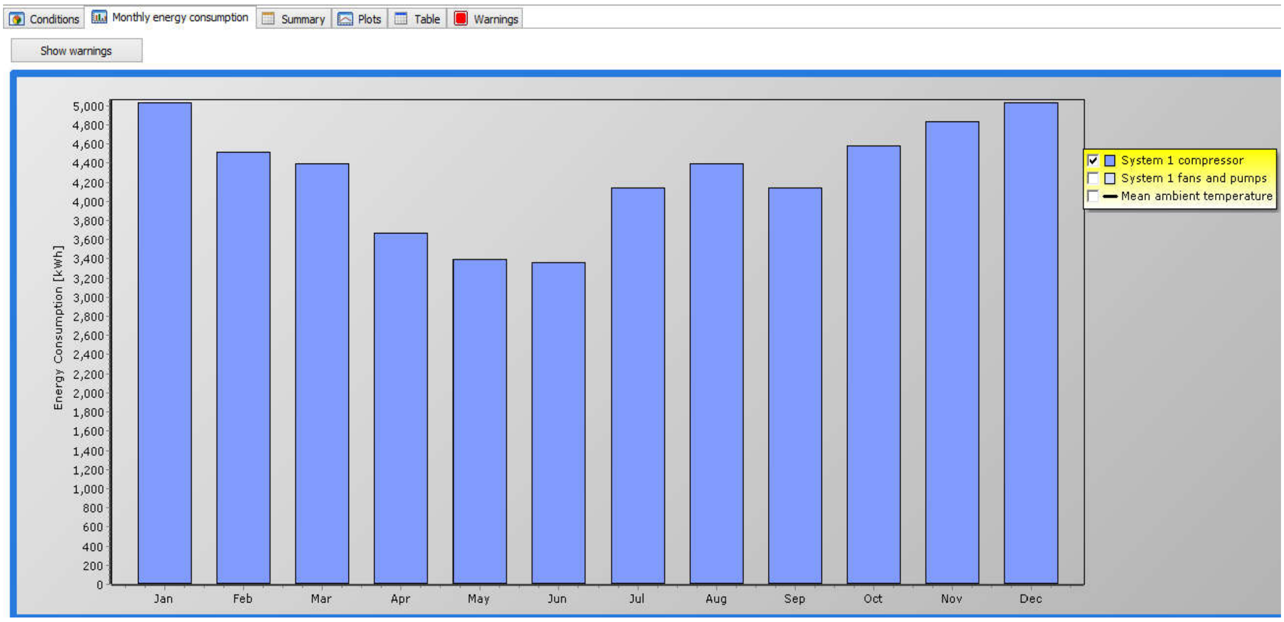

Figure 4. Energy consumption of compressor over the year

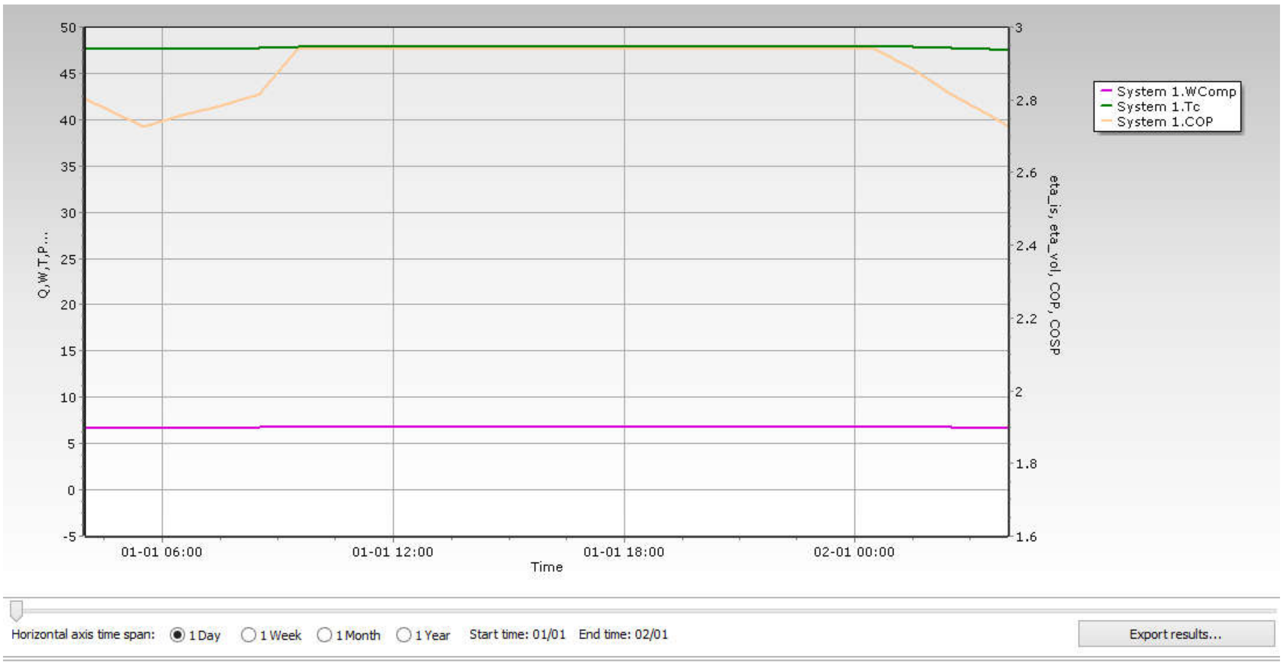

Figure 5. Simulation graph for one day

1. Energy consumption of compressor over the year

The compressor consumption is near about 4800 kWh for the months as an averanging. For thr month april to july it goes low due lessconsumption of electricity.The consumption of compressor for januwary and december remains same.

2. Simulation graph for one day

The designed compressor capacity is 6.58 kw. As the performance is simulated in pack calculation pro software, the compressor consumption capacity matches.

The cop of the system is 3.10. The condenser can reject heat near to 50^0 C.

3. Simulation graph for one month

The designed compressor capacity is 6.58 kw .As the performance is simulated in pack calculation pro software , the compressor consumption capacity matches .The cop of the system is fluctuates for some months .Where as the condenser can reject heat near to 50^0 C.

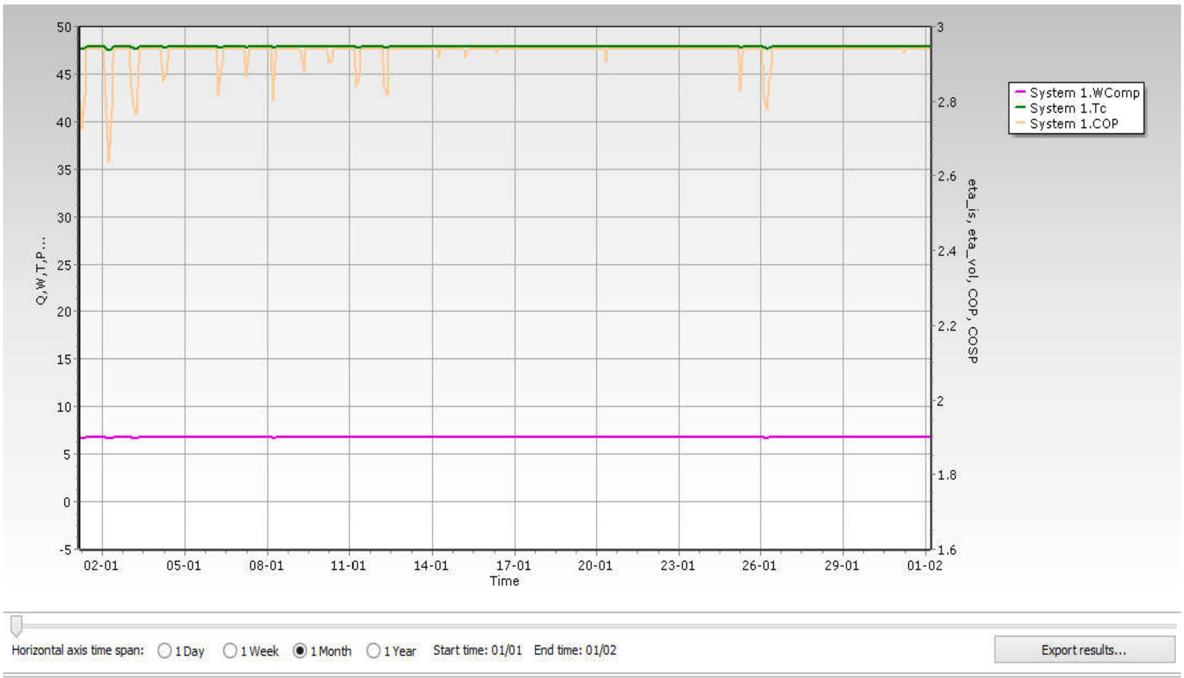

Figure 6. Simulation graph for one month

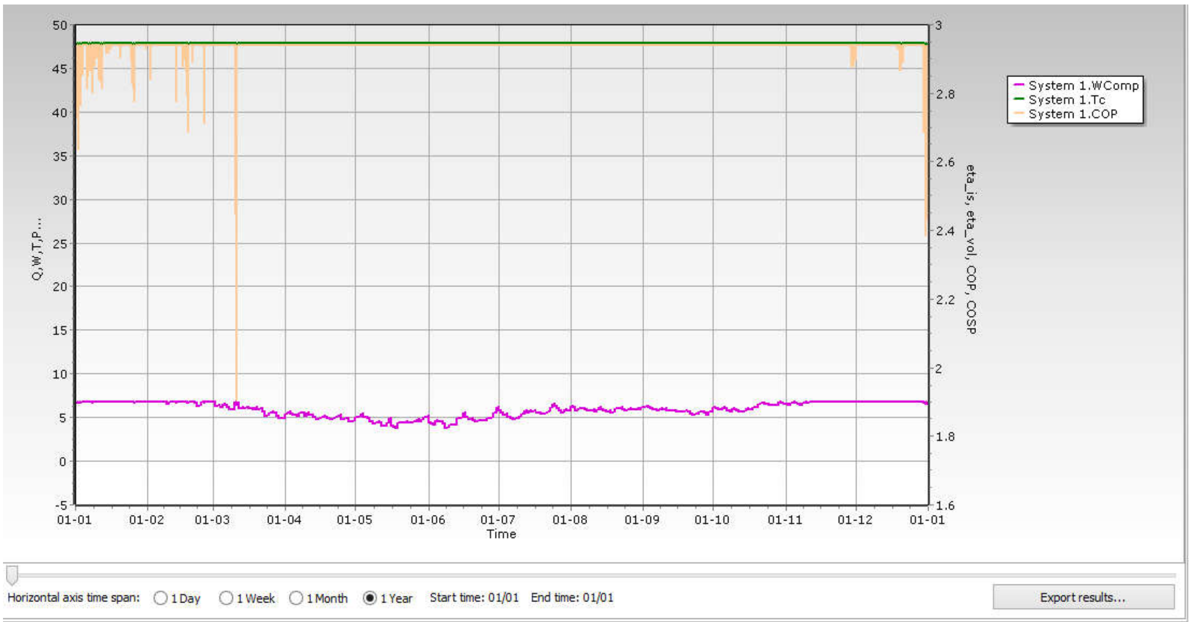

Figure 7. Simulation graph for one year

4. Simulation graphs for one year

The compressor consumption over the year consumes 6.58 kw average. For month February to October the fluctuation occurs and it is below average. The cop of the system is in between 2.8 to 3 but it goes low in initial months and after words it is continuous. The condenser can reject heat near to 50^0 C continuously

III. Cost benefit and energy consumption analysis

The cost benefit for heat pump, electric heater and simulated result are shown in below table. The compressor consumption can be considered for analysis.

The above graph shows the consumption difference for electric heater and heat pump. The heat pump consumes less energy as compared to electric heater. The heat pump saves one third of energy consumption. The average compressor consumption is 7.50 kw. The electrical consumption is more .By using heat pump more amount of energy saved.

As the initial condition compressor started, the consumption is some increases and after required temperature is maintained, the compressor consumption is somewhat in steady state. The simulated results for compressor are constant for a day and is less than the heat pump consumption.

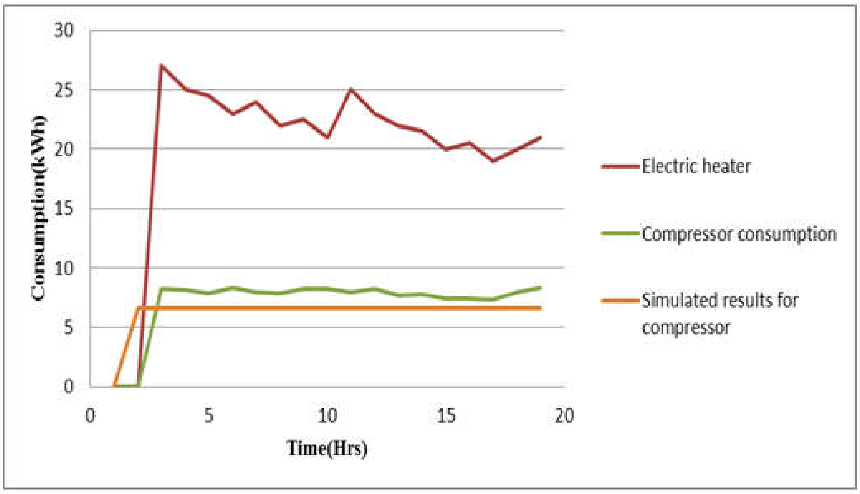

Figure 8. Cost benefit and energy consumption analysis

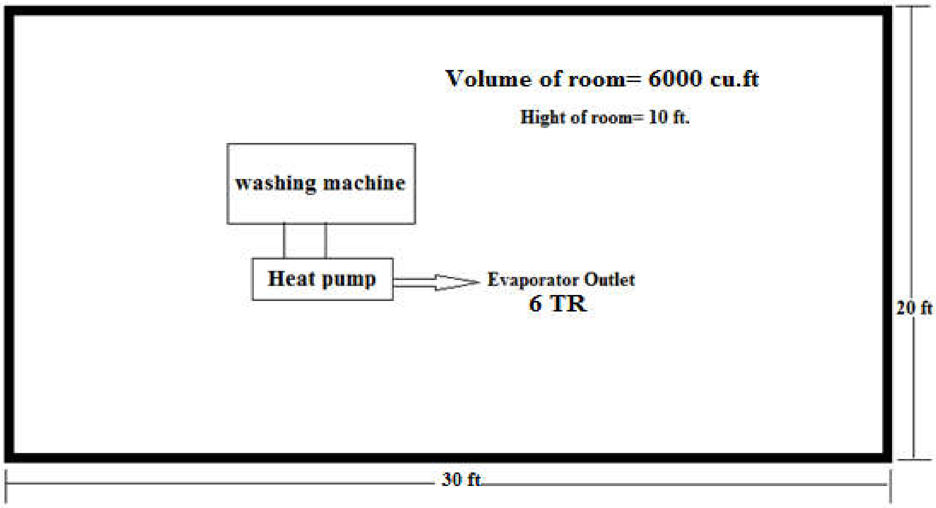

Figure 9. Cooling effect for a space air conditioning

IV. Indoor environment quality improvement

IEQ objectives vary with the programmed use for the building and industry. Each aspect of IEQ must be considered. Acoustical comfort may require specific focus because of the nature of activities inside and around the facility. For a certain prescribed noise criteria that must be provided to allow for intended operation. In design the cooling effect from evaporator is nearly 21 kW. i.e.6 tons of refrigeration.

$Q_{Cooling}$ =6 TR

The above figure shows the room dimensions for cooling from evaporator outlet. The overall dimension will be 6000 cu. ft. Heat pump can be cooled near 6000 cu.ft. Area is placed to that of heat pump. Heat pump is very beneficial in view of environmental conditions. It can maintain the IEQ of room or that work space.

V. Conclusion

Vapor compression system has been designed and electrical consumption has been worked out. The performance evaluation for heat pump has been done. The simulation results shows that saving electrical energy units of the order of 5,86,080 kWhr/year by heat pump design where as by simulated results it comes to be 6,61,728kWh / year. The indoor environmental quality, for designed heat pump, for cooling purpose has been done for a room. The design of heat pump point 6.2 and 6.16 and 6.21 not only used for heating but also cooling the surrounding environment.

REFERENCES

ASHRAE, Handbook, "IEQ and Energy Standard for Buildings except Low-Rise Residential Buildings".

ASHRAE, Handbook, HVAC Systems and Equipment, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA, USA, 2007

Donald Q. Kern 1965. Process Heat Transfer. McGraw Hill.441.

Dr. Reyad Shawabkeh. Module. Steps for design of Heat Exchanger.14.

Durgesh J Bhatt, Prof. Priyanka M Jhavar, Prakash J Sakariya, "Review Paper on Analysis of Heat Transfer in Shell and Tube Type Heat Exchangers" *International Journal for*

Scientific Research & Development| Vol. 2, Issue 06, 2014 | ISSN (online): 2321-0613.

Kumar, Ph.D., Member ASHRAE, and William J. Fisk, P.E., Member ASHRAE," IEQ and the Impact On Building Occupants" ASHRAE Journal, April, 2002.

NPTEL .Module 2. Mechanical Design of Shell and Tube Heat Exchanger. 16.

Sadik Kakac, Hong tan liu (Second Edition). Heat Exchangers selection, Rating and Thermal Design. CRC Press.522.

Shikhalgar N.D., I.K. Ganechari, Rashmi Sapali, R.R. Arkererimath, S.G. Taji, "Case study on economic and energy analysis of eco-friendly heat pump system" International Conference on Recent Advances in Mechanical Engineering In collaboration with International *Journal of Engineering and Management Research (IJEMR),* Page Number: 192-195.

****