IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 7.047 ⁜ Vol. 10, Issue 1, January 2022

DOI 10.17148/IJIREEICE.2022.10108

HVAC PERFORMANCE ASSESSMENT OF CHILLER PLANTS

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Abstract: Energy audit provide the means to identify energy consumption patterns and components of existing HVAC system and thus energy conservation opportunities can be identified and prioritized. So, it is possible to identify and avoid unnecessary expenditures in buildings that involve chiller plants while improving operation and comfort. This research paper aims at an energy audit of the major load consumption HVAC of Saraswati complex. The HVAC performance assessment of chiller unit is proposed and recommendations of HVAC system are suggested for improving energy savings.

Keywords: chiller, EER, heating, ventilation and air conditioning (HVAC), load, parameters, refrigeration capacity, system etc.

1. INTRODUCTION

Ensuring the comfortable air quality for people, using the heating, ventilation and air conditioning (HVAC) system, in the commercial center buildings is extremely important. This is directly related to the design of the controllers for two channels of the air-conditioning, temperature and humidity of the indoor air.

The air-conditioning plant is designed to produce a conductive atmospheric environment for human beings or a special environment for some industrial and scientific processes. Temperature, humidity, air motion, and air purity within a space are controlled with an air-conditioning system

The indoor air quality of an enclosed space has a significant effect on the health and productivity of its occupants since a person may spend much time indoors. The comfort air-conditioning system is employed to produce a comfortable environment for people. Researches over many years have identified the major factors contributing to the human thermal comfort: temperature, relative humidity, air movement, and radiant effects, among which temperature and relative humidity are generally controlled. Because man is more sensitive to temperature than to humidity, most of the comfort air-conditioning systems is designed to provide relatively accurate temperature control while keeping the relative humidity floating within some larger range, which is usually defined from 30% to 60% [5].
Some industrial and scientific processes require simultaneous and accurate control of temperature and humidity. Some scientific experiments can only be performed properly only under some specific environments. Industrial air-conditioning systems are designed for such applications [2].

The increasing demand for air-conditioning systems has resulted in greatly increased energy consumption. The energy consumed by heating, ventilating, air-conditioning (HVAC) equipment in industrial and commercial buildings constitutes 50% of the world energy consumption [1].

It is estimated that in Singapore, commercial buildings account for about 30% of the total electrical energy consumed in the country. Of this about 50% to 60% is consumed by air-conditioning and mechanical ventilation systems [3].
Energy resources are limited in supply and are ever increasing in price and therefore it is essential to find ways to improve the efficiency of HVAC systems.

The first thing in the energy auditing is the proper energy accounting. Energy accounting is the process of identification, collection, analysis and monitoring of energy usage in the industries, commercial buildings, universities etc. Thus, Energy accounting & Energy Audit goes hand in hand.

In this paper, Energy Audit of HVAC will be carried out in which EER is calculated for name plate data and actual operating data. Based on the comparison of data, energy losses are calculated. Finally, recommendations for the improvement in usage of energy, reducing losses and savings for each segment will be given.

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The paper is organized as Section -2 includes the Electrical infrastructure details of Saraswati complex.Section-3 gives the layout of chiller plant whereas section-4 gives theHVAC performance assessment.Section-5includes the Conclusion.

2. ELECTRICAL INFRASTRUCTURE OF SARASWATI COMPLEX

DeenbandhuChhotu Ram University of Science & Technology, Murthal is located on the National Highway No. 1(G.T. Road) 48 Km. from ISBT, New Delhi towards Chandigarh &spread over 273 acres and has a fully residential campus. This section provides a brief description of the electrical layout of D.C.R.U.S.T Murthal that includes the 33/11 KV substation and the load distribution of Saraswati complex (University library).

2.1 33/11KV Electrical Substation

A UHBVN 33/11 KV substation is located inside the premises of D.C.R.U.S.T Murthal is being fed from 132KV HVPNL grid situated at Murthal. There are five 11KV outgoing feeders namely colony feeder, workshop feeder, nangal feeder, Raveli feeder &Anand diary feeder.
The worshop feeder gives the power supply to university teaching Departments, administration block, library, workshop, CIPET& boys hostels. The 11 KV feeder gives the supply to the separate transformer of 990 KVA rating which is used for giving the supply to the library complex.

2.2 Details of Substation:

The 11kV feeder line coming to the substation and voltage is step down to 3-pahse 415 V. As the transformer rating at the substation of Library is 990kVA, 11/0.4 kV, star connected mode, the cable size for power distribution is 3 core, 300mm^2 copper unarmored PVC cable, the cable is DUCT installed, 3 cores means 3 cables for three phases of dimension 300 mm^2 and wire indicates neutral wire of 150mm^2.Two DG's sets (kirloskar make) of capacity 620 KVA & 300 KVA are also installed for backup arrangements.

2.3 Load Distribution for Saraswati Complex:

Following are the details of the load distribution of Saraswati complex (library) that is fed from 990 KVA DT:

- Two nos. three-phase, 4 pole standard induction type motors of capacity 40 hp are used for Fire system.
- One 7.5 hp motor is used as water pump.
- Chiller plant is installed for cooling purposes in which three units are installed each of capacity 150TR. So, total capacity of chiller plant is 450TR.
- 3 AHU are used for air flow in chiller plant in which 10 hp motors are used.
- 6 Air suction units are used to suck air from land & that air than goes to AHU in each suction unit 5 hp motor is used.

The above load is presented in fig 2.1 in the form of pie chart.

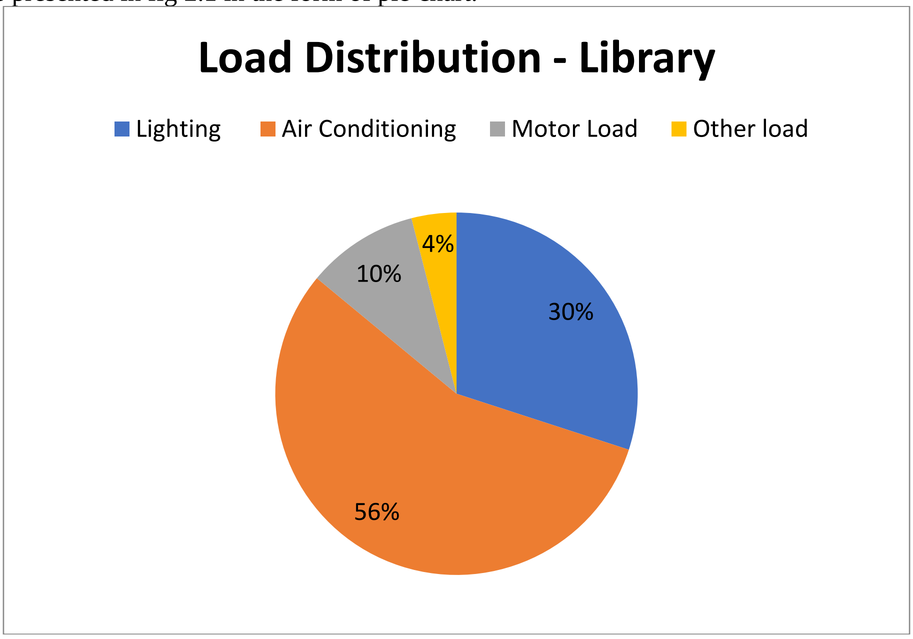

Fig 2.1: Load distribution

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3. INTRODUCTION OF CHILLER PLANT INSTALLED IN SARASWATI COMPLEX

In Saraswati complex of DCRUST murthal 3 units each of 150 TR is installed having 3 AHU, 6 Air Suction units

6.2.1 Layout of Chiller plant

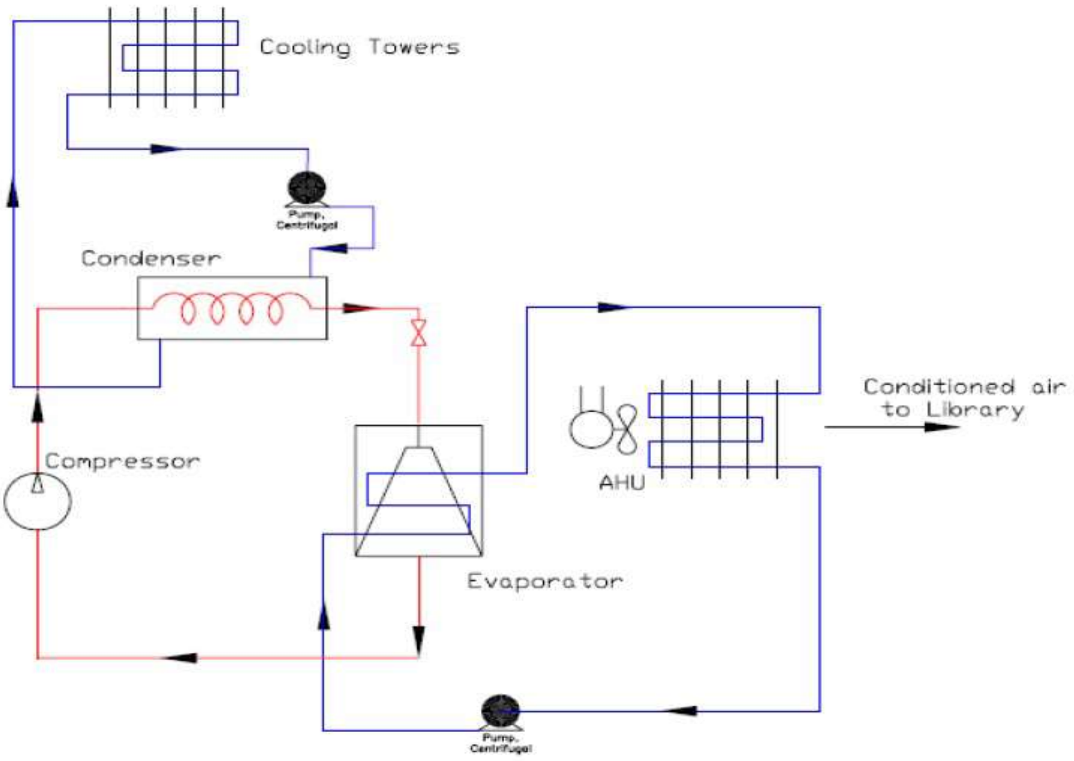

Figure 6.6: Layout of chiller plant installed at Saraswati complex

3.1 Parts of Chiller Plant

The parts of chiller plant as described in the catalogue of the library are as:

i. **Screw type compressor** In this chiller plant screw type compressor is used which has a mono/twin rotary screw having refrigerant R-134a is used. It is manufactured from forged steel the profile of screw permit safe operation upto 3000 RPM for 50 Hz operation .The compressor housing made of high grade caste iron, rotor mounted on antifriction bearing designed to reduce friction and power input, built in reservoir is there to ensure full supply of lubricants to all bearings and check valve to prevent backspin during shut down [4].

Interlocking The compressor motor shall be interlocked with following

- Differential pressure switch in the chilled water line
- Anti-freeze thermostat.

ii. **Compressor motor-**The electrical motor driving the compressor is Squirrel cage induction motor class F insulation suitable for operation on 415v 3 phase, 50 Hz.

iii. **Condenser**

Type: Air cooled

Material & Construction Condenser is fabricated of hard drawn copper tubes and aluminum fins of 0.18 mm minimum thickness, fins spacing ranging 3 to 5 fins per cm . Condenser is designed so as to hold 1.25 times the refrigerant charge in the system air velocity in the condenser coil is maintained up to 200 MPM.

iv. **Chiller** Air cooled type chiller is used having refrigerant R-134a

Features

- Reliable design
- Direct driven compressors

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- Patented rotor profiles
- Step less capacity modulation
- Integrated high efficiency oil separator.

v.Microprocessor Controller

Each chilling unit composed with a microprocessor based interactive control console in a Locked enclosure factory mounted, prewired with all operating and safety controls and tested. It will provide start, stop, safety, interlock, capacity control and indications for operation.

vi.Factory Build Air handling Unit

Type: Double skin construction
Material & Construction: Casing of air handling unit is of double skin construction
Cooling/Heating coil: Coil is made up of seamless solid drawn copper tubes having thickness0.5mm.

4. PERFORMANCE ASSESSMENT OF HVAC SYSTEM

4.1Name Plate Data collection of Refrigeration & Performance Assessment:

The first step to do AC audit is name plate data collection
Name Plate data for Unit 1

Model no	GSACDXR1501SMA
Evaporator test pressure	
Shell side	190 PSIG
Tube side	315 PSIG
Condenser test pressure	
Tube side	412 PSIG
Capacity	150 TR
Max. Power consumption	154 Kw
Main supply	400v(3 phase)
Control Supply	230v(1 phase)
Fan motor KW×QTY.	2.2 × 8
Refrigerant	R134a
Refrigerant Charge	135 Kg

Table 4.1: shows Name plate data of unit 1

Other two units have same data as shown in table. So for simplicity we consider only one unit and calculate the EER using name plate data.

4.1.1 Calculation of EER using Name plate data

Rated TR = 150 TR

Rated KW = 154KW

Rated KW/Ton = $\frac{154}{150} = 1.03$

Coefficient of Performance = $\frac{3.516}{\text{kW/ton rating}} = \frac{3.516}{1.03} = 3.41$

EER = $\frac{\mathbf{12}}{\textbf{kW/ton rating}} = \frac{\mathbf{12}}{\mathbf{1.03}} = \mathbf{11.65}$

4.2 Calculation of EER using measured data

Actual data is measured using power analyzer and other instruments which are shown in tables below
Measured data of unit 1

Voltage	415 V
Current(Rms)	179 A
Temp. IN	11^0C
Temp. out	9^0C
Pressure IN	30 PSI
Pressure OUT	28 PSI
Flow rate	90848 kg/hr

DOI 10.17148/IJIREEICE.2022.10108

Pf	0.85
Input power	109.35 kw
Specific Heat capacity of R134a	0.8754kCal/kg^{0}C

Table 4.2: shows measured data of unit 1

Performance assessment of unit 1

Based on eq performance assessment is calculated as

Net Refrigeration capacity(TR)= $\frac{m \times C_p \times (t_{in} - t_{out})}{3024}$

$= \frac{90848 \times .8754 \times (11-7)}{3024}$

=**105.19 TR**

KW/ton rating=$\frac{\text{Measured compressor power,kW}}{\text{Net refrigeration capacity(TR)}}$

$= \frac{109.35 \text{ kW}}{105.19 \text{ TR}}$

.

= **1.039 kW/TR**

Coefficient of performance= $\frac{3.516}{\text{kW/ton rating}}$

$= \frac{3.516}{1.039}$

.

= **3.384**

Energy Efficiency ratio(EER)= $\frac{12}{\text{kW/ton rating}}$

$= \frac{12}{1.039}$

= **11.54**

Measured data for unit 2:

Voltage	416 V
Current(Rms)	162 A
Temp. IN	11^{0}C
Temp. out	8^{0}C
Pressure IN	38 PSI
Pressure OUT	32.5 PSI
Flow rate	90750 kg/hr
Pf	0.81
Input power	94.54 kW
Specific Heat capacity of R134a	0.8754kCal/kg^{0}C

Table 4.3 showing measured data for unit 2

Now performance assessment of unit 2 is calculated similarly as unit 1

Net Refrigeration capacity (TR) = 78.81 TR

KW/ton rating = 1.19 kW/TR

Coefficient of performance= 2.95

Energy Efficiency ratio (EER) = 10.08

Measured data for unit 3

Voltage	415 V
Current(Rms)	158 A
Temp. IN	11.5^{0}C

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DOI 10.17148/IJIREEICE.2022.10108

Temp. out	8^0C
Pressure IN	37.5 PSI
Pressure OUT	32 PSI
Flow rate	90700 kg/hr
Pf	0.83
Input power	94.26 kW
Specific Heat capacity of R134a	$0.8754kCal/kg^0C$

Table 4.4 shows measured data for unit 3

Performance Assessment of unit 3
Net Refrigeration capacity(TR) = 91.89 TR
KW/ton rating = 1.025 kW/TR
Coefficient of performance= 3.43
Energy Efficiency ratio(EER)= 11.7

Energy Saving calculations
For Unit 1 Calculated TR =105.19
Actual kW/TR =1.039
Rated KW/TR =154/150=1.03KW/TR
Energy Loss = (Actual KW/TR–Rated KW/TR) x Calculated TR
=(1.039 -1.03) × 150= 1.35kW
Annual Monetary loss: 1.35×10×300×4.90=1587

For Unit 2: (1.19-1.03)×150=24kW
Annual Monetary loss: 24×10×300×4.90=282240

For Unit 3: zero loss
So, the total losses from all three units amounts to Rs. 283827/-

4.3 General Recommendations for HVAC
There are some general recommendations for chiller plants that helps in the energy savings.
a) Cold Insulation
Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains; and choose appropriate (correct) insulation.
b) Building Envelope
Optimize air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by air curtains.
c) Building Heat Loads Minimization
Minimize the air conditioning loads by measures such as roof cooling, roof painting, efficient lighting, pre-cooling of fresh air by air- to-air heat exchangers, variable volume air system, optimal thermo-static setting of temperature of air conditioned spaces, sun film applications, etc.
e) Process Heat Loads Minimization
Minimize process heat loads in terms of TR capacity as well as refrigeration level, i.e., temperature required, by way of:
i) Flow optimization
ii) Heat transfer area increase to accept higher temperature coolant
iii) Avoiding wastages like heat gains, loss of chilled water, idle flows.
iv) Frequent cleaning / de-scaling of all heat exchangers
f) At the Refrigeration A/C Plant Area
i) Ensure regular maintenance of all A/C plant components as per manufacturer guidelines.
ii) Ensure adequate quantity of chilled water and cooling water flows, avoid bypass flows by closing valves of idle equipment.
iii) Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying process load.
iv)Make efforts to continuously optimize condenser and evaporator parameters for minimizing specific energy consumption and maximizing capacity.
v) Adopt VAR system where economics permit as a non-CFC solution.

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4.4 Specific recommendations:

These are the specific recommendations based on the performance assessment of HVAC systems.

- Replacing air conditioning refrigerant from R13a to Cold*22 as Cold*22 is an environmentally friendly refrigerant which can save up to 20% of electrical energy usage
- Replacing low efficient air-conditioning unit with high efficient unit.

5. CONCLUSION AND FUTURE SCOPE

Energy audit provide the information that energy auditors and energy managers need to identify energy consumption patterns and components of HVAC system and document existing conditions, energy conservation opportunities can be identified and prioritized. By taking a methodical approach to the audit process, it is possible to identify and avoid unnecessary expenditures in buildings involving chiller plants while improving operation and comfort. This paper focused on energy audit of the major load consumption HVAC consisting of chiller plants of Saraswati complex. The HVAC performance assessment of chiller unit is calculated and recommendations are suggested for improving energy savings.

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