

Evaluation and Application of Hourly Analysis Program Software for Estimating Cooling Load

Mahesh M Nair¹, Jayan M.C.²,

¹M.Tech Holder, Department of Mechanical Engineering, Govt.Model Engineering College, Thrikkakara, Ernakulam, India

²Assistant Professor, Department of Mechanical Engineering, Govt.Model Engineering College, Thrikkakara, Ernakulam, India

Abstract – HVAC is an acronym of Heating, Ventilation, and Air Conditioning. HVAC denotes to the different systems and machines used for moving air between outdoor and indoor areas, along with heating and cooling both commercial and residential buildings. These systems keep you warm and convenient in the winter and feeling cool and fresh in the summer. In other words, these systems filter and clean indoor air to keep you healthy and maintain humidity levels at optimal comfort levels. In this paper, we have calculated the heating load and cooling load through simulations using Hourly Analysis Program (HAP) and compare the results with real time performance of a commercial buildings, suggested the methodology to improve the load calculations and to make optimum solutions for designing HVAC systems. The heating load is the amount of heat energy that would need to be added to a space to maintain the temperature and humidity in an acceptable range. The cooling load is the amount of heat energy that would need to be removed from a space (cooling) to maintain the temperature in an acceptable range. The calculation of heating load and cooling load is carried out by taking into account the ASHRAE and other relevant standards.

Key Words: HVAC, Heat Load, HAP, Heat load simulation, Real time building performance.

1. INTRODUCTION

HVAC systems are one of the main energy consumers in residential and commercial buildings i.e. up to 40 percent of their total energy consumption. So, HVAC systems have become a target of study that currently represents a great deal of scientific effort or the reduction of energy consumption and preservation of resources. Two main ways are possible for solving this problem, either by implementing strategies for reducing power demand, or by improving the efficiency of the involved energy systems. On the first way of improving energy efficiency, production equipment such as chillers are one of the areas that present the greatest potential for improvement since these are one of the largest consumers in buildings. So, for designing chillers we have to understand the load undertaken by the respective building. For that HAP simulation can be done to understand the TR required in the building.

Chiller should not be under design or over design. It should be of optimum design to undergo any load required by the building efficiently.

Heating and cooling loads are the measure of energy needed to be added or removed from a space by the HVAC system for the desired level of comfort within a space. Selection of right-size HVAC systems start with an accurate understanding of the heating and cooling loads on a space. Right-sizing is selecting HVAC equipment and designing the air distribution system to meet the accurate heating and cooling loads of the house. Actually the heating and cooling load calculation have a direct impact on construction costs along with the operating energy efficiency, occupant comfort, indoor air quality, and building durability.

This work deals with the selection of chiller based on the load required by building determined by simulation software "HAP". And its accuracy is validated comparing the simulated results by the real time data available in DeJoule.

Hourly Analysis Program (HAP) is a computer tool produced by Carrier, a company providing solutions for air conditioning, heating, and refrigeration.

Smart Joules Pvt Ltd is an energy saving company (ESCO) whose mission is to eliminate energy waste through innovations in continuous energy optimization Building Management System called DeJoule, which consists of high performance IoT devices and software for effective and instant computation and user-friendly interaction.

2. HEATING VENTILATION AND AIR CONDITIONING (HVAC) SYSTEMS

HVAC deals with the systems and machine used for moving air between outdoors and indoors, along with warming or cooling the buildings to keep the occupants in the building healthy and to maintain humidity at optimal comfort levels.

The process of ventilation happens in two different ways, natural ventilation and artificial ventilation. Air moves in and out through windows, doors, vents, and other openings in natural ventilation whereas in mechanical ventilation, it uses a mechanical system for the movement of air in and out. The air inside the building goes to an air handling unit through filters which removes the dirt, dust, allergens, and other

particles. Then, air is either heated or cooled and it is directed to the rooms.

Ventilation is the process of swapping or replacing air to control temperature or remove moisture, heat etc. Ventilation can be categorized into two types, mechanical or forced and natural. Air conditioning system is used to produce comfortable temperature, humidity, air purity and air motion in an enclosed area. Any system which cools air can be called as air conditioning.

2.1 CENTRAL AIR CONDITIONING UNIT

Most of the central air conditioning units are working on vapor compression refrigeration cycle as in figure 1, in which refrigerant enters the evaporator in the form of a cool, low-pressure mixture of liquid and vapor. Heat is transferred from the relatively warm air or water to the refrigerant, causing the liquid refrigerant to boil. The resulting vapor is then drawn from the evaporator by the compressor, which increases the pressure and temperature of the refrigerant vapor. The hot and high-pressure refrigerant vapor leaves the compressor and enters into the condenser, where heat is transferred to ambient air or water at a lower temperature. Inside the condenser, the refrigerant vapor condenses into a liquid. This liquid refrigerant then flows to the expansion device, which creates a pressure drop that reduces the pressure of the refrigerant to that of the evaporator. At this low pressure, the remaining liquid refrigerant gets cooled to the desired evaporator temperature. This cool mixture of liquid and vapor refrigerant moves to the evaporator to repeat the cycle.

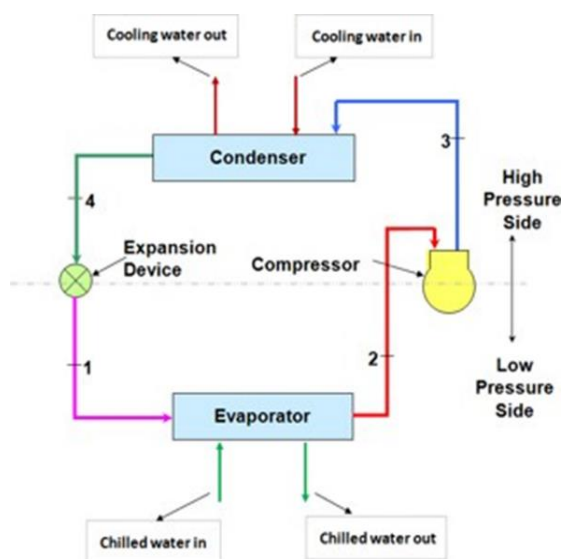


Figure 1. Central air conditioning system

2.2 COMPONENTS OF CENTRAL AIR CONDITIONING SYSTEM

All the components of the system are arranged in one room and conditioned air is distributed from the central room to the required area through the extensive ducting.

Major components of this system are:

- Chiller
- HVAC Pumps
- Cooling Towers
- Air Handling Units

2.2.1. CHILLER

Chiller is an essential component of HVAC System and recognized as the single largest consumer of electrical energy in a wide variety of commercial buildings such as hotels, hospitals, sports arenas, industrial plants, etc. They consume more than 50 percent of the total electrical load. Generally, a chiller facilitates the transfer of heat energy from an internal environment to an external environment. So, this can be a heat-transfer device depends upon the physical state of a refrigerant as it circulates through the chiller system. It provides a continuous flow of chilled water at the desired temperature range of 6.7°C to 10°C. This chilled water is then pumped through the process, extracting heat out from an area of a building. A chiller works on the principle of vapour-compression or vapour absorption.

2.2.2. HVAC Pumps

The most common type of pump used in HVAC systems is the centrifugal pump. Centrifugal pumps include volute or axial flow pumps.

2.2.3 COOLING TOWER

The cooling tower is an equipment which removes heat from the hot water that is pumped from the condenser to the cooling tower.

2.2.3 AIR HANDLING UNIT.

Inside the air-handling unit, chilled water circulation is provided. This chilled water comes through the pipe from the evaporator, which is situated at the chiller. Air which comes out from the air handling unit passes across the chilled water piping coil, the temperature of the air is decreased and the cool air is sent through the duct to the required rooms. The chilled water removes the heat from the air and hence the temperature of chilled water is slightly increased. Now this water is again circulated to the evaporator in chiller.

3. HOURLY ANALYSIS PROGRAM (HAP) SOFTWARE

3.1 LOAD CALCULATIONS

Cooling load calculation has to be done to determine the volume flow rate of the air system and tons of refrigeration required for the system. It provides the inputs to the system in order to select optimal design alternatives. Cooling load usually can be classified into two categories:

1. External cooling load
2. Internal cooling load

3.1.1 EXTERNAL COOLING LOAD

This load is formed because of heat gains in the conditioned space from external sources through the building wall and the partition walls. Sources of external load include the following cooling loads:

- Heat gain entering from the exterior walls and roofs.
- Solar heat gain transmitted through the windows.
- Conductive heat gain coming through the windows.
- Heat gain entering from the partition walls and interior doors.
- Infiltration of outdoor air into the conditioned space.

3.1.2 INTERNAL COOLING LOADS

This load is formed by the release of sensible and latent heat from the heat sources inside the conditioned space. These sources contribute internal cooling load:

- People.
- Electric lights.
- Equipment and appliances

For design, heat loads should be calculated based on the procedures outlined in the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbook of Fundamentals. The calculation of space heat load using the transfer function method (TFM) consists of two steps. First, heat loss from exterior walls, roofs, and floors is calculated using conduction transfer function coefficients; and the solar and internal heat gains are calculated directly for the scheduled hour. Second, room transfer function coefficients are used to convert the heat gains to cooling loads, or the heat losses to heating loads. Most of the widely adopted computer software programs for space load calculations, HAP software in our case, are based on the TFM.

3.2 HAP

HAP is a computer tool produced by Carrier, a company providing solutions for air conditioning, heating, and refrigeration. Figure 2 shows the HAP main programme window. The aim of this program is to assist engineers in designing HVAC systems for commercial buildings. The program is split into two parts: HAP system design features and HAP Energy Analysis. In the first part, HAP can perform the following tasks:

- To calculate design cooling and heating loads for spaces, zones, and coils.
- To determine the required airflow rates for spaces, zones, and system.
- To size cooling and heating coils.
- To size air circulation fans.
- To size chillers and boilers.

During the energy analysis, HAP performs the following tasks:

- To simulate an hour-by-hour operation of all plant equipment.
- To simulate an hour-by-hour operation of non-HVAC systems.
- To calculate the total energy use and energy costs based on the previous simulations.
- To generate tabular and graphical reports of hourly, daily, monthly and annual data.

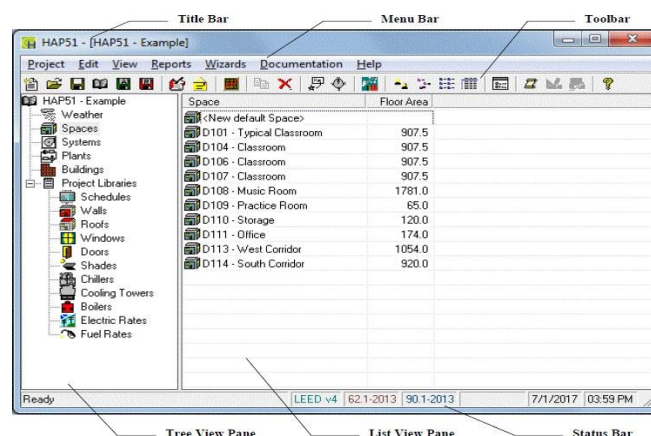


Figure 2. HAP main programme window

4. METHODOLOGY

4.1 EXISTING SITE DETAILS

We have selected a live site named A. The data of the chiller have been collected for making comparison with simulations. Auto CAD drawings of the site are collected from site engineers. From the drawings, areas of air-conditioned rooms are determined to know the load required in certain spaces. Total 141 spaces were considered in the site which is served by 88 systems. NABH standards are considered for the temperature and humidity requirement for spaces.

After visiting the site, windows area and material of construction were analyzed and noted. 25 Schedules were created for different spaces. The amount of equipment's in space were noted to determine the heat load of a particular equipment. Occupancy factor was considered randomly. All the details were collected as shown in table 1 and given as input values in HAP for simulations.

Parameters considered for the site A
Area (sqft)
Partition wall (sqft)
Exposed wall (sqft)
Windows
External wall (sqft)
Wall material

Table 1. Parameters Considered

4.2 . STEPS INVOLVED IN THE PROCESS

HAP is used to find the required cooling capacity of the system in building by energy-based simulations and load calculations. The steps involved in the process are:

- a. Collecting building documents.
- b. Using AutoCAD for coordinate building documents.
- c. Estimation of heat loads and simulations as per relevant standards.
- d. Collecting real time data from DeJoule and compare with simulations.
- e. Analyse the methods and find methods to reduce the degree of variance.

4.3 . STANDARDS CONSIDERED FOR HEAT

LOAD SIMULATIONS

- NBC – National Building Code
- ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers
- NABH - National Accreditation Board for Hospitals Healthcare Providers
- a. For determining U Value for walls. (External, Partition)
- b. For determining the temperature and humidity to be maintained in spaces as per NABH standards.

All design work requires the same general five step procedure:
(Refer Figure 3)

- Define the Problem. First define the scope and objectives of the design analysis. For example, what type of building is involved? What type of systems and equipment are required? What special requirements will influence system features?
- Gather Data. Before design calculations collect information about the building, its environment and its HVAC equipment must be gathered. This step involves extracting data from building plans, evaluating building usage and studying HVAC system needs. Specific types of information needed include:
 - Climate data for the building site.
 - Construction material data for walls, roofs, windows, doors, exterior shading devices and floors, and for interior partitions between conditioned and non- conditioned regions.
 - Building size and layout data.
 - Internal load characteristics determined data.
 - Data concerning HVAC equipment, controls and components to be used.
- Enter data such as climate, building and HVAC equipment into HAP. From HAP main programme window (detail in Section 3.2), first create a new project or open an existing project. Then define the

following types of data which are needed for system design work:

- Enter Weather Data. Weather data defines the temperature, humidity and solar radiation conditions the building encounters during the course of a year. These conditions play an important role in influencing loads and system operation. To define weather data, a city can be chosen from the program's weather database, or weather parameters can be directly entered. Weather data is entered using the weather input window.
- Enter Space Data. A space is a region of the building comprised of one or more heat flow elements and served by one or more air distribution terminals. However, the definition of a space is flexible. For some applications, it is more efficient for a space to represent a group of rooms or even an entire building. To define a space, all elements which affect heat flow in the space must be described. Elements include walls, windows, doors, roofs, skylights, floors, occupants, lighting, electrical equipment, miscellaneous heat sources, infiltration, and partitions.
- Enter Air System Data. An Air System is the equipment and controls used to provide cooling and heating to a region of a building. An air system serves one or more zones. Zones are groups of spaces having a single thermostatic control. This data is entered on the air system input window.
- Enter Plant Data. A Plant is the equipment and controls used to provide cooling or heating to coils in one or more air systems. Examples include chiller, changeover, hot water, service hot water and steam boiler plants. This step is optional; it is only required if you are sizing the plants.
- Generate Design Reports. Once weather, space, air system and plant data has been entered, HAP can be used to generate system and plant design reports. To generate design reports, go to the main program window and select the desired air systems or plants. Next choose the "Print/View Design Results" menu bar option, toolbar button, or pop-up menu option. For systems this displays the System Design Reports window; for plants this displays the Plant Design Reports window. Select the desired report options on this window. If calculations are needed to supply data for these reports, the program will automatically run the calculations before generating the reports.

5. DeJoule

Smart Joules solutions Pvt ltd has developed a Building Management System (BMS), DeJoule, which is an IoT based continuous energy optimization platform for bringing energy efficiency. It receives data from various sensors, VFD and motorized actuator valves, through an in-house developed controller and then processes this data for an HVAC site, allowing the user to monitor and control energy consumption of various HVAC assets. DeJoule is integrated to the building for continuous monitoring, control, management, and operation providing efficient energy management and allowing the desired indoor environment to be maintained. It is allowing users through data driven actionable intelligence for eliminating energy waste and diagnostic. Savings of 5 percent of overall chiller plant energy consumption are typically associated with utilization of platforms that enable real-time monitoring, automated analytic, target setting and system-generated alarms that prompt corrective action. The Data Quantity Index (DQI) of DeJoule is sixty data points in one hour, which means ideally we should get one data point every minute for all the devices configured in DeJoule. DeJoule has data with four different climatic conditions - moderate, composite, warm and humid, hot and dry. The availability of this vast historical data bank in DeJoule makes machine learning a useful feature in selection of chiller plant.

From DeJoule, real time data is obtained by considering particular time period (Jan 2021- Dec 2021) and TR trend data is plotted. And these datas are used for comparing with HAP simulations. Based on the TR available TR bins are created and is shown in Fig 4 to know the percentage consumption of chiller. And fig 5 depicts the monthly average analysis of the site for a particular year. And this data is compared with the simulations.

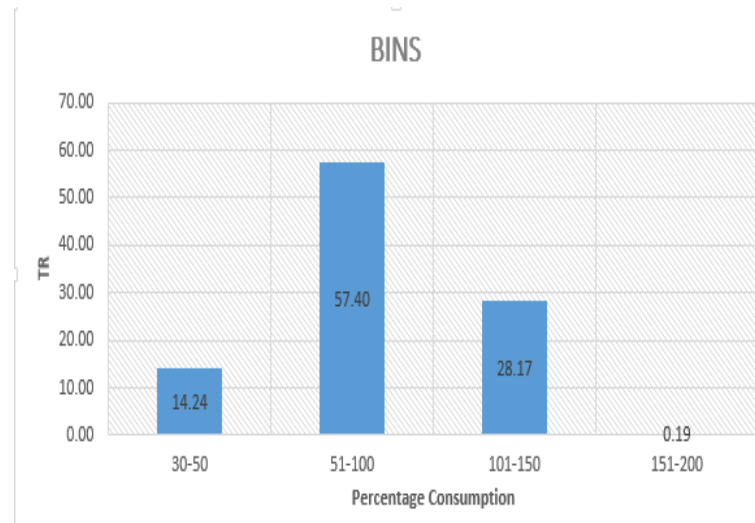


Figure 4 :BINS Created using real time data

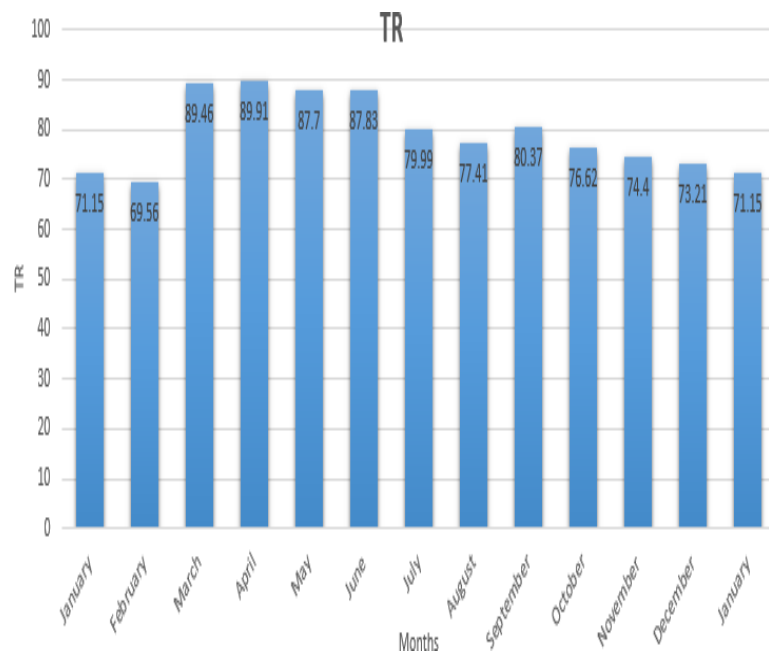
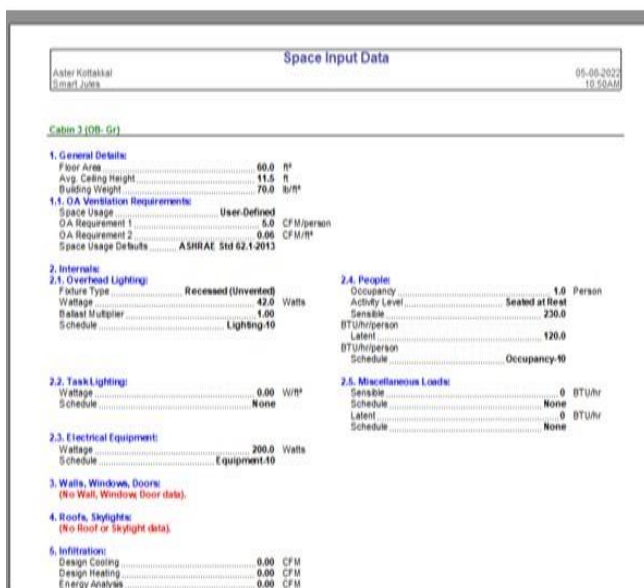


Figure 5 : Monthly Average Analysis of Real time data

CREATE SPACES (141 SPACES CREATED)



Space Input Data

Aster Kottakal
Smart_Jules
05-08-2022
10:50AM

Cabin 3 (DB-G)

1. General Details:

- Floor Area: 60.0 ft²
- Avg. Ceiling Height: 11.5 ft
- Building Weight: 70.0 lb/ft²

1.1. OA Ventilation Requirements:

- Space Usage: User-Defined
- OA Requirement 1: 5.0 CFM/person
- OA Requirement 2: 0.06 CFM/ft²
- Space Usage Defaults: ASHRAE Std 62.1-2013

2. Interiors:

2.1. Overhead Lighting:

- Fixture Type: Recessed (Inverted)
- Wattage: 42.0 Watts
- Ballast Multiplier: 1.00
- Schedule: Lighting-10

2.2. Task Lighting:

- Wattage: 0.00 W/ft²
- Schedule: None

2.3. Electrical Equipment:

- Wattage: 200.0 Watts
- Schedule: Equipment-10

2.4. People:

- Occupancy: 1.0 Person
- Activity Level: Seated at Rest
- Sensible: 230.0 BTU/hr/person
- Latent: 120.0 BTU/hr/person
- Schedule: Occupancy-10

2.5. Miscellaneous Loads:

- Sensible: 0 BTU/hr
- Schedule: None
- Latent: 0 BTU/hr
- Schedule: None

3. Walls, Windows, Doors:

- (No Wall, Window, Door data)

4. Roofs, Skylights:

- (No Roof or Skylight data)

5. Infiltration:

- Design Cooling: 0.00 CFM
- Design Heating: 0.00 CFM
- Energy Analysis: 0.00 CFM

Figure 3. HAP Input Report

6. RESULTS AND DISCUSSION

6.1.HAP SUMULATIONS

- Total 141 spaces considered for site A.
- Total 88 systems were considered. And 6 Plants were considered for doing simulations.
- The Total TR required in site is approximately 220-230 TR (Peak Load).
- Average monthly results were showing that site required 80-120 TR in an average.
- The load is estimated by considering relevant standards.
- The Peak load is generating in the month of June at 15:00 according to simulation.
- Total floor area served by plant is 27190 square feet.

(Refer Figures 6 and 7)

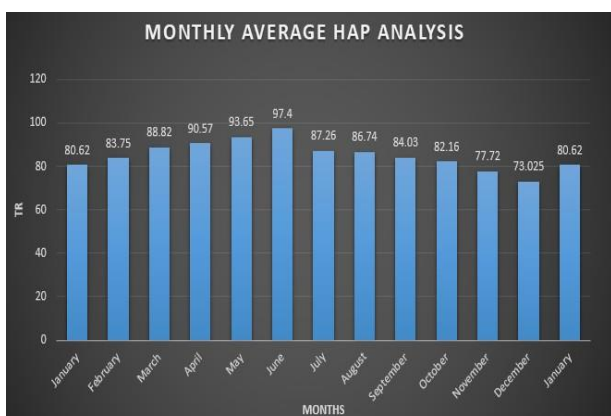


Figure 6: Monthly Average HAP Analysis

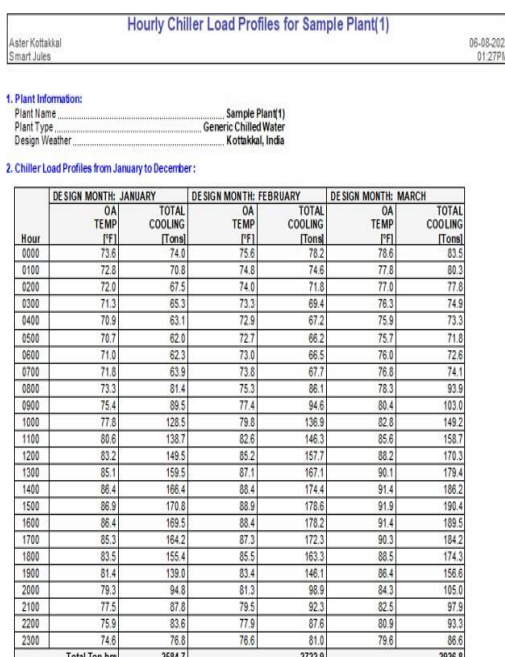


Figure 7. HAP Results

6.2. DIFFERENCE ARISING BETWEEN SIMULATIONS AND REAL TIME DATA

- Peak load is arising in the month of June in simulations. As per real time data obtained, Peak load is arising at April.
- HAP calculations are done on the peak side.
 - Average TR consumption of chiller is 80-100 TR.
 - The variation of cooling load between the two methods was due to that the values were inbuilt in HAP software randomly.
 - Variation is also due to occupancy factor.
 - In general, both results from real time data and HAP were within an acceptable range of the required cooling load for the site.

(Refer Figures 8 , 9 and 10)

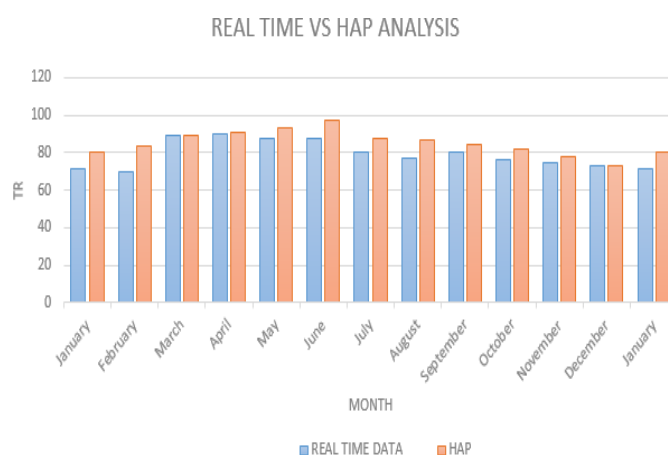


Figure 8: Difference between real time data and simulations

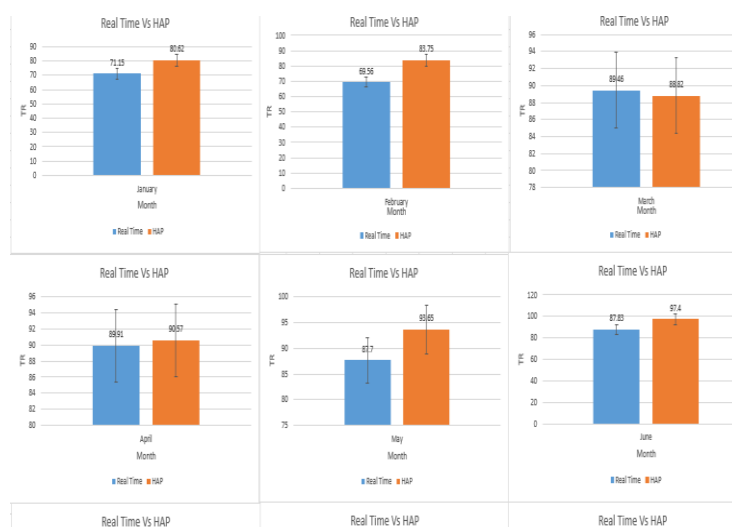


Figure 9. Difference between real time data and simulations from January to June

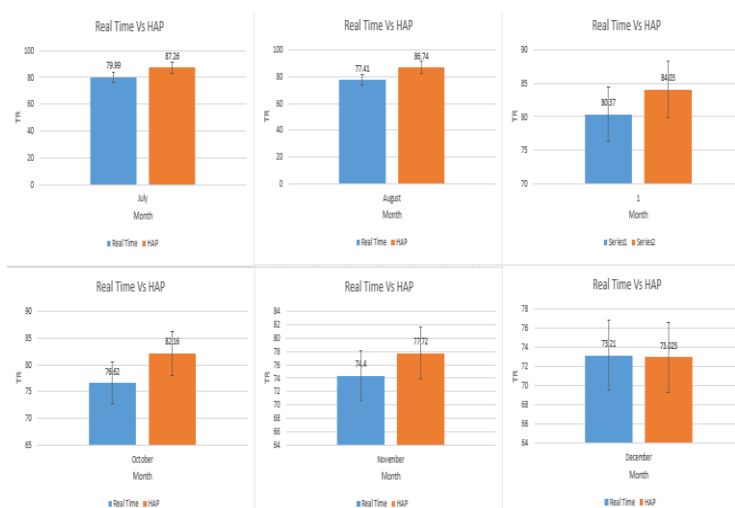


Figure 10. Difference between real time data and simulations from July to December

7. CONCLUSIONS

Results obtained of analyzing simulation and real time data, both results were within an acceptable range of the required cooling load. Nearly 9 percentage of average difference is arising between the real time data and HAP simulations. The difference is due to the occupancy factor which is varied. And also the difference is due to the HAP simulations loads are calculated in peak side load. After comparing the real time data from DeJoule and HAP simulations, these were the conclusion made from the results.

- 250 TR variable speed chiller is the optimum design for the site.
- We can design HVAC systems according to HAP simulations in an optimum way.
- As the Variable Speed chillers can deliver substantially superior efficiency under part load conditions.
- So we have considered 250 TR chiller in order to cater minimum and maximum load after considering future construction that may took place.

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