Energy Cost Optimization

A thesis
submitted in fulfillment of the requirements
for the award of the degree of

BACHELOR OF TECHNOLOGY
&
MASTER OF TECHNOLOGY

submitted by

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Candidate's Declaration

I hereby declare that the work presented in the thesis entitled **"Energy Cost Optimization"** in partial fulfillment of the requirements for the award of the Degree of **Bachelor of Technology & Master of Technology** and submitted in the Department of Electrical Engineering of the Indian Institute of Technology Madras is an authentic record of my own work carried out during a period from May 2019 to June 2020 under the supervision of **Prof. Ashok Jhunjhunwala**, Department of Electrical Engineering, Indian Institute of Technology Madras.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institute/University.

Ganesh Kumar Khatik
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This is to certify that the above statement made by the candidate is true to the best of our knowledge and belief.

Prof. Ashok Jhunjhunwala
Professor, EE Department
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Place: Chennai
Date:

ACKNOWLEDGMENTS

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I wish to express my appreciation to my co-guides/supervisors Mr. S Sree Hari Nagarajan and Mr. Durai Bose , Chakra Network Solutions Pvt. Ltd., IITM Research Park, and grateful thanks for their help and motivation throughout my Project work. Their valuable guidance throughout my project have been instrumental in completing my project.I also would like to express my deep and sincerely thanks to my friends and all other persons whose names do not appear here, for helping me either directly or indirectly in all even and odd times.

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Finally, I am indebted and grateful to the Almighty for helping me in this endeavor.

Ganesh Kumar Khatik

ABSTRACT

One of the biggest challenges the current century faces is the energy use and saving problem. Increasing energy consumption, especially in buildings, has made energy savings and efficiency strategies an important target for energy policies.

In general, there are several ways to save energy, and one of the most effective ways is through efficiency measures. Building Management System (BMS) is a key means of achieving energy saving goals. In a dynamic environment, smart buildings are affordable by the integration of four main elements: systems, structure, service, management, and the relationship between them. Intelligent buildings provide these benefits through intelligent control systems.

In this Project, while introducing the BMS in buildings, we study its applications, communication protocols and also its effects on management and optimization of energy consumption.

The IITMRP building in Chennai, India with 1.2 million square feet workspace area is considered as a case study for this project.

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List of Acronyms/Abbreviations

BMS	Building Management System
RTU	Roof top unit
IP	Internet Protocol
HVAC	Heating, ventilation, and air conditioning
AHU	Air handling Unit
VCR	Vapour Compression Cycle
WBT	Wet Bulb Temperature
F1	Sum of Flow rates of all the chillers
F2	Flow rate in common header
F3	Flow rates in Bypass Line
BACnet	Building Automation and Control Network
BBMD	BACnet Broadcast Management Device
BDT	Broadcast Distribution Table
DG	Diesel Generator
VFD	Variable frequency device
GPM	gallon per minute
rpm	revolutions per minute

List of Symbols

%	Percentage
$\leq$	Less than equal to
$\geq$	Greater than equal to
$>$	Greater than
$<$	Less than
$^\circ$	Degree Celsius

Chapter 1

Background

This Chapter provides a brief description of Building Management System (BMS) and data exchange protocols

1.1 Background

Corporate office buildings are expensive to operate, especially when we talk about the cost of the electricity (tariffs). Thus, it is natural to look for ways to reduce costs and improve overall efficiency. One common method known as Building Management system is a vital means to bring about savings at large, as it provides the ability to monitor and maintain the various systems in a building.

BMS operates through efficient exchange of data and uses a common data structure and a common channel or medium of communication. A master BMS communicates with different devices in a building on a local network, and these devices include roof-top units (or RTU), refrigeration controllers, energy meters, and other input/output boards within a building. The master device also uses the Internet to share temperature, operating parameters, or energy data with remote users through enterprise servers or personal computers.

A BMS communication protocol defines the format and meaning of each data element, in much the same way a dictionary defines the spelling and meaning of words.

The data exchange often occurs through a physical wire such as a twisted-pair RS485 or an Ethernet (CAT5 cable). It may also occur over wi-fi network, using an internet protocol (or IP).

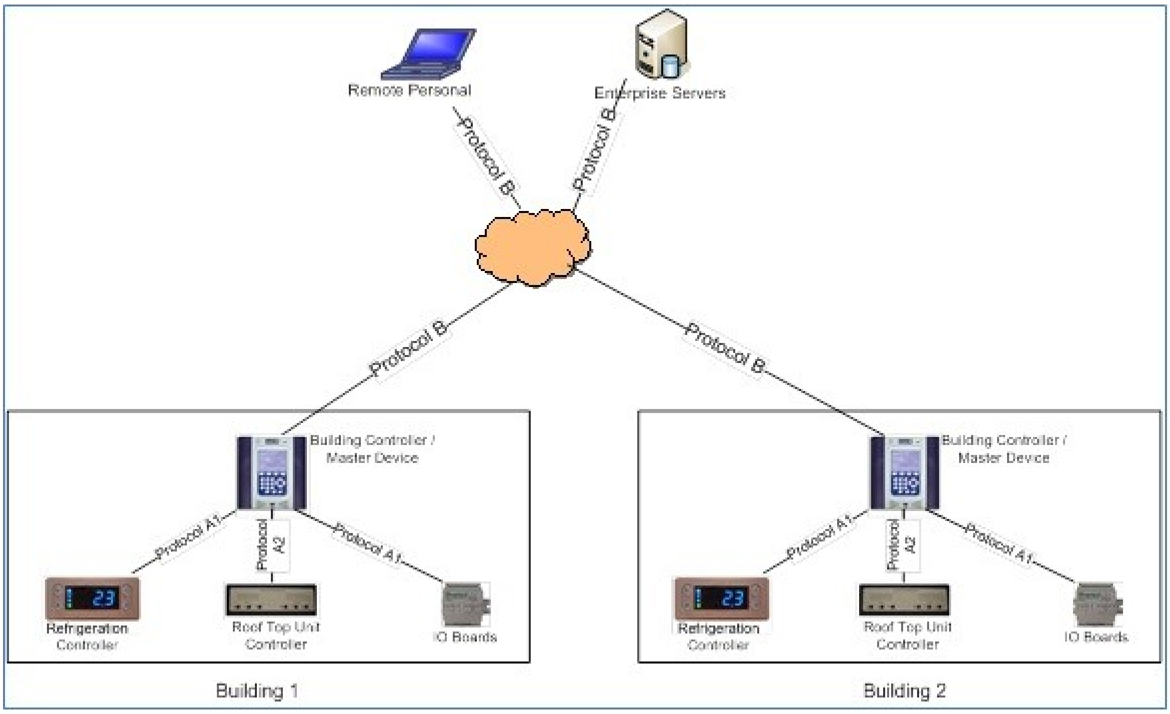

Figure 1.1: BMS Communication on a local network

Chapter 2

Introduction

This Chapter provides a brief description of BMS , Chiller functioning, HVAC, Cooling Tower. The motivation and objectives of the project work and problem statement are presented. It also highlights the organization of the thesis.

2.1 Building Management System

A building management system (BMS), is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. In order for signals to be exchanged across the network of building management system, there must be a communication protocol. Here comes the use of Modbus and BACnet Protocols. Each of the competing protocols claims to be the best. Communication Protocols must be selected based on the needs of the facility and its ability to support a particular protocol. Building management systems are used to monitor and control building services.

Like: Alarms, HVAC, Lighting, Lifts, Solar, AHUs etc.

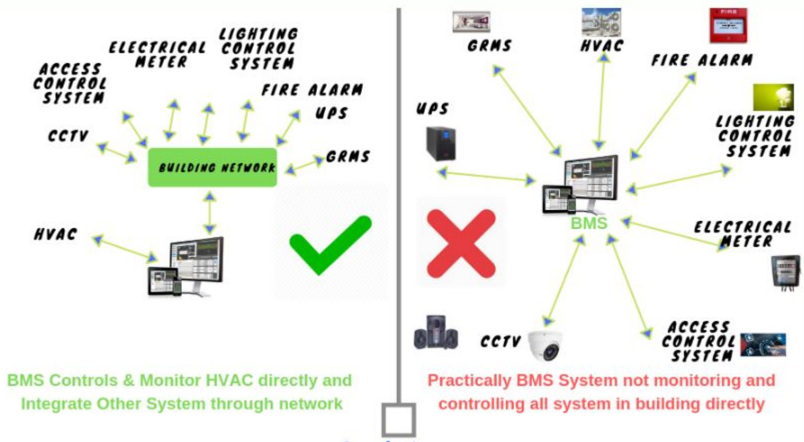

Figure 2.1: BMS Architecture

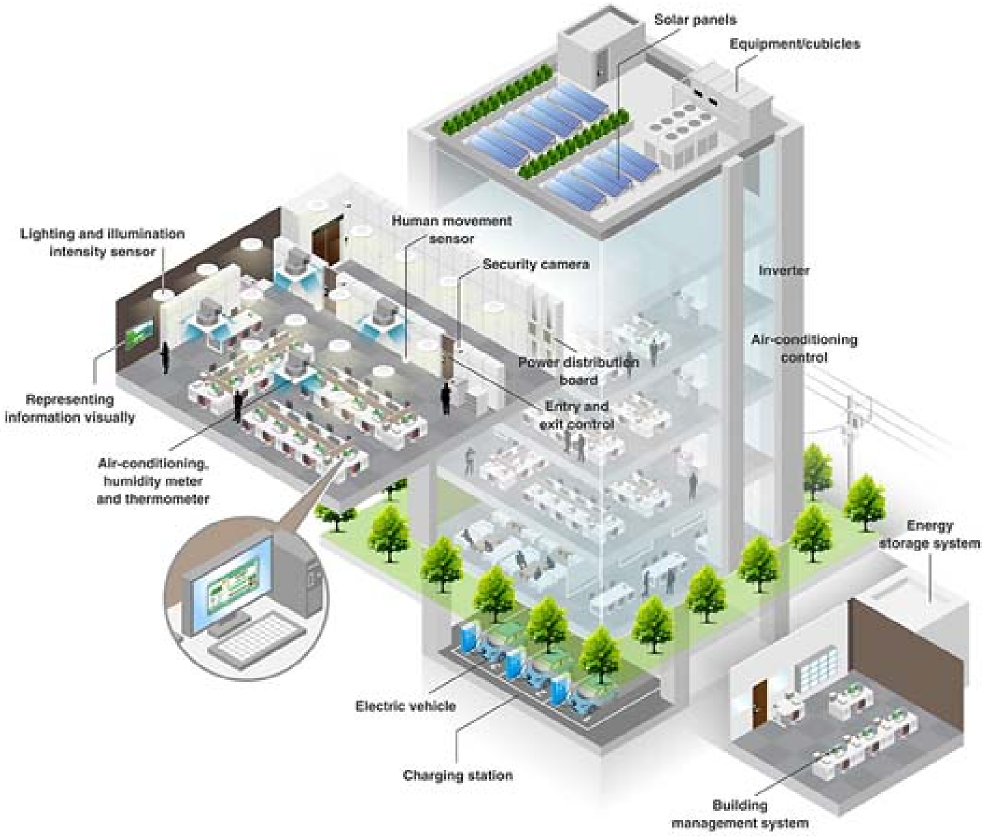

Figure 2.2: Building Management System

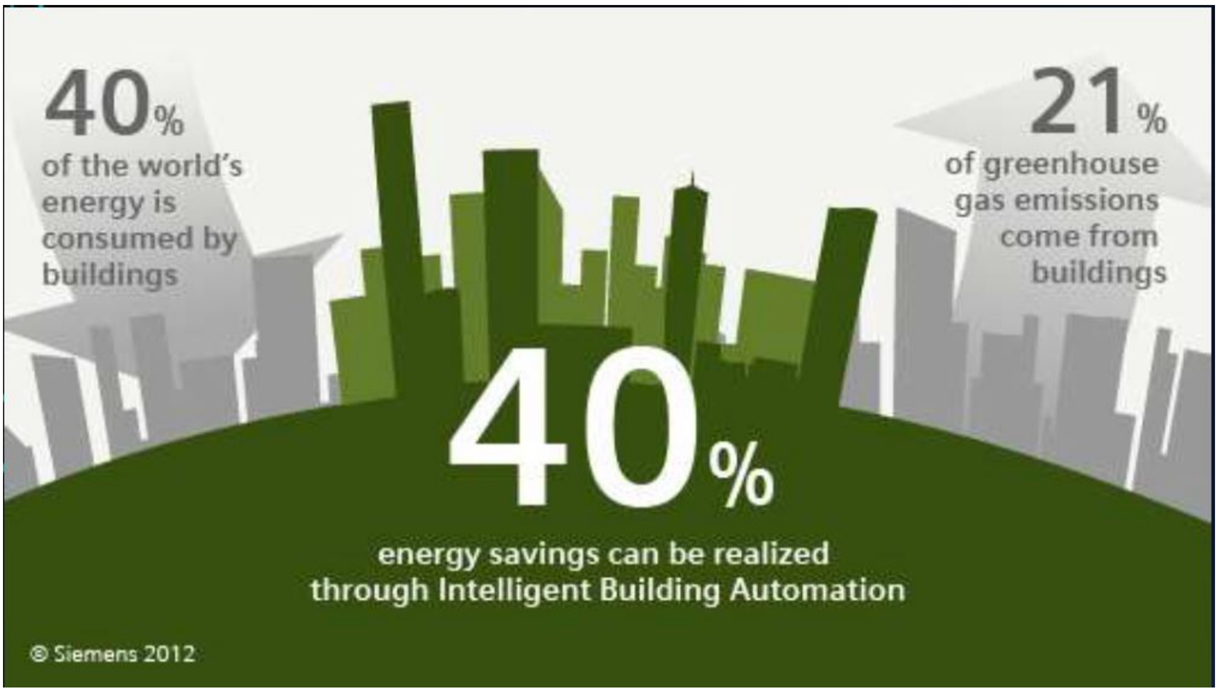

Figure 2.3: BMS Energy Saving

2.2 HVAC

The three major functions of heating, ventilating and air conditioning (HVAC) are interrelated, especially with the major need to provide thermal comfort within the responsible installation, operation and maintenance costs.

The goal of the HVAC system is to control thermal comfort of a building.

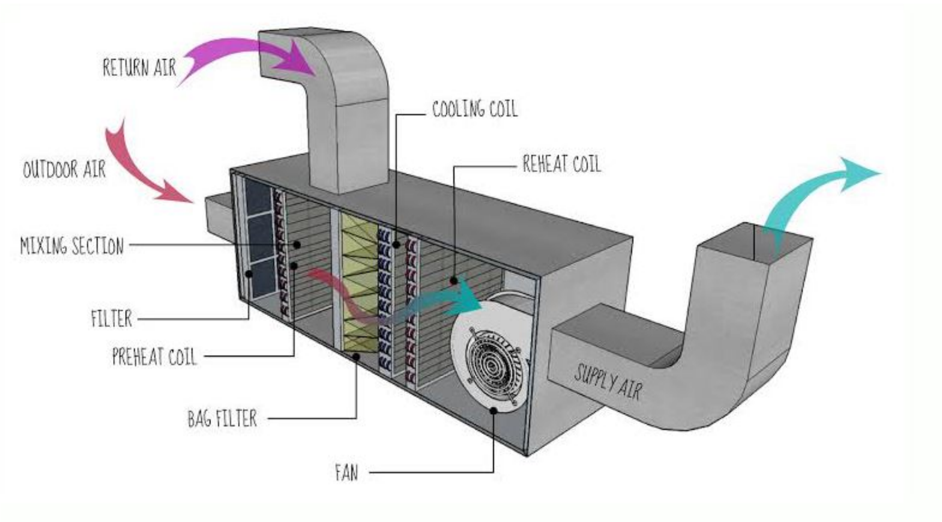

Figure 2.4: HVAC

2.3 Functioning of Chiller

Chiller works on the principle of Vapor Compression Refrigeration (VCR) Cycle. Refrigeration has been accomplished in a variety of ways over the period, but vapor-compression refrigeration systems (VCRS) have become the preferred option because of their efficiency and reliability.

2.3.1 Vapour Compression Cycle (VCR)

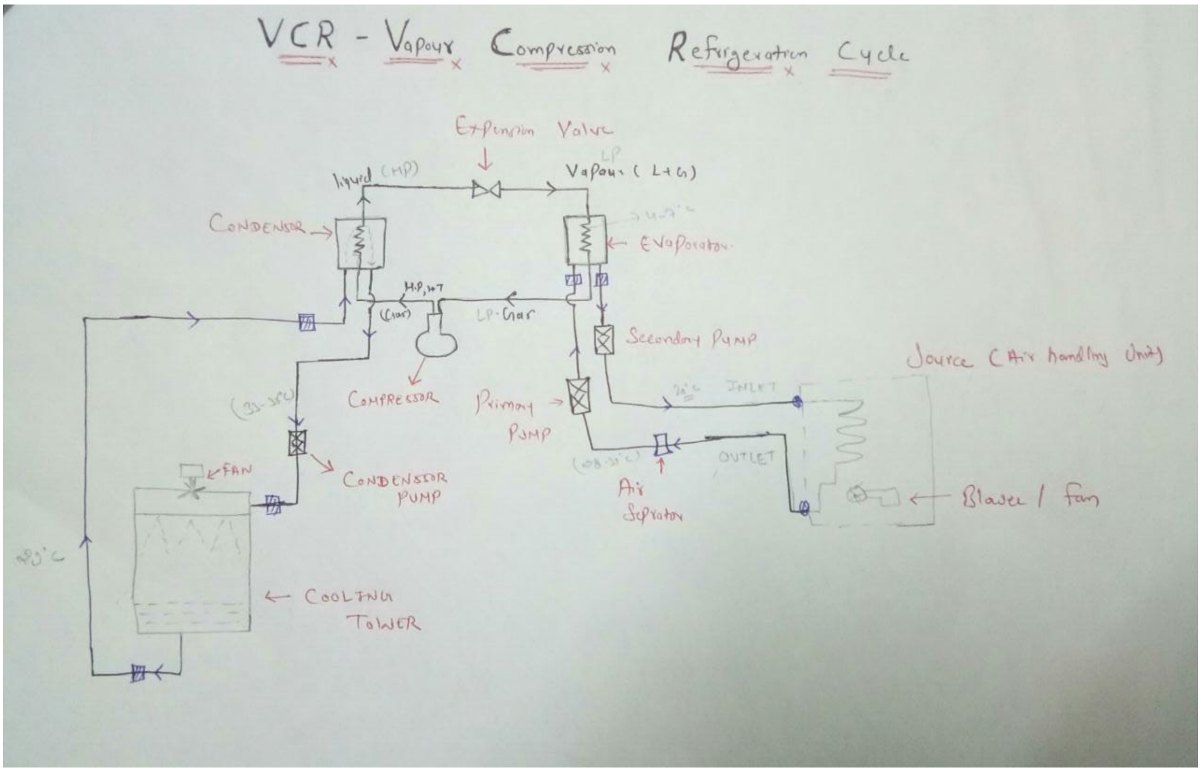

Figure 2.5: VCR

The compressor raises the pressure of the vapor refrigerant so that it creates a pressure difference, the pressure difference is required for the refrigerant to flow, here high pressure fluids flow towards lower pressure fluid.

Compressor is raising the pressure of the refrigerant so that the refrigerant will flow to the lower pressure refrigerant in the evaporator coil. The compressor raising the pressure will also increase the temperature.

The direction of heat transfer is from a higher temperature substance to a lower temperature substance, the lower temperature being in the evaporator coil and the hotter being in the compressor and condenser.

TThe refrigeration cycle starts with a low-pressure liquid/gas mix entering the evaporator. In the evaporator, heat from the process water boils the refrigerant, which changes it from a low-pressure liquid to a low-pressure gas. The low-pressure gas enters the compressor where it is compressed to high-pressure gas. The high- pressure gas enters the condenser where ambient air or condenser water removes heat to cool it to a high-pressure liquid. The high-pressure liquid travels to the expansion valve, which controls the amount of liquid refrigerant enters the evaporator. Thereby, beginning the refrigeration cycle again.

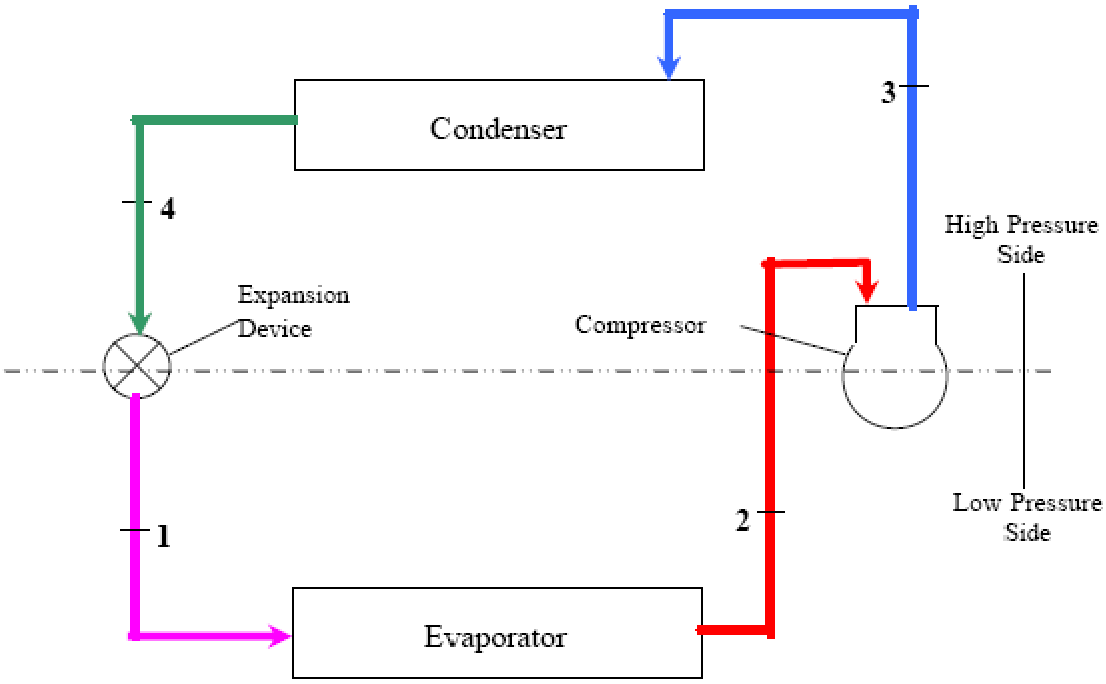

Figure 2.6: Single Stage Vapour Compression Cycle

2.3.2 Components of Chiller

1. **Condenser** : It is a heat exchanger that eradicates heat from refrigerant vapor and transfers it to the water running through it. This water goes to a cooling tower for cooling.

2. **Expansion Valve**: It is a device used to maintain the pressure difference between the high pressure & low pressure sides of the chiller system.

3. **Evaporator**: The part of the chiller system where cool liquid refrigerant absorbs heat from the chilled water circuit.

   The return water which reaches the evaporator via primary pump is of a higher temperature than that of what is leaving the AHU (Air Handling Unit) via secondary pump.

4. **Compressor**: It is used to increase the pressure & temperature of the refrigerant vapor.

5. **Primary Pump**: In circuit the chillers cool the water which is circulated around by the primary pumps in a continuous loop between the chiller or boiler and the low loss header.

6. **Secondary pump**: The secondary pumps are used to transfer thermal energy into the rooms or equipment within the building.

7. **Condenser pump**: The condenser pump circulates return condenser water from the chiller back to the cooling tower. The cooling tower then cools the condenser water, and the condenser water is supplied back to the chiller.

8. **Air Separator**: It eliminates air quickly and efficiently from closed loop heating and cooling systems.

9. **Cooling Tower**: A large heat exchanger unit which provides cooling water to remove heat from a coolant.

10. **Motor Fan**: Condenser fan motors are installed in air conditioner condensing units to power the fan blades that cool the refrigerant in the unit's condensing coil.

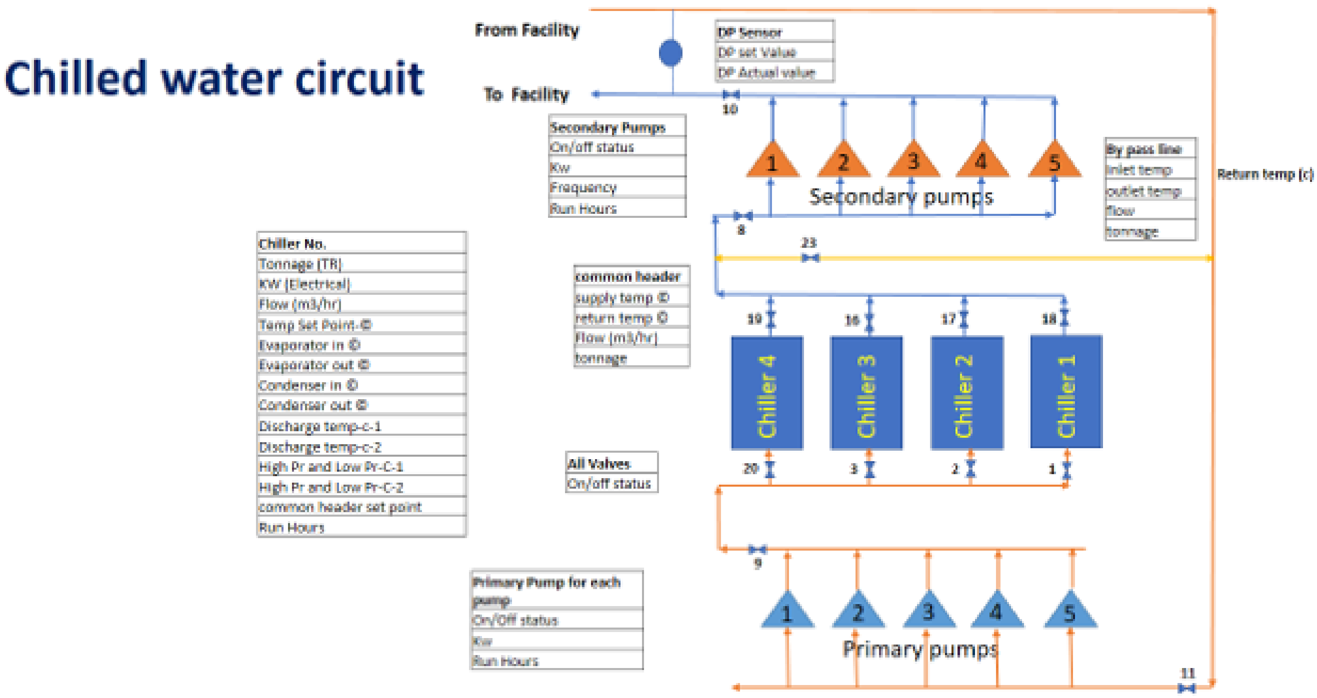

Figure 2.7: Chilled Water Circuit

2.3.3 Cooling Tower

It is a large heat exchanger unit which provides cooling water, to remove heat from a coolant (most often water) that has been used to cool machinery, process fluids, or buildings. When the cooling water meets with air, a small portion evaporates, lowering its temperature. This process is known as 'evaporative cooling.'

Heated water from the complexes enters into the condenser and flows through the pipework into the cooling tower for heat removal, or flows directly through the tower. Spray nozzles inside the tower spray the water on a fill material whose larger surface area allows for maximum contact with air and increases the rate of evaporation.

Cooling fans located within the tower aid the cooling process, and the drift eliminators remove the tiny droplets of water produced in the tower air stream during evaporation.

Cooling tower supplies cooled water with their own feed pumps to the condenser exchanger where compressed fluid heat is extracted.

In other words, Hot water is the input to the cooling tower, which gets cooled in this process releasing the heat to the atmosphere. The hot water is the output of the chillers which goes to the cooling tower.

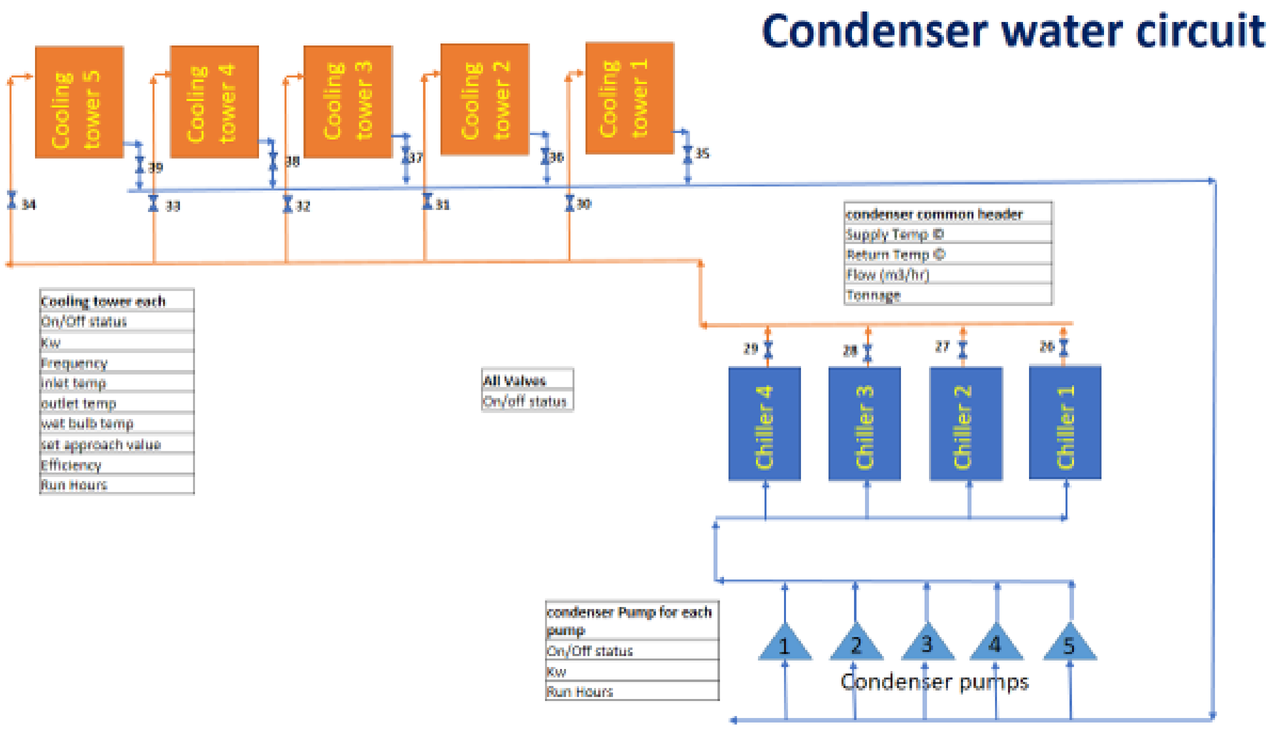

Figure 2.8: Condenser Water Circuit

2.4 Motivation and Objective

Energy efficiency and cost savings are a crucial topic within the framework of sustainable development. Thus, the primary objective of this work is The primary objective of this work is

1. to enhance energy efficiency of the integrated HVAC system
2. to reduce / minimize the operating cost for the HVAC and therefore the building (BMS)

This project helps one to build a management system, through which an operator can optimize the energy usage in a systematic manner. The BMS, enables control of remote devices in the building so as to achieve the above objectives.

Algorithms and Logics are incorporated in the BMS, so that they can be used when needed. At the same time, another objective used is to reduce the noise produced by the cooling towers. The BMS provides the ability to carry out control either manually, or automatically by using algorithms and logic.

2.5 Problem statement

There are several factors which lead to a higher consumption of energy, which eventually leads to higher expenses.

This work concentrates on the energy savings algorithms without compromising on the thermal comfort. To improve HVAC performance, the relevant parameters are adaptively selected on the basis of logic proposed.

The objectives of this project are summarized as follows:

1. **Cooling Tower**
   - **i)** Reduce Noise
   - **ii)** Optimize Power
   - **iii)** Optimize number of unit that will run at any given time
2. **Manage Chiller Operations**
   - **i)** Control number of chillers being run
   - **ii)** Control number of cooling towers being run at any time
   - **iii)** Control the Speed of Secondary pump

2.6 Organization of the thesis

The research work presented in the thesis is organized and structured in the form of seven chapters, which are briefly described as follows:

i) **Chapter 1** Background

ii) **Chapter 2** Introduction

iii) **Chapter 3** Proposed Approach

iv) **Chapter 4** Proposed Logic Algorithms

v) **Chapter 5** Communication Protocols of BMS

vi) **Chapter 6** Uses Of BMS

vii) **Chapter 7** Results of implementing controls at IITMRP.

viii) **Chapter 8** Concludes the project with overall discoveries of the present research work. The scope for future work is also mentioned.

Chapter 3

Proposed Approach

This Chapter presents the approach to solve the problem statement

3.1 Proposed Approach

1. **Cooling Tower**

   i) **Reduce Noise**-: BMS logic to run appropriate number of cooling towers at optimized speeds to reduce noise.

   ii) **Optimize Power**-: BMS logic to run appropriate number of cooling towers at optimized speeds to reduce power.

   iii) **Optimize number of units that will run at any given time**-: To be implemented via BMS logic to run appropriate number of cooling towers at optimized speed

2. **Manage Chiller Operations**

   i) **Control number of chillers being run**-: To be implemented via BMS logic to run appropriate number of chillers based on loading percentage (%) of chillers

   ii) **Control number of cooling towers being run at any given time** -: To be implemented via BMS logic to run appropriate number of cooling towers based on approach and Wet bulb temperature(WBT)

   iii) **Control the Speed of Secondary pump**-: To be decreased or increased based on the flow rates of chillers.

3.2 The Approach Implemented

After analyzing the objectives. One can see that they can be achieved by performing the following three tasks.

1. **Optimizing number of chillers to be run**
2. **Optimizing number of cooling towers to run**
3. **Optimizing Speed of Secondary Pump**

Chapter 4

Proposed Logics/Algorithms

This Chapter describes the logics/algorithms to solve the problem statements discussed in the previous chapter without compromising on thermal comfort.

4.1 Optimizing number of chillers to be run

Table 4.1: Logic to manage chiller operation

Number of Chiller to operate based on load %		
Operating Load		
Existing Load	**Changed Load**	**Action**
$\leq 70\%$	No Change	Maintain number of chiller currently running
$\leq 70\%$	$> 70\%$	Run one more chiller (maximum upto 4)
$> 70\%$	No Change	Maintain number of chiller currently running
$> 70\%$	$\leq 70\%$	Shut down one chiller (if it is not the only chiller)

Explanation:

1. If the existing load on a chiller is less than or equal to 70% and there is no change in load then maintain the number of chillers currently running.

2. If the existing load on the chiller is less than or equal to 70% and the changed load is greater than 70% then increase the number of chiller currently running by 1(but it can go maximum of 4, as the number of chillers available in IITMRP are 4).

3. If the current load on the chiller is greater than 70% and the changed load is same as that of current/existing load (i.e. greater than 70%), then maintain the number of chillers currently running.

4. If the current load on the chiller is greater than 70% and the changed load is less than or equal to 70% then shut down one of the chillers currently running (only if it is not the only chiller which is running).

4.2 Optimizing number of cooling tower to be run

Table 4.2: Logic to optimize number of cooling towers to run

CWT and WBT based approach to decide number of cooling tower to operate %	
Condition	**Number of cooling tower to be operated**
$CWT <= (WBT + 4)$	N
$CWT > (WBT + 4)$	N+1
	N= Number of chillers in operation
Legend	
WBT	Wet Bulb Temperature
CBT	Condenser water outlet Temperature

Explanation:

1. The logic to optimize number of cooling tower is based on the "wet bulb temperature(WBT)" and the "Condenser outlet temperature(CWT)".

2. If $CWT \leq (WBT + 4)$, then maintain the same number of cooling tower in operation.

3. If $CWT > (WBT + 4)$, then increase the required number of cooling tower will be 1 more than the currently running.

4.3 Optimizing Speed of Secondary pump

Table 4.3: Logic to optimize speed of secondary pump

Secondary pump logic	
Condition	**Logic**
if, F1=F2+-10% of F1	Run Secondary pump at same speed
if, F1=F2+F3+-10% of F1	Increase the speed of the secondary pump by 2% till F1=F2 other wise run at same speed
if, F1=F2-F3+-10% of F1	Reduce the speed of the secondary pump by 2% till F2 $\leq F1$
Legend	
F1	Flow rate of chiller 1+chiller 2+chiller 3+chiller 4
F2	Flow rate in common header
F3	Flow rate in By pass line

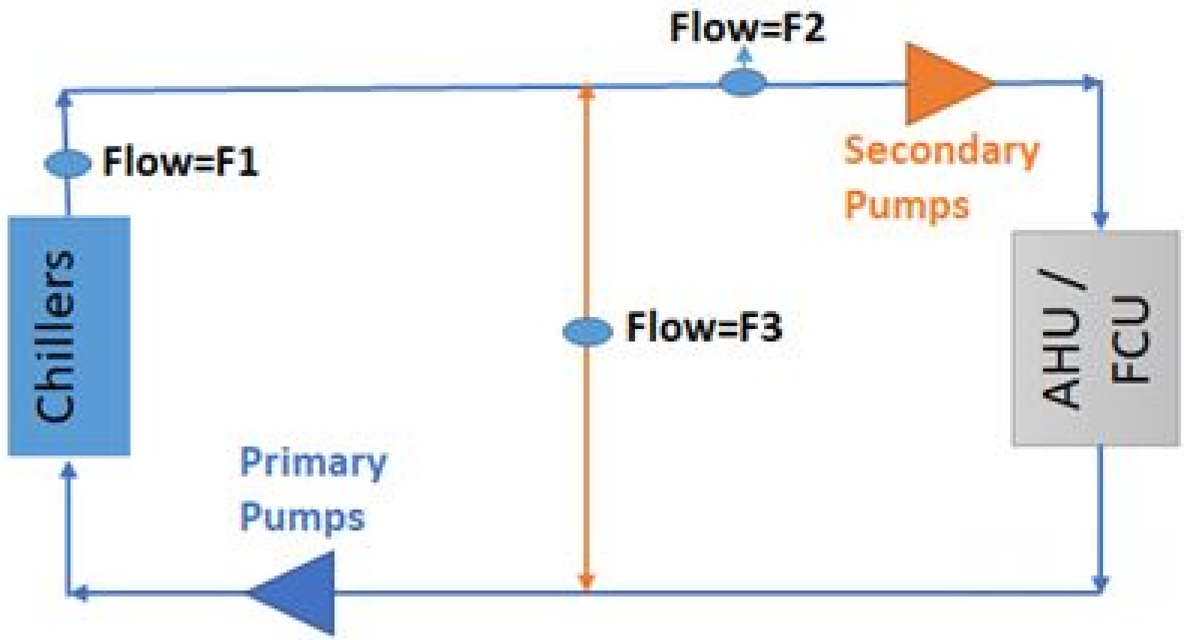

Figure 4.1: Secondary Pump Logic

Explanation:

1. The above described logic to optimize the speed of the secondary pump is based on the flow rates of the chillers, common header and bypass line.

2. 2. From the above figure it can be seen that when F1 >F2, then increase the speed of the secondary pump by 2% till F1=F2.

3. Similarly from the above figure, when F1 $<$ F2 than increase the speed of secondary pump by 2% till F1 >F2.

4.4 Summary

The proposed algorithm helps one to reduce the operation costs and noise produced by the chillers along with improving the efficiency of the chillers and reducing rpm of the fan without compromising on the thermal comfort of the customer.

Chapter 5

Communication Protocols of BMS

Protocols are languages by which two devices communicate and exchange data. These devices are microprocessor-based products, such as an input/output board, roof top unit controller (RTU), Chiller controller, user's laptop/desktop computer or even central enterprise servers.

In a building management system (or BMS), it is important to understand how it communicates information with devices such as controllers, meters, and input/output boards, and computers.

The details are important because some BMS use languages or technical protocols that lock you into using their vendor's proprietary technology. Use of such protocols may force you and your client to pay higher prices for software and hardware available from only one vendor or its licensees.

Protocols fit in one of four categories, depending on their relative "openness:"

1. **Open:** The protocol is readily available to everyone.
2. **Standard:** All parties agree to a common data structure. The protocol may be an industry standard, such as BACnet and Modbus.
3. **Inter-operable:** The protocol is vendor agnostic. A controller from one vendor can replace one from a different vendor.
4. **Proprietary:** The data structure is restricted to the creator of the device.

A BMS with proprietary protocols locks the system owner into using a single BMS vendor. For example, you cannot remotely change the set points of a proprietary BMS unless you use the vendor's software.

In contrast, with open and standard BMS communication protocols you can shop for alternative providers of digital devices and enterprise software that is why use of proprietary protocols is inconsistent with best practice.

In summary, one can say that the open and standard BMS communication protocols (Modbus and BACnet) will be a good choice for a better and productive BMS system.

5.1 Modbus

Modbus consists of messaging structure. It supports traditional serial and Ethernet protocol.

The original version of Modbus includes two transmission modes ASCII and RTU. Later Modbus IP was developed allowing the Modbus protocol to be transmitted over TCP/IP based networks.

The device requesting the information is called the Modbus Master and the devices supplying information are Modbus Slaves. In a standard Modbus network, there is one Master and up to 247 Slaves, each with a unique Slave Address from 1 to 247. The Master can also write information to the Slaves.

The data is sent as a series of ones and zeros called bits. Each bit is sent as a voltage. Zeroes are sent as positive voltages and ones as negative.

5.2 BACnet

BACnet is developed to facilitate the facility managers or the building owners in the building to communicate all the devices with common standard protocol.

It allows data to be shared and equipment to be worked together easily, otherwise one should have a separate system or software for each system.

BACnet uses IP broadcasts to locate and communicate with other BACnet devices. These broadcasts are normally blocked by IP routers. The BACnet specification outlines a method of using a BACnet Broadcast Management Device (BBMD) that allows BACnet/IP communication across IP routers.

Every subnet with a BACnet/IP router must have a BBMD configured in order for broadcasts from controllers on that subnet to reach the rest of the routers on the network.

Every BBMD has a Broadcast Distribution Table (BDT). A BDT lists all of the IP addresses of other BBMD's on the network.

5.3 IITM-RP BMS Communication protocols

Modbus protocol is used in IITMRP to communicate between devices in a network.

Modbus is open protocol so it doesn't require a specific Media or Physical Layer, unlike many proprietary protocols, so Modbus networks are built on inexpensive and common infrastructure such as RS485, RS422, RS232, and Ethernet links.

A dedicated Modbus master is capable of handling a system that is scalable and will effectively distribute and route your monitoring load.

Chapter 6

Uses of BMS

A BMS calculates values based on the data items provided through network.

6.1 Introduction

Building Management System ensures safety, comfort and efficient resource consumption of a building.

Smart sensors around the building gather data and send it to the BMS, where it is stored in a database. By monitoring real-time energy use, one has more actionable data to pinpoint power-consuming, inefficient lights and equipment, change one's usage patterns to avoid high demand charges, and make deliberate improvements to reduce one's energy consumption.

6.2 Example Reports generated by BMS

1. Energy consumption pattern calculation for weekdays as well as weekends.
2. Energy Generated by DGs on hourly basis for year 2018.
3. Cost/Kwh for a DG
4. Top 10 Consumers of IITMRP from the date 01/08/2018

6.2.1 Energy consumption pattern calculation for weekdays as well as weekends for Office-1

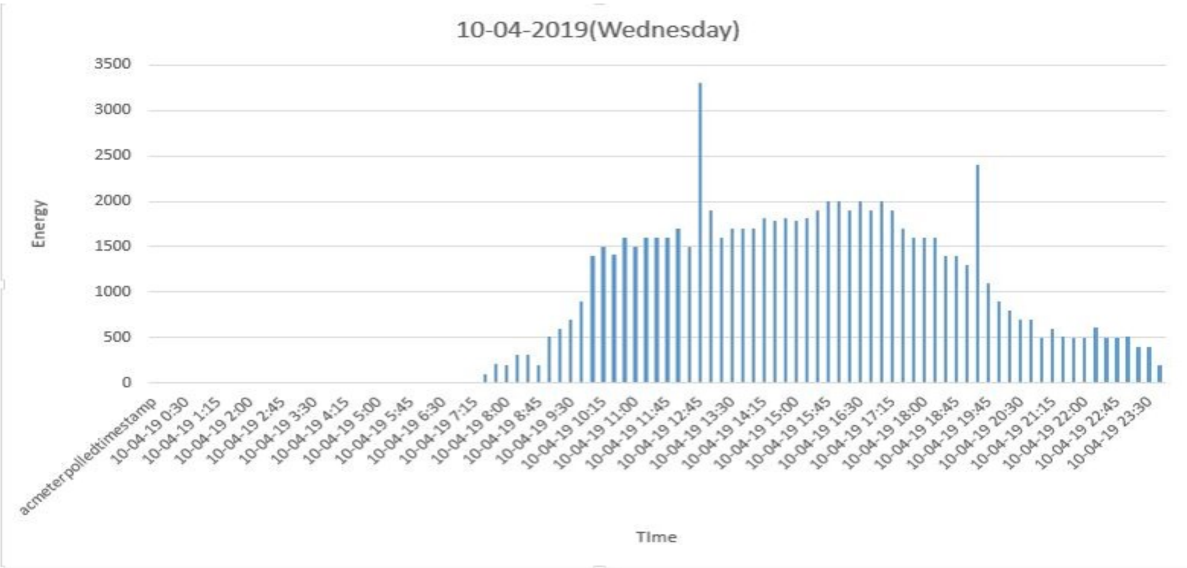

Figure 6.1: Energy Consumption Pattern of a weekday i.e. Wednesday

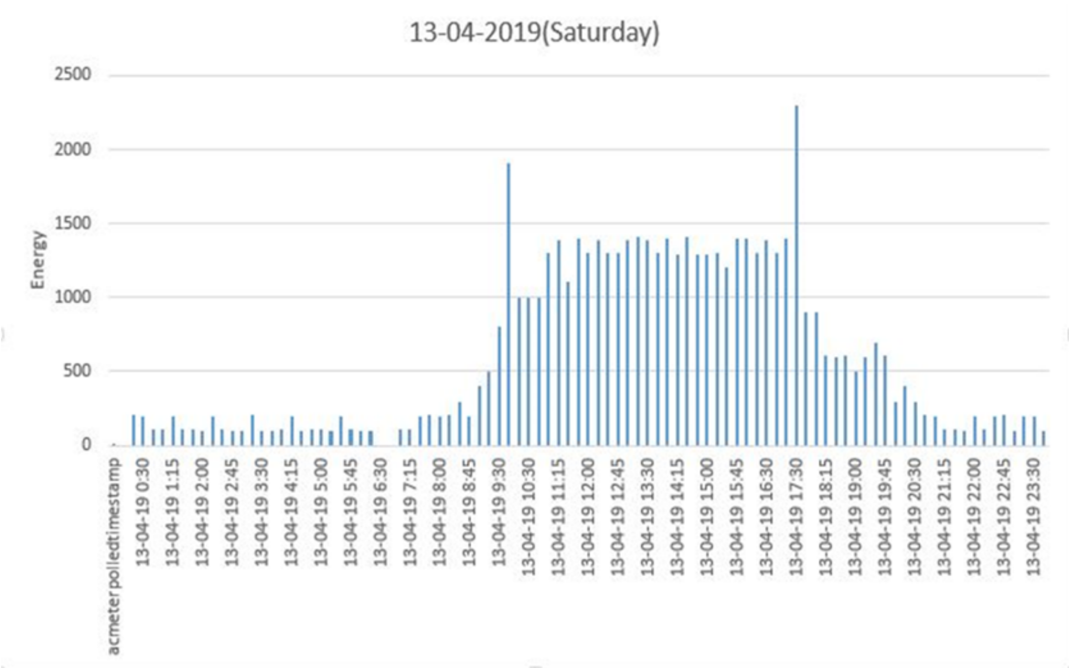

Figure 6.2: Energy Consumption Pattern of a weekends i.e. Saturday

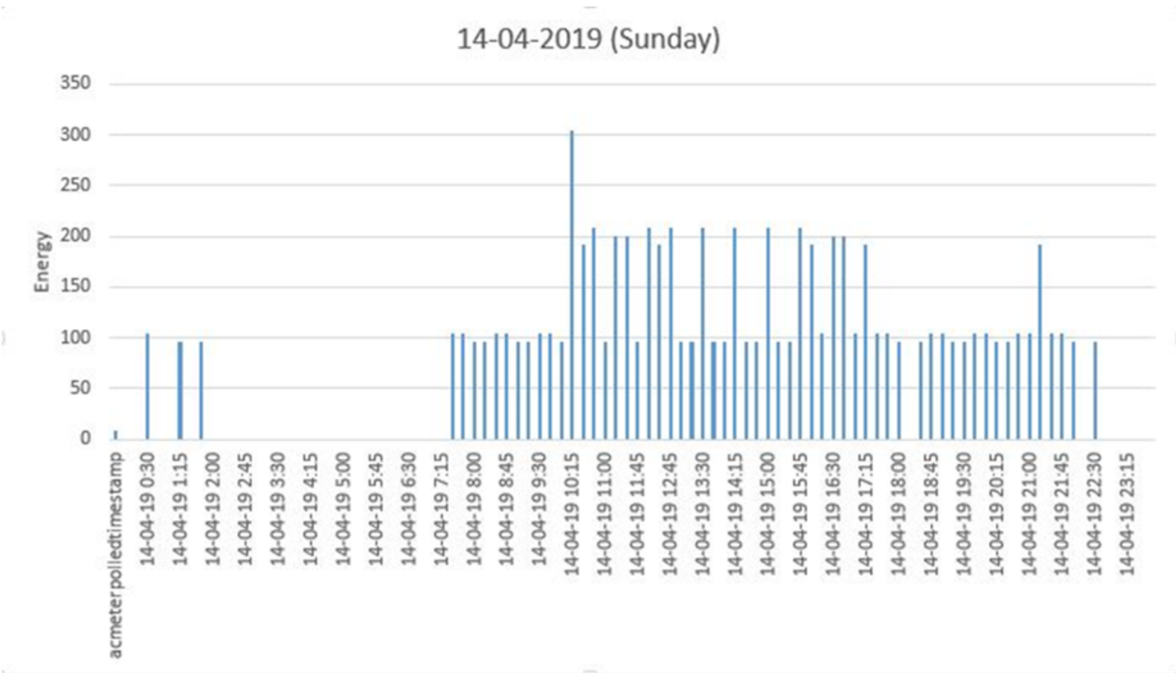

Figure 6.3: Energy Consumption Pattern of a weekends i.e. Sunday

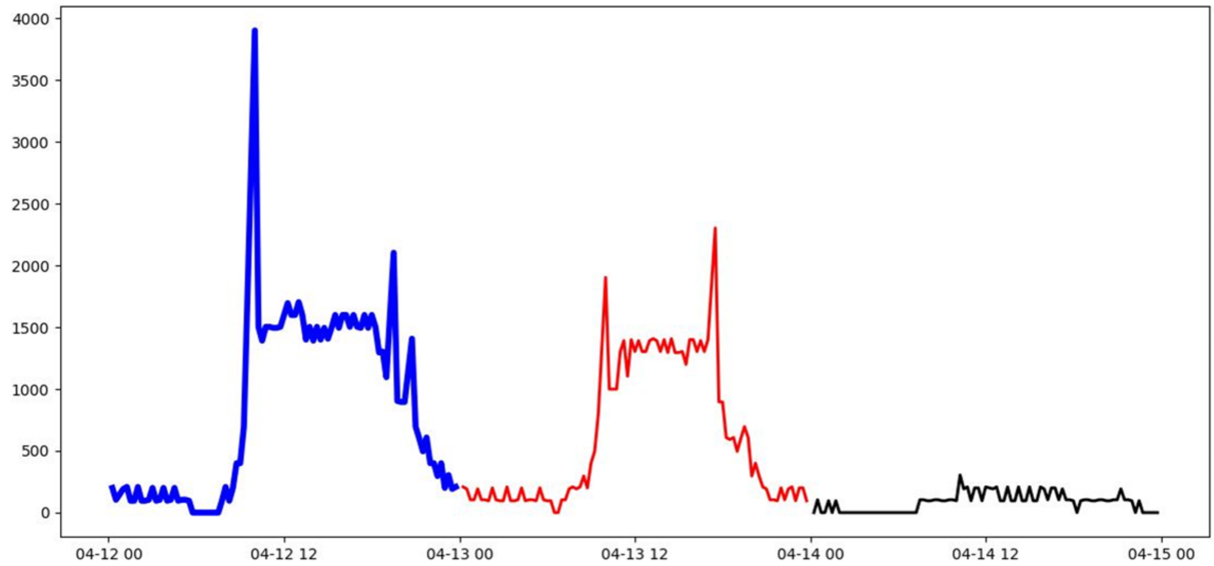

Figure 6.4: Comparison of energy consumption pattern for weekdays and weekends

Explanation: As one can see from Figure 6.1 there is almost no energy consumption between 12am to 7 am. As the day progresses the energy consumption starts to increase due to use of different appliances during office hours.

As one can see the peak consumption is from 1pm to 5 pm also, the pattern of Saturday's energy consumption is almost similar to that of Wednesday. But the point to note is that the overall consumption on Saturday is less than that of Wednesday. This is because the number of offices which work on Saturdays are less, but the usage pattern is similar.

On a holiday or a Sunday, the energy consumption is quite low even compared to that for a Wednesday or a Saturday. But as one can see from the figures, energy consumption is not negligible. This energy consumption occurred because some lights were ON and many servers and equipment were ON in the office. This may be due to security reasons or otherwise.

6.2.2 Energy Generated by DGs on hourly basis for year 2018

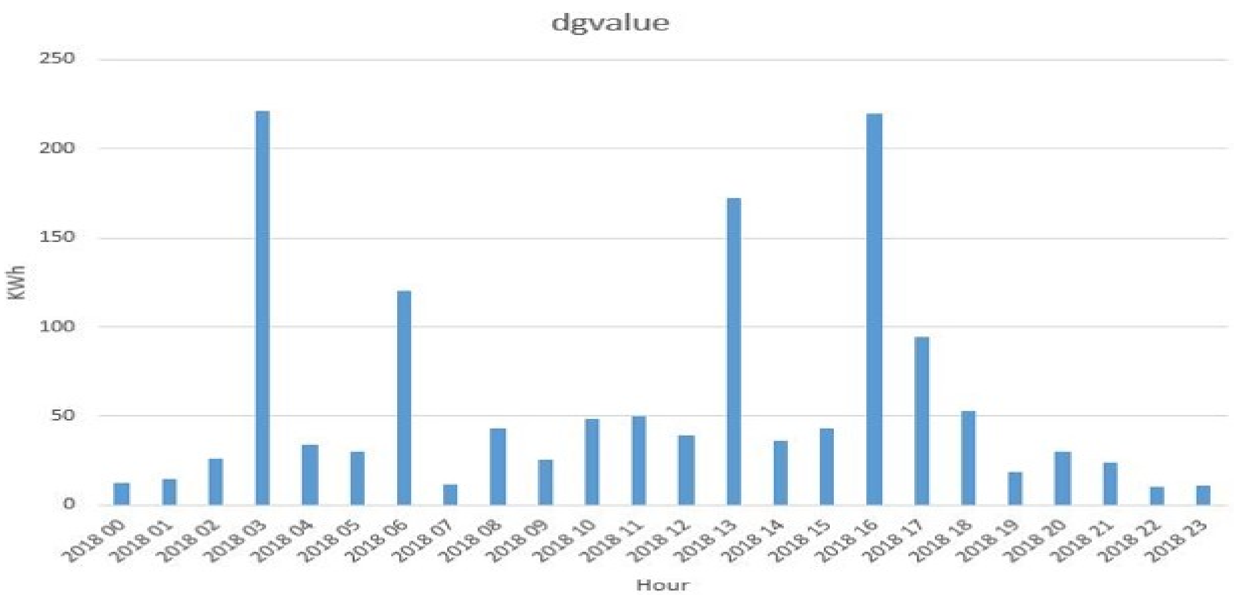

Figure 6.5: Energy generated by DG with respect to Hours

The above figure is obtained by taking complete 2018 year's data into consideration. While observing the above figure one can see that most power cuts occur at 3AM and 4PM.

6.2.3 Cost/Kwh of DG

Table 6.1: Cost/Kwh of DG

Month	Energy Generated(kWh)	Fuel Consumed	Cost of fuel	Cost/kWh
Sept-18	5983.55	1950	136500	22.81
Oct-18	0	0	0	0
Nov-18	8479.29	3290	230300	27.169
Dec-18	9284.8	2930	205100	22.08
Jan-19	21048.9	5597.8	391846	18.61
Feb-19	1468.88	410	28700	19.53
Mar-19	0	0	0	0
Apr-19	5234.75	1528	106960	20.43
May-19	8289.89	2540	177800	21.44
Jun-19	0	0	0	
Jul-19	3869.28	1570	109900	28.40
Aug-19	3411.	1115	78050	22.87
Sep-19	21246.82	5900	413000	19.43
Oct-19(till 16th)	20	8.72	610.4	30.52

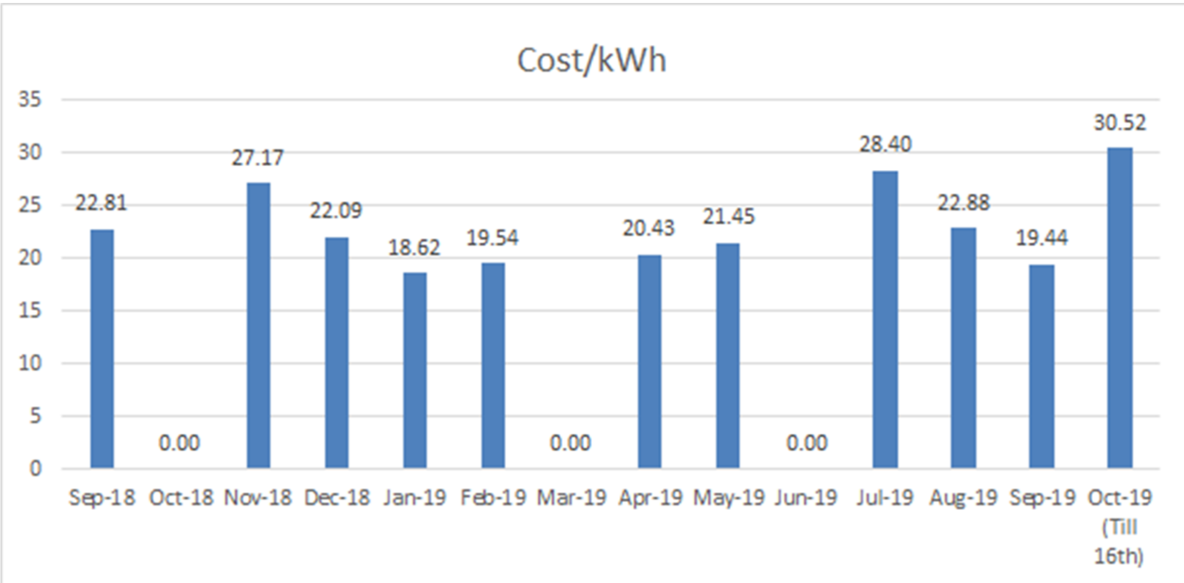

Figure 6.6: Cost/Kwh of DG

Explanation: The above graph present the actual operational cost/kWh of diesel generators for the period of sep-18 to oct-19.

Price of the fuel was taken as 70Rs/litre.

The cost was than computed as **Cost/kwh=Cost of the total fuel used/Total energy generated by the DG in a month**

The zero costs in some months is because DG was not needed in those months. One can observe that there is variation in costs. It appears that when DG sets run at full power, their efficiency is high. But when they do not run to their capacity, the efficiency is less. It appears that in January and February 2019 and in September, 2019, the DGs were running partially when power-cuts took place. Similarly, in some months, the cost per kWh is quite high (above 25 per kWh). This variation can be justified by the argument that maintenance of DG takes place in between a specific time period and after servicing the DG works more efficiently.

6.2.4 Top 10 Consumers with respect to 01-08-2018:

Table 6.2: Top 10 Consumers with respect to 01-08-2018

acmetersubsystemid	Energy Consumed	subsystemdetlneid	floorshortname	buldshortname	groupname
20	49744313450	4	Floor-3	IITMRPP1	IITMRP
29	388511208	4	Floor-3	IITMRPP1	IITMRP
674	353398484	196	Floor-2	A Block	IITMRP
520	174363900	178	Ground Floor	C Block	IITMRP
675	136186016	196	Floor-2	A Block	IITMRP
518	119856550	178	Ground Floor	C Block	IITMRP
26	100834692	4	Floor-3	IITMRPP1	IITMRP
855	77312800	259	Basement-1	D Block	IITMRP
514	71361940	178	Ground Floor	C Block	IITMRP
516	52805420	178	Ground Floor	C Block	IITMRP

Chapter 7

Results of implementing controls at IITMRP

A BMS calculates values based on the data items provided through network. In this chapter, Results of the proposed logic is given with respect to date 02/12/2019

7.1 Optimizing number of chillers to run

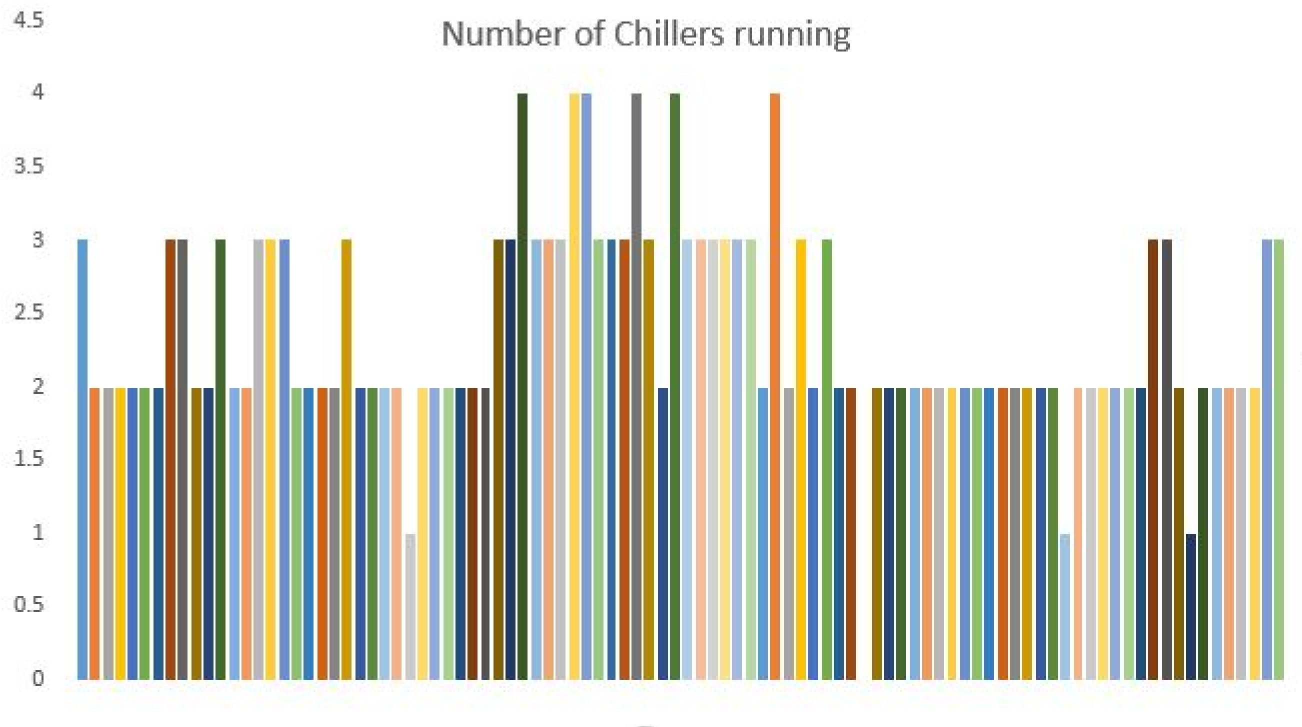

Figure 7.1: Number of Running Chillers

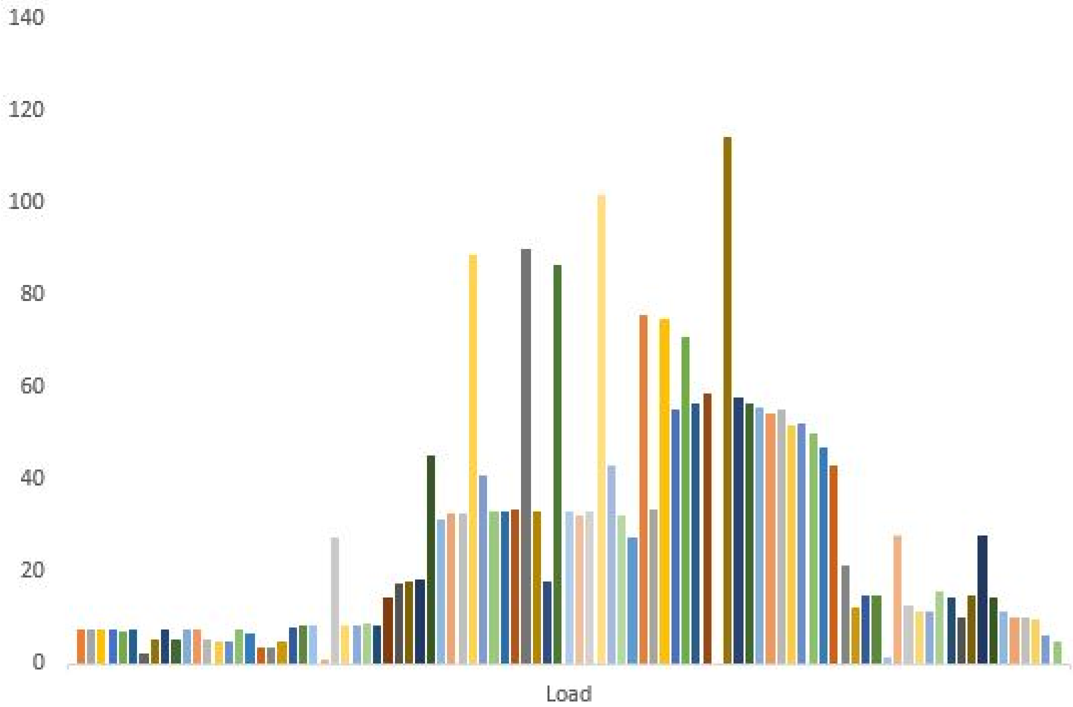

Figure 7.2: Load percentage

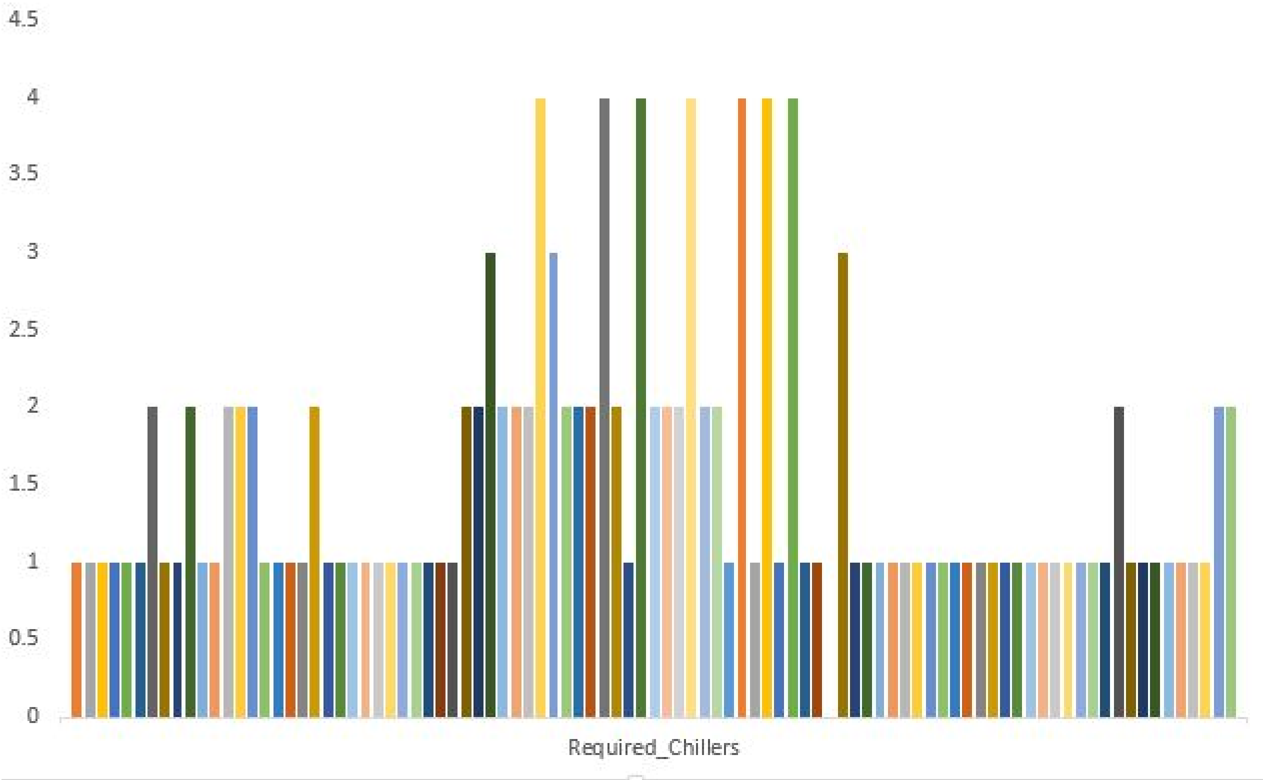

Figure 7.3: Number of required Chillers

Analysis: As we can see from the previous figures that whenever the load profile of an office is below 70% and the number of running chillers is greater than 1 than it decreased the running chiller number by 1.

According to the data obtained, the average number of chillers running is 2.36 whereas the average number of required chillers is 1.57. Which shows the reduction in the numbers of chillers by 33.47%.

As one can see from the above values that the average number of required chillers decreased. It will lead to the energy saving without any compromise in thermal comfort.

7.2 Optimizing number of Cooling Towers to run

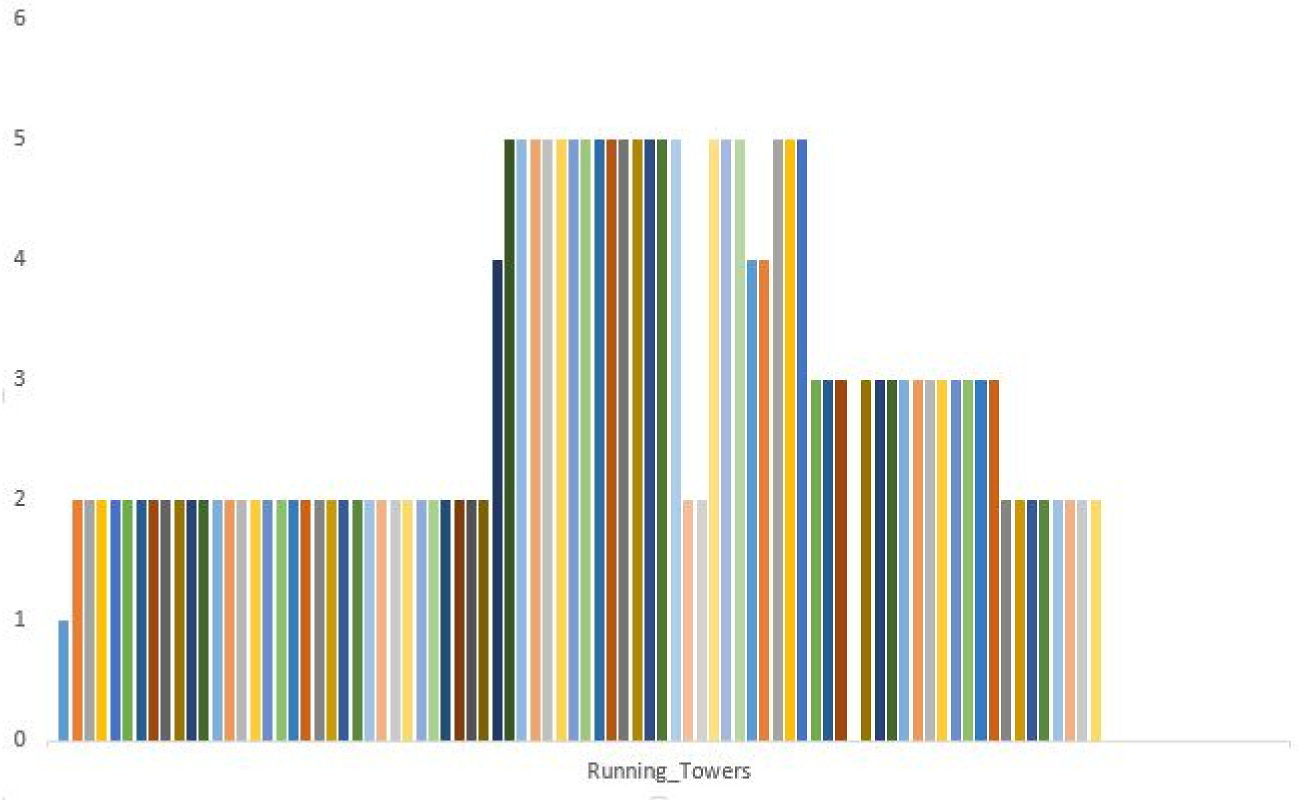

Figure 7.4: Number of Running Towers

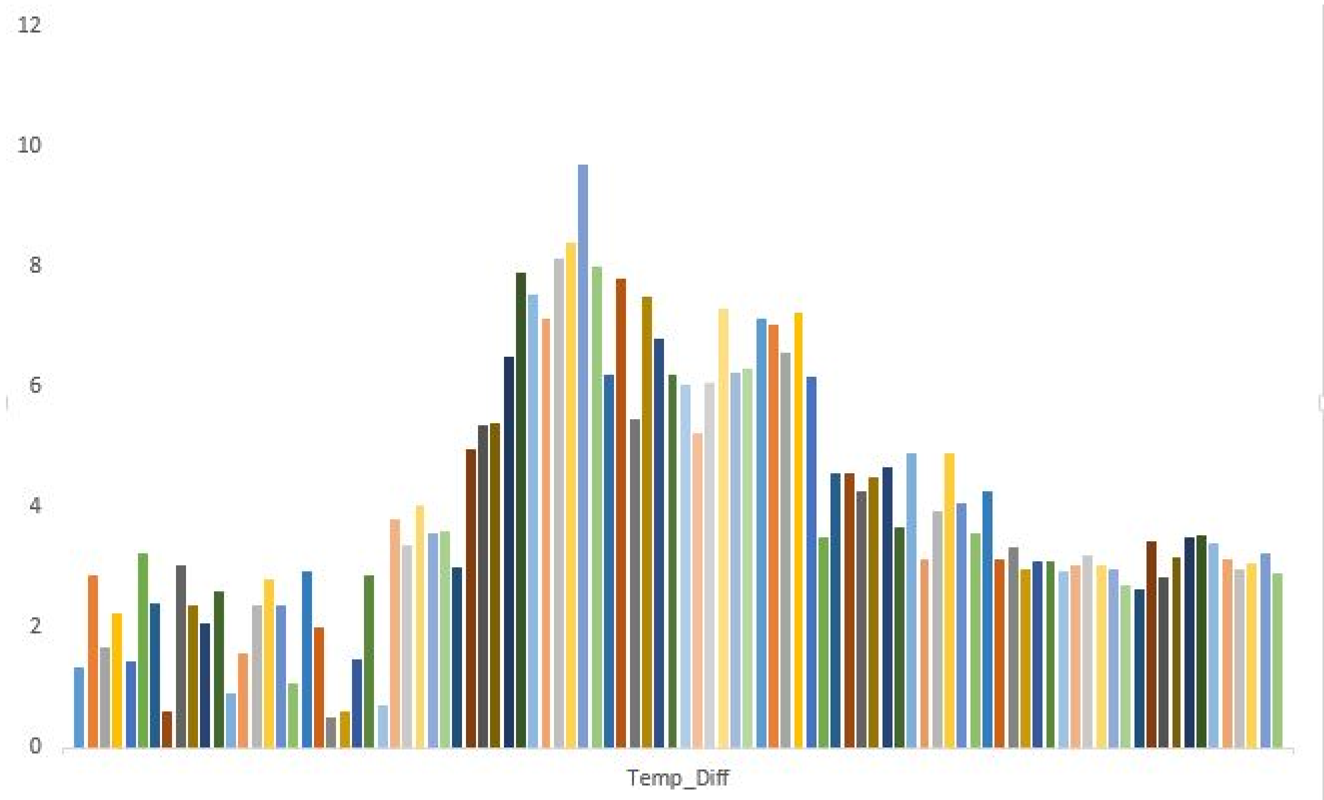

Figure 7.5: Temperature variation

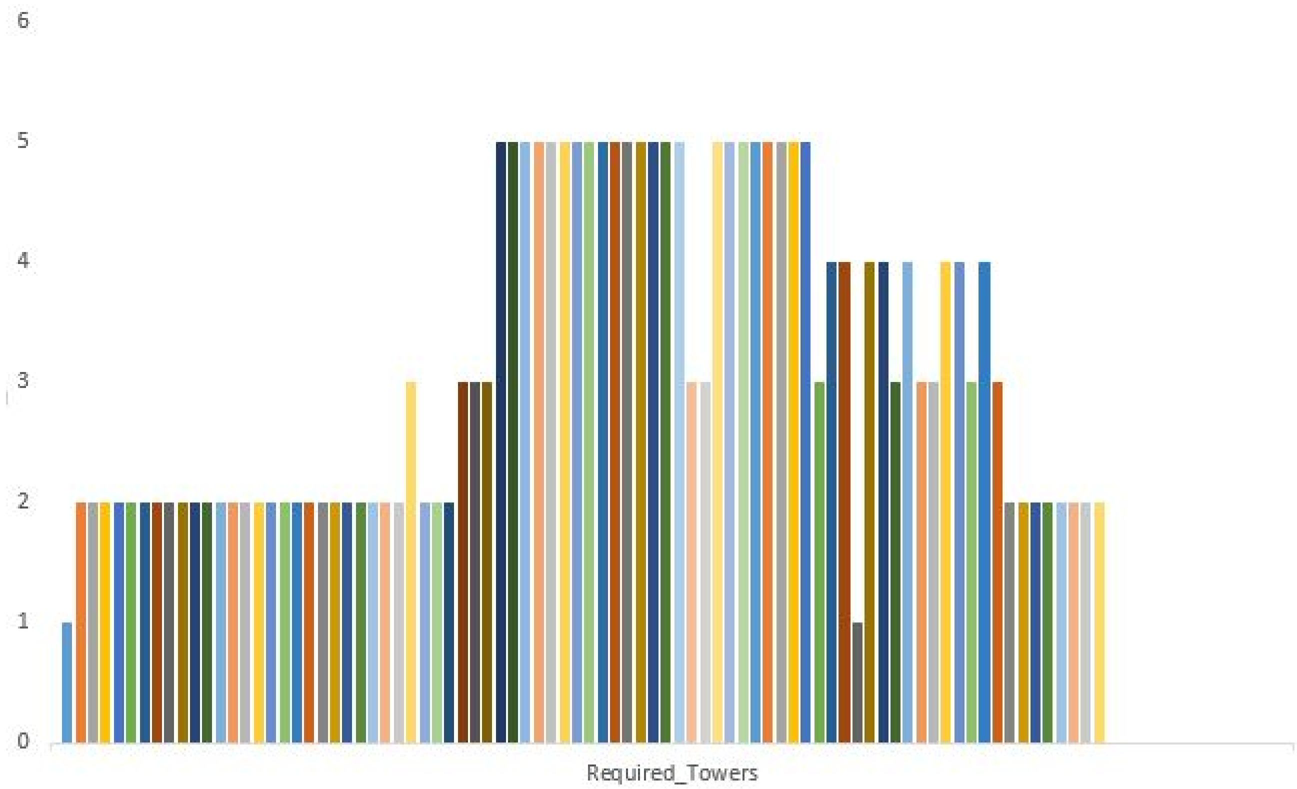

Figure 7.6: Number of Required Towers

Analysis: According to the proposed algorithm whenever the temperature difference between inlet and outlet exceeds 4 degree, increase the number of cooling towers by 1. Whereas when the temperature difference is less than or equal to 4 degree, the same number of cooling towers will operate to give better efficiency of the cooling tower.

According to data obtained, Average number of running towers is 2.52 whereas the average number of towers required is 2.71.

The above result can be verified by the "Temperature variation" graph. Which shows the temperature difference between inlet and outlet.

The increment in the number of cooling towers can be seen as the increment in energy consumption but it will lead to higher performance and maximum work output with minimum chiller capability and electricity consumption.

7.3 Optimizing speed of secondary pump

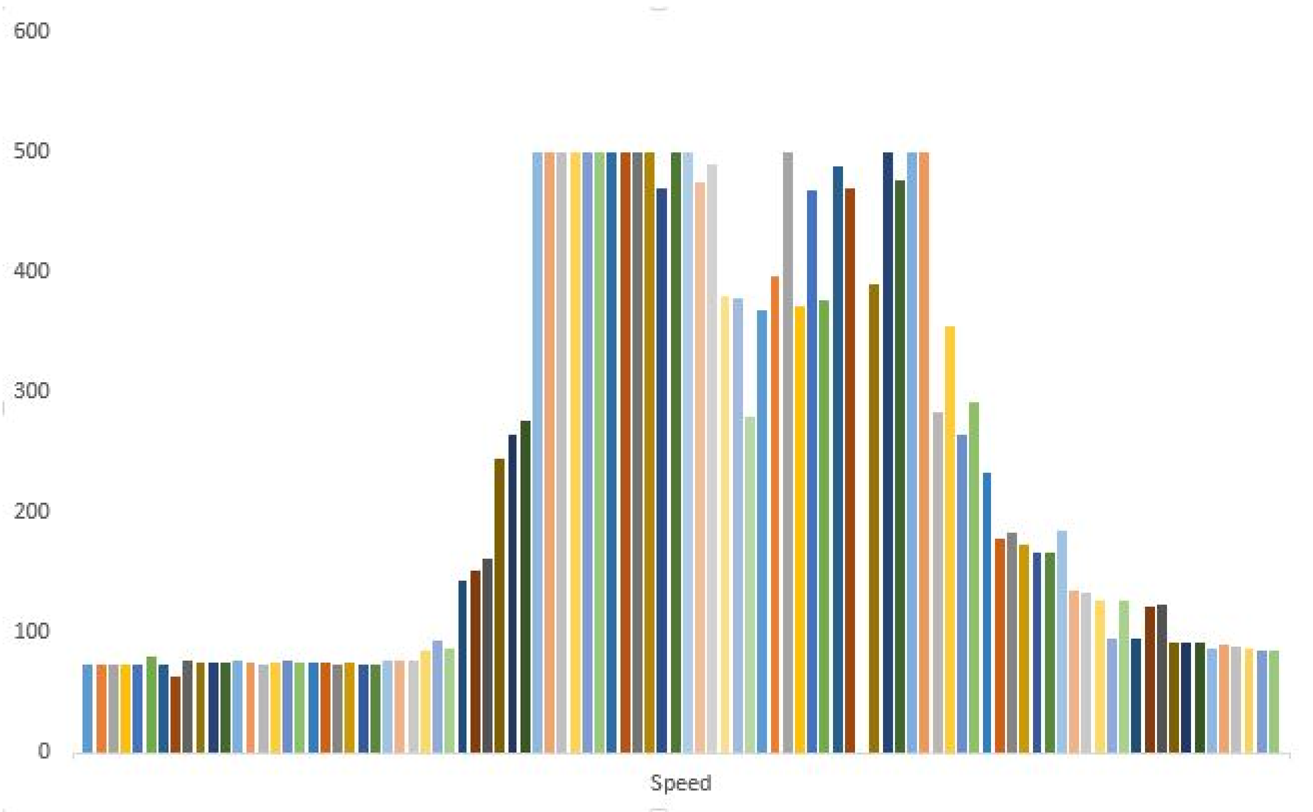

Figure 7.7: Current Speed of the Secondary pump

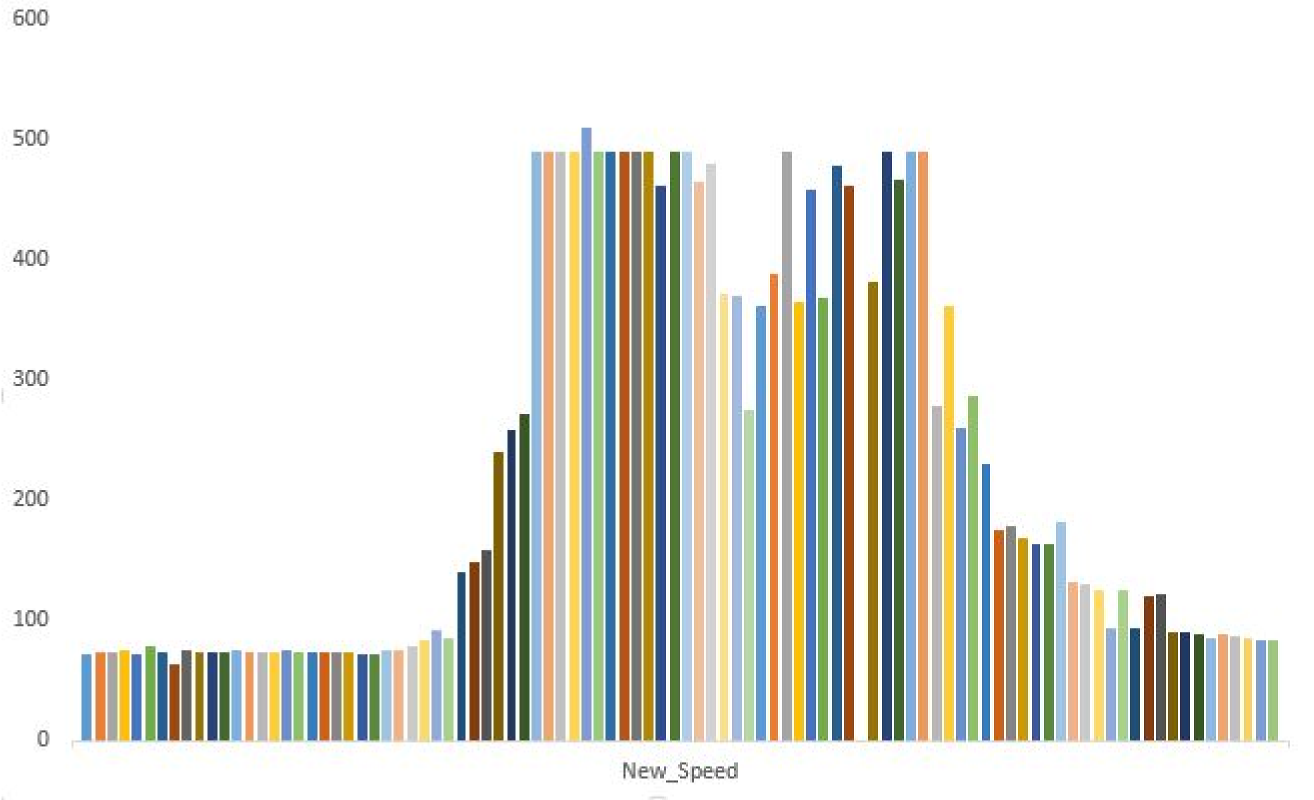

Figure 7.8: Optimized speed of Secondary pump.

Analysis: The secondary pump's variable-frequency drives (VFDs) modulate their speed (flow) to maintain a differential pressure set point in the system with a variable-flow primary-pumping system at the majority of loading conditions, no chilled water is returned back to the chiller, without being used by the load.

VFDs are usually employed to serve the purpose to provide good control over speed of pump which in turn changes the GPM's (gallon per minute) being supplied to the load end.

The HP required for a chiller pump to run varies with the cube of its motor speed, resulting in large energy and cost savings when the motor speed is allowed to modulate in response to demand.

Chapter 8

Summary, Conclusions and future directions

The work presented in this project is mainly to optimize the number of chillers, Cooling Towers and the speed of Secondary Pumps to reduce the energy consumption by the chillers without compromising the thermal comfort of the customer.

8.1 Summary of the results

From the previous figures, the number of chillers and cooling towers can be optimized with the help of data provided by the BMS network and a new set of numbers can be achieved by using proposed logics/algorithms.

According to the proposed algorithm, if the load on the chillers is greater than 70%, then the logic suggests that one must increase the number of chillers by one. As result of this modification there will be division of load between the chillers and chiller will work more efficiently.

Similarly, for the Cooling Towers, if the Temperature difference is greater than 4 then one should increase the number of towers by one. Resulting in reduction of energy consumption by the cooling towers.

With the use of VFDs, Speed of the motors are allowed to be modulated in response to the demand. This too results in a significant energy saving.

8.2 Conclusion and Scope for future study

The work started with the motivation to decrease the noise produced by the chillers, and at the same time reduce the energy consumption by increasing the efficiency of operations.

With the help of obtained results, it can be said that on implementing the proposed algorithms a significant amount of energy consumption can be reduced. The proposed algorithm, which continuously updates the number of units that needs to operate at any given time, based on the defined logic, results in saving of a significant amount of energy. However, the productivity of this algorithm can be checked only when we get the information on energy consumption and other relevant data with respect to the updated algorithm.

Due to COVID-19, the system setup was not completed on time. So, the results produced here are based on the past data. Once the IITMRP implements the new system with respect to HVAC completely, the efficiency of the proposed algorithm can be validated.

References

[1] https://www.modbustools.com/modbus.html

[2] https://en.wikipedia.org/wiki/Modbus

[3] http://www.bacnet.org/

[4] https://dms.hvacpartners.com/docs/1000/Public/04/11-808-417-01.pdf

[5] https://bms-system.com/understand-the-basics-of-hvac-system/

[6] https://www.dpstele.com/blog/top-three-pros-and-cons-of-modbus-protocol.php

[7] https://www.achrnews.com/articles/123996-variable-speed-pumps-reduce-energy-use