IJEW 国际工程期刊 International Journal of Engineering Works انجینئرنگ کاموں کا بین الاقوامی جرنل

International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 7, Issue 01, PP. 68-73, January 2020
https://www.ijew.io/
https://doi.org/10.34259/ijew.20.7016873

# Implementation of Chiller Plant Management System to Optimize the Building Primary HVAC System Energy Consumption

Muhammad Waseem Khan[1], Umar Ibrahim [2]
[1,2] Department of Mechanical Engineering, University of Engineering and Technology, Peshawar, Pakistan
waseem.pwmec@gmail.com[1], umar.marwat@gmail.com[2]
Received: 22 January, Revised: 29 January, Accepted: 30 January

***Abstract***— The heating, ventilation and Air conditioning (HVAC) system in Pakistan consumes more than 50% of total energy utilized by the building sector. Due to current energy crises in Pakistan there is a need renewed focus on energy optimization in building sector. The aim of this research paper is to reduce building HVAC system energy consumption by implementing chiller plant management system to control on electrical energy consumption in existing primary HVAC system (Chillers, Pumps, Boilers and Cooling towers). The Johnsons control international building automation protocol has been implemented with weather load profile of Pakistan (Islamabad). The chiller plant management system has improved plant performance and decreased annual energy consumption. The results of implemented modern chiller plant management system shows at least 12.57% of energy saving. It is also observed that the chiller plant management system closely follow outdoor dynamic weather profile and indoor load profile.

***Keywords***— HVAC, BMS, CPM, Building Automation, PID

## I. Introduction

The chiller plant management system (CPM) is the automatic control, operation and monitoring of chillers, pumps, cooling tower and air handling unit etc. It not only automate the primary HVAC system but also enhance indoor human comport level and increase system efficiency, reduced maintenance and operational cost. The chiller plant management eliminates unnecessary operation of system it only operates those HVAC system equipments which are needed as per internal/external dynamic heating/cooling load. Therefore, reducing unnecessary operation increase building HVAC system energy efficiency and better control over all the system [1]. According to (ASHRAE) studies the chiller plant management system or building management system (BMS) reduces energy consumption up to 20% compare to building without building HVAC automation system [2]. Therefore, the implementation of building management system not only automate various building services but also increase sustainability, efficient operation of building systems, improved human comfort level in conditioned space, reduced energy consumption and operational costs and improved equipment expected life [3]. In past decades, various control strategies has been developed to ensure this [4]. In current research work, our focus is to optimize the energy consumption of a chiller plant for a portion of a centralized HVAC system taken (Chiller plant consist of chillers, boilers, Pumps and cooling tower) by implementing chiller plant management system considering the weather profile of Islamabad.

## II. The HVAC System Model Description

The capacity of plant is 6000TR located in Islamabad region serve main passenger terminal building. The package chiller and boiler Plant include the following major equipments.

TABLE I. DESCRIPTION OF PRIMARY HVAC SYSTEM

| H | Equipment | Qauntity | Capacity |
|---|---|---|---|
| 1 | Chiller's | 6 | 1200 TR (740 KW) |
| 2 | Cooling Tower | 6 | 1560 RT, P = (5.5x8) KW Each |
| 3 | Space hot water boiler | 3 | 1410KW |
| 4 | Secoundry chilled water pump | 7 | 185KW,367Amp,Flow242L/s,Head 62m |
| 5 | Primery chilled water pump | 6 | 45KW,83.5Amp,Flow 218 L/s |
| 6 | Condenser water pump | 6 | 90KW,168Amp,Flow 262 L/s,Head 26m |
| 7 | Primary hot water pump | 3 | 15KW,51.1Amp,Flow 68L/s |
| 8 | Non chemical water treatment system motor | 6 | 4KW,15.1 Amp |
| 9 | Boiler recirculation pump | 6 | Flow 22 L/s, H = 17 m, P = 7.0 KW Each |
| 10 | Booster pump | 2 | 21 Kw,30Amp,Flow 26.2 L/s |
| 11 | Cooling tower expansion Tank | 2 | 7 m3 |
| 12 | Chilled water expansion tank | 9 | 16.7 m3(sys-1) ,8.9m3(sys-2) |
| 13 | Cooling tower Expansion tank Pumps | 2 | Q = 426.2 L/s, H = 26 m, P = 2.5 KW Each |

The return chilled water from the air handling units at main terminal building is pumped by constant speed primary chilled water pumps to centrifugal chillers and cooled to the designed chilled water temperature. Heat is rejected by the condenser water which is pumped by the condenser water pumps through the cooling towers. The supply chilled water is pumped to the passenger terminal building by variable speed secondary chilled water pumps via two secondary loop distribution-piping networks that is connected to constant speed primary chilled water loop across the de-coupler. Each chiller is equipped with a microprocessor control panel. The CPM is communicate with the chiller panels through a hardwire connection using software interface (Johnson Control). Other equipment such as pumps, cooling towers etc is the hardwire connected with the CPM for monitoring and control.

## III. Control Philosophy

The chiller plant is controlled as per the total cooling load requirement as evidenced by the change in return chilled water temperature. The total cooling load requirement is calculated based on the feedback from the supply chilled water header flow transmitter and the temperature differential between the supply and return primary chilled water heaters. Chillers is added or subtracted based on the feedback received from the bypass de-coupler flow transmitter and its flow direction & secondary temperature below the set-point. Chillers are being added based on the supply chilled water temperature feedback received from the secondary chilled water header once the set-point exceeds. The individual chillers are loaded / unloaded by the local chiller microprocessor panel based on the chiller leaving chilled water temperature set point. Similarly, whenever a chiller is started, cooling tower (CT) fan variable frequency drives (VFD) is enable and getting started. The temperature of cooling tower supply water to condenser is controlled at minimum limit of 33°C for stable operation of the chiller. This is accomplished by measuring the temperature of the cooling tower water returning to condenser and using this as input to a feedback-control algorithm The VFD also ramp up/down the fan speed of CT cells as per feedback command receive from condenser water supply temperature sensor. The CPM minimizes the potential for multiple boilers operating at reduced loads, thereby reducing boiler efficiency. It will also improve plant reliability, increase equipment life expectancy and reduce maintenance costs.

## IV. Chiller Plant management system Model

The chiller plant management (CPM) is designed and implemented to minimize the combined electrical energy consumption of the operating chiller(s), chilled and condenser water pump(s), and cooling tower fan(s) as constrained by meeting the building chilled water load and temperature requirements. The CPM also minimize the potential for multiple chillers operating at reduced loads, thereby reducing any peak demand charges caused by unnecessary cycling. It also improves plant reliability, increase equipment life expectancy and reduce maintenance costs. The schematic diagram of implemented building management system sensors and control wiring between the chiller plant components is shown in figure 3. In the Chiller Plant Management System all the equipment interface is through ethernet TCP/IP to the others chiller plant control system server located at the Chiller Plant room. The interface method is BACnet protocols. The Field Equipment Controller (FEC) is a programmable digital controller that communicates via BACnet Master-Slave/Token Passing (MS/TP) protocol is connecting to each individual HVAC system equipment as shown in figure 1 [5].The digital and analog input signals like humidity, temperature ,equipment start/stop status is transfer to the chiller plant management system (CPM) through BACnet communications protocol .Digital/ Analog outputs from respective controller to connected equipment such as motorized valves, pumps, cooling towers and fans command their settings accordingly or to switch devices on and off. The field equipment controller is combined with the Input/ Output Module (IOM) shown in figure 2 which is BACnet Advanced Application Controllers (B-AACs) with integral RS-485 MS/TP communications. Typically, input output module (IOM) are install in two position (1) when installed on actuator or sensors bus of a field equipment controller (FEC) the IOMs expand the point count of these controllers (2) when installed on the Field Controller (FC) bus as point multiplexors, IOMs allow a Network Automation Engine (NAE) or Network Control Engine (NCE) to monitor and control supervisory points directly. The field equipment controller arrangement in series are shown in figure 5 and serial port connection in figure 5.


Figure 1. Field Equipment Controller (FEC)


Figure 2. Input/ Output Module (IOM)

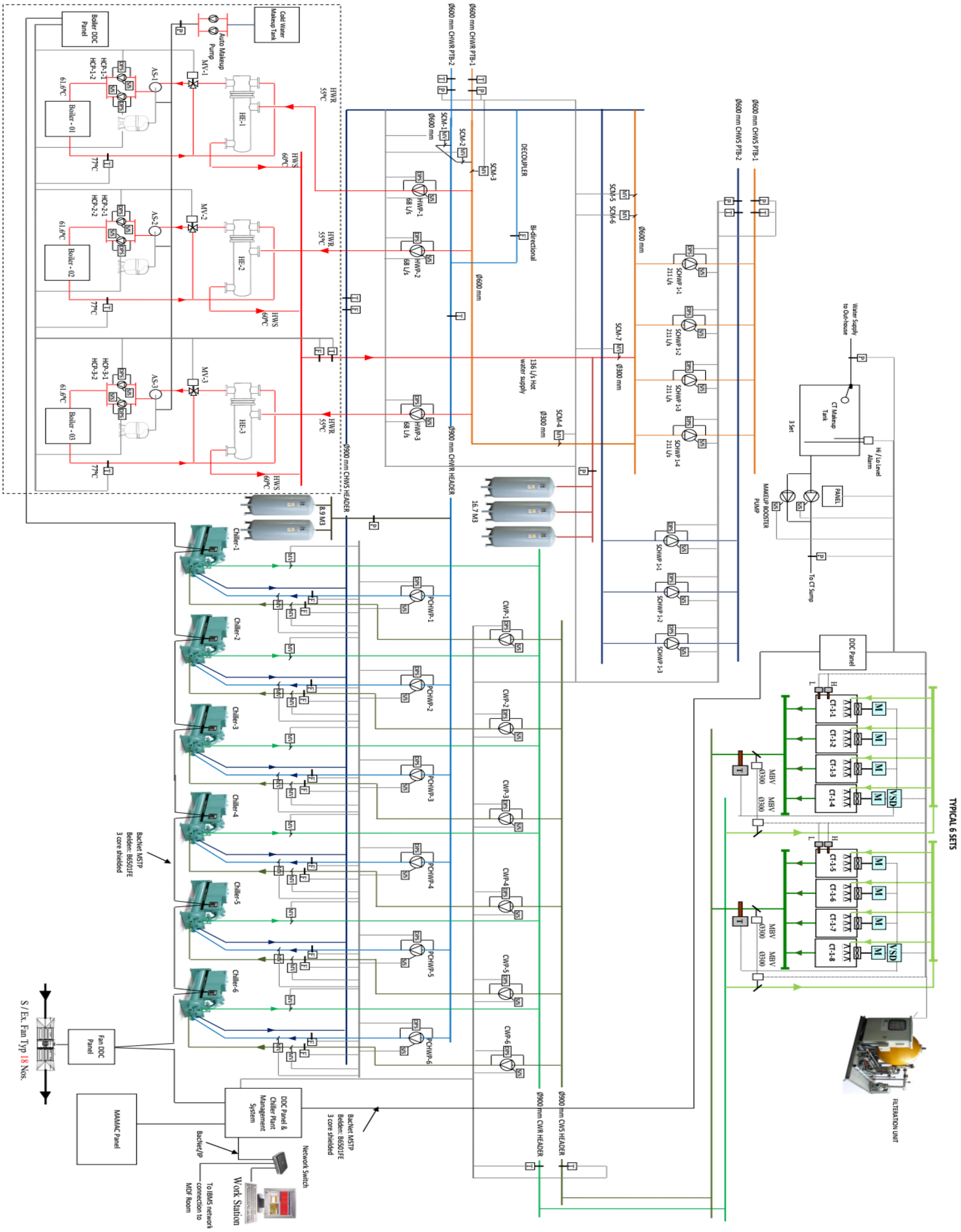

Figure 3. Schematic Diagram of Implemented chiller plant management system (CPM)

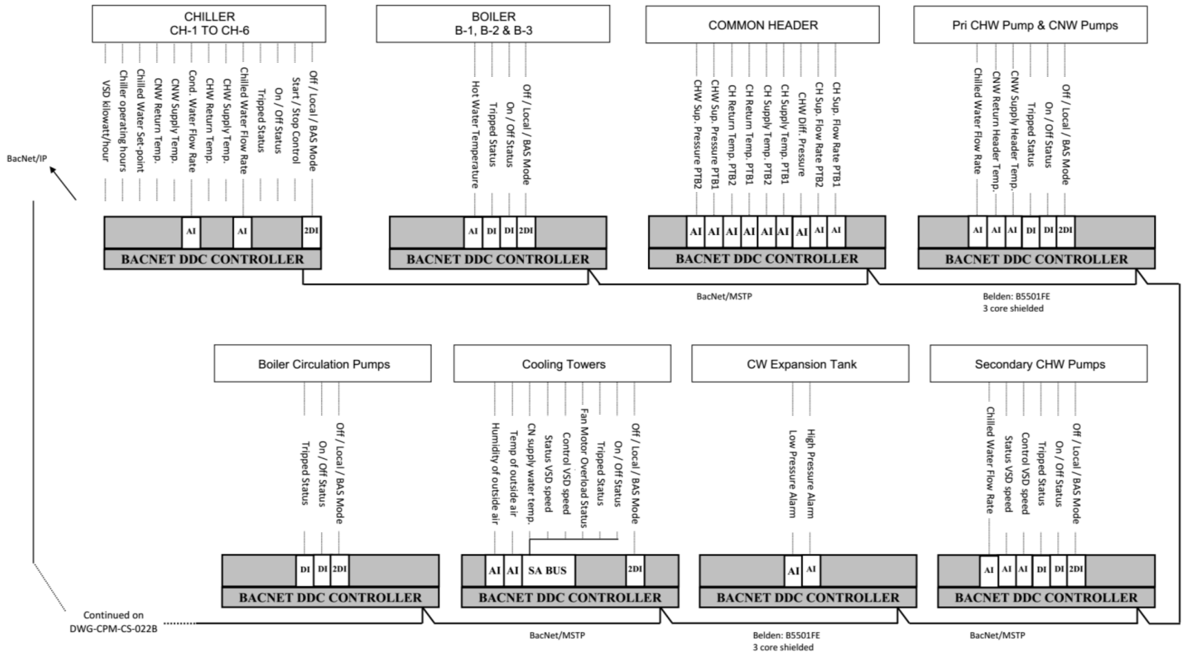


Figure 4. Control Logic of Chiller plant management system (CPM)

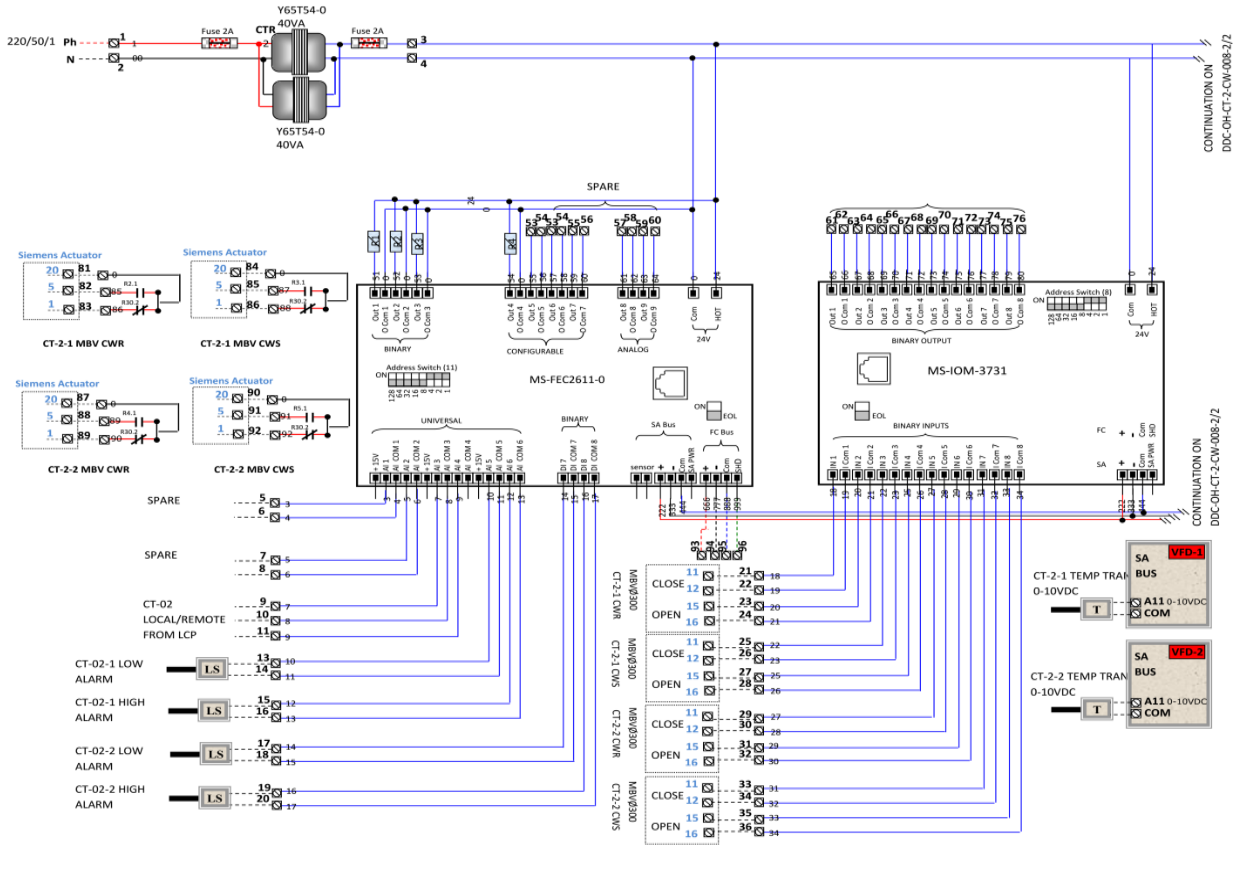


Figure 5. Field Equipment Controller connection detail


Figure 6. Real time data logging of implemented CPM system

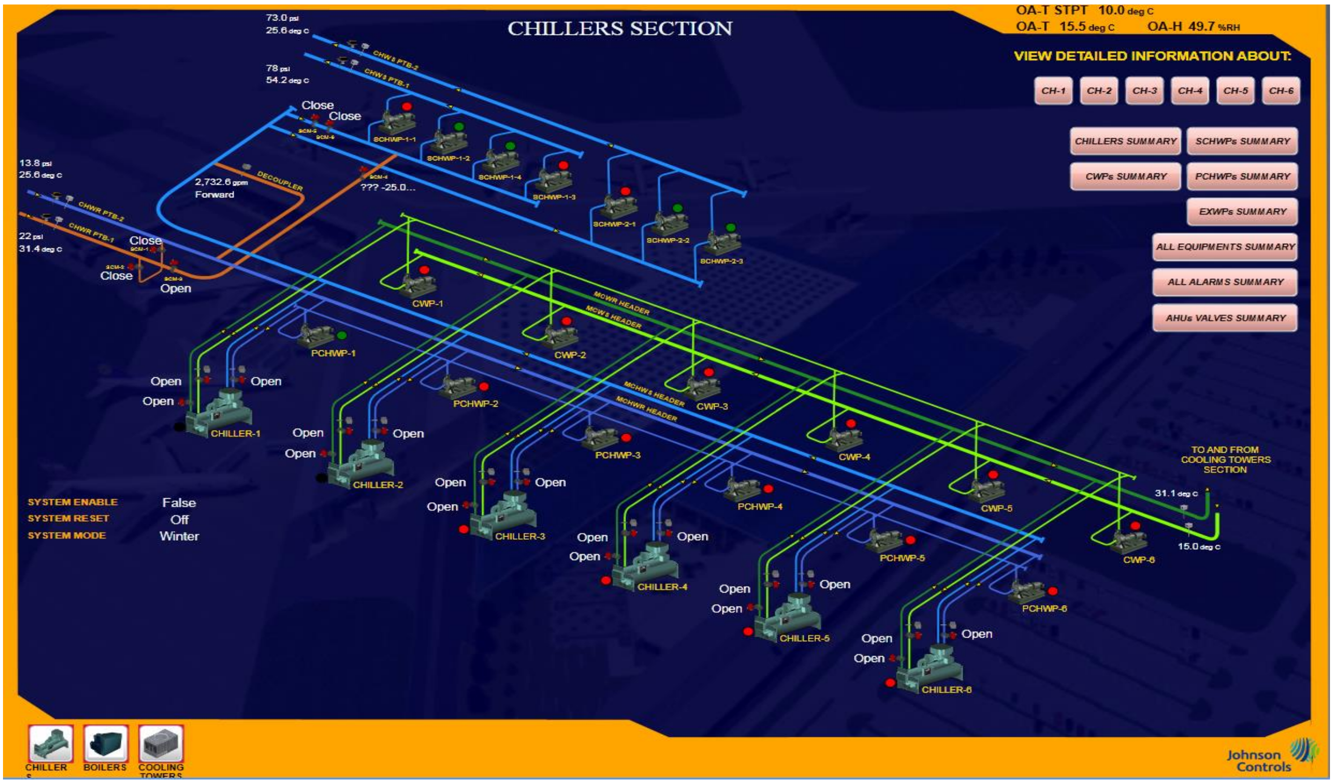


Figure 7. Graphic interface of CPM in METASYS Softwar

## V. RESULTS AND DISCUSSION

Summary of real time data for the energy consumption by existing chiller plant from Dec 9, 2018 to Dec 14, 2018 without chiller plant management system and from Dec 9, 2019 to Dec 14, 2019 are presented in figure 8. Real time data present the operation of chiller plant in winter season where heating load at the highest while minimum cooling load available due to computer server rooms baggage handling system and ELV riser. It can be observed that the chiller plant energy consumption in case of without CPM control is the highest for the reference time. By comparing CPM control of HVAC system present the energy reduction up to 101845.5 KWh (12.57%) then without CPM control of chiller plant. Similarly, the energy consumption of the pump(s) also reduces, from 141112.8 KWh to 89856.8 KWh (36.32%). In the graph it can be observed that energy saving in pumps is the greatest and it is due to VFD drive secondary chilled water pumps pumping chilled water to Air handling Units. The monitoring facilities of a CPM system also monitor environmental conditions, plant operational status, and energy consumption. The current CPM system assist operator to log real time data of the building chiller plant operation process and to generate customized reports of alarms, trends, messages, and to log key cooling/heating plant performance indices as shown in figure 6 and 7.

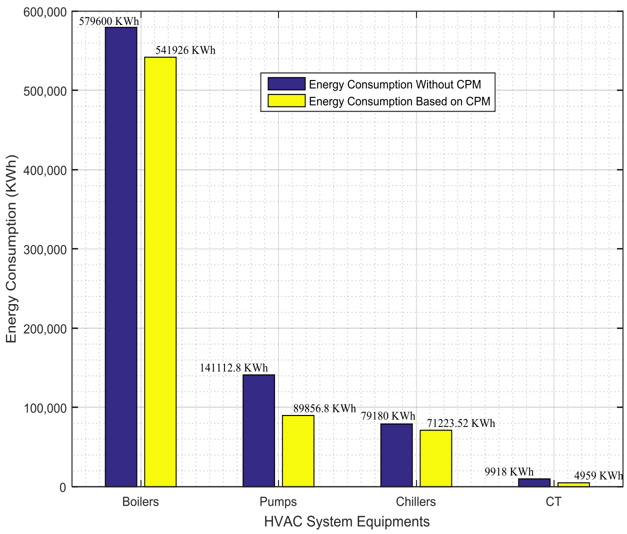


Figure 8. Energy consumption with and without CPM system

## CONCLUSION

This paper has presented practical implementation of chiller plant management system (CPM) for automation of chiller plant. Due to the implementation of CPM system Significant improvement were achieved as the total energy saving by the Chiller plant for the reference days with CPM control is 101845.5 KWh (12.57%).The CPM system gives real time data that are beneficial for buildings owner facilitation management department providing information such as preventive maintenance requirement, the energy usage, and the generated alarm. The real time data is also crucial for accurate calculation of budget and allow the building’s owner and managers to take decision of right time.

## REFERENCES

[1] Foresti, G.L., Remagnino, O., 2005. Ambient intelligence: a new multidisciplinary paradigm. IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans, pp. 1–6.

[2] ASHRAE, 2015. ASHRAE Guideline 13-2015, Specifying Building Automation Systems. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)., Atlanta-USA.

[3] SAYED, K., GABBAR, H.A., 2018. Energy Conservation in Residential, Commercial, and Industrial Facilities, First Edition. ed. The Institute of Electrical and Electronics Engineers, Inc. Published 2018 by John Wiley & Sons, Inc, Canada.

[4] Kwon, B., Lee, S., 2014. Joint energy management system of electric supply and demand in houses and buildings. IEEE Transactions on Power Systems, pp. 2804–2812.

[5] Johnson Controls, 2010. Field Equipment Controller (FEC) Series. USA.