IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 21, Issue 2 Ser. 2 (Mar. – Apr. 2024), PP 01-05
www.iosrjournals.org

Central Ac Plant System Retrofit Survey And Analysis Of A Military Hospital In Pune

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Abstract
The HVAC system is one of the largest consumers of energy in a building. In many military buildings, viz. administrative headquarters, auditoriums and especially in Military Hospitals, Central AC system are functional which are largely based on rule of thumb parameters, conservative estimates or calculations and considerable range for factor of safety. Moreover, over the period of time, a large inventory of Chiller stock with relative vintage has been created as an operational asset. This increases not only the cost of the system but also energy consumption. In hospitals, HVAC systems are crucial since cooling parameters (temperature and relative humidity setpoints) and ventilation (fresh air change rates) necessity are more specific as compared to other buildings.
The paper presents a survey analysis of a 650-bed multi-specialty military hospital building in warm-humid climate (Pune), focusing on the HVAC system performance estimated through measured energy audit data and impact of few measures identified during the monitoring for onwards potential Retrofitting of the system to accrue better energy efficiency and cost savings.
Keywords—*military hospital, energy efficiency, HVAC system, Retrofitting (keywords)*

Date of Submission: 16-04-2024 Date of Acceptance: 26-04-2024

I. INTRODUCTION

In India, with rapid urbanization and economic development, the nationwide Cooling Demand, in Tonnage of Refrigeration (TR), is projected to grow 8 times by 2037-38 as compared to 2017-18 baseline. (ICAP report March 2019: Min of Environment, Forest & Climate Change, Govt of India). Concurrently, global warming and environmental impacts that the modern society are having on planet has resulted in a range of complex and inter connected challenges. In India, air conditioning which was earlier perceived as a luxury, has now become a necessity due to changing climatic conditions. India's growing trillion-dollar economy, low air-conditioning penetration, rising per capita income, rapid urbanization and tropical climate is resulting in sizeable cooling requirement. The country is forecasted to be affected by heat stress due to global warming. Building sector will have eleven times increase in Cooling Demand by next decade. Total energy use of 1560 Twh/yr is projected in India's cooling demand. Space cooling will be have 65% share of these estimate projection and 21% of Space cooling demand will be from commercial building.

Heating ventilation and air-conditioning (HVAC) system consumes the maximum energy in most of the buildings. For hospitals in particular, it becomes more essential because of specific setpoints, Indoor Air Quality (IAQ) and round the clock operation as compared to the other buildings. The variation in HVAC energy consumption in hospital buildings varies between 30-65% (ECO-III, 2009).

This paper presents a perspective study of a government hospital, a multi-specialty 650 bedded Military Hospital located in Pune, and details out:

- EPI index of the hospital vis-à-vis mandated BEE standards for a government hospital.
- Results of performance monitoring of Chillers of the HVAC system
- Feasible retrofits that can be done to improve the EPI indices and enhance Energy efficiency of the building

II. TECHNICAL PAPER

Building Description. The Military Hospital under study is a Multi-speciality Hospital located at Khadki Garrison in Pune. The hospital is a primary and tertiary care centre for troops, dependents and veterans stationed in Pune. It is one of the biggest orthopaedic centre, Joint Replacement centre and specialized centre for spinal cord injury cases.

Key details of the building.

- The hospital plinth area is 34,461.40 sqm.(excluding the non AC ventilated area)
- The hospital is a ‘G+3’ storey building which is fed by the (200TR X 3) Water Cooled Screw Chiller Centralized AC Chiller Plant, which has been taken as a test case for the Energy Efficient Retrofitting measures in the overall scope.
- The building houses all critical wards and laboratories as tabulated below, and therefore the overall performance of the centralized HVAC system is crucial for the day-to-day functioning of the hospital.

SNo	Storey	Wards/Laboratories
1.	Ground Floor	MI Room, X-ray ward, Physiotherapy Ward, Ortho OPD
2.	‘G+1’ Floor	Medical OPD, Diagnostic Lab, ECHS Section
3.	‘G+2’ Floor	Gyan logy OPD, Family Ward, Offr Family Ward
4.	‘G+3’ Floor	Operation Theatre (1 to 5), ICU, Surgical Ward, Otho Ward

Overall *energy performance*

The electricity consumption data for 12 months (Apr 22 to Mar 23), collected during the monitoring is shown in Figure 2.1.

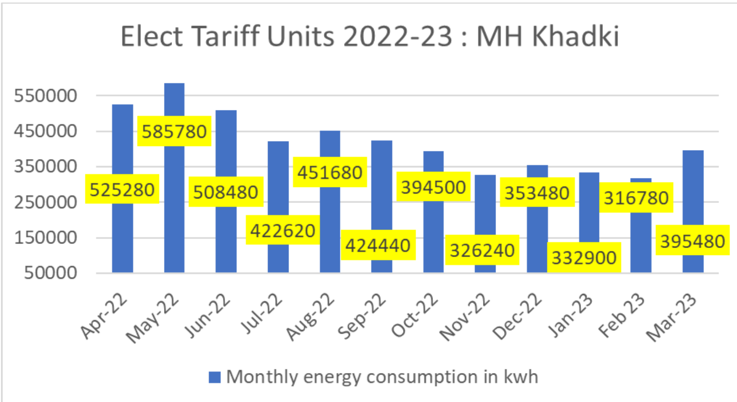


Fig 2.1: Monthly energy consumption pattern of MH, Khadki in Kwh(units)

The Military Hospital has an annual energy consumption of 50,37,620 units(kwh). Multi-specialty hospitals in hot & dry and temperate zones were observed to have higher Energy Performance Index (EPI) than ones in cold and composite zones. The ones in warm & humid zones had the lowest EPIs amongst multi-specialty hospitals.

The Key findings of National Benchmarking Study done by USAID (United States Agency for International Development) & BEE (Bureau of Energy Efficiency) India stipulates for government hospitals to have a benchmarking Indices of an EPI Index of 88kWh/ m2/year.

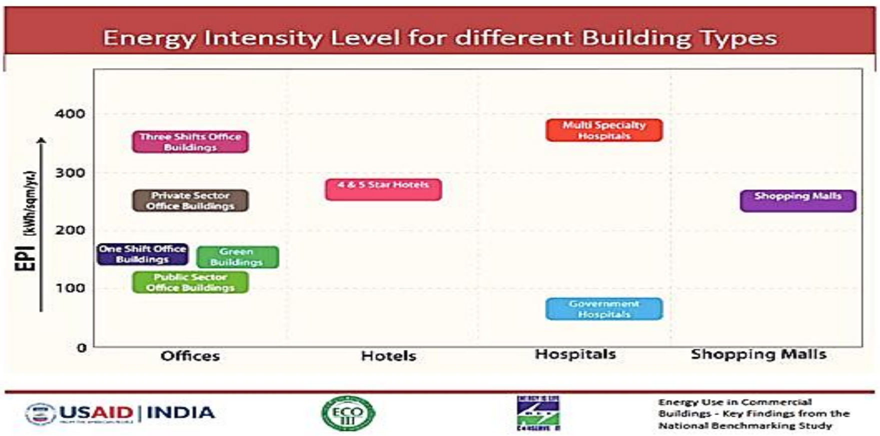


Fig 2.2: Benchmark EPI Indices as per BEE & USAID for different End Users

The EPI Index of MH Khadki is calculated as below from the monitored annual energy consumption data:

(a) EPI = (Total Energy Consumption per annum) / (Built up area in square meters)

(b) Now, Total Energy Consumption per annum:

= 50,37,620 kWh (annual Electricity consumption Units, summation of datachart of Fig 1)

\+

2,51,881 kWh (annual Energy consumption due to Gensets Power supply on account of Loadshedding taken as 5% datum of annual electricity tariff)

= 52,89,501 kWh

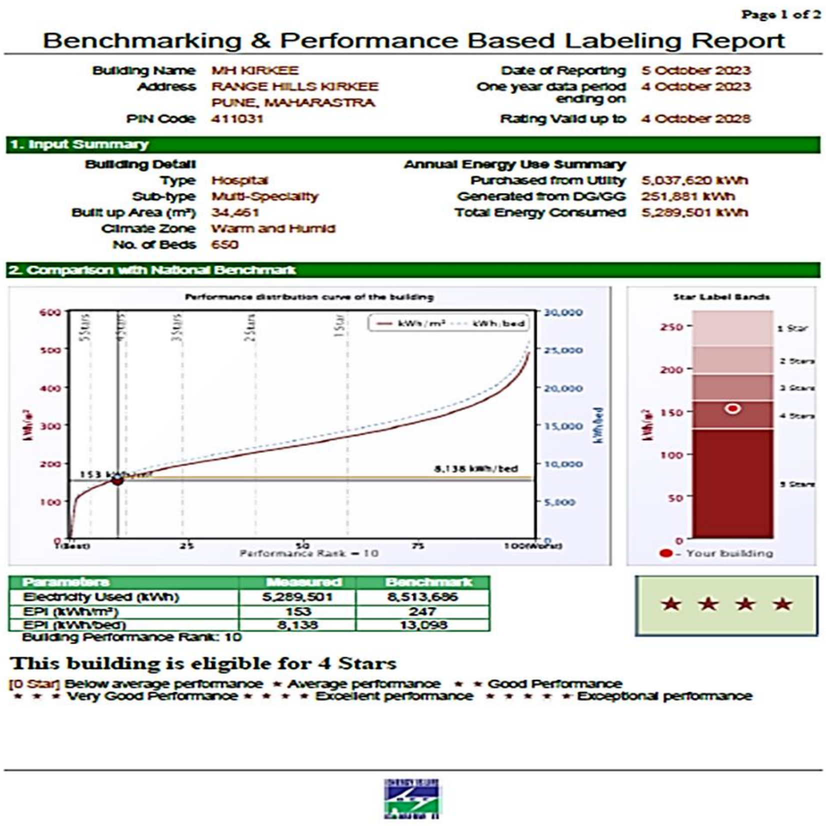
(c) Built up area in square meters = 34,461.40 sqm

(d) Calculating, The EPI Indices for MH Khadki

= 52,89,501 kWh/34,461.40 sqm

= 153.49 kWh/m^2/yr

The energy performance of the building was also evaluated under the BEE star rating of hospital using the ECO bench software tool, which is the energy benchmarking and rating assessment for hospitals. The results obtained through the simulated software tool (Fig 2) show that MH Khadki qualifies just within the threshold of 3/4-star rating, with the simulation giving a 4-star rating, but EPI value of 153.49 kWh/m^2/yr is above the benchmarked value of 88kWh/ m2/yr. The ECO bench tool also gives the energy consumption pattern in kWh/bed for MH Khadki at 8,138 kWh/bed for the 650-bed hospital



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Benchmarking & Performance Based Labeling Report

Building Name	MH KIRKEE	Date of Reporting	5 October 2023
Address	RANGE HILLS KIRKEE PUNE, MAHARASTRA	One year data period ending on	4 October 2023
PIN Code	411031	Rating Valid up to	4 October 2028

1. Input Summary

Building Detail		Annual Energy Use Summary	
Type	Hospital	Purchased from Utility	5,037,620 kWh
Sub-type	Multi-Specialty	Generated from DG/GG	251,881 kWh
Built up Area (m²)	34,461	Total Energy Consumed	5,289,501 kWh
Climate Zone	Warm and Humid		
No. of Beds	650		

2. Comparison with National Benchmark

Parameters	Measured	Benchmark
Electricity Used (kWh)	5,289,501	8,513,686
EPI (kWh/m²)	153	247
EPI (kWh/bed)	8,138	13,098

Building Performance Rank: 10

★ ★ ★ ★

This building is eligible for 4 Stars

[0 Star] Below average performance ★ Average performance ★ ★ Good Performance
★ ★ ★ Very Good Performance ★ ★ ★ ★ Excellent performance ★ ★ ★ ★ ★ Exceptional performance

Fig 2.3: Snapshot of EPI Indices of the military hospital done through ECO Bench (BEE) simulation

III. HVAC System Monitoring

The (200TR X 3) Water Cooled Centralized AC Chiller Plant of the hospital was analyzed for performance parameters to identify the viable measures for Retrofitting of Energy Efficient components and thereby improving overall EPI Indices of the hospital nearing to 88kWh/ m2/yr.

The Chiller plant is of 2006 vintage. The Chiller Plant primarily consist of three water cooled screw chillers of capacity 200TR each. Two are in operational mode as per heat load demand of the hospital and one is kept on standby mode. All three chillers installed for comfort air conditioning are non VFD types. Two cooling towers of induced draft type are co-located outdoor. The details of the chillers is tabulated as below(Table 3.1).

Equipment	Identification	Make	Model	Capacity	Type	Qty
Chiller	Chiller 1	Kirloskar MacQuay	KW4 155.1	200 TR	water cooled screw chiller	1
Chiller	Chiller 2	Kirloskar MacQuay	KW4 155.1	200 TR	water cooled screw chiller	1
Chiller	Chiller 3	Kirloskar MacQuay	KW4 155.1	200 TR	water cooled screw chiller	1

Table 3.1: Installation Equipments of the (200x3) TR Chiller Plant

Calculation of EER using name plate data

The benchmarked index of Chiller performance from various rating and monitoring agencies pertaining to India is given below in Table 3.3(ECB-2017 ratings). Although voluntary by nature, yet to achieve the necessary efficiency performance parameters, it is imperative for an existing stock chiller to take Retrofit measures for achieving requisite the benchmark indices of chiller performance. The comparative table chart of the three chillers measured performance value against benchmarked value is also tabulated in Table3.5. The part load ratings (Specific power consumption) based on ARI and ASHRAE standard considering Pune's climatic conditions with constant condenser entering water temperature is 0.58. During onsite plant performance evaluation, performance tests were carried out for the operating chillers and the measured chiller specific power consumption is 1.25 for chiller 1, 1.59 for chiller 2 and 1.28 for chiller 3 which is very poor.

Table 5-1 Minimum Energy Efficiency Requirements for water cooled Chillers

	ECBC Building		*ECBC+ Building*		*SuperECBC Building*	
Chiller Capacity (kWr)	COP	IPLV	COP	IPLV	COP	IPLV
<260	4.7	5.8	5.2	6.9	5.8	7.1
≥260 & <530	4.9	5.9	5.8	7.1	6.0	7.9
≥530 &<1,050	5.4	6.5	5.8	7.5	6.3	8.4
≥1,050 &<1,580	5.8	6.8	6.2	8.1	6.5	8.8
≥1,580	6.3	7.0	6.5	8.9	6.7	9.1

Table 5-2 Minimum Energy Efficiency Requirements for air cooled Chillers

	ECBC Building		*ECBC+ Building*		*SuperECBC Building*
Chiller Capacity (kWr)	COP	IPLV	COP	IPLV	COP/ IPLV
<260	2.8	*3.5*	3.0	*4.0*	NA
≥260	3.0	*3.7*	3.2	*5.0*	NA

Table 3.2: ECBC guidelines Minimum Energy Efficiency requirements for water cooled chillers

The three Water Cooled Chillers of capacity of 200TR each were monitored using power analyzer, Hydrometer and other instruments. The following tabulated data (Table 3.3) of three chillers gives out the onsite measured performance value in comparison with benchmark value of monitoring agencies.

PART LOADING	ECBC-2017 COP INDICES	ASHRAE kW/TR INDICES	CHILLER-1		CHILLER-2		CHILLER-3	
			COP	kW/TR	COP	kW/TR	COP	kW/TR
COP @100% LOAD RG	5.4	0.58	3.55	0.99	3.90	0.90	4.0	0.88
COP @75% LOAD RG			3.95	0.89	2.81	1.25	4.04	0.87
COP @65% LOAD RG			2.81	1.25	2.21	1.59	2.75	1.28
COP @50% LOAD RG			2.96	1.19	2.18	1.61	2.86	1.23

Table 3.3: Comparative performance analysis with benchmark indices

Observation, analysis and possible EEM scope of the Chiller performance

The chiller usage details of the three chillers collated from the daily log data suggest that the chiller plant operates majority of the duration annually at 65%-part load of the hospital heat load. From Table 3.3 it is seen that the observed COP values and specific power consumption of all the three chillers at different load range is poor and below the benchmark efficiency indices. The need to improve these efficiency parameters so as to be nearer to the benchmark indices is necessary. Suitable EEM will ensure potential energy savings. The proposed Retrofit measures wrt chillers is discussed in the following points:

(a) The Kirloskar-McQuay make chillers of 200 TR capacity are of 2006 vintage. On present date, the chillers have had a life of 17 years functioning. For the more recently installed chillers, median replacement age is about 15-22 years.. The daily heat load being around the range of 63-67% of the peak load annually for the hospital, the part load efficiency has to be better. Based on the annual operating hours of each of the three chillers, it is proposed to replace chiller 1 & 2 with energy-efficient variable speed screw chiller to fulfill the air-conditioning demands. Specific power consumption of proposed chiller would be 0.6kW/TR at 7°C chilled water leaving and 32°C condenser entering water temperature. The chiller type can be selected based on the loading conditions throughout the year and maximum base load requirement of the facility.

(b) The estimated benefits is summarized below with detail calculation covered in Table 3.4:

(i) Estimated benefits on replacement of 02 x chillers with new VSD-screw chillers

Recurring Annual Cost Savings : Rs. 48.00 Lacs
One-time Cost of Implementation : Rs. 150.00 Lacs
Payback : 38 months
Savings measurement : Direct

(ii) Two chillers have annual operating hours of around 3557 hours with an average daily load of 260 hours, annually. The third chiller which is used as a standby mode has an effective zero annual operating hours. The three chillers are randomly shuffled and operated as per operating staff assessment and hospital heat load requirement. So to make a capital investment of Rs150 Lacs for the chiller replacement energy saving proposal, only two chillers are considered for replacement with a calculated payback period of 38 months as shown in Table 3.6. The feasibility of third chiller replacement can be assessed after potential savings are accrued over a period of 38 months.

(iii) Calculation details of the estimated benefits

IV. CONCLUSION

The study paper tries to identify the potential energy efficiency measures (EEM) that can be effectively implemented in a Chiller Plant system. The targeted retrofit measures were particularly aimed at the old chillers of 2006 vintage which are also the largest energy consuming component of the entire HVAC system in the hospital. The two retrofit proposals as suggested in section 3 are feasible for a government hospital per se wrt the investment required both in short and long payback period of 4 months and 38 months as brought out in calculation analysis for each of the retrofit proposal. The calculative analysis as proposed in this paper are justifiable and followed a logical sequence in identifying and suggesting suitable Retrofit measures for enhancing the energy saving potential.

Considering the 24 x 7 functionality requirement of the HVAC system under study, by the hospital in ensuring requisite thermal comfort to its occupants and the criticality of maintaining the IAQ (indoor air quality) of the hospital, the proposed EEM measures are a necessity. The same will also ensure better energy efficiency and overall reduction of the hospital building EPI index.

ACKNOWLEDGMENT

The author gratefully acknowledge the contributions of Dr. P R Dongarwar, Prof of College of Military Engineering, Pune in guiding at every phase during the onsite data collation and analysis of the chiller plant . Also acknowledging the authorities of the Military Hospital who were instrumental in allowing the author to access the Chiller plant for the above study.