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Energy audit of split air conditioners and pumps at government medical college trivandrum

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***Abstract*— Energy audit is the crucial element in ascertaining the efficiency of energy management process. This paper presents a detailed energy audit of split air conditioners and pumps at Government medical college, Trivandrum. The medical college at Trivandrum is the first and biggest medical college in public sector. From the walk-through audit conducted at the college the audit team identified that most of the equipments in the hospital are inefficient or not in working condition. The energy audit provides an insight into how much efficient the equipments are and assess the energy efficient measures that are currently adopted by the institution. The audit was conducted on a normal working day so as to clearly understand the energy consumption processes and the duration of each process. The audit report containing a technical summary of each equipment will be submitted to the college administration so that they will be able to implement the necessary measures for improving the energy efficiency. The measurements and analysis are done according to the guidelines stipulated by the bureau of energy efficiency, Government of India.**

Keywords—Energy Efficiency Ratio, Combined efficiency.

I. INTRODUCTION

Hospitals are public service providers and cater to a large number of people and consume a huge amount of energy. This creates an urgent need for energy management in hospitals. A detailed energy audit of split air conditioners and pumps have been carried out at Govt. Medical College, Trivandrum. The hospital has many electricity consuming devices, out of which the air conditioning systems consume more than 40% of the total energy. The pumping system in the hospital is very much necessary because water is a primary essential. The efficiency of pumps by default is less than 60% and the energy efficiency analysis will provide an insight into the performance of the pumping system.

Air conditioners transfer heat from lower temperature to higher temperature, i.e. from inside to outside, by means of a refrigerant cycle. The system can be considered as a reversible heat pump. The main components of an air conditioning system are the evaporator, condenser, compressor, thermal expansion valve. And in addition a fan and a blower to force the air in and out. Out of the different types of air conditioners available in the market the commonly used are: -

– Window air conditioners are compact and all the essential components are in a single unit. They are less efficient and needs a gap through the insulation, for the installation.

– Split ACs consists of two units. Outdoor unit consists of condenser and compressor, which expels heat outside. The inside unit consists of an evaporator, blower and duct which sucks in the hot air from inside the room. The two units are linked by copper tubes which carry the refrigerant. Any number of indoor units can be connected to the outdoor unit

– Packaged ACs are similar to split ACs and are used when the cooling load is above 3 tons and less than 20 tons. They are generally obtainable in fixed capacities of 3,5,10 and 15 tons.

The Energy Efficiency Ratio or EER of the air conditioner is taken as the criteria for analysing the efficiency of the AC. Pumping systems are an essential part of any large organisation. It is mainly used for pumping water from wells or from lower height to a higher area. Pumps are generally driven by an electric motor whose shaft acts as the prime mover. Pumps convert kinetic energy to hydrodynamic energy of the fluid, and thus moves the fluid from one point to another. The typical efficiency of motors is in the range of 80 to 85% and that of pumps are in the range of 70 to 75 % and therefore the combined efficiency of the pump will be 60 to 65%. The pumping system in the medical college has great scope for energy conservation opportunities, and the inefficient pumps could be replaced at manageable costs.

II. DESCRIPTION OF LOCATION

A. Split AC

The government medical college Trivandrum is situated in Trivandrum city, the capital of Kerala. It is the biggest public sector medical college in Kerala. It is situated right in the centre of the city and has always access to continuous power supply. It provides service to more than 2000 people per day and consumes a large amount of power. During the energy audit, it was found that the air conditioning systems consume more than 50% of the total power. The first phase of the audit was a walk through audit of the entire medical college, and

several energy conservation opportunities were identified. There are 394 split ACs distributed in 10 blocks of the medical college. Table 1 shows the break-up of split ACs.

TABLE 1: LIST OF SPLIT ACs

Block	Number
Main hospital	183
Principal's office	26
Medical college Office	5
SAT Golden Jubilee	36
SAT Main	49
OP	19
Blood bank	39
PMR	6
De-addiction centre	3
Pharmacology	28

B. Pumps

There are 21 pumps in the medical college. Water for the medical college is supplied by the Kerala water authority. Pumps are located at six different places and pumping is done as and when required. Table 2 shows the break-up of pumps.

TABLE 2: LIST OF PUMPS

Location	Code	Type
Main PH pump-1	P1	Centrifugal
Main PH pump-2	P2	Centrifugal
Main PH pump-3	P3	Centrifugal
Main PH pump-4	P4	Submersible
Main PH pump-5	P5	Centrifugal
Main PH pump-6	P6	Submersible
Main PH pump-7	P7	Centrifugal
Main PH pump-8	P8	Centrifugal
Old MCH	P9	Monoblock
Old MCH	P10	Submersible
STP	P11	Centrifugal
STP	P12	Centrifugal
STP	P13	Centrifugal
From pulayanarkotta-1	P14	Centrifugal
From pulayanarkotta-2	P15	Centrifugal
From pulayanarkotta-3	P16	Submersible
SAT-1	P17	Monoblock
SAT-2	P18	Monoblock
New OP block-1	P19	Monoblock
New OP block-2	P20	Monoblock
New OP block-3	P21	Monoblock

The water is collected in 4 sumps of 1 lakh litre capacity and in 1 sump of 10 lakh litre capacity.

III. MEASUREMENT AND ANALYSIS

A. Split AC

A normal working day was chosen for the energy audit so that the normal operating conditions will apply to the test. In the walk-through audit, nameplate ratings of all the ACs were noted and the average working hours per day of each AC was obtained from the respective on-site staff.

Figure 1: NANOVIP PLUS power and harmonic analyser

Fig. 1 shows NANOVIP PLUS power and harmonic analyser with which the electrical parameters were measured. The power consumption in kilowatts was obtained from the power analyser.

Figure 2: GENERAL EP8711P hygrometer

Fig. 2 shows GENERAL EP8711P hygrometer with which the relative humidity of the rooms were measured. The zone in which most humans feel comfortable is the comfort zone and the conditions are when the temperature is between 220C and 270C, the relative humidity in the range 40% to 60%. The relative humidity is a very important factor concerning air conditioning. If the percentage of humidity is more than the comfort zone, the body will sweat very easily, and if the humidity is less, skin will start to dry up.

Figure 3: HIOKI 3419-20 HITESTER infrared thermo tester

Fig. 3 shows HIOKI 3419-20 HITESTER infrared thermo tester with which the temperature of the air coming out of the vent and the inlet temperature of air is measured. The difference in temperature is used for the calculation of Δh, which is the change in enthalpy expressed in kJ/kg, the amount of heat energy removed from the room by the AC.

Figure 4: METRAVI – AVM02 vane anemometer

Fig. 4 shows METRAVI – AVM02 vane anemometer with which the velocity of air from the output vent is measured.

1) Technical Analysis

Energy Efficiency Ratio (EER)

The performance of small ACs are measured using energy efficiency ratio. EER is calculated as the ratio of actual cooling capacity in watts to the input power in watts at full load conditions. The temperature of the input air is $t_1{}^0$C, the temperature of the air coming out is $t_2{}^0$C. h_{in} is the enthalpy corresponding to t_1, and h_{out} is the enthalpy corresponding to t_2. The enthalpy is obtained from the psychrometric chart by extending the intersection point of dry bulb temperature and relative humidity to the enthalpy of dry air and is expressed in kJ/kg. Δh is the change in enthalpy. The velocity of the air measured by the vane anemometer is in m/s. The area of the out duct of the split AC is 0.08m2. The density of air is 1.225 kg/m3. Q is the flow rate of air coming out of the duct in m3/hour. The mathematical equations for finding the EER is obtained as follows.

Q = Velocity of air* area of duct* 60* 60

Actual AC load in TR = (Area of duct* Q* ρ* Δh)/3024

Actual AC load in watts = Actual AC load in TR*3516

EER =(Actual AC load in watts)/(Power drawn by the AC)

Where TR – Tonnes of refrigeration

The EER for each AC was found out using the measured values. The EER is defined when the AC is running at full load or at its maximum cooling capacity. The energy audit at Govt. Medical College, Trivandrum was conducted on a normal working day at normal working conditions and therefore it was uncertain that all the ACs were working at full load. To determine the EER at maximum cooling capacity, the calculated EER was adjusted to projected EER.

Projected EER=EER/ (Actual AC load in TR)

The bureau of energy efficiency, under the ministry of power, Government of India, has issued the minimum EER required for ACs in India. For ACs with 5-star rating, 3.50 is the minimum EER required to qualify it as energy efficient. In this work, the ACs with projected EER less than 4.0 are suggested to be replaced immediately. The expected annual energy consumption is calculated as the product of measured combined power consumption of split ACs to be replaced and annual working hours.

2) Financial Analysis

The expected energy savings in kWh, annual financial savings and approximate investment required in lakhs (Rs.) in replacing the inefficient ACs with BEE labelled 5-star ACs is calculated as follows.

Expected Annual Energy Savings = expected annual energy consumption*0.3

Annual financial saving = (Expected Annual Energy Savings*cost of power)/100000

Approximate investment required = Total number of ACs to be replaced*0.35

It is assumed that the new ACs will consume 30% less power than the inefficient ones and the cost per unit of a 5 star rated AC is Rs. 35,000. The cost of power is Rs.7 per unit. The simple payback period and internal rate of return for the investment required to replace the inefficient ACs are calculated so that the investor will have an understanding whether the project will be profitable.

B. Pumps

During the walk-through audit, the nameplate ratings of all the pumps were noted.

Figure 5: HIOKI 3286-20 clamp on POWER HITESTER

Fig. 5 shows HIOKI 3286-20 clamp on POWER HITESTER with which electrical power of pumps were measured. The flow rate of water was obtained from the online flow meters installed on the pipelines. Q is the flow rate in m3/s. The head in metre was calculated from the readings of the pressure gauge, 1 bar = 10m. The density of water 'ρ' is taken as 1000 kg/ m3.

1) Technical Analysis

Calculation of efficiency and the performance of motor pump system is assessed by calculation of combined efficiency.

Combined η = (Q*9.8*Head*ρ) / Electrical power in watts)*100%

IV. RESULTS AND DISCUSSION

A. Split AC

There are 394 split ACs in Government medical college, Trivandrum, distributed in 10 blocks at various locations. During the audit, it is found that 147 ACs are not in working condition. From the analysis, it is understood that 325 of the total 394 ACs are inefficient or not in working condition. Proposal for replacement of the 325 ACs with BEE rated 5-star ACs. The following observations were made.

1. All the existing air conditioners are aged and work in the office hours. As per the information from the officials, the 80% of the ACs are utilised.
2. The maintenance of ACs were found poor. The filters were not cleaned frequently.
3. The outdoor units were exposed to sunlight and it affects the performance of the AC.
4. Unwanted door/window openings and other leakages were observed through which outside hot air infiltrates.
5. The voltage stabilizers that are used for the ACs are extremely old and affects the overall power quality.
6. The on-site staff lacks knowledge of energy efficient measures which is one of the main reasons of unwanted energy loss.

The technical and financial summary of the findings are as follows.

1) Technical summary

TABLE 2: TECHNICAL SUMMARY OF SPLIT ACs

Location	Number of ACs to be replaced	Expected annual energy consumption (kWh)	Expected annual energy savings (kWh)
Main hospital	164	574050	114810
Principal's office	18	58440	11688
Medical college office	5	16512	3302
SAT Golden Jubilee	14	50568	10113
SAT Main	24	142920	28584
OP	18	78024	15604
Blood bank	47	287676	57375
PMR	6	14504	6126
De-addiction centre	3	13680	2736
Pharmacology	26	98100	19622

2) Financial summary

TABLE 3: FINANCIAL SUMMARY OF SPLIT ACs

Location	Financial savings in Lakhs(Rs.)	Investment required in Lakhs(Rs.)	Simple payback period in months	Internal rate of return in %
Main hospital	8.04	57.40	73.46	3
Principal's office	0.82	6.30	79.20	0.45
Medical college office	0.23	1.50	77.87	0.95
SAT Golden Jubilee	0.71	4.20	71.19	4.10
SAT Main	2	8.40	43.18	24.60
OP	1.09	6.30	59.32	10.83
Blood bank	4.03	16.45	42.01	25.90
PMR	0.43	2.10	50.37	8.50
De-addiction centre	0.19	1.05	56.39	13
Pharmacology	1.37	9.10	68.14	5.65

B. Pumps

There are 21 pumps at various locations in Government medical college, Trivandrum. 6 pumps are not in working condition. Optimal efficiency of pumps is in the range of 65% to 70%. The average combined efficiency of all the pumps is found to be 59.04 %. The maximum combined efficiency of the pumps is 81 % while the minimum combined efficiency is 32.82%. The overall power factor is not good and causes energy loss in the distribution system. The following observations were made.

1. Most of the pumps are old.
2. Operating conditions are unclean.
3. Several leakages were observed in the water lines.
4. Pipes which carry the water are rusty.
5. Scale deposition was found inside the pipes which reduce the flow of water.

The technical summary of the findings of the 21 pumps is as follows.

TABLE 3: TECHNICAL SUMMARY OF PUMPs

Code	Power (kW)	Power factor	Head (m)	Q m3/s	Combined η (%)	Comments
P1						Not Working
P2						Not Working
P3						Not Working
P4	19.2	0.81	35	0.03	62.03	
P5	19.7	0.82	35	0.03	60.46	

P6	31.1	0.91	30	0.03	32.82	
P7	8.59	0.82	35	0.01	55.46	
P8	33.2	0.87	45	0.03	53.12	
P9	10.6	0.88	30	0.01	41.60	
P10	14.2	0.91	40	0.02	55.21	
P11	31.3	0.89	47	0.05	73.58	
P12						Not Working
P13						Not Working
P14	22.8	0.9	91	0.01	70.80	
P15	29.3	0.94	91	0.01	55.09	
P16	10.8	0.78	45	0.02	81.67	
P17	7.96	0.67	45	0.01	76.95	
P18	7.85	0.85	30	0.01	52.43	
P19	8.09	0.89	34	0.01	55.60	
P20	7.53	0.82	34	0.01	59.74	
P21						Not Working

V. CONCLUSION

The energy audit of split ACs and pumping system conducted at Government medical college, Trivandrum has revealed that most of the ACs are inefficient and should be replaced with efficient, star rated ACs. The average payback period for the project is 61.8 months. The internal rate of return is also calculated, and values as high as 25.90% is observed, which will be a profitable investment. The combined efficiency of each pump is calculated. Out of the 16 working pumps, only 6 have efficiency above 60%, the optimal value. The usage of inefficient ACs and pumps will lead to unwanted energy loss.

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