Phone : 91-172-2792325,2795001
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Punjab State Council for Science & Technology

A Scientific & Industrial Research Organization approved by DSIR & Central Govt. under Clause (ii) of Sub-Section (I) of Section 35 of Income Tax Act, 1961

(A State Govt. Undertaking)

MGSIPA Complex, Institutional Area, Sector 26, Post Box No. 727, Chandigarh-160 019 (India)

Ref. No. : PSCST/ Ac/369 Dated 30/10/2014

Registrar,
Punjab Technical University,
Jalandhar-Kapurthala Highway,
Kapurthala

Subject: Energy Audit of PTU's Administrative Building at Kapurthala.

I am grateful to Punjab Technical University (PTU) for awarding the work of carrying out detailed energy audit of its complex at Kapurthala. PSCST has completed the field audit and has recommended 8 energy saving options based on the energy conservation measures (ECM) identified during audit. A summary of annual savings identified is as below:

Short term energy saving proposals (5 nos.)

- Annual Savings with zero investment (2 nos.) : Rs. 8.60 lacs
- Annual Savings with investment of Rs. 2.0 lacs (3 nos.) : Rs. 2.64 lacs

Long term energy saving proposals

- Annual Savings with investment of Rs. 47.55 lacs (3 nos.) : Rs. 20.52 lacs

I am enclosing copy of draft detailed energy audit report for perusal and comments. Further, before finalizing the report, findings & comments can be discussed with implementation team at mutual convenient date & venue, preferably in mid November, 2014.

With regards,

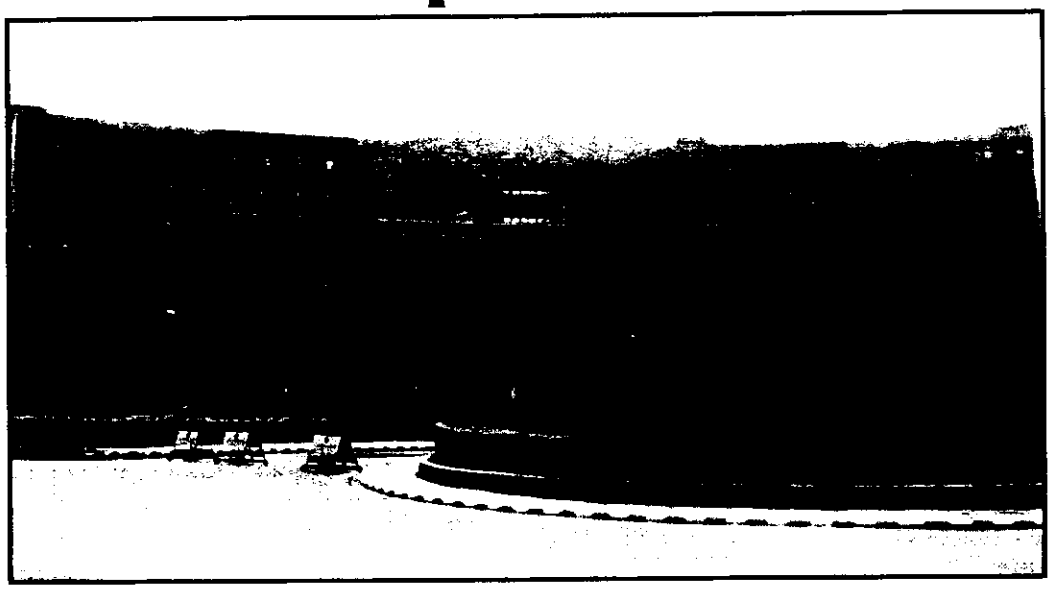
DA: Draft Report

29/10/14
Additional Director

Detailed Energy Audit Report

for

Punjab Technical University Kapurthala



Draft report
October 2014

Punjab State Council for Science & Technology
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ACKNOWLEDGEMENT

We express our gratitude to Punjab Technical University (PTU), Kapurthala for giving us an opportunity to undertake the energy audit of their complex. The energy audit is indeed a very important assignment as the electricity tariffs are increasing day by day and the reduction in energy bill has become very important.

During field studies, the management was found to be progressive as it has done very well on energy conservation front by implementing several energy conservation initiatives, such as:

- Maintaining power factor above 0.95
- Good electrical transmission & distribution system
- Separate feeders for inside & outside lights
- Separate floor wise control panel for indoor lights
- Utilization of T8 & CFL light fixtures in indoor lighting
- Energy Conservation by switching ON alternate street lights
- Good insulation practices in HVAC system

We are also thankful to Shri H.P. Singh, Executive Engineer and Shri. Vishal Beri, Estate Officer for coordinating the field visits and providing all possible help during energy audit in the campus. We also express our profound thanks to the officers and staff of Punjab Technical University, especially Sh. P.C. Thakur, AAE; Sh. Pankaj Sharma, Sh. Ram Singh and Sh. Jasbir Singh, technicians for their assistance to the energy audit team.

The PSCST team worked in close collaboration with the team of CII-AVANTHA Centre for carrying out the detail energy audit of the complex. We are especially grateful to Sh. R. Narayanan, Head, CII-AVANTHA Centre for readily agreeing to take up this assignment with us, Sh. Sanjay Namdeo, Senior Counselor for his comments from time to time, and the CII team comprising Sh. Manpreet Singh & Sh. Mohd. Khalid for their active participation.

Additional Director

ENERGY AUDIT TEAM

S. No.	Name & Designation
1.	Sh. S.K. Jain, *Additional Director, PSCST*
2.	Sh. Pritpal Singh, *Senior Engineer, PSCST*
3.	Sh. Krishan Kant Singla, *Certified Energy Auditor,* *Process Engineer, PSCST*
4.	Sh. Manpreet Singh, *Certified Energy Auditor,* *Counsellor, CII*
5.	Sh. Mohd. Khalid *Engineer, CII*
6.	Ms. Rajeena *Steno Typist, PSCST*

CHAPTER 1.0
EXECUTIVE SUMMARY

Punjab Technical University (PTU) was established in the Year 1997 under the Punjab Technical University Act, 1996 (Punjab Act No. 1 of 1997) to provide for the establishment and incorporation of a University for the advancement of technical education and development thereof in the State of Punjab and for matters connected therewith. In pursuance of this Act, the University has 494 affiliated colleges. At present, after 15 year of its existence, PTU is providing education to approximately 5 lac students from Punjab and other States in the fields of Engineering, Management, Architecture and Pharmacy.

Punjab Technical University is propelled by the vision and wisdom & is continuously strived to discharge its duties for the overall improvement of quality of education and to make sure that the courses it offers remain relevant to society and useful to students in the globalized work environment.

Punjab Technical University has evinced interest in availing the services of the Punjab State Council for Science and Technology, Chandigarh for conducting a detailed energy audit of their Complex, Kapurthala. The annual power consumption of the PTU Complex during the year 2013 (January to December 2013) was 13.21 lacs kWh and energy bill for this period was Rs. 1.01 crores.

PSCST team carried out the preliminary energy audit on 26.05.2014 & detailed energy audit of their energy intensive equipments from 30.06.2014 to 02.07.2014 jointly with CII-AVANTHA Centre for Competitiveness for SMEs.

1.1 Methodology

1.1.1 Pre-audit Visit

A preliminary visit of Punjab Technical University Complex was made for finalizing the audit schedule and discussions were held with senior management. A walk-through audit was also conducted so as to familiarize with institution activities and to get first hand information like building layout, energy consumption data, electrical distribution system, specifications of the energy intensive equipments & existing instrumentation. The requisite information for all energy intensive equipments installed in their campus was supplied by Punjab Technical University Complex management on the questionnaire provided by PSCST. The data was analyzed & it was observed

that the total connected load of the equipments installed is 3300kW, with its distribution as under:

Table-1.1: Total Load of equipments installed at PTU

Area	Load (kW)	Load (% age)
HVAC (Chillers 4nos,Primary Pumps 4 nos., Secondary pumps 3 nos. & fresh air fans 18 nos.,AHUs 41 nos.,CDS pumps)	1240	52%
Split/Window AC (30 nos of ACs)	94.50	4%
Hot water generator	400	17%
Lighting	178	7.5%
Pumping, Plumbing And Fire Fighting pumps (Submersible pump 1 no, Sump pumps 3 nos., fire pump 1 no., terrace pump 1 no., fountain pumps 2nos., jocky pumps 1 no & STP pumps)	160	6.7%
Fans / Water coolers	75	3.0%
General Load (Dispenser, Oven, Heater, Computer, projector)	210	9%
Lifts (4 nos.)	23.12	0.8%
Total	**2380**	**100%**

1.1.2 Detailed Energy Audit

Detailed energy audit of various equipments installed in the PTU Complex was carried out by using various digital energy audit instruments such as Three Phase power analyzer, ultrasonic flow meter, pressure gauge, lux meter, distance meter, multimeter, power clamp meter, hygro-thermometer. During the detailed study, the following observations were made:

Power Distribution System

- Two 1000kVA transformers are being operated throughout the year, as working load during day time in summers is 670-740 kW. However, the average running load during night time throughout the year is only 30-50kW.
- The average annual Power Factor (PF) during the period January 2013 to December 2013 was 0.96. Average Power Factor at substation during day time & night time was observed to be 0.98-0.99.
- Automatic Power Factor Control (APFC) panel of 350 kVAR each has been installed on the two 1000kVA transformers to maintain the power factor. The capacitor banks were working efficiently.

Heating, Ventilation & Air-conditioning (HVAC) System

- No control system to regulate the flow of chilled water to HVACs in the isolated/unoccupied areas.
- The specific power consumption of air cooled screw chiller plant was 1.46 kW/TR. Whereas, water cooled screw chillers have specific power consumption of 0.7 to 0.8 kW/TR.
- The available head of return water from AHUs, at inlet of chiller plant is 2.9 kg/cm^2 which is sufficient for the operation in chilling plant & at times may not require primary water pumps.
- Low temperature (20-24^{0}C) maintained in the centrally air conditioned areas. No automated sensor based system to maintain the inside temperature.

Lighting

- Operation of the indoor lights during night time even when there is no occupancy.
- Use of T8 fixtures for indoor lighting

1.1.3 Analysis & Report Preparation

The data collected during these field studies was analyzed for identifying the scope of energy conservation. The Cost Benefit Analysis with regards to recommended Energy Conservation Measures (ECM) was prepared for calculating the payback period.

The report has been prepared considering the minimum number of hours of operation of following equipments in consultation with the concerned staff/ officers.

Table-1.2: No. of Operating Hours of Various Equipments

Equipment/ Location	No of hours/day/ equipment	Total no. of hours/ year / equipment
• Transformers	24 hrs/d	8760
• HVAC		
o Chillers	10 hrs/d	1250
o Chilled water pump	10 hrs/d	1250
o Condenser water pumps	10 hrs/d	1250
• Indoor lights	10-20 hrs/d	3000-6000
• Street light	10hrs/d	3650
• Submersible pumps	6-12 hrs/d	1800-3600

1.1.4 Recommendations

Based on the energy conservation measures identified, the cost benefit analysis like simple payback period of all the ECMs has been calculated. It has been observed that there is a annual energy saving potential of

4,02,604 kWh amounting to Rs.30.92 lacs besides power factor incentive of Rs.0.84 Lacs. Thus, there is total annual saving potential of Rs.31.76 Lacs with an investment of Rs.49.55 lacs. The simple pay-back period of the investment is only 1.6 years. The investment cost has been prepared while taking into account the prevailing market rates.

The recommendations which have early payback period are termed as short term measures and recommendations which have long payback period are termed as long term measures. It is proposed that the energy conservation measures requiring no investment should be implemented immediately and the remaining ECMs are proposed to be implemented in two phases as short term measures and long term measures.

Short Term Measures:

The following ECMs can lead to saving of Rs. 8.60 lacs with zero investment.

- Optimize operation of transformers.
- Optimize the contract demand power supply from PSPCL.

Further, the following ECMs are recommended to be implemented in the first phase which has a saving potential of Rs. 2.64 lacs per annum with an investment of Rs. 2.0 lacs having simple payback period as 9 months.

- Improve overall power factor of complex to unity.
- Modify chilled water circulation system & eliminate the use of primary pumps.
- Optimize power consumption of lighting by automation.

Long Term Measures:

The following ECMs are recommended to be implemented in the second phase which has a saving potential of Rs. 20.52 lacs per annum with an investment of Rs. 47.55 lacs having simple payback period as 28 months.

- Replace existing air cooled screw chiller with water cooled screw chiller.
- Replace 36 W fluorescent tube lights with 18 W LED tube lights.
- Replace 18 W fluorescent tube lights with 9 W LED tube lights.
- Replace 150 W HPSV Street Lights With 60 W LED Street Light.
- Replace 70 W HPSV Street Lights With 30 W LED Street Light

1.1.5 Summary of annual savings identified

Short Term Energy Saving Proposals

Annual Savings with zero Investment *(2 Proposals)*	:	Rs. 8.60 Lacs
Annual Savings with Investment of Rs.2.00 Lacs *(3 Proposals)*	:	Rs. 2.64 Lacs

Long Term Energy Saving Proposals

Annual Savings with Investment of Rs.47.55 Lacs *(3 proposals)*	:	Rs. 20.52 Lacs
Total annual savings with investment of Rs.49.55 Lacs. ***(8 Proposals)***	:	**Rs.31.76 Lacs**
Average payback period for capital proposals	:	1.6 years

Each Energy Conservation Idea should be seen as an opportunity for improvement. The management of PTU Complex should have a firm commitment so that the complex:

- Achieves energy conservation on a time bound basis.
- Make energy conservation a permanent activity.
- Achieve lowest auxiliary energy consumption.
- Implement the recommended proposals and reap the benefit.
- Achieve the status of best energy efficient complex in India.

List of Energy Saving Proposals at Punjab Technical University, Kapurthala

Sr. No.	Energy saving proposals	Annual Savings (Rs. in Lacs)	Invest. Required (Rs. in Lacs)	Simple Payback (Months)
1	Optimize operation of transformers	0.56	-	-
2	Optimize the contract demand power supply from PSPCL	8.04	-	-
3	Improve overall power factor of complex to unity	0.84	0.50	7
4	Replace existing air cooled screw chillers with water cooled screw chiller.	11.52	25	25
5	Modify chilled water circulation system and eliminate use of primary pumps.	0.80	0.50	8
6	Replace 36 watts & 18 watts fluorescent tube lights with 18 watts & 9 watts LED tube lights	5.32	12.55	28
7	Replace 150W HPSV street lights with 60 watts LED & 70W HPSV with 30W LED street lights.	3.68	10.0	12
8	Optimize power consumption of lighting by automation	1.0	1.0	12
	Observations			
1	Optimize power consumption of lighting by switching off indoor lights in night.			
2	Install Roof top Solar Photovoltaic system			
	Total	**31.76**	**49.55**	**19**

CHAPTER 2.0
INTRODUCTION

Punjab Technical University (PTU) was established in the Year 1997 under the Punjab Technical University Act, 1996 (Punjab Act No. 1 of 1997) to provide for the establishment and incorporation of a University for the advancement of technical education and development thereof in the State of Punjab and for matters connected therewith. In pursuance of this Act, the University has 494 affiliated colleges. At present, after 15 year of its existence, PTU is providing education to approximately 5 lac students from Punjab & other States in the fields of Engineering, Management, Architecture and Pharmacy.

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Punjab Technical University has evinced interest in availing the services of the Punjab State Council for Science and Technology, Chandigarh for conducting a detailed energy audit of their Complex, Kapurthala.

Preliminary visit of PTU Complex was carried out on 26.05.2014 and discussions were held with the senior management. A walk through audit of the campus was also conducted so as to familiarize with the institution activity, obtain first hand information like building layout, energy consumption data, electrical distribution system, identification of energy intensive equipments and existing instrumentation. The information w.r.t. all energy intensive equipments installed in the campus was supplied by PTU on the questionnaire provided by PSCST. The detailed energy audit of PTU Complex was carried out from 30.06.2014 to 02.07.2014 to study the existing energy consumption pattern and identify energy conservation measures.

The contents of this report are based on the actual data provided by the PTU officials and measurements carried out by PSCST and CII energy audit team.

The management was found to be progressive as it has done very well on energy conservation front by implementing several energy conservation initiatives such as:

- Maintaining power factor above 0.95
- Good electrical transmission & distribution system

- Separate feeders for inside & outside lights
- Separate floor wise control panel for indoor lights
- Utilization of T8 & CFL light fixtures in indoor lighting
- Switching ON alternate lights in street lighting
- Good insulation practices in HVAC system

CHAPTER 3.0
GENERAL & TECHNICAL ASPECTS

3.1 General/ Administrative

Table-3.1: General Aspects

Parameter	Description
Name of the Institution	Punjab Technical University, Kapurthala
Land area and year of construction	74 acres, 2008
Total Built up area (Sq. m) approx.	24,749
Total number of employees in the office	610
Occupancy information *(5 days a week, daily 9.00 AM to 5 PM)*	60,000 visitor/ Annum
Power Tariff :	
• Energy Charges	Rs.7.68 per kWh *However, basic tariff rate excluding PF incentive, ED and rentals works out to Rs. 6.39 per kWh*
• Minimum charges (monthly)	Rs.5.98 Lacs
• P.F Penalty/Rebate	Yes, applicable
Status of Bill Payments on time/Delay in Bill Payments, percentage paid	On Time

3.2 Detail of Visitors

Punjab Technical University remains open for 5 days (except Saturday, Sunday and Public Holidays) in a week. As such it remains open for around 270-280 days in a year. As per the data provided by the management, approximately, 60,000 persons visit the University Complex during the period January, 2013-December 2013.

The technical data is provided in table-3.2 below:

Table-3.2: Technical Aspect

S.No.	Item	Description
1.	Source of Supply	Punjab State Power Corporation Ltd.
2.	Voltage Level of Incoming Supply	11 kV-HT line
3.	a) Main Transformer	1000 kVA – 02 No.
4.	Break up of all major loads	Details at Table 4.3
5.	Power Requirement of the plant: *(Based on Monthly Energy bill period Jan 2013- Dec2013)*	
	a) Connected Load	2380 kW
	b) Contract Demand	2000 kVA
	c) Maximum Demand	998 kVA
	d) Average power factor	0.95 to unity
	e) Annual electricity bill	Rs 1.01 Crore *(Approx.)*
	f) Annual electricity consumption- table-4.2	13.19 Lacs kWh
6.	Other Sources of Power Supply	
	• Installed DG capacity	2 No. - 380 kVA each 1 No. – 62.5 kVA
	• Total electricity generated from DG	Only during power break-down
7.	LT Capacitor Bank Details *(Installed in substations or load centre with APFC)*	350 kVAR Capacitor Bank *(25 kVAR- 6 nos. & 50 kVAR- 4 nos. for each transformer)*
9.	Major Equipments/Main motors	• Transformers • HVAC Plant • AHU's • Hot Water Generator • Pumps • DG Sets • Lighting • Lifts
9.	Load distribution pattern	

Equipment	No.	Load(kW)
HVAC Plant	4	1240
Split & Window AC	30	94.5
Hot Water Generator	1	400
Lighting	3262	178
Pumps/motors		160
Fans Water Coolers	825 22	75
General Load	-	210
Lifts	4	23.126
Total		**2380**

CHAPTER 4.0
ENERGY CONSUMPTION PATTERN

4.1 Energy Use Pattern

Punjab Technical University complex receives power from Punjab State Power Corporation Limited (PSPCL) at 11 kV voltage level. D.G. sets are used only during power failure/ break-down. The energy consumption is recorded from the main meter installed on the HT site of 11 kV grid and through the monthly bills. The parameters like energy consumption during day and night, monitoring the energy consumption in different areas, power factor and maximum demand etc. were studied.

The Specific Energy Consumption based on covered area (kWh/sq.ft.) and average occupancy (kWh/person) has been calculated on the basis of data supplied by the organization for the period January 2013- December 2013.

Table-4.1: Specific Energy Consumption (SEC) at PTU Complex

Yearly Data *(Jan 2013- Dec 2013)*	Quantity	Unit	Energy Consumption (in *Lac kcal)*	Av. worked out Unit Cost (Rs.)	Total Cost *(Rs in Lacs)*	SEC based on covered area *(kWh/ Sq.ft./Year)*	SEC based on occupancy (*kWh/ Person)*
Annual Electricity Consumption	1,319,638	kWh	1,134	7.68	101	4.98	6.2
Annual Diesel Consumption	5,000	Litres	45	60	3.0		
Covered area of Building	264,638	Sq.ft.					
Average Occupancy /annum	60,000	Persons					

4.2 Electrical Energy Consumption Pattern

Total electrical energy consumption pattern and energy charges based on the monthly bills of last 12 months is given in the **Table-4.2.** The variation in the Energy Consumption is attributed mainly due to the seasonal variation. The Power consumption goes up in the peak summer & peak winter seasons due to the additional load of HVACs system in summers and utilization of hot water generator in winters.

Table-4.2: Monthly Energy Consumption Pattern

Month & Year *(As per bill cycle)*	MDI *(kVA)*	Total Energy *(kWh)*	Total Energy Bill *(Rs.)*	Actual Power Factor
Jan-13	633.34	162504	10,31,126	Unity
Feb-13	626.80	151088	9,66,350	0.99
Mar-13	597.32	55904	5,69,879	Unity
Apr-13	461.62	34928	5,92,710	Unity
May-13	998.24	100824	7,06,796	0.96
june-13	973.42	133424	9,85,030	0.96
july-13	952.90	155956	11,78,309	0.95
Aug-13	931.82	149812	10,55,090	0.94
Sep-13	931.7	143290	10,11,740	0.93
Oct-13	828.18	111042	7,88,680	0.94
Nov-13	509.94	54830	6,12,624	0.97
Dec-13	613.98	66036	6,41,960	Unity
		1319638	**1,01,40,294**	**0.96 (Average)**

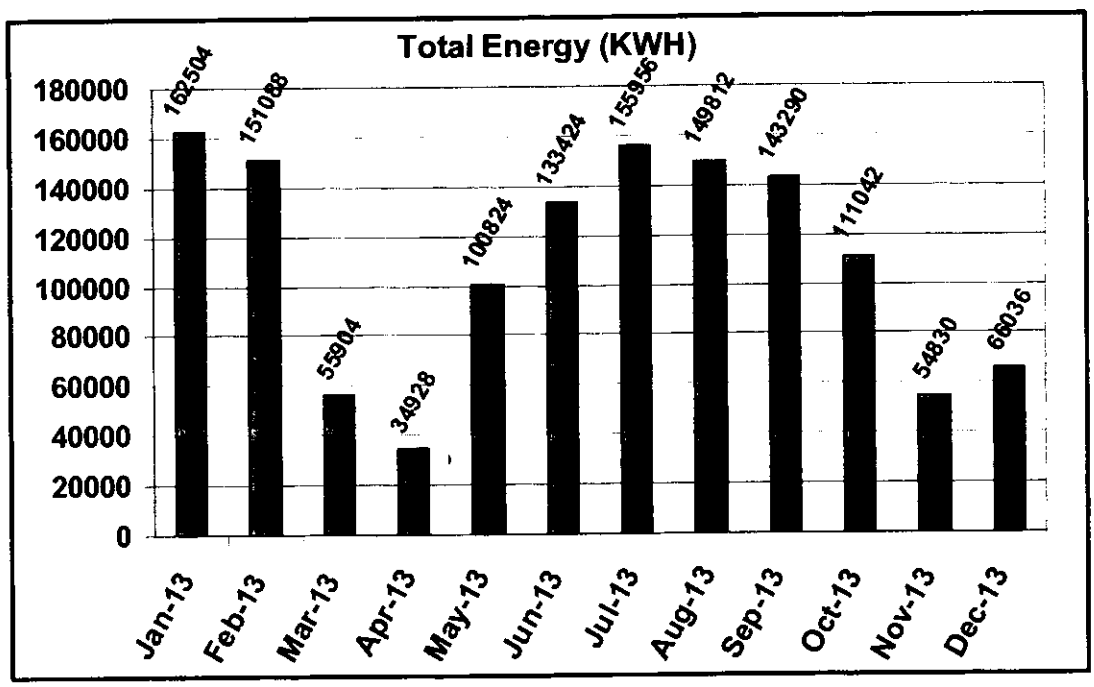


Figure-4.1: Energy Consumption Pattern (May 2013- April 2014)

From the above, maximum energy consumption has been observed during the winter months of January & February *(1.5 lac to 1.62 lac kWh)* whereas, Maximum Demand Index (MDI) during this period was only 626 to 633 kVA. The MDI during summer months *(May to September)* ranged between 930-1000 kVA with energy consumption ranging between 1.0 lac to 1.43 lac kWh. Minimum monthly charges has been levied during the months March – April & November – April due to low MDI & energy consumption.

While auditing, power consumption during working hours ranged between 670-740 kW whereas, power consumption during non-working hours was only 30-50 kW. The connected load of outdoor lighting during non-working hours was only 18 kW.

4.3 Connected Load Details

Table-4.3: Connected load Details at Punjab Technical University Complex

Area	Load (kW)	Load (% age)
HVAC *(Chillers 4nos, Primary Pumps 4 nos., Secondary pumps 3 nos. & fresh air fans 18 nos., AHUs 41 nos., CDS pumps)*	1240	52%
Split/Window AC *(30 nos of ACs)*	94.50	4%
Hot water generator	400	17%
Lighting	178	7.5%
Pumping, Plumbing And Fire Fighting pumps *(Submersible pump 1 nos, Sump pumps 3 nos., fire pump 1 nos., terrace pump 1 nos., fountain pumps 2nos., jockey pumps 1 nos, STP pumps)*	160	6.7%
Fans / Water coolers	75	3.0%
General Load *(Dispenser, Oven, Heater, Computer, projector)*	210	9%
Lifts *(4 nos.)*	23.12	0.8%
Total	**2380**	**100%**

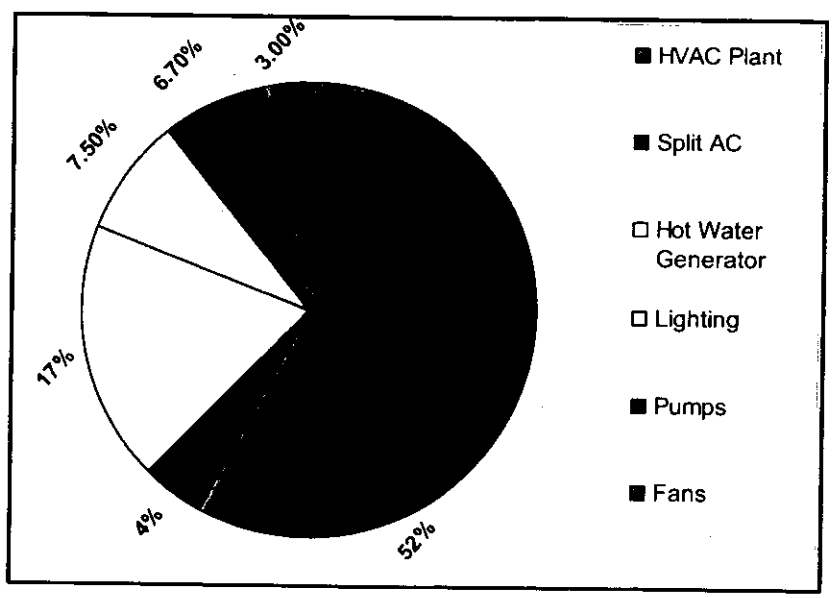


Figure-4.2: Connected load Break-up

It is evident from the above that 73% of the total connected load is for HVAC & heating ventilation system only and HVAC/heating plant is used, depending on the season (summer or winter). Whereas, remaining 27%

connected load is for pumps, lighting system and other auxiliary load. It was also noticed that the actual electricity load is less than the total connected load as the MDI varied between 509 to 1000 kVA against the sanctioned contract demand of 2000 kVA. Therefore, the sanctioned load can be optimised/ reduced so as to avoid monthly minimum charges.

4.4 Electrical power Distribution System:

Punjab Technical University Complex receives power from PSPCL at 11 kV and steps down to 400 V through 1000 kVA Transformer, which is supplied to the main complex.

The design specifications of transformers are given in Table-4.4 below:

Table-4.4: Design Data for 11/0.4 kV Transformers

Sr. No.	Description	Transformer 1	Transformer 2,
1	Make	VOLTAMP	VOLTAMP
2	Type	ONAN	ONAN
3	Rating (kVA)	1000	1000
4	Primary Voltage (kV)	11	11
5	Primary Current (Amps)	52.49	52.49
6	Secondary Voltage (kV)	0.400	0.400
7	Secondary Current (A)	1443.38	1443.38
8	OLTC (With/Without)	WITH	WITH
9	Rated No Load Loss (kW)	1.2	1.2
10	Rated copper loss (kW)	12	12

4.4.1 Loading Pattern of Transformers

The log of power data for 2 transformers was noted using portable instrument on HT/LT side of the transformer. The logging for each of the transformer was made to ascertain the actual load variation on the transformer. During the study period, the maximum load, average load and minimum load registered on each of the transformer are presented in Table-4.5 & Figures-4.3 to Figure-4.5 below.

As informed by the management, two transformers of 1000 kVA each operate throughout the year. During audit, the average loading on the transformers was found to be low. During day time, operating load on transformer no.1 & transformer no.2 varied between 240-290 kW and 430-450 kW respectively. Energy consumption during the night hours was in the range

of 30-50 kW, which is 3-5% of the total connected load. The voltage range during the night was 380-420 volts.

Table-4.5: Load Distribution on all Transformers

Sl. No.	Transformer no.	Maximum load (kVA)	Minimum load (kVA)	Average load (kVA)	Percentage loading (%)
	During working hrs				
1	Transformer 1	290	240	265	24– 29 %
2	Transformer 2	450	430	440	43-45%
	During non working hrs.				
3.	Transformer 1	50	30	40	3-5%

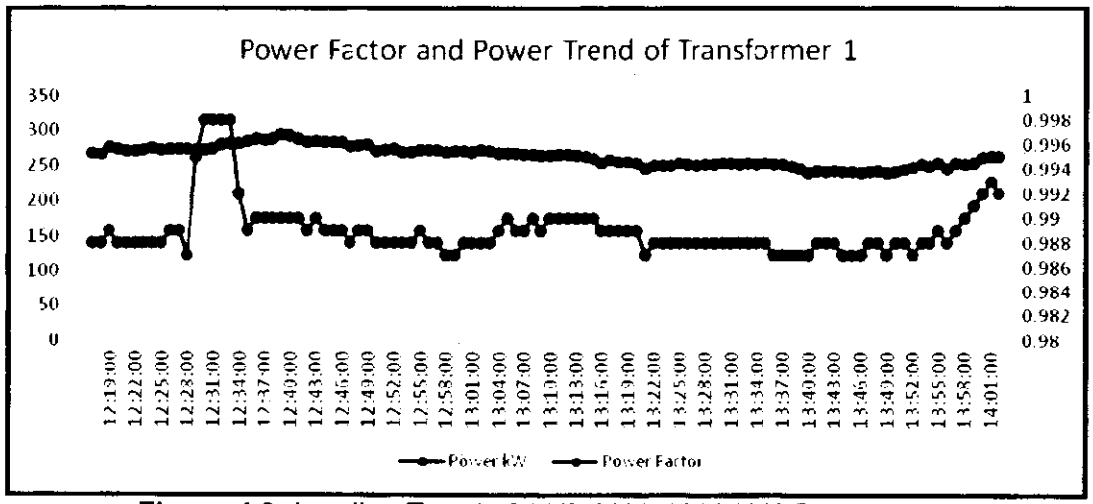


Figure-4.3: Loading Trend of 11/0.4 kV, 1000 kVA Transformer

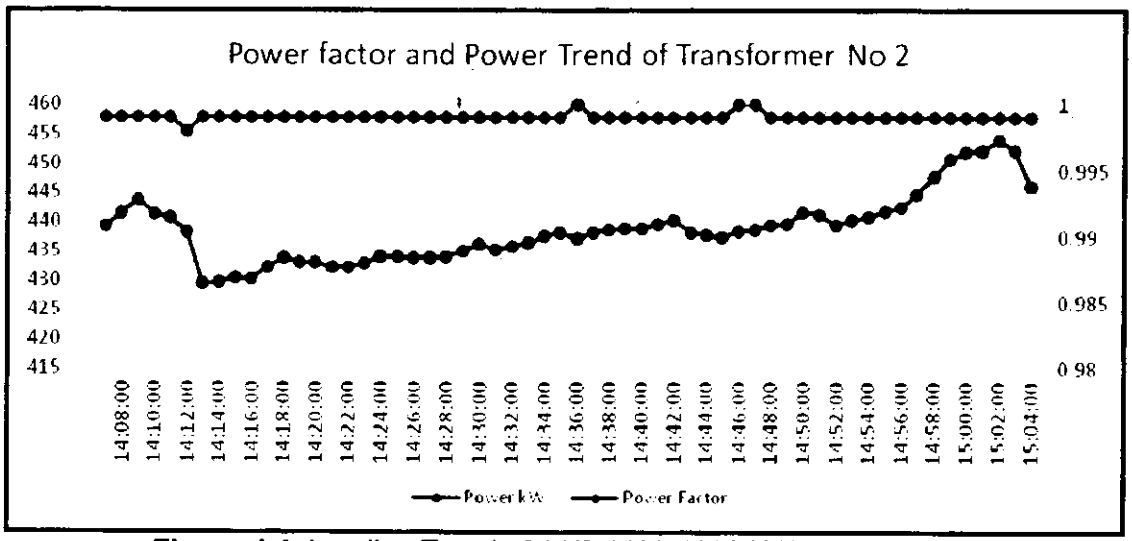


Figure-4.4: Loading Trend of 11/0.4 kV, 1000 kVA Transformer

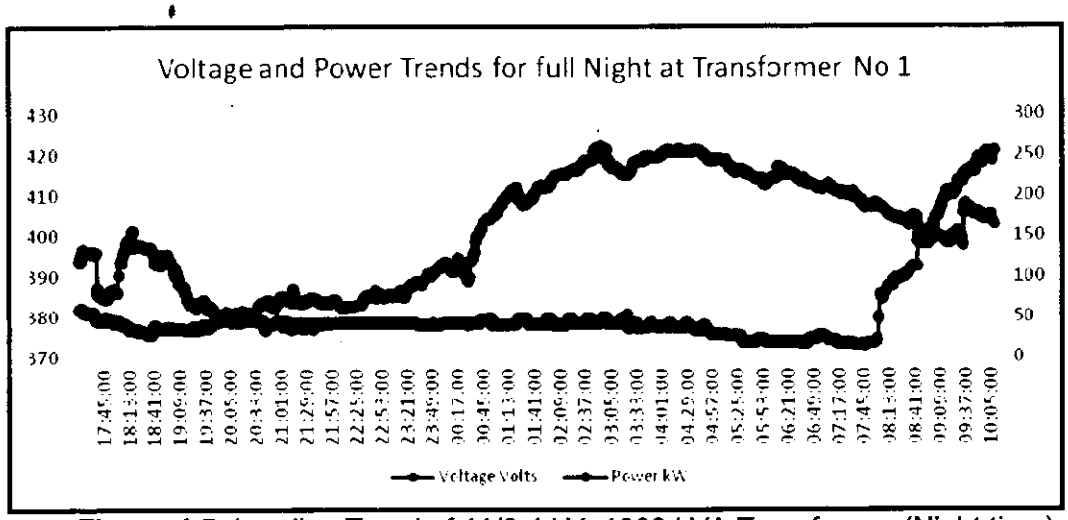


Figure-4.5: Loading Trend of 11/0.4 kV, 1000 kVA Transformer (Night time)

4.4.2 Harmonic Distortion:

The devices like motors with drives, computers, UPS, Air Conditioners, fax machines, photocopies, printer etc. are extensively being used in the complex. All these devices draw non sinusoidal currents and cause distortion in voltage and current waveforms leading to harmonics. Harmonics occurs as spikes at intervals which are multiples of the main frequency and these distort the pure sine wave form of the supply voltage and current. These can be measured with the help of advanced electrical measuring instruments.

Many problems can arise from harmonic current in a power system. These include overheating of neutral conductors, motors, transformers, switch gears, voltage drop, low power factor, reduced capacities, capacitor failures, circuit breaker, tripping with no apparent reason etc. These problem leads to increased electricity bills besides being operational and maintenance concerns.

The harmonic trends at main incomer, LT side of transformer no.1 & 2 was checked by using digital power analyzer. Total harmonic distortion (THD) in voltage at HT side of transformer was observed to be in the range of 1-2% and current harmonic distortion was observed to be in the range of 3-10% as shown in figure-4.6 below:

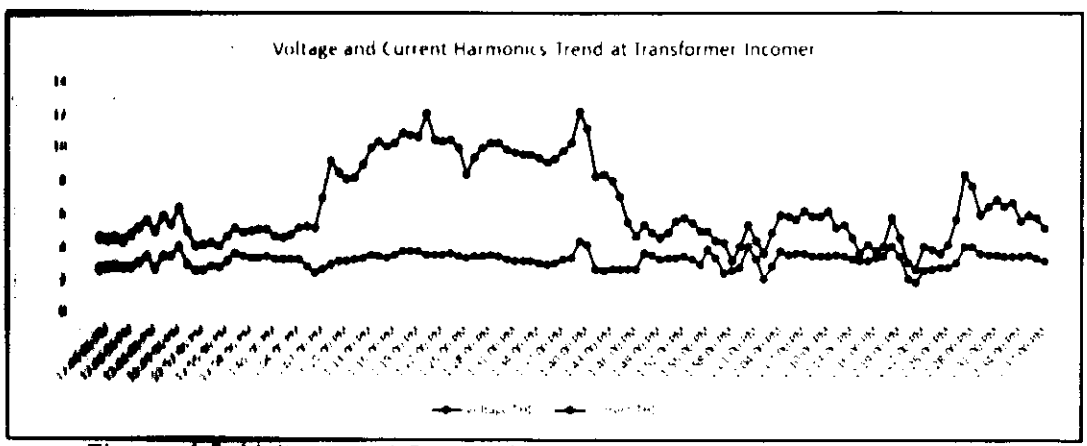


Figure-4.6: Voltage and Current Harmonics Trend at Transformer Incomer

The total voltage harmonics at LT site of 11 KVA transformer no. 1 was observed to be in the range of 1.5 to 2.0% and current harmonics were in the range of 5.5 to 7.0%. Similarly, the voltage harmonics on LT side of transformer no. 2 was 0.6-0.8% and the current harmonics was observed to be in the range of 1.2-1.8% as shown in figure-4.7 & figure-4.8 below. These observations are well within the permissible range of 3-5% for voltage and upto 10% for current harmonics.

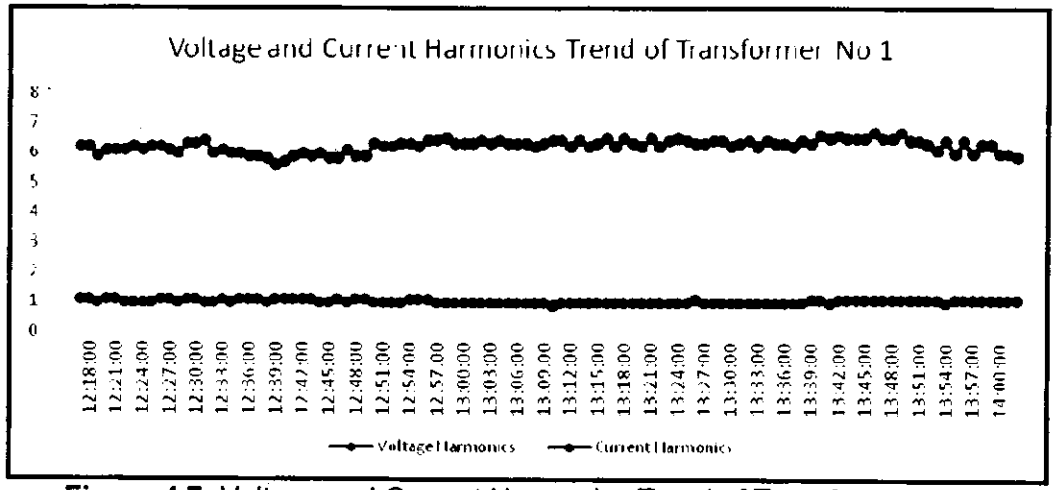


Figure-4.7: Voltage and Current Harmonics Trend of Transformer No. 1

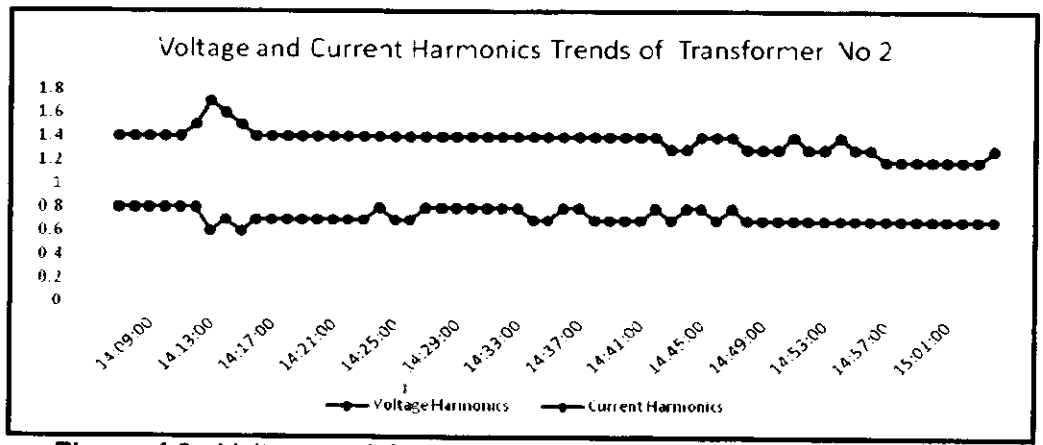


Figure-4.8: Voltage and Current Harmonics Trend of Transformer No. 2

4.5 Recommendations

1. Operate only one 1000 kVA transformer during night time (6 PM to 7AM) throughout the year.
2. Operate only one 1000 KVA transformer during the holidays.

4.6 Benefits

The annual saving potential is **Rs. 0.56 Lacs**, which requires no investment. Details are given in Energy Saving Proposal-1.

ENERGY SAVING PROPOSAL No. 1

Optimise operation of transformers

As observed during the audit, the average loading on transformers is very less. During day time, it varies between 25-45% whereas, during night time, it is less than 10%.

Existing Scenario

- 2 Nos of 1000 kVA transformers operate throughout the year
- Average loading of complex in May to October = 900 kW
- Average loading of complex in November to April = 550 kW
- Average Loading of complex during night time = 30-50 kW

A. Recommendations

1. *Operate only one 1000 kVA transformer during Night Hours (6 PM to 7 AM) throughout the year*
2. *Operate only one 1000 KVA transformer during the holidays*

Existing Scenario:

- Two Transformers (1000 kVA) are operated
- Actual total effective load is 50 kW
- % load to the individual transformers is 2% & 3%
- Losses
  - ❑ Iron loss = 1.2* kW
  - ❑ FL. Copper losses = 12* kW

*Standard losses of transformer

Losses calculation:

- When both transformers are in operation : 2.41 kW
  [(1.2) + 12 x (0.02)^2] + [(1.2) + 12 x (0.03)^2]
- When one transformer in operation : 1.24 kW
  (1.2) + 12 x (0.05)^2
- Saving potential in kW : 1.17 kW
  (2.41 kW – 1.24 kW)
- Annual Savings on working days : **0.30 Lacs**
  1.17 x 13 hrs/day x 20 days/month x 12 months x Rs.7.68/unit
- Annual Savings during non working days : **0.26 Lacs**
  1.17 x 24 hrs/day x 120 days/annum x Rs. 7.68/unit

B. Savings:

Annual Savings (0.30+0.26) : **0.56 Lacs**

Investment : **Nil**

ENERGY SAVING PROPOSAL No. 2

Optimize the contract demand power supply from PSPCL

As analyzed from the electricity bills of the complex, the Maximum Demand Index (MDI) is very less compared to contract demand.

Existing Scenario

- Contract Demand of the Complex = 2000 kVA
- MDI of Jan,2013 - Dec,2014 = 998 kVA
- Minimum monthly charges based on contract demand = Rs. 5,98,000
- PTU paid the energy bills of March, April, November & December 2013 on minimum monthly charges (MMC) bases.

Table-4.6: Monthly Energy Consumption Pattern

Month & Year *(As per bill cycle)*	MDI	kVAh	Total Energy *(kWh)*	Total Energy Bill *(Rs.)*	Actual Power factor	*(Rs./ kWh)*
Jan-13	633.34	163198	162504	10,31,126	Unity	6.34
Feb-13	626.80	151904	151088	9,66,350	0.99	6.39
Mar-13	**597.32**	**56082**	**55904**	**5,69,879**	**Unity**	**10.19**
Apr-13	**461.62**	**34992**	**34928**	**5,92,710**	**Unity**	**16.96**
May-13	998.24	104564	100824	7,06,796	0.96	7.0
June-13	973.42	138320	133424	9,85,030	0.96	7.38
July-13	952.90	163650	155956	11,78,309	0.95	7.55
Aug-13	931.82	149134	149812	10,55,090	0.94	7.04
Sep-14	931.7	153990	143290	10,11,740	0.93	7.06
Oct-14	828.18	118034	111042	7,88,680	0.94	7.10
Nov-14	**509.94**	**56418**	**54830**	**6,12,624**	**0.97**	**11.17**
Dec-14	**613.98**	**66298**	**66036**	**6,41,960**	**Unity**	**9.72**
		1356584	**1319638**	**1,01,40,294**	**0.96 (Average)**	

PTU management has got approval of contract demand of 2000 kVA based on the connected load is around 1950 kW, which includes, the load of stand by motors/equipments installed in the campus. Whereas, the MDI during the last one year has never exceeded 1000 kVA as shown in the table above. Therefore, the levy of monthly minimum charges (MMC) during the four months can be avoided by re-scheduling/optimizing the contract demand by declaring the connected load of standby equipment/motors & subsequently take approval

obtaining approval of PSPCL for the same. The annual MDI trend of PTU is as shown in figure-4.9.

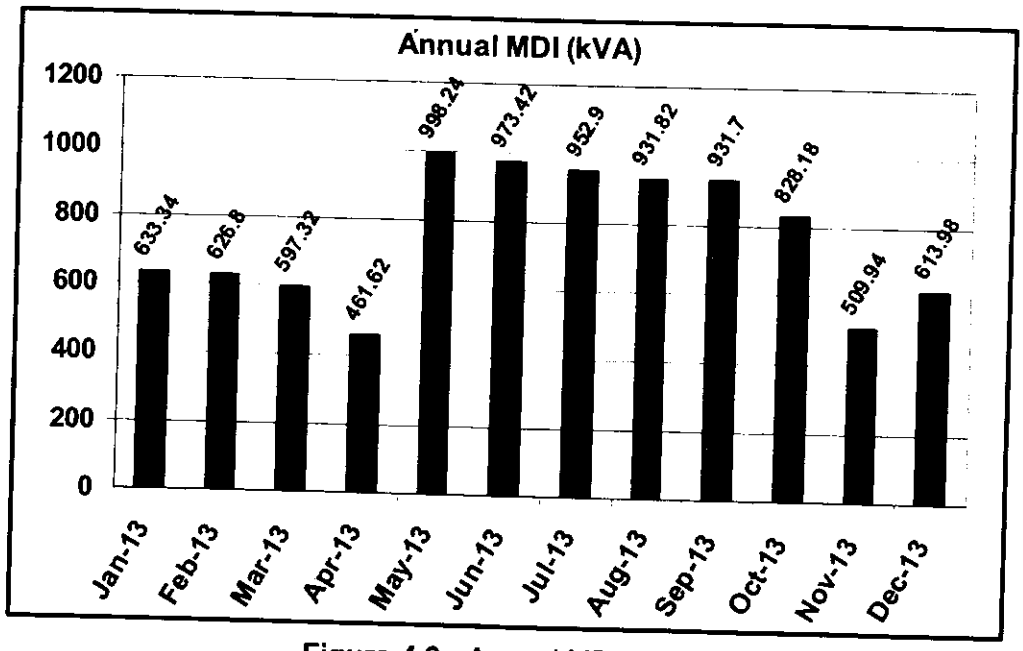


Figure-4.9: Annual MDI Trend

Recommendations:

- Reduce the contract demand of 2000 kVA to 1300 kVA from PSPCL

A. Savings Due to Recommendation

Month	Basic unit rate	Existing MMC (for 2000 kVA Contract Demand)	Energy Consumption	Energy Cost	Proposed MMC (for 1300 kVA Contract Demand)	Energy Cost After Reducing contract demand to 1300 kVA	Saving Potential
	Rs./kWh	Rs.	kWh	Rs.	Rs.	Rs.	
Jan-13	6.39	598000	162504	1038401	388700	1038401	0
Feb-13	6.39	598000	151088	965452	388700	965452	0
Mar-13	6.39	598000	**55904**	357227	388700	388700	209,300
Apr-13	6.39	598000	**34928**	223190	388700	388700	209,300
May-13	6.39	598000	100824	644265	388700	644265	0
Jun-13	6.39	598000	133424	852579	388700	852579	0
Jul-13	6.39	598000	155956	996559	388700	996559	0
Aug-13	6.39	598000	149812	957299	388700	957299	0
Sep-13	6.39	598000	143290	915623	388700	915623	0
Oct-13	6.39	598000	111042	709558	388700	709558	0
Nov-13	6.39	598000	**54830**	350364	388700	388700	209,300
Dec-13	6.39	598000	**66036**	421970	388700	421970	176,030
B. Savings due to Recommendation							**803,930**
C. Investment							**Nil**

Power Factor Analysis

The management has installed Automatic Power Factor Correction Panel (APFC panel) at transformer end and is maintaining power factor above 0.95. During the study, it was observed that Power Factor (PF) at 11 kV grid varied between 0.982 to 0.99 (figure-4.9). The Power Factor at 11kV transformer no. 1 was in the range of 0.988 to 0.998 during day time and 0.998 to unity at night time. The trend of power factor recorded during the study period *(during the day time)* at 11 kV main incomer & both the transformers is shown in figure-4.10, figure-4.11 & figure-4.12. However, the average Power factor analysed from the energy bills provided by the management for the period January 2013 to December 2013 is 0.968, which can be further improved to nearly unity. Improving the power factor at the mains would result in rebate from State Electricity Board (SEB).

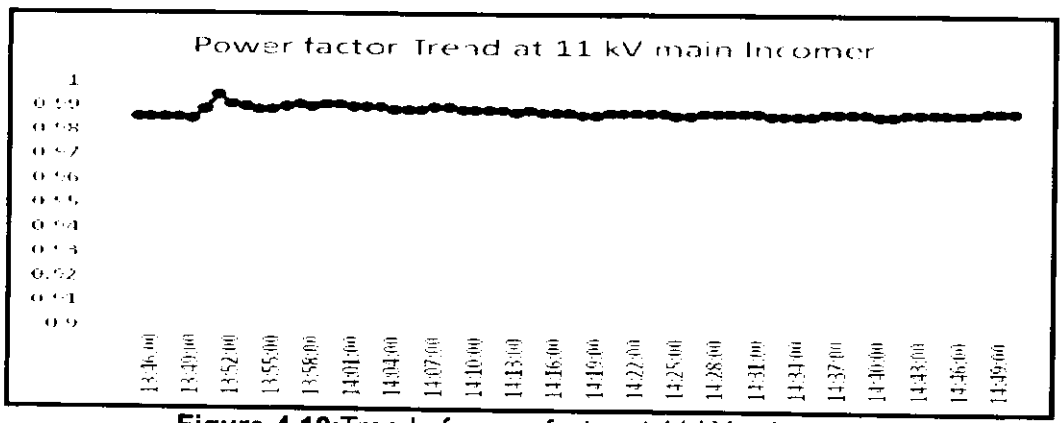


Figure-4.10:Trend of power factor at 11 kV sub station

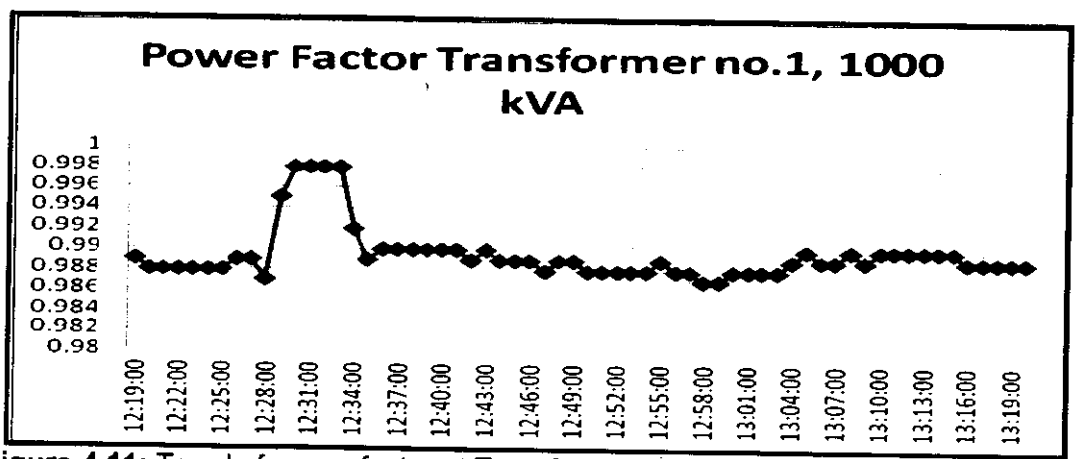


Figure-4.11: Trend of power factor at Transformer 1000 kVA Transformer1 (day time)

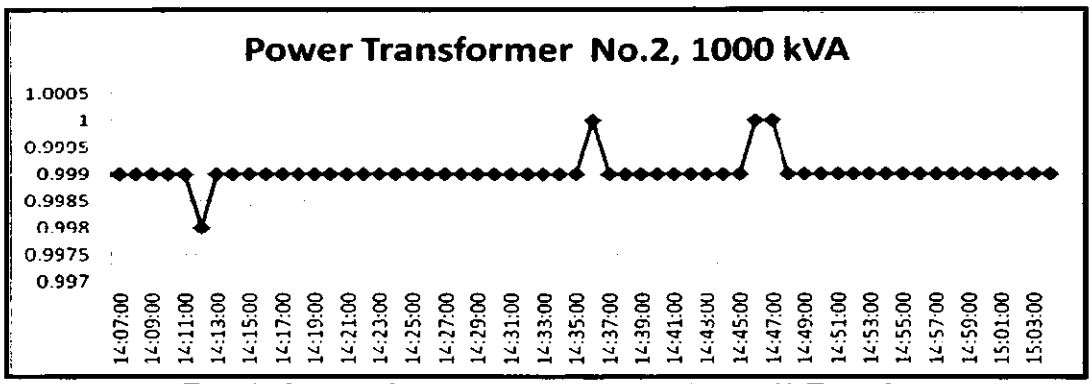


Figure-4.12: Trend of power factor at Transformer 1000 KVA Transformer 2 (day time)

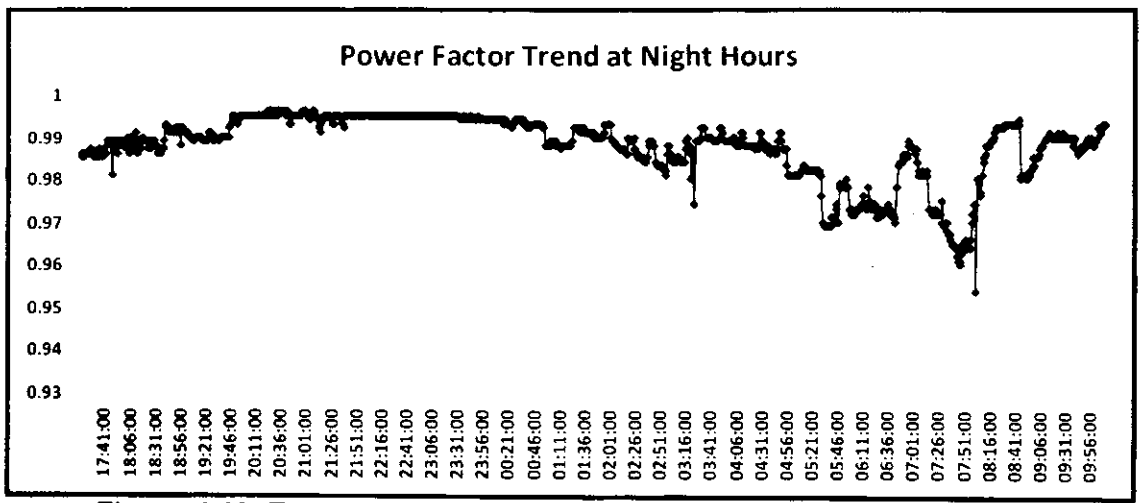


Figure-4.13: Trend of power factor at Transformer 1000 KVA (Night time)

It was noted that, each transformer has APFC panel of 350 kVAR with 6 capacitor banks of 25kVAR and 4 capacitor banks of 50 kVAR on each transformer. From the above, it is clear that the minimum capacity of capacitor bank is 25kVAR. Lot of fluctuations in the hourly power consumption have been observed during the study for which capacitor bank of small steps such as 2kVAR, 5kVAR & 10kVAR are recommended to maintain the power factor to near unity.

It is, therefore, proposed that 2 APFC Panels of small capacitor bank of 25 kVAR of small steps (10 kVAR x 1 nos, 5 kVAR x 3 nos) for both transformers of 1000 kVA be provided.

Capacitor Health Checkup

The output of all the capacitor banks installed in both the transformers at 11 kVA substations was checked with details as below:

Table-4.7: Capacitor Health Checkup 1000 KVA Transformer 1

Rated Parameters			Measured Parameters Current				
Capacitor No	kVAR @ 440V	kVAR @ 400V	Current	R	Y	B	Actual kVAR
C1	25	20.7	29.8	28.2	28.2	29.1	19.6
C2	25	20.7	29.8	27.9	28.6	28.3	19.1
C3	25	20.7	29.8	28.6	28.6	28.9	19.7
C4	25	20.7	29.8	27.2	28.3	28.8	19.4
C5	25	20.7	29.8	28.6	28.6	28.9	19.7
C6	25	20.7	29.8	27.5	27.7	28.5	19.2
C7	50	41.3	59.6	56.5	56	57.1	38.4
C8	50	41.3	59.6	28.8	57	56.7	33
C9	50	41.3	59.6	56.6	56.3	55.1	37.5
C10	50	41.3	59.6	55.8	56.7	56.8	38

Table-4.8: Capacitor Health Checkup 1000 KVA Transformer 2

Rated Parameters			Measured Parameters Current				
Capacitor No	kVAR @ 440V	kVAR @ 400V	Current	R	Y	B	Actual kVAR
C1	25	20.7	29.8	28.4	29.3	30.1	19.4
C2	25	20.7	29.8	28	27.7	28.2	18.88
C3	25	20.7	29.8	29	28.2	28.8	19.4
C4	25	20.7	29.8	28.1	28.6	29.3	19.8
C5	25	20.7	29.8	27.6	28.8	29	19.6
C6	25	20.7	29.8	28.5	28	28.4	19.4
C7	50	41.3	59.6	57.1	58.5	57.2	38.9
C8	50	41.3	59.6	55.4	57.8	57.2	38.5
C9	50	41.3	59.6	55.8	56.7	57.3	38.9
C10	50	41.3	59.6	56.8	57.8	57.6	39.2

The performance of all the capacitors at transformer no. 1 and transformer no. 2 was found to be satisfactory.

Recommendations

- Maintenance of existing APFC relay system
- Installation of small capacitors in the system to maintain the power factor as during the night, load is less and system required small sized capacitance to maintain the PF near unity.
- Therefore, add 10/5 kVAR capacitor banks in the system to maintain the PF near unity in night time also.

- Regularly, check the health of capacitor banks after every 15 days. If the output current of capacitors reduces less than 70%, the capacitor should be replaced with new capacitor.

Benefits

The annual savings potential is **Rs. 0.84 Lacs**. The investment required is **Rs. 0.50 Lacs**, which will be paid back in **7 Months**.

ENERGY SAVING PROPOSAL No. 3

Improve overall power factor to unity

It is possible to achieve power factor of unity at 0.4 KV sub-station by adding small capacitor banks in all the existing APFC panels. The energy saving potential has been worked out as under:

Table-4.9 : Saving Potential by Improving the Power Factor to Unity

Month & Year *(As per bill cycle)*	Energy Bill *(Rs.)*	Actual Power factor	Saving opportunity @ Unity PF
Jan-13	10,31,126	Unity	0
Feb-13	9,66,350	0.99	2,415
Mar-13	5,69,879	Unity	0
Apr-13	5,92,710	Unity	0
May-13	7,06,796	0.96	7,067
june-13	9,85,030	0.96	9,850
july-13	11,78,309	0.95	14,728
Aug-13	10,55,090	0.94	15,826
Sep-14	10,11,740	0.93	17,705
Oct-14	7,88,680	0.94	11,830
Nov-14	6,12,624	0.97	4,594
Dec-14	6,41,960	Unity	0
	1,01,40,294	**0.96 (Average)**	**84,015**

The %age saving in energy bill is feasible by improving the power factor to unity is worked out as under:

Table-4.10 : Saving Potential by Improving the Power Factor

Avg. Power Factor	Total Bill amount during the Last 1 Year	Saving Opportunity	
		PF = Unity	% age
0.968	1.01 Crores	0.84 Lacs	0.82 %

Annual Savings = **0.84 Lacs**

Investment = **Rs 0.50 Lacs**

(Investment estimated for 2 APFC Panels of small capacitor bank of 25 kVAR of small steps of (10 kVAR x 1 no, 5 kVAR x 3 Nos) for both 1000 kVA transformers @ Rs. 1000/ kVAR; necessary electrical modification, if required, @ Rs. 25000/transformer).

Payback = 7 **Months**

CHAPTER 5.0

HEATING, VENTILATION & AIRCONDITIONING SYSTEM

5.1 Chiller System

Heating, Ventilation Air Conditioning (HVAC) system is provided in Punjab Technical University Complex, Jalandhar mainly for Offices, Examination Room, meeting room and library for human comfort application. A detailed energy audit for the HVAC system of PTU was conducted. This plant consists of 4 air-cooled screw chillers with specifications given in the table-5.1 below:

Table-5.1: Details of Chilling Unit

System Details	Unit	Air cooled screw
Manufacturer	Climaventta, Italy	
Model No.	FOCS-3602/B-S	
Rated capacity at full load	TR	200
Installed capacity	TR	3 x 200 & 1x 50
Refrigerants		R134A
Drive motor name plate rating	kW	289.9
Voltage	V	400
Frequency	Hz	50

5.1.1 Vapour Compression Refrigeration system

The vapor compression refrigeration cycle for the chiller is given in the figure-5.1.

As shown, heat flows naturally from a hot to a colder body. In refrigeration system, the opposite must occur i.e. heat flow from a cold to a hotter body. This is achieved by using refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. The gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature source.

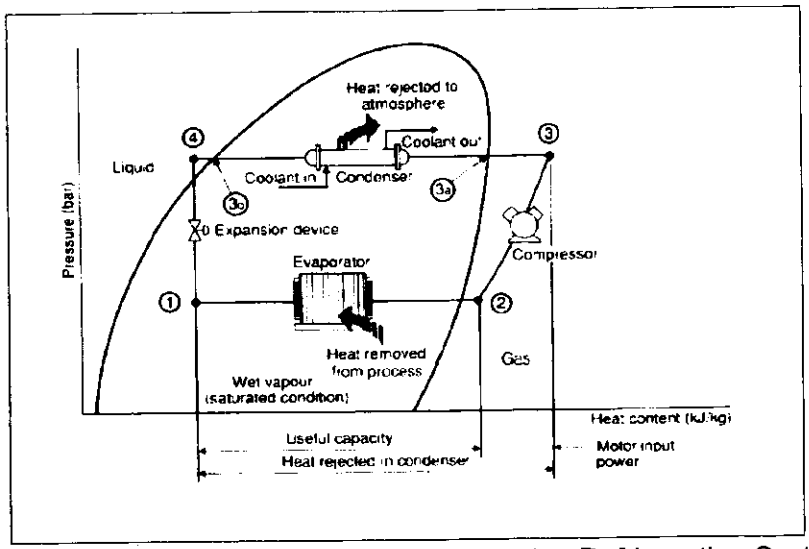


Figure-5.1: Schematic of a Basic Vapor Compression Refrigeration System

The refrigeration cycle can be broken down into the following stages (refer fig.-5.1)

1- 2: Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2- 3: The superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy input into the compression process is transferred to the refrigerant.

3-4: The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3 - 3a) de-superheats the gas' before it is then turned back into liquid (3a - 3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4–1: The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator.

It can be seen that the condenser has to be capable of rejecting the **combined heat** inputs of the evaporator and the compressor; i.e. (1 - 2) + (2 - 3) **has to be the same** as (3 - 4). There is no heat loss or gain through the expansion **device.**

5.2 Connected load pattern of HVAC system equipment

The connected load of HVAC system equipments *(including hot water generator)* is approximately 1640.55 kW. The details of different equipments installed are given in the table-5.2 below:

Table-5.2: Connected Load Details of HVACs

S. No	Description	Qty	Connected Load *(kW)*	Load *(% age)*
1	200 TR Air Cooled Chillers	3	869.7	53.02
2	50 TR Chiller	1	85.9	5.24
3	Fan Condenser for 200 TR Plant	12	52.20	3.18
4	Fan Condenser for 60 TR Plant	6	7.2	0.44
5	Secondary Pumps	3	45	2.74
6	Primary Pumps	4	22	1.34
7	Air Handling Units	41	143.45	8.74
8	CDS Pumps	2	11	0.67
9	Hot Water Generator	1	400	24.38
10	Load of Service lamps in AHU rooms	41	4.1	0.25
	Total		**1640.55**	

The chiller unit and hot water generator operates during the summer and winter months respectively. Therefore, connected load of the HVACs during the summer is 1240.6 kW whereas in winters the connected load of heating system is 592 kW.

3 no. of capacity 200 TR each & 1 no. chiller of 50TR capacity have been installed to meet the cooling load of the facility. The HVAC plant is operated from May to September of every summer season. One chiller plant is operated from may to mid of june & two chiller plants are operated from mid june to end of September. Again only one plant is operated in the month of October.At the time of study also, two chillers were in operation which were connected to a centralized network as illustrated in figure-5.2 below.

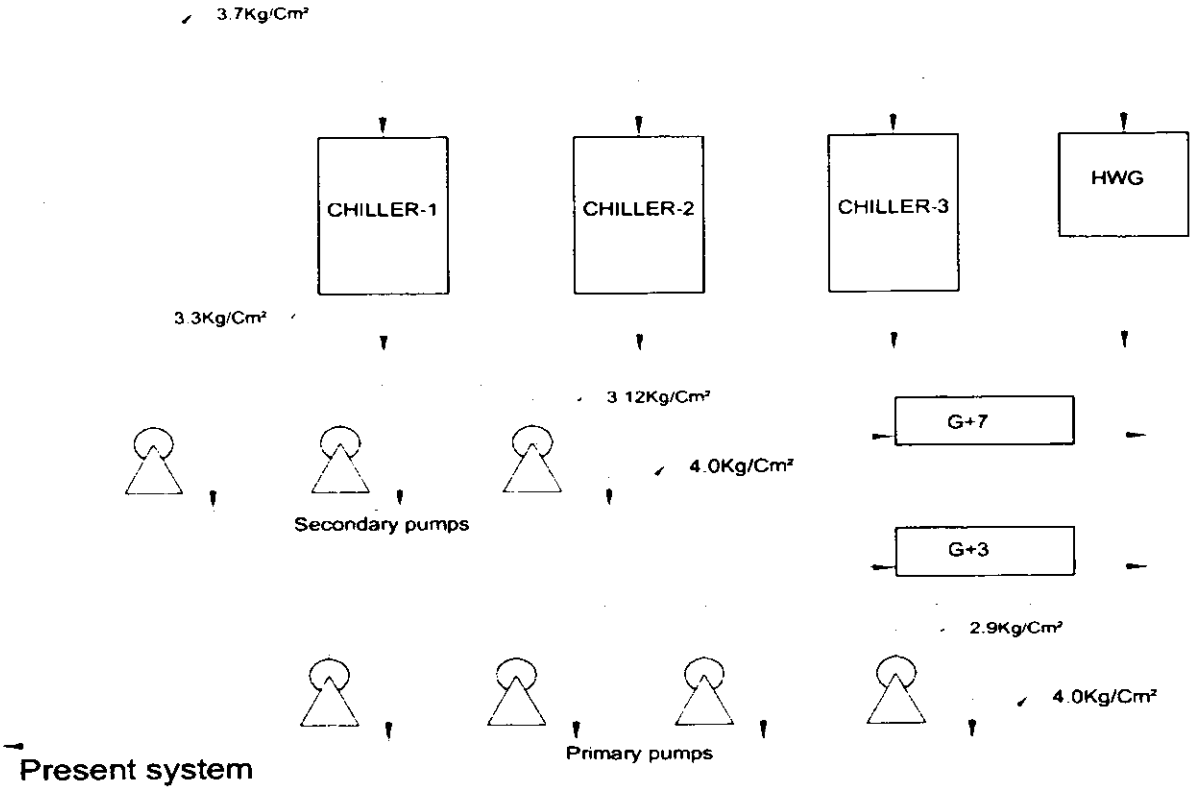


Figure-5.2: Centralized Chiller system for facility

5.2.1 Observations

During the study, chiller 1 & chiller 2 were in operation. The operating parameters of both the 200TR air-cooled screw chiller were monitored at normal load condition. The chilled water temperature in supply line (input) and return line (output) were monitored and also noted from the control panel of chillers. Similarly operating electrical parameters of compressors mainly voltage, current, power factor and kW were measured by using portable power analyser. Chilled water flow rate was monitored by using ultrasonic flow meter. The electrical parameters measured are given in table-5.3 below:

Table-5.3: Electrical Parameters Measurement

	Voltage *(V)*	Current *(Amps)*	PF *(%age)*	Power *(kW)*
Chiller No.1	386	470	0.87	273
Chiller No.2	386	330	0.86	183

The average specific power consumption (kW/TR) of chiller1 & chiller 2 was calculated in table-5.3(a) & 5.3 (b) given below:

Table-5.3 (a): Specific Power Consumption of Chiller-1

Power Consumption (kW)	Inlet Chilled Water Temperature (°C)	Outlet Chilled Water Temperature (°C)	Chilled Water Flow (m^3/hr)	TR Generated	SEC (kW/TR)
273	12.4	7.1	114	200	1.37
273	12.5	7.2	114	200	1.37
275	12.8	7.4	114	204	1.35
276	12.7	7.3	114	204	1.36
273	12.2	7.0	114	196	1.39
270	12.9	7.8	114	192	1.40
278	12.6	7.3	114	200	1.39
273	12.6	7.4	114	196	1.39
174	11.4	6.9	80	119	1.46

Table-5.3 (b): Specific Power Consumption of Chiller-2

Power Consumption (kW)	Inlet Chilled Water Temperature (°C)	Outlet Chilled Water Temperature (°C)	Chilled Water Flow (m^3/Hr)	TR Generated	SEC (kW/TR)
183	12.2	8.8	123	138	1.32
190	12.5	9	123	142	1.33
195	12.2	8.6	123	146	1.33
173	12	8.9	123	126	1.37
170	11.9	9	123	118	1.44
180	12.9	9.4	123	142	1.26

The SEC of chiller-1 & chiller-2 was observed in the range of 1.35 to 1.45 kW/TR and 1.26 to 1.44 kW/TR. Designed parameters were not available for the comparison. Whereas, the specific energy consumption (SEC) of water cooled screw chillers of same capacity is reported to be less than 0.7 kW/TR.

5.3 Air Handling Unit (AHU) System

Air handling units are installed to maintain a clean environment with controlled temperature and relative humidity in the process areas. 41 AHUs have been installed to maintain a room condition of 22 ± 2°C and 55%± 5%

relative humidity for G+3 & G+7 buildings. During the energy audit, 6 nos. of AHUs were covered to evaluate the performance.

Table-5.4: Details of AHUs installed in the complex

Sr. No	AHU No.	Area Name	Capacity *(CFM)*	Motor Input. *(kW)*
1	AHU-1	Ground Floor(G+7)	6,000	2.2
2	AHU-2	Ground Floor(G+7)	5,000	2.2
3	AHU-3	First Floor(G+7)	5,000	2.2
4	AHU-4	First Floor(G+7)	8,000	3.7
5	AHU-5	First Floor(G+7)	8,000	3.7
6	AHU-6	First Floor(G+7)	8,000	3.7
7	AHU-7	Second Floor(G+7)	7,000	3.7
8	AHU-8	Second Floor(G+7)	7,000	3.7
9	AHU-9	Second Floor(G+7)	7,000	3.7
10	AHU-10	Second Floor(G+7)	8,000	3.7
11	AHU-11	Third Floor(G+7)	8,000	3.7
12	AHU-12	Third Floor(G+7)	7,000	3.7
13	AHU-13	Third Floor(G+7)	7,000	3.7
14	AHU-14	Third Floor(G+7)	8,000	3.7
15	AHU-15	Fourth Floor(G+7)	8,000	3.7
16	AHU-16	Fourth Floor(G+7)	7,000	3.7
17	AHU-17	Fourth Floor(G+7)	7,000	3.7
18	AHU-18	Fourth Floor(G+7)	8,000	3.7
19	AHU-19	Fifth Floor(G+7)	10,000	5.5
20	AHU-20	Fifth Floor(G+7)	8,000	3.7
21	AHU-21	Fifth Floor(G+7)	7,000	3.7
22	AHU-22	Fifth Floor(G+7)	6,000	2.2
23	AHU-23	Sixth Floor(G+7)	8,000	5.5
24	AHU-24	Sixth Floor(G+7)	7,000	3.7
25	AHU-25	Sixth Floor(G+7)	7,000	3.7
26	AHU-26	Sixth Floor(G+7)	6,000	2.2
27	AHU-27	Seventh Floor(G+7)	10,000	2.2
28	AHU-28	Seventh Floor(G+7	7,000	3.7
29	AHU-29	Seventh Floor(G+7	4,000	5.5
30	AHU-30	Ground Floor(G+3)	2,000	2.2
31	AHU-31	Ground Floor(G+3)	1,600	1.1
32	AHU-32	Ground Floor(G+3)	5,000	0.75

33	AHU-33	First Floor(G+3)	5,000	2.2
34	AHU-34	First Floor(G+3)	8,000	3.7
35	AHU-35	First Floor(G+3)	10,000	5.5
36	AHU-36	Second Floor(G+3)	8,000	2.2
37	AHU-37	Second Floor(G+3)	5,000	3.7
38	AHU-38	Second Floor(G+3)	10,000	5.5
39	AHU-39	Third Floor(G+3)	5,000	3.7
40	AHU-40	Third Floor(G+3)	8,000	2.2
41	AHU-41	Third Floor(G+3)	10,000	5.5

The air handling systems are located on respective floor or zone in order to facilitate maintenance without disturbance to the process area. A fresh air window is provided in each of the AHU room for mixing it with return air. The AHUs are installed to cater the human comfort-cooling requirement in complex.

The temperature & relative humidity of both delivery air & return air from AHU were measured using hygrometer. The average air velocity across the coil was also checked using anemometer. The measured parameters are given in the table-5.5 below:

Table-5.5: Measured Values of AHU

S.No	Description	Units	AHU 28	AHU 19	AHU 14	AHU 41
1	Filter area	m^2	0.475	0.645	0.57	0.684
2	Supply air dry bulb temperature	°C	20.6	22.8	19.3	18
3	Supply air Relative humidity	%	52	48	48	48
4	Return air dry bulb temperature	°C	27.8	25.8	25.5	26.2
5	Return air Relative humidity	%	61.4	58	58	55.6
6	Air velocity	m/s	4.2	6.5	3.6	8.25

The overall kW/TR of HVAC System was calculated as 1.46

Overall kW/TR (chiller1 + chiller2) = (Total kW)/Total tonnage
= [(kW) chiller1+ (kW) chiller2 + (kW) Primary Pumps + (kW) Secondary Pumps]/ Total Tonnage generated
= (273+176+8.4+12.36)/318
= 1.50 kW/TR

5.4 Recommendations

- It is proposed to replace one existing air cooled screw chiller 1 with water cooled screw chillers which can be operated from May to October.
- One existing air cooled screw chiller can be used during the months of June to September in addition to the proposed water cooled plant.

5.5 Benefits

The implementation of above recommendations has a saving potential of Rs. 11.52 Lacs. The investment for one new water cooled screw chiller, condenser pumps & cooling tower would be Rs. 35.0 lacs. However, the salvage value of existing air cooled screw chiller would be Rs. 10.0 lacs and the net investment required would be Rs. 25 lacs only. This gets paid back within **2.1 Years**.

ENERGY SAVING PROPOSAL NO 4

Replace existing Chiller1 with water cooled screw chiller.

During the detailed energy audit two of the 200 TR chillers were studied to evaluate the saving potential by replacing existing chillers with water cooled screw chillers.

The energy consumption pattern of chiller no. 1 at normal running load was recorded and is given in the figure-5.3 below:

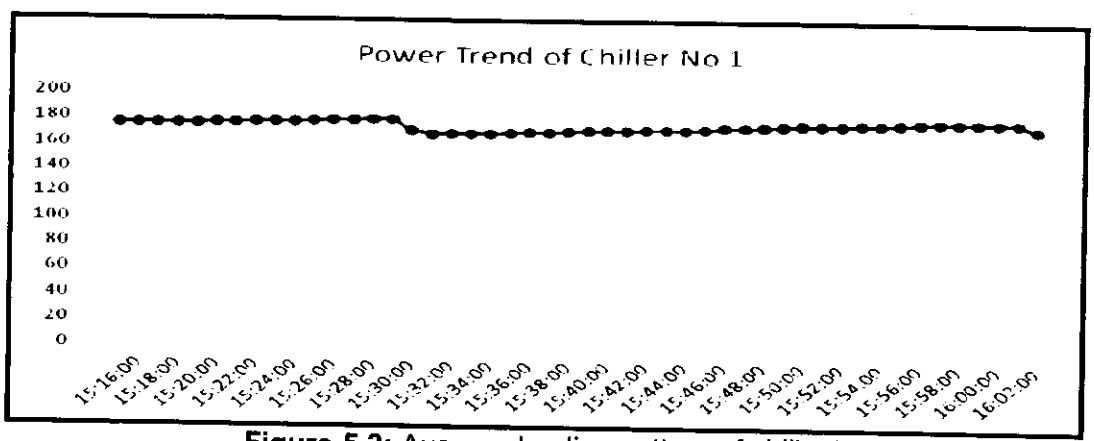


Figure-5.3: Average loading pattern of chiller1

The average power consumption and the TR generated by chiller-1 during the monitoring period was recorded as 273 kW and 200 TR, respectively. Therefore, the average energy consumption worked out to be 1.36 kW/TR. However, the energy consumption of 2 no. chilled primary water pumps was 8.4 kW & power consumption of secondary water pump was 12.36kW respectively. Thus average energy consumption for chiller plant-I works out to be 1.46 kW/TR.

PSCST had recently conducted energy audit of water cooled chillers of capacity 350 TR wherein specific energy consumption of chiller was found to be as low as 0.495 kW /TR. The same can be corroborated with technical literature wherein recommended SEC of similar water cooled chillers at full load is 0.64 kW /TR or less. Further, as per efficiency recommendations Air Conditioning & Refrigeration Institute (ARI) standard 550/590, the recommended full load SEC of air cooled chillers with screw compressor of capacity upto 200 tones is 1.23 kW /TR or less.

The existing air cooled screw chillers are operating at the SEC of 1.46 kW /TR. Replacement of existing system with water cooled screw chiller will reduce the SEC by 0.6 kW/TR.

Recommendation

It is therefore recommended to replace one existing air cooled chiller used from May to September with water cooled screw chillers.

Benefits

Energy Consumption of existing Air Cooled Screw Chiller Plant	=	1.46 kW/TR
Energy Consumption of proposed Water Cooled Screw Chiller Plant	=	0.86 kW/TR
Energy consumption reduction	=	{1.46-0.86} kW/TR
	=	0.6 kW/TR
Operating hours	=	1250 hrs/year
Annual savings	=	*0.6 kW/TR x 200 TR x 1250 hrs/ year x Rs 7.68 /unit*
	=	**Rs. 11.52 Lacs**
Investment *(Investment estimated for 1 new water cooled Screw chillers 200 TR each, condenser water pumps and cooling towers)*	=	**Rs. 35.0 Lacs**
Salvage value of existing chillers	=	**Rs. 10.0 Lacs**
Payback	=	**2.1 Years**

The annual saving potential is **Rs. 11.52 Lacs**, which requires investment of **Rs. 0.25 Lacs**. This gets paid back within **2.1 Years**.

ENERGY SAVING PROPOSAL NO 5

Modify chilled water circulation system and eliminate use of primary pumps.

The performance of the existing operation of the primary chilled water pumps and secondary chilled water pumps was analysed. Four primary chilled water pumps are installed before the chillers and three secondary pumps are installed after the chillers as illustrated in figure-5.4 below. Out of these, 2 primary pumps and 1 secondary pumps were in operation during the audit. The rated/design and measured values of chilled water pumping system is given in the Table-5.6.

Table-5.6: Parameters for Chilled Water Circulation Pumping Network

S.No	Unit	Rated Values				Measured Values				
		Q (m^3/hr)	H (m)	kW	Efficiency (%)	Q (m^3/hr)	H suction (kg/cm^2)	H discharge (kg/cm^2)	kW	Efficiency (%age)
1	Primary Pump 1	109.39	12	5.5	65	79.66	2.9	4.0	4.2	57.06
2	Primary Pump 2	109.39	12	5.5	65	79.66	2.9	4.0	4.1	58.45
3	Primary Pump 3	109.39	12	5.5	65	79.66	2.9	4.0	4.1	56.06
4	Secondary Pump	NA	NA	NA	NA	240	3.1	3.7	12.36	26.35

Analysis:

The chilled water circulation pump transfers the chilled water in the circulation circuit of the network. The chilled water from chillers is pumped by the secondary pumps to AHUs for G+7 & G+3. The water is returned by gravity flow at the inlet of primary pumps. Primary pumps are used to pump the water to the condensers of the chillers as illustrated in figure below. As seen from the above table, the measured head at the inlet of primary pumps is already high *(more than 2.9 kg/cm^2)*. Therefore, return chilled water of AHUs can be directly sent to the chillers, bypassing the primary chilled water pumps. However, the primary pumps can be used during exigencies by providing pressure switch with transmitter, when available head at the outlet of secondary pumps is less than the required head.

Present System

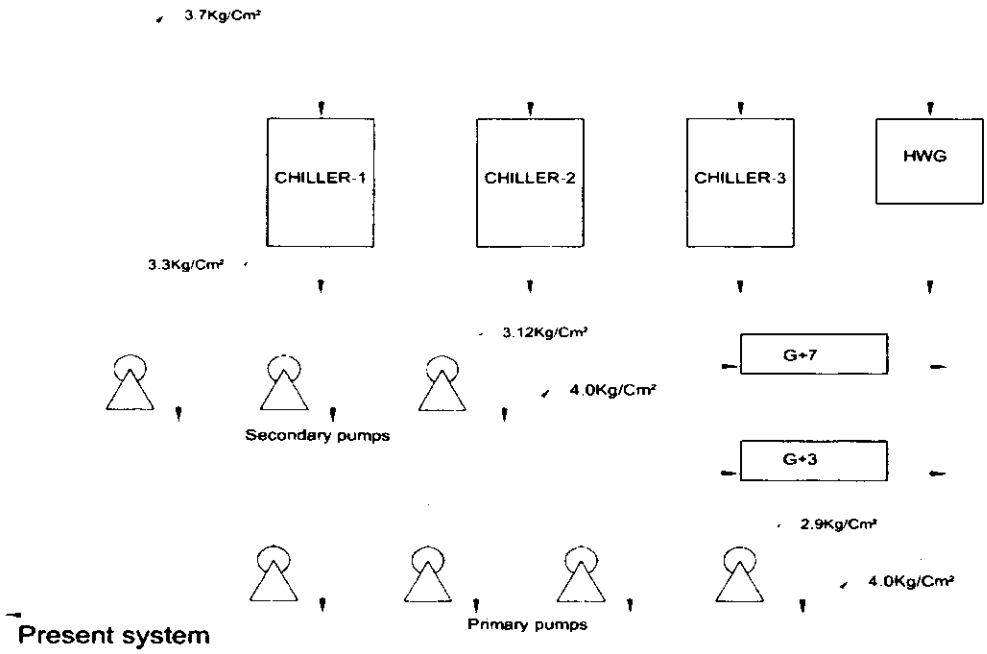


Figure-5.4: Present Chilled Water Circulation System of HVAC Plant

Proposed System

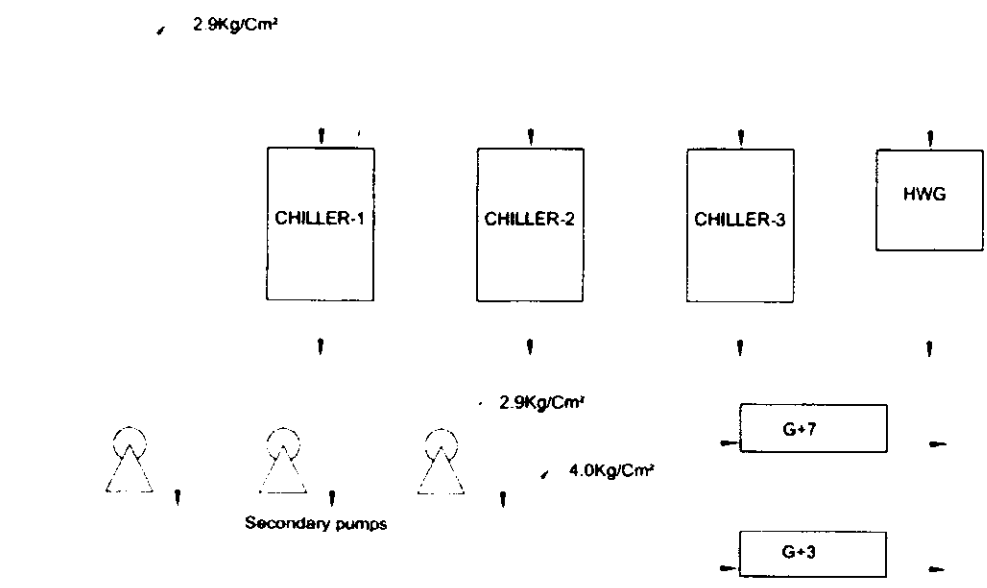


Figure-5.5: Proposed Chilled Water Circulation System of HVAC Plant

Recommendations

- Eliminate the use of primary chilled water pumps.
- Feed the return water of AHUs directly to the inlet of chillers

Benefits

Operating hours	=	10 Hrs/day x 25 days x 5 months
	=	1250 hrs/year
Saving potential by eliminating primary pumps	=	8.4 kW
Annual savings	=	8.4 kW x 1250 hrs/ year x Rs. 7.68/ unit
	=	**Rs. 0.80 lacs**
Investment *(Estimated investment for modification of existing chilled water line)*	=	0.50 Lacs
Payback	=	8 months

The annual saving potential is **Rs. 0.80 Lacs**, which requires investment of **Rs.0.50 Lacs**. This gets paid back within **8 Months**.

CHAPTER 6.0
DIESEL GENERATOR

Three Diesel Generator sets have been installed to takecare backup electrical power in case of power failure. Rating of 2 DG sets is 350 kVA each and 1 DG set is 62.5 kVA. Performance analysis was carried out on DG sets-of 350 kVA to check the specific power generation of DGs.

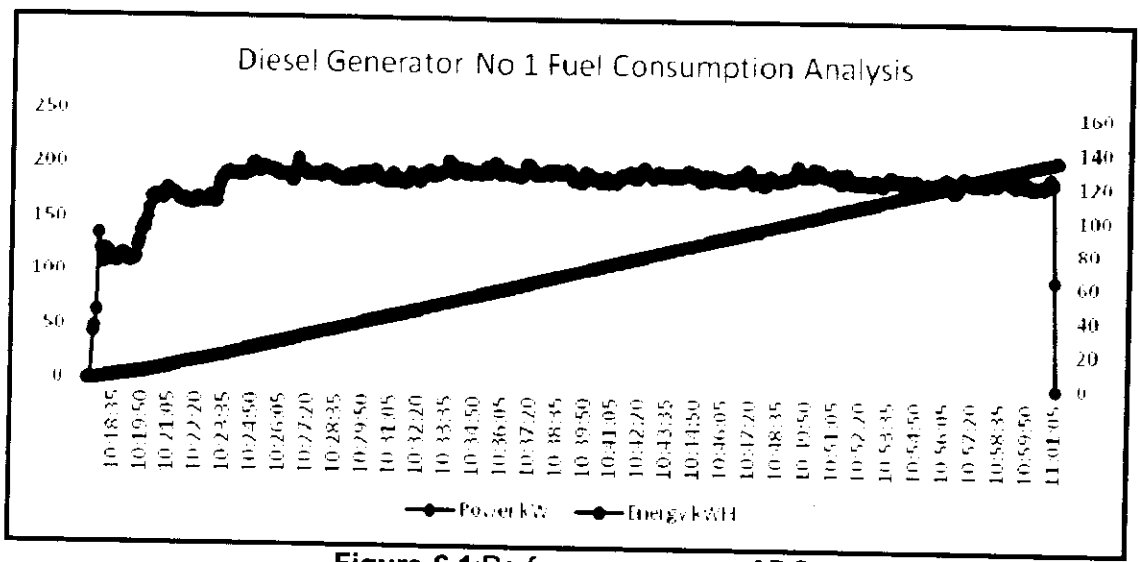


Figure-6.1:Performance curve of DG set-1

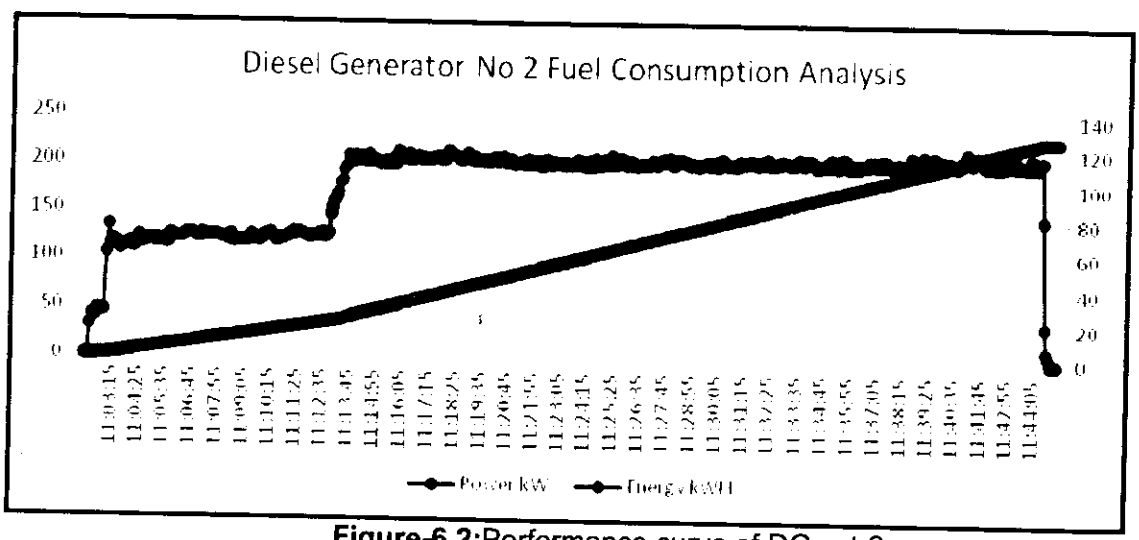


Figure-6.2: Performance curve of DG set-2

In the figures above, blue (upper) line is showing average loading in kW on the DG and red (below) line is showing units generated in kWh by DG set. The Specific Power Generation was worked out as given in the table-6.1 below. The average loading of DG set 1 was 190-200 KVA & the loading of DG set 2 was 200-210 KVA. The average loading of the DG sets was found to be in the range 55-60%.

Table-6.1: Calculation of Specific Power Generation of DG set

Description	Units	DG-1	DG-2
Energy Meter			
Start Reading	kWh	33317	58319
Stop Reading	kWh	33459	58456
Total Units Generated	kWh	142	137
Total Fuel Consumed	Litres	40.3	37.5
Specific Power Generation	kWh/Liter	3.52	3.65

The Specific Power Generation of DG set-1 and DG set-2 was observed as 3.52 kWh/litre and 3.65 kWh/litre respectively, which is above the minimum recommended level of 3.50 kWh/litre. Therefore, the performance of DG sets is satisfactory.

However, it is recommended that Maintenance/ overhauling of DG sets are to be carried out periodically to maximize the sp. power generation.

Chapter 7.0
LIGHTING

The Lighting system and illumination in different areas of Complex was studied in detail. The total connected lighting load of the complex was 178.65 kW with its distribution as under:

Indoor light load - 160 kW
Outdoor light load - 18.65 kW

The indoor lights installed in the complex are 18 Watt & 36 Watt tubes and 18 Watt CFL .The various type of light fixtures installed in the indoor and outdoor lights are given in Table-7.1 below:

Table-7.1: Details of Indoor & Outdoor Light Fixtures

S No.	Type of Fixture	Quantity
A	**Indoor Lights**	
1.	4x18 E. Tube set (PH)	238
2.	1x36 E. Tube set (PH	699
3.	2x36 E. Tube set (PH)	652
4.	2x36 box type. Tube set (PH)	28
5.	1x36 box Tube set (PH)	334
6.	2x18 CFL	1007
7.	1x18 CFL	111
8.	70 W Halide lamp	16
B.	**Outdoor Lights**	
1.	HPSV lamps at 6 meter pole	56
2.	CFL lamps at 4 meter pole	7
3.	Mercury vapour lamps at hump pipes	3
4.	HPSV lamps at 3 meter pole	63
5.	CFL lamps at 1 meter environment lighting	36
6.	HPSV face light	12

As detailed above, the indoor lighting is mostly based on fluorescent tube lights/CFLs. Whereas, sodium vapour lamps/ CFLs have been used for outdoor lighting. As per Bureau of Energy Efficiency (BEE) recommendations, LED tube light fittings provide more lumens and are energy efficient. The LED

fixtures can be replaced within the existing fittings directly. Further, the use of LEDs will also improve power factor in the supply grid.

During the audit, the operation of lights during the day and night time was studied for identifying feasibility of energy conservation in lighting system. The lux levels of lighting in indoor and outdoor area, both during day time and night time were also monitored using lux meter. The average lux levels in various areas are given in table-7.2. It was also observed that the occupancy level is negligible in washrooms and lights are kept ON.

Table-7.2: Measured Lux Levels at Various Locations in the Complex

Area	Lux Level	Fixtures
Banquet Hall	300	FTLs*(4x18 W)* : 58 nos. , FTLs *(2x36 W)* : 10 nos.
Washroom	50	FTLs *(2x36 W)* : 60 nos.
VIP Canteen	120	FTLs *(4x18W)* : 28 nos. FTLs *(28 W)* : 2 nos.
Canteen	100	FTLs *(1x36W)* : 20 nos.
7th Floor, Distance Education Store	120	FTLs *(2x36W,1x36)* : 78 nos.
6th Floor	Not in operation	FTLs *(2x36W,1x36)* : 78 nos.
5th Floor	150	FTLs *(2x36 W)* : 25 nos
4th Floor	120	FTLs *(2x36W,1x36)* : 78 nos.
3rd Floor	120	FTLs *(2x36W,1x36)* : 78 nos.
2nd Floor	120	FTLs *(2x36W,1x36)* : 78 nos.
1st Floor	120	FTLs *(2x36W,1x36)* : 78 nos.
Ground Floor	120	FTLs *(2x36W,1x36)* : 78 nos.
VC Office	120	FTLs *(2x36W,1x36)* : 78 nos.

7.1 Observations

- Around 3400 nos. of 36 watts (T8) & 18 watts Fluorescent Tube Light (FTL) fixtures with electronic chokes are being used for illumination at different areas. Out of these, 2400 are T8 fixtures and 1000 are 18 watts FTL fixtures. Majority of light fixtures are installed in storage rooms/non occupied area which are in use for short duration. Out of the total lights, approximately 35% of the T8 FTL fixtures and 50% of the 18 W FTLs fixtures are commonly used during the day time which can be replaced with the 18W LED fixtures and 9W LED fixtures respectively. The power consumption of remaining fixtures in the stores/un occupied areas can be further reduced by controlling additional light operation/ optimising its operation by installing the sensors.

- 56 nos. of 150 watts High Pressure Sodium Vapour (HPSV) and 63 nos of 70 watts fixtures are being used for street light illumination at different areas. These fixtures are reported to be with Copper Chokes. The 150W HPSV fixtures can be replaced with the 60W LED lamps and 70W HPSV fixtures can be replaced with the 30W LED lamps.

7.2 *Recommendations*

- **Proposal No. 6:** Replace 800 nos. of 36W FTL's & 500 nos. of 18W FTL's with 18W LED tube light fittings & 9W LED tube lights, respectively, which remain operational most of the time in indoor lighting, in a phased manner under the fault replacement policy.
- **Proposal No. 7:** Replace 56 nos. of 150W High Pressure Sodium Vapour (HPSV) fixtures & 63 nos. 70W fixtures with 60W & 30W LED fittings respectively in outdoor lighting.
- **Proposal No. 8:** Iinstallation of occupancy sensor in washrooms and stores.

7.3 *Benefits*

The implementation of above recommendations has a saving potential of **Rs. 7.26 Lacs** with an investment of **Rs. 23.55 Lacs**. The recommendations wise details are as under:

Recommendation	Saving Potential	Investment	Payback Period
Recommendation 6	Rs. 5.32 Lacs	Rs. 12.55 Lacs	28 months
Recommendation 7	Rs. 3.68 Lacs	Rs. 10.0 Lacs	33 months
Recommendation 8	Rs. 1.0 lac	Rs. 1.0 lac	12 months

Energy Saving Proposal no. 6

Replace 800 nos 36 watts with 18 watts LED fluorescent tube lights and 500 nos. of 18 watts fixtures with 9 watts LED tube lights

Approximately 800 nos. of 36W & 500 nos. of 18W Fluorescent Tube Light fixtures are commonly used for illumination of different indoor areas. These fixtures are with electronic chokes. These fittings can be replaced with 18 watts & 9 watts LED Tube light fittings directly.

The advantages of LED tube light fittings are:

- It gives equivalent/more lumens output while consuming less power.
- It has better colour rendering index and gives more bright light
- It Improves Power factor (approx. 0.95 lag.) across the supply grid.

Recommendation

There is a potential of savings by replacing existing fittings with new energy efficient LED fittings Moreover, the LED based fittings have average life of more than 50,000 hrs.

Benefits

Replacement of 800 nos 36 watts fluorescent tube lights with 18 watts LED

Power Consumption Data of 1 fixture

Existing Fixture	=	40 W
Proposed (LED based)	=	18 W
Power saving per fitting	=	40-18 W
	=	22 W
Total No. of fittings	=	800 nos.
Total Savings Potential	=	22W x 800 nos.
	=	17.6 kW
Annual savings	=	17.6 kWx3000hrs.x Rs7.68/Unit
	=	**Rs 4.05 Lacs**
Investment *(Investment estimated for 800 new LED fixtures and necessary electrical modification if required in the system @ Rs. 1100 /fixture)*	=	**Rs 8.8 Lacs**
Payback	=	**2.17 years**

Replace 500 nos 18 watts fluorescent tube lights with 9 watts LED

Benefits

Power Consumption Data of 1 fixture

Existing Fixture	=	20 W
Proposed Fixture (LED)	=	9 W
Power saving per fitting	=	20-9 W
	=	11 W
Total No. of fittings	=	500 nos.
Total Savings Potential	=	11W x 500 nos.
	=	5.5 kW
Annual savings	=	5.5 kWx 3000hrs.x Rs 7.68/Unit
	=	**Rs 1.27 Lacs**
Investment *(Investment estimated for 500 new 9 watts LED fixtures and necessary electrical modification if required in the system @ Rs. 750 /fixture)*	=	**Rs 3.75 Lacs**
Payback period	=	**2.95 years**

The annual savings potential is **Rs 1.27 Lacs**. The investment required is **Rs. 3.75 Lacs**, which will be paid back in **2.95 Years**.

ENERGY SAVING PROPOSAL NO 7

Replace 150W HPSV street lights with 60 watts LED & 70W HPSV with 30W LED street lights.

56 nos. of 150 watts High Pressure Sodium Vapour (HPSV) fixtures & 63 nos. of 70 watts fixtures are being used for street light illumination at different areas. These fixtures are with traditional Copper Chokes. We can replace 150W HPSV fixtures with 60W LED lamps & 70W HPSV fixtures with 30W LED lamps.

LED fixtures have the following advantages –

- Gives equivalent/more lumens output while consuming very less power.
- Better Colour rendering index.
- Gives more bright light
- Improved Power factor (approx. 0.95 lag.)
- Life of the LED lamps is 50,000 hours (10 years) whereas, the life of HPSV lamp is 15,000 hours (4 years).

Benefits

Replacement 56 nos 150 watts High Pressure Sodium Vapor fixtures with 30 watts LED

Power Consumption Data of 1 fixture

Existing Fixture	=	165 W
Proposed (LED based)	=	60 W
Power saving per fitting	=	165-60 W
	=	105 W
Total No. Of fittings	=	56 nos.
Total Savings Possible	=	105 W x 56 nos.
	=	5.9 kW
Annual savings	=	5.9 kW x 3650 hrs. X Rs 7.68 /Unit
	=	**Rs 1.65 Lacs**
Saving on account of reduction in the repair/ maintenance/replacement @ Rs. 1000/- per HPSV lamp per annum	=	**Rs. 0.56 lacs**
Total Annual Saving	=	**Rs. 2.21 lacs**
Investment *(Investment estimated for 56 new LED street lights and necessary electrical modification if required in the system at the rate of Rs.10,000 / street light)*	=	**Rs 5.6 Lacs**
Payback	=	**2.5 years**

Replace 63 nos 70 watts lighting fixtures with 30 watts LED

Power Consumption Data of 1 fixture		
Existing Fixture	=	77 W
Proposed (LED based)	=	30 W
Power saving per fitting	=	77-30 W
	=	47 W
Total No. Of fittings	=	63 nos.
Total Savings Possible	=	47 W x 63 nos.
	=	3.0 kW
Annual savings	=	3.0 kW x 3650 hrs. X Rs 7.68/Unit
	=	**Rs 0.84 Lacs**
Saving on account of reduction in the repair/ maintenance/replacement @ Rs. 1000/- per HPSV lamp per annum	=	**Rs. 0.63 lacs**
Total Annual Saving	=	**Rs. 1.47 lacs**
Investment *(Investment estimated for 63 new LED street lights and necessary electrical modification if required in the system at the rate of Rs. 7,000 / street light)*	=	**Rs 4.41 Lacs**
Payback period	=	**3.0 years**

ENERGY SAVING PROPOSAL NO 8

Optimize power consumption of lighting by automation

During audit, it was observed that the occupancy in washrooms is very low. Therefore the lights remain ON continuously. Each Washroom has 3 nos. of 2x36 watt lighting fixtures. The total connected load of washrooms is about 12 kW.

Recommendation

It is recommended to optimize power consumption of washroom lighting system by identifying and removal of unwanted/extra lights and by installing occupancy sensors. It is estimated that there would be around 30% reduction in the energy in the washrooms by installation of occupancy sensors.

Benefits

Annual Savings = 12 kW x 30% x12 hrs.x 300 days/annum x Rs.7.68/Unit
= **Rs.1.0 Lacs**

Investment = **Rs. 1.0 Lacs**
(For Occupancy Sensors)

Simple Payback = **1 year**

The total annual saving potential is **Rs. 1.0 lacs**. The investment required is **Rs. 1.0 Lacs**, which will be paid back in 1.0 **year.**

Chapter 8.0

OTHER OBSERVATIONS

Optimize power consumption of lighting by switching off indoor lights in night.

As per the data provided by Punjab Technical University in the questionnaire, the indoor lights are kept ON from 8:30 AM to 5:30 PM during day time & outdoor lights are kept ON from 7:00 PM to 5:30 AM. The total connected load of the outdoor lighting is 18 kW. However, during the energy audit, it was observed that in most of the areas, the indoor lights during night time were also kept ON & the total working load during the night (i.e. 7:00 PM to 5:00 AM) was in the range of 34-44 kW and the load from 5:00 AM to 8:00 AM reduced to 17-22 kW due to switching off the outdoor lights.

As per the total connected load of outdoor lighting, the total working load during night should not exceed 20 kW/hr. The unwanted indoor lights can be switched off during the night/non working hours which will result in saving of at least 5 kW/hr.

Recommendations

Switch off the indoor lights during night/non-working period.

Benefits

Total working load measured during night *(7:00 PM to 5:00 AM)*	=	34-44 kW
Total connected/working load of outdoor lights	=	18 kW
Power Consumption of indoor lighting during night time	=	10-15 kW
Saving Potential by Switching off the indoor lights	=	5 kW
Annual Savings	=	5 kW/hr x 3000 hrs.x Rs. 7.68/unit
	=	**Rs. 1.15 lacs**
Investment	=	**Nil**
Payback	=	Nil

CHAPTER 9.0
MANAGEMENT ASPECTS & CONCLUSIONS

9.1 *Objectives of Punjab Technical University, Kapurthala should be*

- To have a firm top management commitment so that the complex achieves energy conservation on a time bound basis.
- To make Energy conservation a permanent activity
- To achieve lowest auxiliary energy consumption.
- To achieve the status of best energy efficient complex in India.
- To implement the recommended proposals and reap the benefits.

9.2 *Approaches to an Energy Conservation Idea*

- Each energy conservation idea should be seen as an opportunity for improvement. The approach must be on how to implement each proposal and overcome the problems, if any.
- It is easier to say a proposal is not possible or not implementable, but the benefit comes from the actual implementation, which needs lot of courage, conviction and will power to implement.

9.3 *Specific Recommendation*

- Punjab Technical University should form an energy conservation committee. The committee should consist of senior operating and maintenance personnel.
- The committee should meet once in a month with a specific agenda to review the progress of implementation of proposals and to guide the implementation team.
- The management should also select a senior person, as Energy Manager and he should co-ordinate all implementation activities.
- The main responsibility of implementing the proposals and achievement of savings should be with the concerned operating and maintenance personnel and not with the Energy Manager.
- The immediate task of Team should be to implement the identified proposals and get the savings.
- It is recommended to introduce a suggestion scheme for energy conservation. The energy conservation committee should review all suggestions and good proposals should be implemented.

9.4 *Assign specific responsibility*

- While, the overall responsibility for energy conservation rests with the top management, the concerned operating / maintenance personnel should implement and periodically report progress on energy saving proposals.
- Therefore, each energy saving proposal should be assigned to a specific operating / maintenance personnel for implementation and monitoring.
- Specific time bound action plan is required for implementation and monitoring of energy saving proposals.

9.5 *Monitoring of proposals*

- All the implemented proposals are to be monitored on a proposal-by-proposal basis for actual achievement of savings on a monthly basis.

9.6 *Motivational aspects*

- The successful management of energy depends on motivation of technical personnel and their commitment. It is recommended that operating / Maintenance staff be deputed for training programs in specific areas like
  - Pumps
  - HVAC
  - Cooling towers
  - DG sets
  - Motors
  - Electrical distribution
  - Lighting

9.7 *Conclusions*

The detailed energy audits conducted jointly by the plant and energy teams have identified an annual energy saving potential of **Rs. 31.76 Lacs**, based on the present energy cost.

The summary of annual savings identified

Total annual saving (8 Proposals)	= Rs.31.76 Lacs
Annual Savings without Investment (2 Proposals)	= Rs. 8.60 Lacs
Investment required (6 proposals)	= Rs.49.55 Lacs
Average payback period for capital proposals	= 19 Months

It is proposed that the management should

- Assign specific responsibility for implementation of proposals.
- Monitor savings achieved on a proposal by proposal basis.
- Punjab Technical University team, should have the goal of a achieving the best energy efficient complex status in the country.

ANNEXURE – I

PROPOSED FORMAT FOR MONITORING THE IMPLEMENTATION OF ENERGY SAVING PROPOSALS

FORMAT FOR MONITORING THE IMPLEMENTATION OF ENERGY SAVING PROPOSALS

S No	Energy saving proposals	Annual Savings (Rs Lacs)	Investment (Rs Lacs)	Simple Payback (Months)	Dept / Person Responsible	Target Dates	Remarks
1							
2							
3							
4							
5							
Total							

ANNEXURE - II

LIST OF INSTRUMENTS

List of Instruments used during Energy Audit

1. Three Phase Electrical Power Analyzer
2. Digital Ultra Sonic Water Flow Meter
3. Digital Pressure Gauge
4. Digital Lux meter
5. Digital Distance Meter
6. Digital Multi-meter
7. Digital power clamp meter
8. Power factor meter
9. Digital Hygro Thermo Meter
10. Digital Anemometer

ANNEXURE-III

LIST OF ENERGY EFFICIENT EQUIPMENTS SUPPLIERS

ADDRESS OF ENERGY SAVING EQUIPMENT SUPPLIERS

SUPPLIER OF TRANSFORMER	
1. Crompton Greaves Limited. (Transformer Division) Kanjur Marg (East), Mumbai-400042, India. Tel: +91-022-25782974, 67558000,67558202, 67558211,67558390, FAX: +91-022-67558305. 25798214 Contact Person: Mr. B Ukil Email: cg.power@cgl.co.in	2. EMCO Limited Plot # F-5, Road No. 28, Wagle Industrial Estate, Thane-400 604. (India Tel : (91-22) 40404802 Fax :(91-22) 2582 0571 Contact Person: Mr M.K. Pradhan Mobile:996 757 8113 Email:pradhan@emcoindia.com
3. Bharat Heavy Electricals Ltd. Integrated Office Complex Lodhi Road, New Delhi – 110 003 Tel : (011) 26001010 Fax : (011) 26493021 (011) 26492534	4. ABB Ltd. 14 Mathura Road , Faridabad, 121003 Tel : (0129) 227 5592 Fax : (0129) 227 9692 Contact Person Mr. Sanjib Chaudhuri Email: sanjib.chaudhuri@in.abb.com

SUPPLIER FOR SOFT START-CUM-ENERGY SAVER	
1. BHEL BHEL House, Siri Fort, New Delhi- 110049, Tel : 011 26001010 Fax : 011 26493021 Contact Person : Mr. N Ramakrishna Contact No. - 9945530146	2.Danfoss Industry Pvt Ltd VI floor, JMD Pacific Square,Sector – 15,N.H.-8, Hoshiarpur -122001 Tel : 0124 4036677 Fax : 0124 4039321 Contact Person: Mr. Mahendra Chalke Contact No.-09967971799
3. Siemens Ltd. Thane Belapur Road Thane – 400601, Tel : (022)27623502 Fax :(022)27623727 Contact Person Mr. Rajesh Jain Contact No. 9987089336	4. ABB Ltd. 14 Mathura Road , Faridabad, 121003 Tel : (0129) 227 5592 Fax : (0129) 227 9692 Contact Person Mr. BV Ravishankar / Mr. R Narayanan Contact No. (080) 222318231

AUTOMATIC STAR-DELTA-STAR CONVERTOR	
1. BHEL BHEL House, Siri Fort, New Delhi- 110049, Tel : +91 11 26001010 Fax : +91 11 26493021 +91 11 26492534	2.Danfoss Industry Pvt Ltd VI floor, JMD Pacific Square,Sector – 15,N.H.-8, Hoshiarpur -122001 Tel : +911244036677 Fax : +911244039321

Contact Person : Mr. N Ramakrishna Contact No. - 9945530146	Contact Person: Mr. Mahendra Chalke Contact No.-09967971799
3. Siemens Ltd. Thane Belapur Road Thane – 400601, Tel : (022)27623502 Fax :(022)27623727 Contact Person Mr. Rajesh Jain Contact No. 9987089336	4. ABB Ltd. 14 Mathura Road , Faridabad, 121003 Tel : (0129) 227 5592 Fax : (0129) 227 9692 Contact Person Mr. BV Ravishankar Contact No. (080) 222318231
5. Phoenix Contact A - 58/2, Okhla Indl. Area, Phase - II, New Delhi -110 020 Tel (011) 30262 800 Fax (011) 26383 285 Email:works@phoenixcontact.co.in Contact Person Mr. Ashish Manchanda Contact No. - 9350043430	6. PMI ASSOCIATES 114,GH-3 DDA Flats, Paschim Vihar, New Delhi -110063(India) Tel : 011-25253104 Fax : 011-25280319 Contact Person: Mr. Sandeep Sharma Contact No. 0910037099

SUPPLIER FOR APFC

1. BHEL BHEL House, Siri Fort, New Delhi- 110049, Tel : +91 11 26001010 Fax : +91 11 26493021 +91 11 26492534 Contact Person : Mr. N Ramakrishna Contact No. - 9945530146	2.Danfoss Industry Pvt Ltd VI floor, JMD Pacific Square,Sector – 15,N.H.-8, Hoshiarpur -122001 Tel : +911244036677 Fax : +911244039321 Contact Person: Mr. Mahendra Chalke Contact No.-09967971799
3. Siemens Ltd. Thane Belapur Road Thane – 400601, Tel : (022)27623502 Fax :(022)27623727 Contact Person Mr. Rajesh Jain Contact No. 9987089336	4. CONZERV SYSTEMS PVT LTD 87, 1st Floor Industrial Development Colony (IDC) Mehrauli Road Hoshiarpur - 122 001, Tel:- 0124 4268899 Fax:- 0124 4268957 Email: del.sales@conzerv.com
5. NAAC Energy Controls (P) Ltd C-135 Hosiery Complex, Phase II (Extn.), Noida – 201305 Tel.: 0120-4221631, 32, 33, 34 Contact Person: Mr. Chander M. Kapoor Cell: 09811199085	6. EPCOS India Pvt Limited 11'th Floor, 28 Dr. Gopal Das Towers Barakhamba Road, New Delhi- 110 001 Tel: 011 23704143, 23704144 Fax: 011 23704146

SUPPLIER FOR CAPACITORS BANK

1. BHEL BHEL House, Siri Fort, New Delhi- 110049, Tel : +91 11 26001010 Fax : +91 11 26493021 Contact Person : Mr. N Ramakrishna Contact No. - 9945530146	2. ABB Ltd. Plot Nos 5 & 6 2nd Phase 560058 Bangalore Phone: 08022949328 Fax : 080 22949339 Contact Person: Mr. Uday Sampat

3. Siemens Ltd. Thane Belapur Road Thane – 400601, Tel : (022)27623502 Fax :(022)27623727 Contact Person Mr. Rajesh Jain Contact No. 9987089336	4. MAGNEWIN MAGNETICS L - 49, M.I.D.C., Kupwad - 416436. Dist. Sangli, Tel.: 0233 - 2645041 / 2645456 Fax : 0233 – 2645856
5. NAAC Energy Controls (P) Ltd C-135 Hosiery Complex, Phase II (Extn.), Noida – 201305 Tel.: 0120-4221631, 32, 33, 34 Fax: (91)-(120)-4221635 Contact Person: Mr. Chander M. Kapoor Cell: 09811199085	6. EPCOS India Pvt Limited 11'th Floor, 28 Dr. Gopal Das Towers Barakhamba Road, New Delhi- 110 001 Tel: 011 23704143, 23704144 Fax: 011 23704146
7. Madhav Capacitors Pvt. Ltd. B-5-2, M.I.D.C. Indl. Estate, Bhosari, Pune - 411 016. Tel: 020 - 27122360/27122762 Fax : 020 - 2712 27 62	8. HOC_AGE Engineering Ltd. 165, HSIDC KUNDLI, Indl. Area, Distt. Sonepat – 130128 Tel: 0130 – 6452667

SUPPLIER FOR ENERGY EFFICIENT MOTORS

1. BHEL BHEL House, Siri Fort, New Delhi- 110049, Tel : +91 11 26001010 Fax : +91 11 26493021 Contact Person : Mr. N Ramakrishna Contact No. - 9945530146	2. Crompton Greaves Limited (LT Motors Division): A/6-2, MIDC Industrial Area, Ahmednagar- 414111 Tel: 0241- 2777500, 2777372 FAX: 0241-2777508, 2776103 Contact Person: Mr. Ramesh Kumar Email:ramesh.kumar@cgl.co.in
3. Siemens Ltd. Thane Belapur Road Thane – 400601, Tel : (022)27623502 Fax :(022)27623727 Contact Person Mr. Rajesh Jain Contact No. 9987089336	4. Kirloskar Brothers ltd Jeevan Tara Building, 5, Parliament Street, New Delhi 110 001 Tel : +91-011-41501055 to 62 Fax : +91-011-23342002 Email delhi@kbl.co.in
5. Bharat Bijlee Ltd. Milap Niketan, 4th Floor, 8A, Bahadur Shah Zafar Marg, New Delhi, 110 002. Tel: 011-23356033, 23319694 Fax: 011-23319413 Email: bbldelhi@del.bharatbijlee.com Contact Person: Ms. Pratibha Chopra Cell : 09810096684	**6.** Navyug Electric Motors & Pumps Ltd. Plot-4, Phase-II, GIDC, Vatva, Ahmedabad - 382 445 Tel : 079 25831432, 25831433 Fax : 079 25831434

SUPPLIER FOR ENERGY EFFICIENT PUMPS

1. BHEL BHEL House, Siri Fort, New Delhi- 110049, Tel : +91 11 26001010 Fax : +91 11 26493021 Contact Person : Mr. N Ramakrishna Contact No. - 9945530146	2. Crompton Greaves Limited (LT Motors Division): A/6-2, MIDC Industrial Area, Ahmednagar- 414111 Tel: 0241- 2777500, 2777372 FAX: 0241-2777508, 2776103 Contact Person: Mr. Ramesh Kumar Email:ramesh.kumar@cgl.co.in
3. BHARAT BIJLEE LTD. Milap Niketan, 4th Floor, 8A, Bahadur Shah Zafar Marg, New Delhi, 110 002. Tel: 011-23356033, 23319694 Fax: 011-23319413 Contact Person: Ms. Pratibha Chopra Cell : 09810096684 Email: bbldelhi@del.bharatbijlee.com	4. Kirloskar Brothers ltd Jeevan Tara Building, 5, Parliament Street, New Delhi 110 001 Tel : +91-011-41501055 to 62 Fax : +91-011-23342002 Email delhi@kbl.co.in Contact Person: Mr. P K Tayal Cell: 09425048723
5. Shakti Pumps (India) Limited, Plot no. 401,402 & 413, Sector 3, Pithampur-454775 Tel: 07292- 410500, 410700 Fax: 07292 407044	6. Grundfos Pumps India Pvt. Ltd. B - 1/ D-5, 1st Floor Mohan Co-operative Indl Estate Mathura Road, New Delhi - 110044 Tel: (011) 4222 6090 Fax: (011) 4222 6020 E-mail: salesindia@grundfos.com

SUPPLIER FOR VARIABLE SPEED/FREQUENCY DRIVES/PROCESS AUTOMATION

1. Amtech Electronic (I) Ltd, E-6, GIDC, Electronics Zone, Gandhinagar - 382028, Tel : (079)-23289101, 23289102, Fax : (079)-23289111 Email: info@amtechelectronics.com Contact Person Mr. S B Mahajani Contact No. - 9913143673	2. Crompton Greaves Ltd (LT Motors Division) A/6-2, MIDC Industrial Area, Ahmednagar- 414111 Tel: (0241)- 2777500, 2777372 FAX: (0241) 2777508, 2776103 Contact Person: Mr. Ramesh Kumar Email:ramesh.kumar@cgl.co.in
3. Rockwell Automation India Ltd A-66,Sector-64, Noida-201301(U.P) India Tel : (0120) 4671477 Fax : (0120) 4217928 Contact Person Mr. Meenu Singhal Contact No. - 9811150530	4. Phoenix Contact A - 58/2, Okhla Indl. Area, Phase - II, New Delhi -110 020, Tel (011) 30262 800 Email:works@phoenixcontact.co.in Contact Person Mr. Ashish Manchanda Contact No. - 9350043430
5. Honeywell Automation India Ltd 86, Ist Floor,Okhla Phase III New Delhi - 110020 Tel.: 011-66116300 Fax: 011-66116327 Contact Person Mr. Prabhat Verma Contact No. - 9818230888	6. ABB Ltd. Plot Nos 5 & 6 2nd Phase Bangalore 560058 Tel: 080- 22949355 Fax: 080-22949389 Contact Person Mr. K Sreevatsa Cell: 099014 90980

SUPPLIER OF ELECTRONIC BALLAST	
1. OSRAM India Private Limited Signature Towers, 11th Floor Tower B, South City - 1 122001 Hoshiarpur, Tel.: 0124 238 31 80 Fax: 0124 238 31 82	2. Bajaj Electricals 1/10, Asaf Ali Road New Delhi 110002 Tel +91-11-23236055 Fax +91-11-23230214 E-mail: del_cic@bajajelectricals.com
3. Philips Electronics India Ltd Ashoka Estate, 9th Floor, 24, Barakhamba Road, Connaught Place New Delhi – 110001 Tel: 011-43529800, 23353280 Fax: 011 23314332 Contact Person: Mr. S K. Dangi Email: s.k.dangi@philips.com	4. G.K. Energy Marketers Pvt. Ltd. F. No 601 , B No 11 B , Opp Data Mandir , Lokmanya Nagar , LBS Road , Navi Peth, PUNE - 411030 Ph. no – (020) 2432 1115 Fax No – (020) 2432 1115 Contact Person : Mr. Gopal Kabra Cell – 09970450000

SUPPLIER OF CFL & METAL HALIDE LAMPS	
1. OSRAM India Private Limited Signature Towers, 11th Floor Tower B, South City - 1 122001 Hoshiarpur, Tel.: 0124 238 31 80 Fax: 0124 238 31 82	2. Bajaj Electricals 1/10, Asaf Ali Road New Delhi 110002 Tel +91-11-23236055 Fax +91-11-23230214 E-mail: del_cic@bajajelectricals.com
3. Philips Electronics India Ltd Ashoka Estate, 9th Floor, 24, Barakhamba Road, Connaught Place New Delhi – 110001 Tel: 011-43529800, 23353280 Fax: 011 23314332 Contact Person: Mr. S K. Dangi Email: s.k.dangi@philips.com	4. Crompton Greaves Limited (Lighting Division) Kanjur Marg (East), Mumbai -400 042. India. Tel: 022-67558000, 67558425/26 FAX: 022- 25787283 Contact Person: Mr. B Chakrabarti Email: biswa.chakrabarti@cgl.co.in

SUPPLIER OF LED & T- 5 LAMPS	
1. OSRAM India Private Limited Signature Towers, 11th Floor Tower B, South City - 1 122001 Hoshiarpur, Tel.: 0124 238 31 80 Fax: 0124 238 31 82	2. Bajaj Electricals Ltd 1/10, Asaf Ali Road New Delhi 110002 Tel +91-11-23236055 Fax +91-11-23230214 E-mail: del_cic@bajajelectricals.com
3. Philips Electronics India Ltd Ashoka Estate, 9th Floor, 24, Barakhamba Road, Connaught Place New Delhi – 110001 Tel: 011-43529800, 23353280 Fax: 011 23314332 Contact Person: Mr. S K. Dangi Email: s.k.dangi@philips.com	4. Crompton Greaves Limited (Lighting Division) Kanjur Marg (East), Mumbai -400 042. Tel: 022-67558000, 67558425/26 FAX: 022- 25787283 Contact Person: Mr. B Chakrabarti Email: biswa.chakrabarti@cgl.co.in

SUPLLIER OF LIGHTING SYSTEM & ENERGY SAVER

1. Crompton Greaves Limited (Lighting Division) Kanjur Marg (East), Mumbai -400 042. India. Tel: +91-022-67558000, 67558425/26 FAX: +91-022- 25787283 Contact Person: Mr. B Chakrabarti Email: biswa.chakrabarti@cgl.co.in	2. N. N. Projects Limited C-102, 10th Floor, Super M I, DLF City, Phase IV Hoshiarpur - 122 002, Tel: +91-(124)- 4042483 Fax : +(91)-(124)- 2386431 E-mail: info@nnprojects.com Contact Person: Mr. Gurdeep Singh Juneja Contact No. 9910018286
3. Duex Industrial Systems H-312, Sharad Industrial Estate, Lake Road, Bhandup (W), Mumbai 400078 Tel: 022-32688683 Contact Person: Mr. Nitin Thakur Contact No. 09324082483	4. CONZERV SYSTEMS PVT LTD 87, 1st Floor Industrial Development Colony (IDC) Mehrauli Road Hoshiarpur - 122 001, Phone:- 0124 4268899 Fax:- 0124 4268957 Email: del.sales@conzerv.com

SUPPLIER OF SOLAR PV & LIGHTING SYSTEMS

1.Tata BP Solar India Ltd UG/70-74, World Trade Centre Hotel Intercontinental Complex Barakhamba Road, New Delhi 110 001 Tel : 011 2341 1537 / 8 Fax : 011 2341 1520 Contact Person Mr. Amit Kumar Contact No. 09910018286	2. NEPC India Limited G-39, 3rd Floor, Pawan House, Connaught Circus, New Delhi-110001 Tel: 011 -43581298 / 1299 Fax: 011 41516499 Contact Person Mr.Rakesh Gupta Cell No: 9810106461 mailto:rakeshgupta@nepcindia.co.in Email: rakeshguptanepc@yahoo.com rakeshgupta@nepcindia.co.in
3. G.K. Energy Marketers Pvt. Ltd. F. No 601 , B No 11 B , Opp Data Mandir , Lokmanya Nagar , LBS Road , Navi Peth, PUNE - 411030 Ph. no – (020) 2432 1115 Fax No – (020) 2432 1115 Contact Person : Mr. Gopal Kabra Mob - 09970450000	4. Emmvee Solar Systems (P) Ltd. First Floor , No: 6 & 8 , R-23 , North Enclave , Opp : Nehru Place , Kalkaji, New Delhi – 110 019 Tel : 011-40502620 / 22 Fax : 011 40502623 Contact Person : Mr. Krishan Kumar Mobile : 098119 73344
5. Maharishi Solar Technology Ltd A-14, Mohan Co-op Indl Estate, Mathura Road, New Delhi 110044 Tel.: 011-30881700, 26959529 Fax : 011-26959669 Contact Person : Mr. Pawan Kulshrest Mob - 09899704676	6. Bharat Heavy Electricals Ltd. Integrated Office Complex Lodhi Road, New Delhi – 110 003 Tel : (011) 26001010 Fax : (011) 26493021 (011) 26492534

SUPPLIER OF CHILLERS SYSTEMS

1. Kirloskar Pneumatic Co. Ltd. Hadapsar Industrial Estate, Pune 411 031. Tel. : 020-26870133, 26727000 Fax : 020-26870297,,26870634 Contact Person: Mr. Hemadri N. Buzruk Cell: 09881495489	2. Voltas Ltd. EM&R BG, A43, Mohan Co-op Indl. Estate, Mathura Road, Delhi 110044 Tel: 011 66505550-5570 Fax: 011 26950022/26950081 Contact Person: Mr. Rajiv Saxena Email: rsaxena@voltas.com
3. Reynold India Pvt. Ltd C-38 & 39, Sector 2 Noida, 201 301 Tel : 0120-4252000/4664000 Fax No : 0120 -4252005 *Contact Person :* Mr. Vijay Bali Cell No: 09810100836	4. Werner Finley India Ltd. #9, Cauverynagar, Near Swayam Prabha Kalyanamantapa, Kamakshipalya, Magadi Main Road, Bangalore - 560 079 Tel:080-23289889 23288369 Fax: 080-232883191 *Contact Person:* Mr. J.R.Gundu Rao Cell No: 09845511586
5. Flamingo Chillers Pvt Ltd Z - 51-52 Okhla Indl Area, Phase 2, Delhi - 110020 Phone : 011 - 41610234, 35 Fax: 011 - 41610234	6. Schneider Electric (I) Pvt. Ltd. A-29, Mohan Co-Op. Indl. Estate, Mathura Road, New Delhi 110044 Ph.011-39404000, 41590000, Fax-011-41678010, 41678011
7. Hitachi Home & Life Solutions (I) Ltd. Central Air Conditioning Mr. Arpit Akotiya 022-27689287/83 Mob. 09321836063	

SUPPLIER OF EVAPORATIVE COOLING SYSTEM

1. Sumaya HMX Systems Ltd., # A 422, 1st Cross, 1st Stage, Peenya Industrial Area, Bangalore - 560 058 Tel: 080 -372 1065 / 372 2325 Fax: 080 -372 2326	2. Mamata Energy Pvt Ltd Plot No. 858, Kothari Industrial Estate, Behind Hutch Tower, Rakanpur-Santej Road, Santej - 382 721, Telefax : 02764-268328 Contact Person: Mr. Ashish Zha

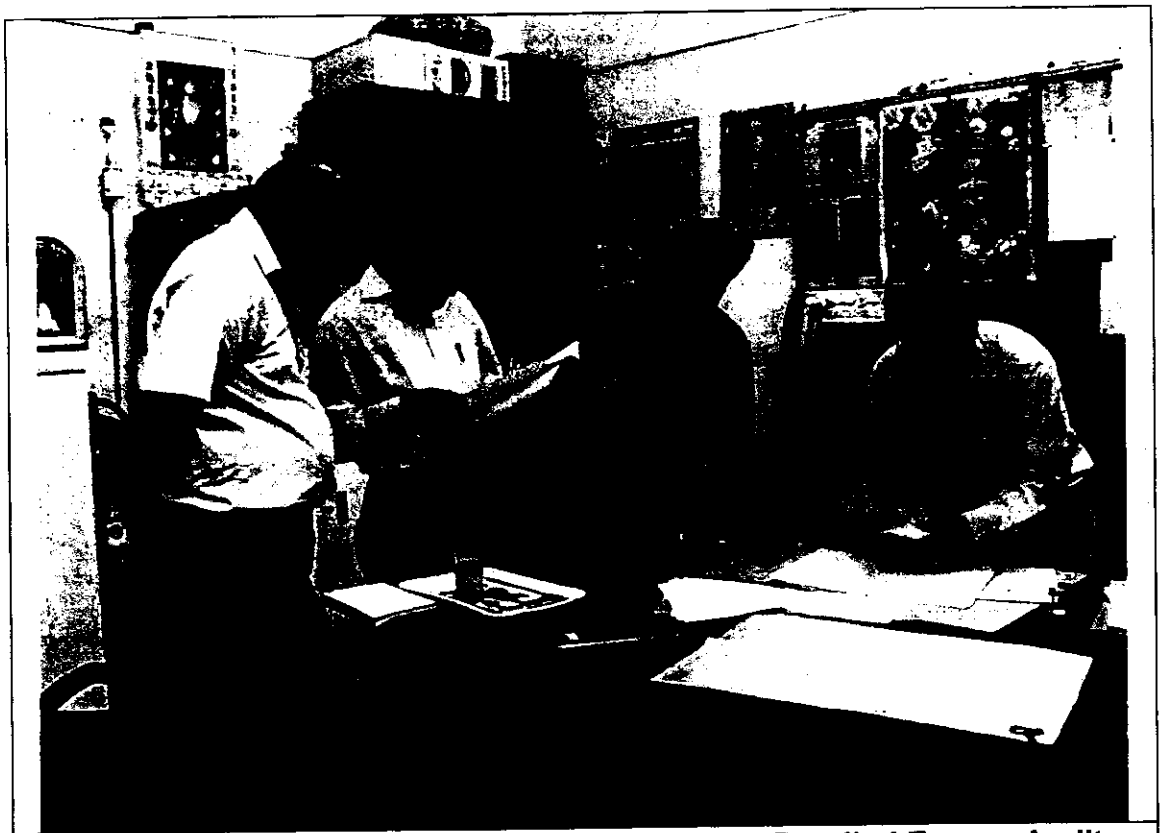
SUPPLIER OF COOLING TOWERS

1. Tekni Engineering Pvt. Ltd. 10, Krishna Apartmnet, Bhudrapura, Ambawadi, Ahmedabad 380 006 Phone : 079-26460313. Contact Person: Mr. A. R. Dhoble Cell No.: 09426069087	2. Gem Cooling Towers Pvt. Ltd. S.F. No. 100A, Arasur, Coimbatore - 641 407, Tel : 0422 2360013, 2360130, 2360131, 2360059, 2360129 Fax : 0422 2360523

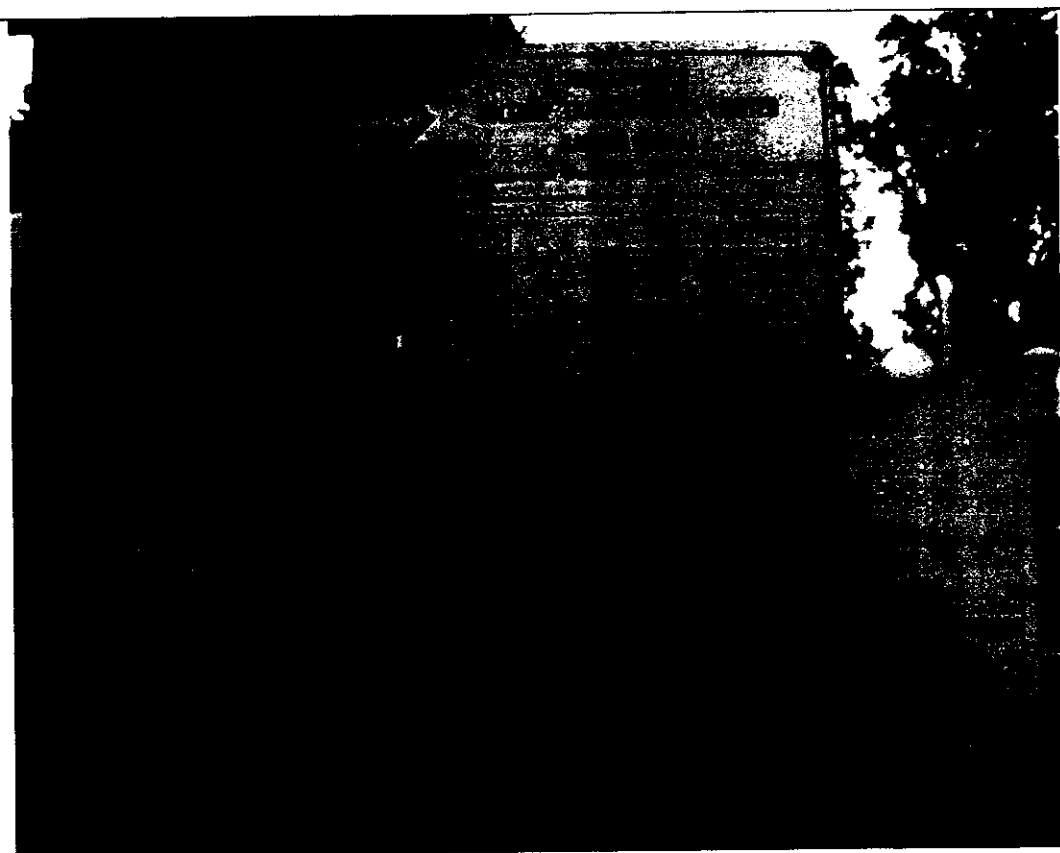
3. Paltech Cooling Towers & Equipments Limited B- 604 Sushant Lok, Phase- 1 Hoshiarpur, Haryana - 122 002 Tel : 0124 4222483/84/85/ Contact Person : Mr. H. P. Yadav Cell : 09871096333 E-Mail: hpyadav@paltech.in	4. Artech Cooling Towers (P) Ltd Plot No. 5021, B/H, Meghmani Organics, G.I.D.C. Ankleshwar - 393 002. Tel: (02646) 250302, 309661 Fax: (02646) 250302
Power Analyzer	
1. Fluke 16/1113, Tank Road Karol Bagh, New Delhi, Delhi 110005 Tel :011 25738858 Mobile : 09818515888	2.Nevco Engineers Pvt Ltd 90-A(2nd Floor),Amrit Puri-B Main Road,East of Kailash,New Delhi-110065 Contact Person Mr.Vinod Bhat Contact No : 09810711178
3. CONZERV SYSTEMS PVT LTD 87, 1st Floor Industrial Development Colony (IDC) Mehrauli Road Hoshiarpur - 122 001, Phone:- 0124 4268899 Fax:- 0124 4268957 Email: del.sales@conzerv.com	4. MECO Instruments Pvt. Ltd. Plot No. EL-1, MIDC Electronic Zone, TTC Industrial Area, Mahape, Navi Mumbai 400710. Tel: 022-27673311-16 Fax: 0091-22-27673310, 27673330
FLOW METERS	
1. Fluke 16/1113, Tank Road Karol Bagh, New Delhi, Delhi 110005 Tel :011 25738858 Mobile : 09818515888	2. Siemens Ltd. Thane Belapur Road Thane – 400601, Maharashtra,India Tel : 022-27623502 Fax : 022- 27623727 Contact Person Mr. Rajesh Jain Cell No. 9987089336
3. ABB Ltd. 14 Mathura Road , Faridabad, 121003 Tel : (0129) 2448131 Fax : (0129) 4023006 Contact Person: Mr. Sudhir Kulkarni Cell No: 098105 06367	4.Nevco Engineers Pvt Ltd 90-A(2nd Floor),Amrit Puri-B Main Road,East of Kailash,New Delhi-110065 Contact Person Mr.Vinod Bhat Cell No : 09810711178

ANNEXURE- IV

PHOTOGRAPHS



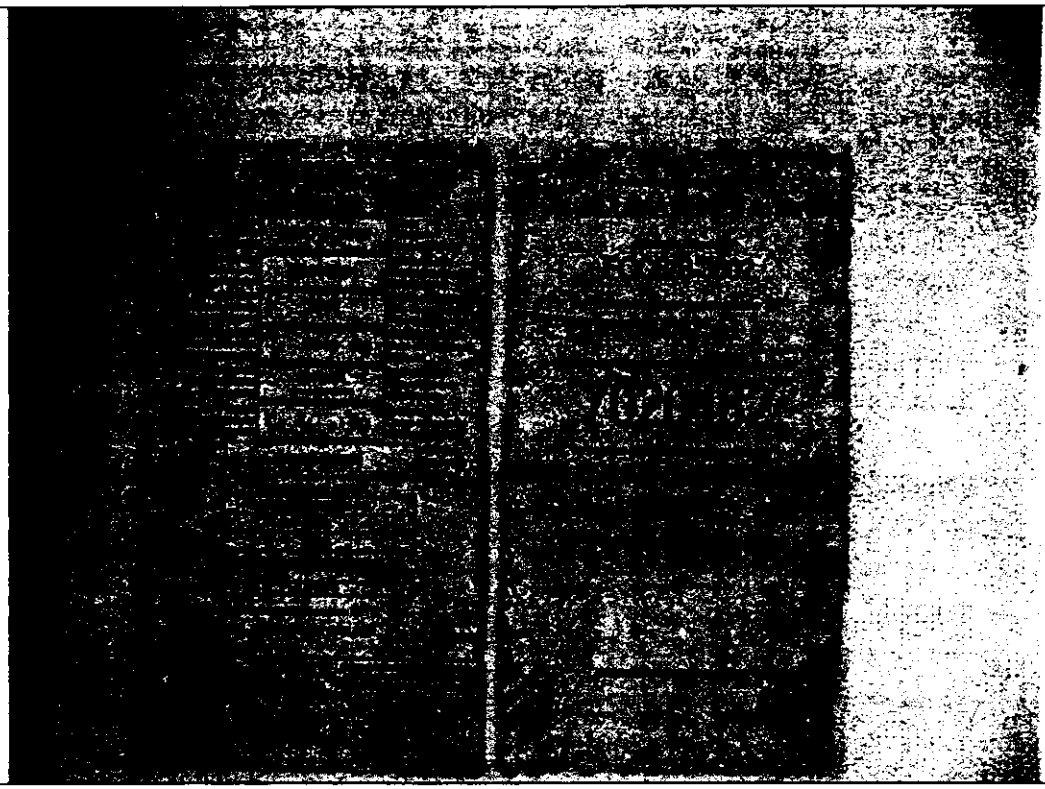
Detailed discussions with PTU Officers before Detailed Energy Audit



Rated Data of 1000 kVA transformer

Measurement of Energy Data at 11 kV Sub Station

View of Primary Chilled Water Pumps



Rated Data of HVAC Air Cold Screw Chillers

View of Detailed Energy Audit of HVAC Plant

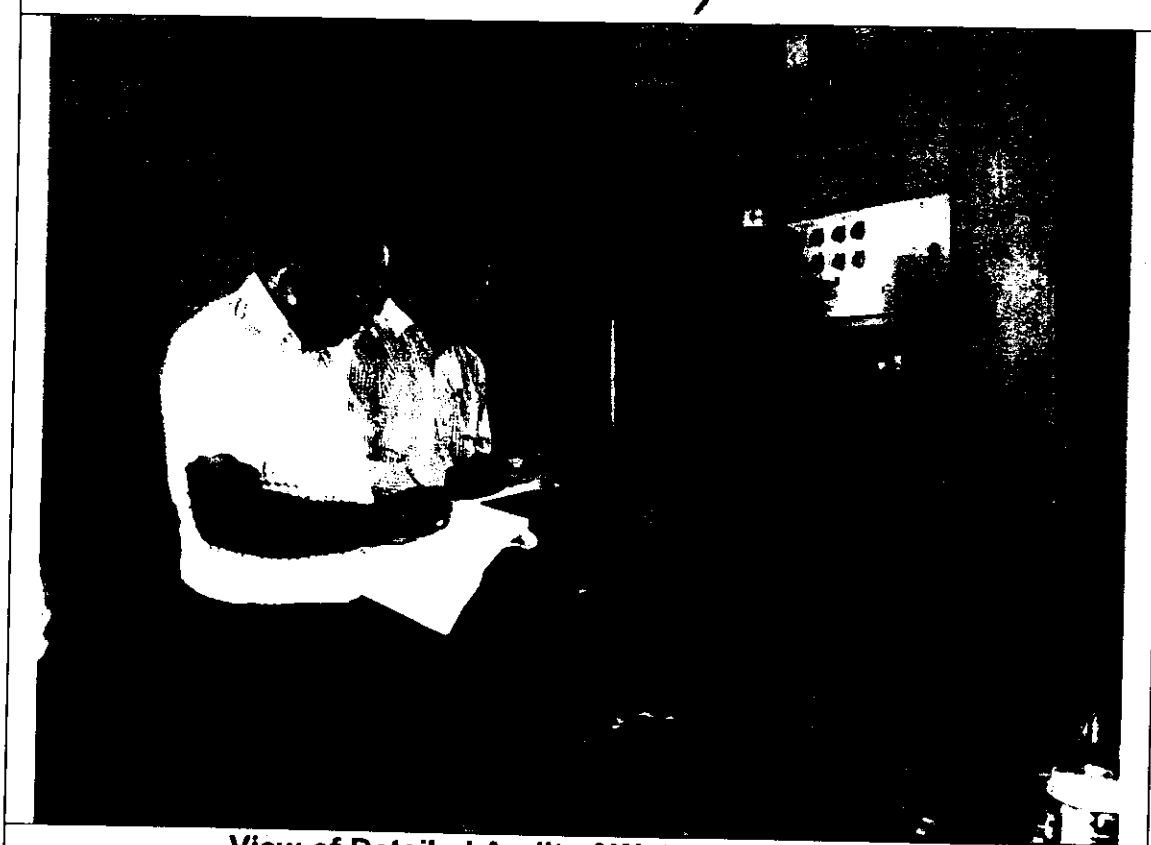
View of Detailed Energy Audit of HVAC Plant

View of Detailed Energy Audit of AHUs

View of Detailed Energy Audit of AHUs

View of Detailed Energy Audit of Submersible Pump

Discussions with the PTU Officials during Detailed Audit



View of Detailed Audit of Water Lifting Pumps

View of Detailed Audit of Air Conditioner

Detailed Discussions with senior officials of PTU

View of detailed audit of indoor lighting

View of detailed audit of outdoor lighting