ENERGY AUDIT REPORT

2019

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

KOCHI, KERALA -682022

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INTRODUCTION

Even though energy wastage is a common phenomenon in small residential areas, the wastage can be considered comparatively low, but in the case of huge buildings like educational institutions the wastage amounts to notable figure. Energy audit has been conducted at School of Engineering, one of the largest energy consuming centres in CUSAT, to estimate and analyse the energy consumption and also to propose energy conservation measures.

The audit is aimed to make CUSAT more energy efficient by balancing it's load, identifying the wastage areas etc. This audit was conducted to seek opportunities to improve the energy efficiency of the campus. The reduction of energy consumption while maintaining or improving human comfort, health and safety were of primary concern. Beyond simply identifying the energy consumption pattern, this audit sought to identify the most energy inefficient appliances that were in the premises. Moreover, some improvements to some daily practices relating to common appliances are also to be provided which may help in reducing the energy consumption. The report is based on certain generalizations and approximations wherever necessary. The views expressed may or may not reflect the general opinion.

School of Engineering is one of the largest energy consuming centres in CUSAT. School of Engineering has a substation of it's own. The major motivation behind conducting energy audit is to identify energy wastage and to suggest recommendations to reduce energy wastage thereby help in reducing the monthly energy consumption and thus reduce the monthly electricity bill.

The experts conducted the Energy Audit are:

1. Dr.G.Madhu
   Professor
   Division of Safety and Fire Engineering
   School of Engineering, CUSAT

2. Dr.P.G Latha
   Associate Professor
   Division of Electrical and Electronics Engineering
   School of Engineering

3. Dr.James Varghese
   Associate Professor
   Division of Mechanical Engineering
   School of Engineering

PRESENT ENERGY SCENARIO

School of Engineering (SOE) is the largest academic unit of CUSAT with more than 2500 students in its roll. SOE campus includes New Laboratory Block(NLB),Software Block, A Block ,Office Block, C Block, Fire & Safety Block Canteen, Thermal Lab, Fluid Mechanics Lab, Machines Lab. Siberia Hostel has a capacity of 106.Sarovar Hostel has a capacity of 188 each. Throughout this report, whenever SOE is mentioned it implies SOE, Sarovar and Siberia Hostel.

School of Engineering, CUSAT has an approximate area of 17 acres with strength of approximately 1200 including students and faculty. SOE has 24 hour electricity supply. SOE has a monthly average consumption of around 30000 KWh. Average operating power factor of around 0.99. SOE campus has a connected load of 303.94 KW and contract demand of 205 kVA.

School Of Engineering is a HT consumer and takes supply from the KSEB's 11KV and distributes energy to the various loads. The Incoming 11KV feeder terminates at a two pole structure. It consists of two PCC poles of 9.15m. AB switch and lightning arrestors are mounted on the pole structure. The handle of the AB switch has been fixed at a height of about 4 to 5 feet for easy operation (See fig 1).

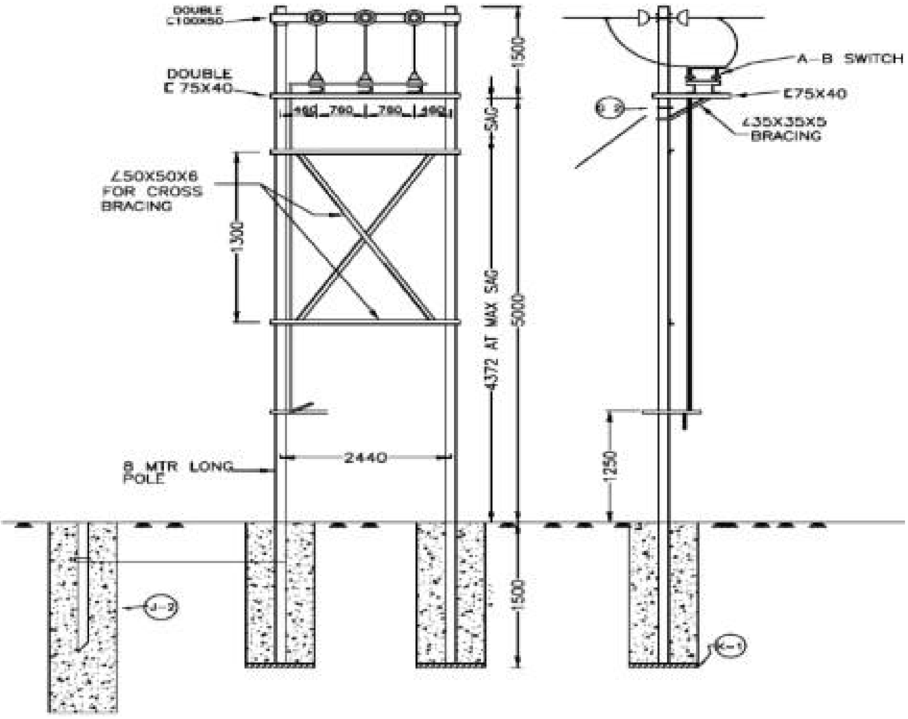

Fig 1: Two pole structure

Fig 2 shows the main equipment in the indoor substation of SOE and the power flow through various equipment's.

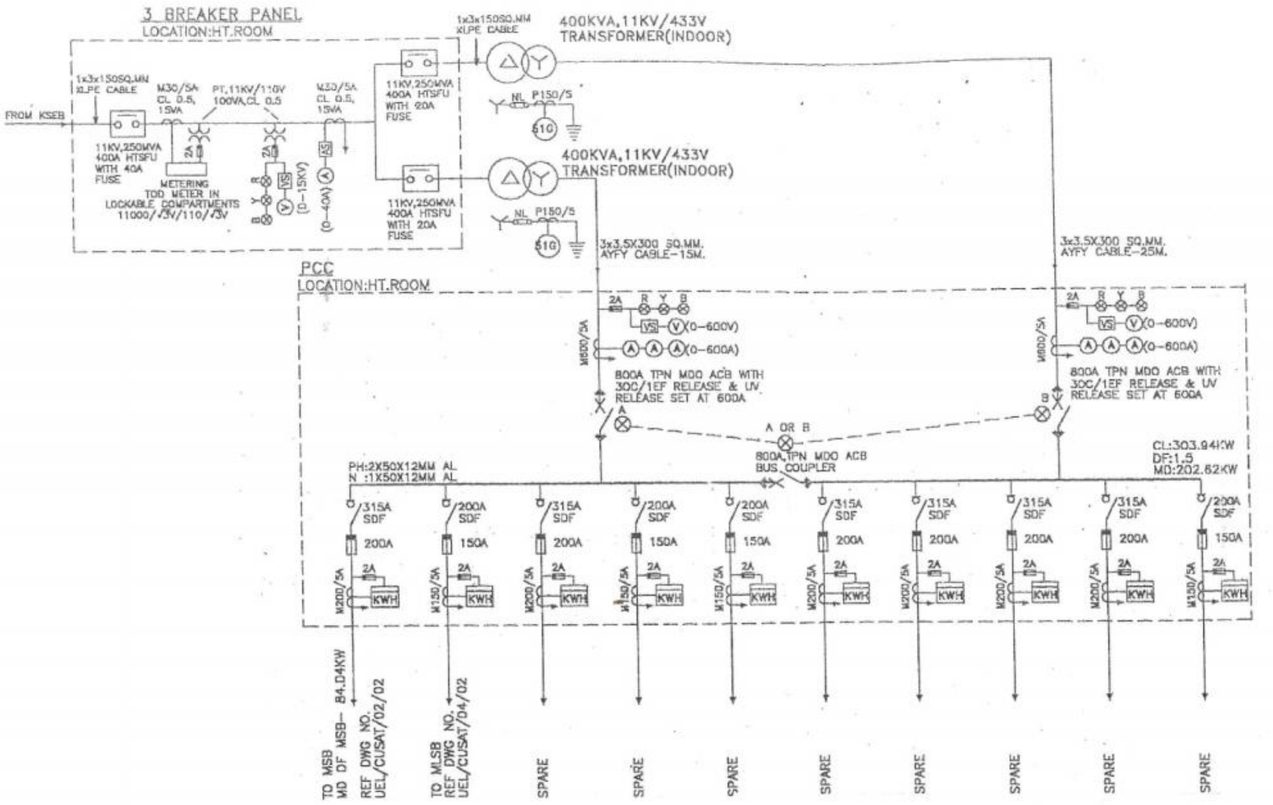

Fig 2: Single line diagram of SOE substation

From the pole structure the supply is brought out through a 3 core XLPE (cross linked poly-ethylene) cable to a Tri Vector Meter. Time of day tariff is a tariff structure in which different rates are applicable for use of electricity at different time of the day. Meter is succeeded by 2 MOCB connected in parallel of rating: 11kV, 250KVA, 400A, with a 20A fuse which provides protection against over voltage and over current.

Through 3 core XLPE cables supply is fed into the HT side of the both the transformers. They have a capacity of 400KVA with HT side voltage of 11000 and LT side 433 volts, HT side current of 20.99 A and LT side current of 533.36 A. From the LT side of the transformer 3 runs of 3.5 core aluminium conductor cables runs to the main circuit breaker in the main switch board panel (MSB).

Main switchboard usually consists of several cabinets mounted on the floor. On the doors of cabinets are installed signalling and control devices, which allow read the status about the operation of the equipment. Six feeders are there in the MSB at SOE substation out of which 2

are spares, 3 SSB and 1 LSB. The MSB consists of Air Circuit Breaker (ACB), Rating 430V 800A set to 500A, 25MVA.

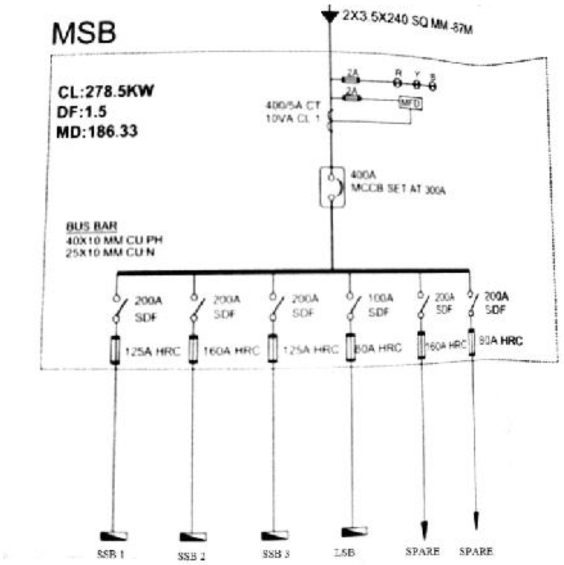

Fig 3: Single line diagram of Main Switch Board(MSB)

The type of energy meter used in SOE electronic type energy meter which measures energy parameters, like active energy, elective energy, apparent energy, power factor, frequency etc. through which energy is received or send can be determined. It is connected in the substation to incoming feeder to find out energy charge and demand charge. The meter offers a flexible tariff structure. During different times of the day for different season, different tariff structure can be programmed.

Fig 4: Tri Vector Meter

The energy meter used is manufactured by L&T and is of their er300p class.

TOD Tariff for HT consumers

Time of day (or TOD) tariff is tariff structure in which different rates are applicable for use of electricity at different time of the day. It means that cost of using one unit of electricity will be different during peak, off peak and normal hours. This means that using appliances during certain times of the day will be cheaper than using them during other times.

There are two transformers inside the SOE substation. The transformers are the main part of the substation. It steps down the incoming 11kV to 433V. The transformers used in SOE CUSAT uses ONAN (Oil Natural Air Natural) method for cooling. The transformers works on 50Hz frequency and has a voltage rating of 400kVA with HT side of 11000V, 20.99A and LT side of 433V 533.36A. Winding used in transformer is Dy 11 – i.e., HV side winding is delta connected and LV side winding is star connected with neutral brought out and LV leading HV with 30degree.

Fig 5: Transformer I

Fig 6: Transformer II

- BILL ANALYSIS

SOE is a HT consumer and consumes about 30000 units of electricity on an average, every month. The college has a contract demand of 205kVA and logs a maximum demand of 85% of CD, about 175 kVA during summer. The power factor is very close to unity. The average monthly expenditure of SOE for electricity is about 2.8 to 3 lakhs (excluding the cost of fuel for the DG).

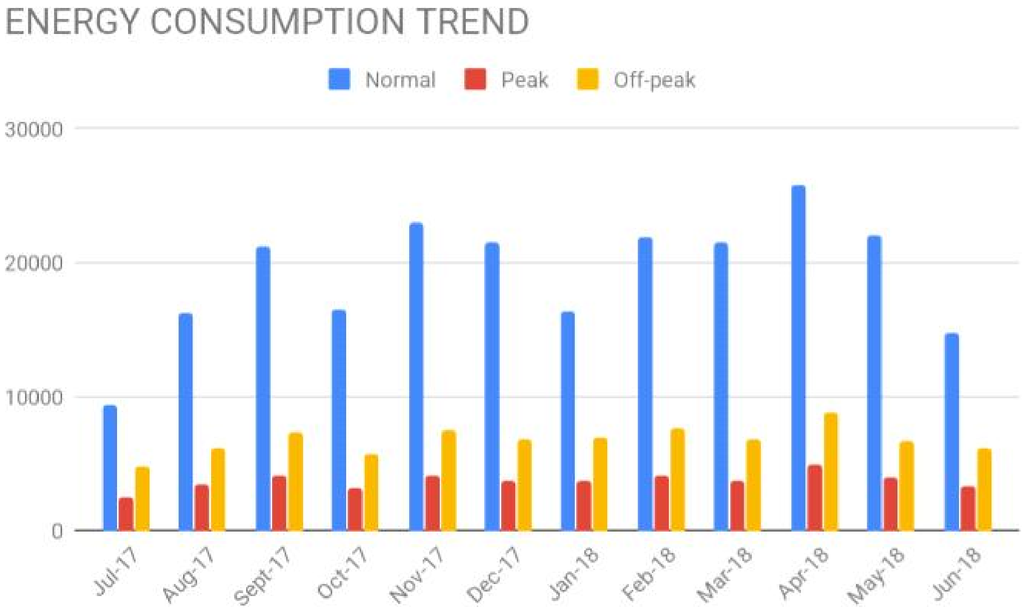

Fig 7: Monthly Units Consumed

The college has a contract demand of 205 kVA and logs a maximum demand of 85% of CD, about 175kVA during summer consumes about 30000 units of electricity on an average, every month. Consumption peaks during April and is the lowest in July.

	Jul-17	Aug-17	Sept-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
Normal	9327	16242	21183	16542	22902	21456	16389	21843	21486	25833	21966	14736
Peak	2445	3462	4086	3217	4143	3681	3693	4113	3681	4953	3996	3321
Off-peak	4794	6132	7362	5757	7506	6816	6879	7617	6816	8757	6642	6081

Table 1: Monthly units distribution

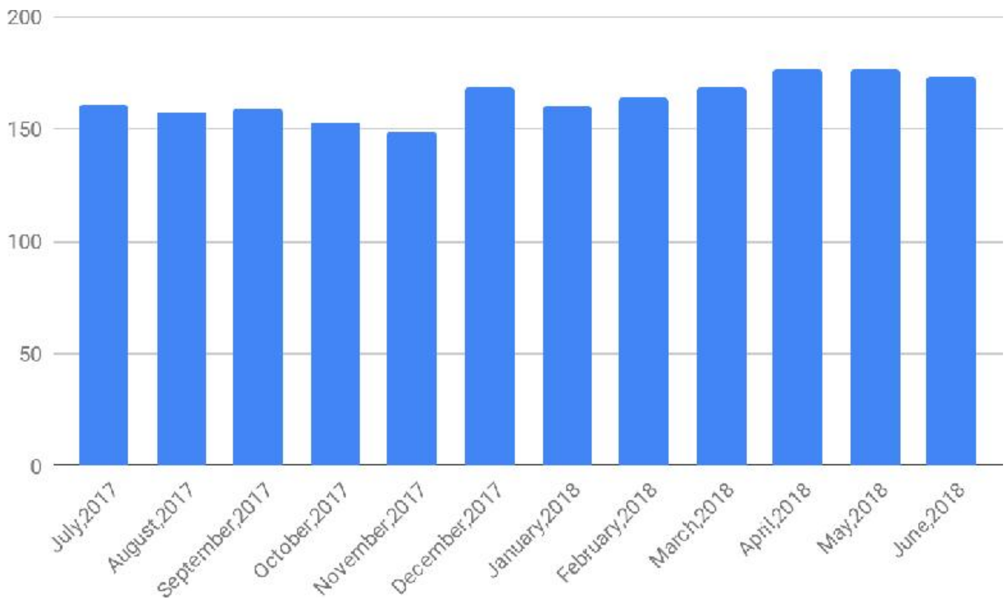

Fig 8: Monthly demand (KVA) at SOE

SOE has an excellent power factor of almost unity every month. SOE is charged under KSEB's HT-II(B)-General Tariff. The total electricity charge comprises of:

- Demand Charge

Demand charge for normal and off peak hours is taken for average KVA even though the demand is less than that. Demand charge for the peak hours is calculated by considering the actual kVA demand during these hours.

- Energy Charge

Energy charge is calculated by considering the units consumed. When the energy consumption for a month is below 30000KWh, SOE is charged at 6.200Rs, 9.300Rs, 4.650Rs for normal, peak and off-peak respectively. But when the monthly consumption exceeds 30000 KWh, the charges are revised to 7.00 Rs ,10.800Rs ,5.400Rs for normal, peak and off-peak respectively.

- Power factor Incentive/Penalty

SOE keeps an excellent power factor of unity every month and never going below 0.97. Incentives are given by KSEB from power factor above 0.9 as 0.25% of energy charges for each 0.01 unit increase in power factor from 0.9. Also penalty is put for power factor below 0.9 as 1% of energy charges for each 0.01 unit decrease in power factor from 0.9. The total energy charge is sum of charges based on energy consumed and pf incentive / penalty. Each month KSEB pays SOE an average of 6000 rupees as power factor incentive

Fig 9: Satellite View of SOE, Sarovar & Siberia Hostel.

- CONNECTION AND LOAD DETAILS

SOE is a HT consumer and takes supply from the KSEB's 11KV line. It has an indoor substation with two 11KV/433V, 400KVA Transformer. An auxiliary supply is provided for SOE by a 62.5 KVA Diesel Generator set with a control panel.

As per the present construction, the overall Connected load of the SOE is 303.94 kW. The college has a contract demand of 205 kVA and logs a maximum demand of 85% of CD, about 175kVA during summer consumes about 30000 units of electricity on an average, every month.

The campus of SOE can be roughly divided into 12 blocks. They include: New Lab Block(NLB), Software Block, C Block, Canteen, Fluid Mechanics Lab, Thermal Lab, Electrical Machines Lab, Sarovar Hostel, Safety Block, A Block, Siberia Hostel.

Block wise details of electrical loads are collected and are given below. Information about the general electrical appliances are collected by observation and interviewing. The condition of wiring is examined. Working condition of equipment is analysed. The day light intensity inside the rooms are measured using Lux meter. The air velocity of celling fans is measured using anemometer. The power quality is monitored using Power quality analyser. Approximations and generalizations are done at places with lack of information.

- DETAILS OF TOTAL CONNECTED LOAD : NLB

SL. NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	FAN	346	80W	27680
2	TUBE	724	40W	28960
3	PROJECTOR	22	150W	3300
4	AC	37	1000W	37000
5	INVERTER	70	200W	14000
6	PC	110	25W	2750
7	PRINTER	7	20W	140
8	COOLER	3	750W	2250
9	WATER PURIFIER	1	10W	10
10	FRIDGE	3	100W	300
11	EXHAUST FAN	19	50W	1350
12	PHOTOSTAT M/C	7	1500W	10500
13	TABLE FAN	4	81W	324
14	STABILIZER	5	50 W	250
15	UPS	2	536W	1072

Table 2: NLB connected load

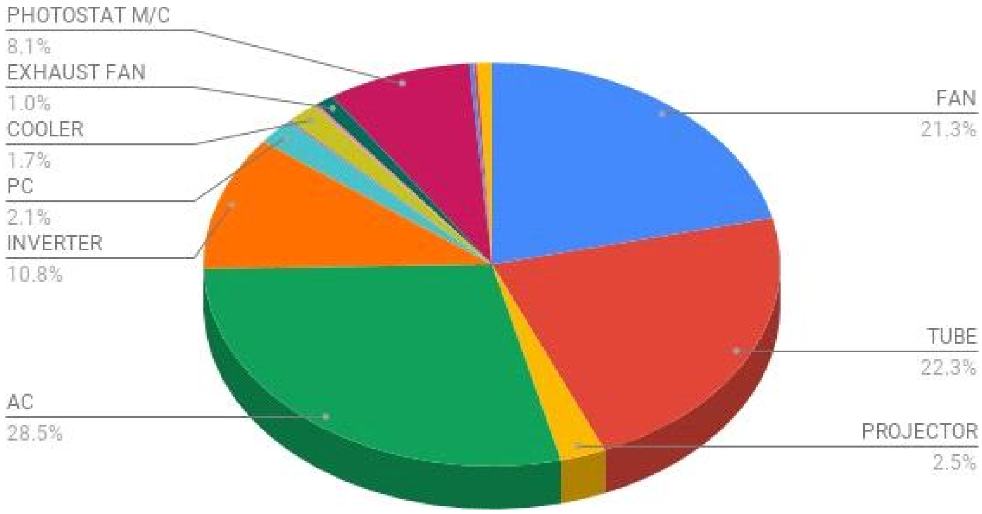

Fig 10: NLB connected load distribution

- DETAILS OF TOTAL CONNECTED LOAD : SOFTWARE BLOCK

SL NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	**FAN**	64	80W	5120
2	**TUBE**	417	40W	16680
3	**PROJECTOR**	20	150W	3000
4	**AC**	51	1000 W	51000
5	**INVERTER**	10	200W	2000
6	**PC**	195	25W	4875
7	**PRINTER**	14	20W	280
8	**COOLER**	3	750W	2250
9	**WATER PURIFIER**	4	10W	40
10	**EXHAUST FAN**	18	50W	9000
11	**PHOTOSTAT M/C**	3	1500W	4500
12	**TABLE FAN**	18	81W	1458

Table 3: SOFTWARE BLOCK connected load

- DETAILS OF TOTAL CONNECTED LOAD : OFFICE BLOCK

SL. NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	FAN	28	80W	2240
2	TUBE	44	40W	1760
3	AC	2	1000W	2000
4	PC	28	25W	700
5	PRINTER	14	20W	280
6	COOLER	1	750W	750
7	INDUCTION COOKER	1	1000W	1000
8	PHOTOSTAT M/C	6	1500W	9000
9	TABLE FAN	9	81 W	729
10	CFL	2	11W	22

Table 4: OFFICE BLOCK connected load

- DETAILS OF TOTAL CONNECTED LOAD : C BLOCK

SL. NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	FAN	58	80W	4640
2	TUBE	103	40W	4120
3	PROJECTOR	5	150W	750
4	PC	3	25W	75
5	PRINTER	3	20W	60
6	COOLER	1	750W	750
7	PHOTOSTAT M/C	1	1500W	1500
8	UPS	1	536W	536

Table 5: C BLOCK connected load

- DETAILS OF TOTAL CONNECTED LOAD : CANTEEN

SL. NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD(W)
1	FAN	33	80W	2640
2	TUBE	38	40W	1520
3	FRIDGE	2	100W	200
4	EXHAUST FAN	2	50W	100
5	COOLER	1	750W	750

Table 6: CANTEEN connected load

- DETAILS OF TOTAL CONNECTED LOAD : FM LAB

SL.NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	FAN	20	80W	1600
2	TUBE	21	40W	840
3	PC	1	25W	25
4	PRINTER	2	20W	40
5	INDUCTION COOKER	1	1000W	1000

Table 7: FM LAB connected load

- DETAILS OF TOTAL CONNECTED LOAD :THERMAL LAB

SL.NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	FAN	21	80W	1680
2	TUBE	27	40W	1080
3	AC	2	1000W	2000

Table 8: THERMAL LAB connected load

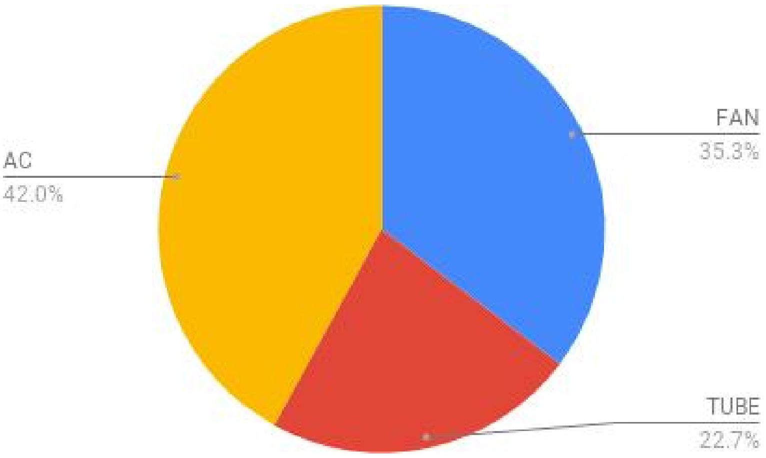

Fig 11: THERMAL LAB connected lab distribution

- DETAILS OF TOTAL CONNECTED LOAD :MACHINES LAB

SL.NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	FAN	30	80W	2400
2	TUBE	83	40W	3320
3	PROJECTOR	2	150W	300
4	PC	3	25W	75
5	AC	1	1000W	1000
6	INDUCTION COOKER	1	1000W	1000
7	COOLER	1	750W	750
8	WATER PURIFIER	1	10W	10
9	EXHAUST FAN	2	50W	100
10	TABLE FAN	5	81W	405

Table 9: MACHINES LAB connected load

- DETAILS OF TOTAL CONNECTED LOAD : SAROVAR HOSTEL

SL NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD (W)
1	FAN	130	80 W	10400
2	TUBE	125	40 W	5000
3	COOLER	5	750 W	3750
4	FRIDGE	1	100 W	100
5	EXHAUST FAN	5	50 W	250
6	GRINDER	1	370 W	370

7	**STABILISER**	1	3 KVA	3
8	**MIXER**	1	145 W	750
9	**TV**	1	145W	145

Table 10 : SAROVAR HOSTEL connected load

- DETAILS OF TOTAL CONNECTED LOAD :SAFETY BLOCK

SL NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	**FAN**	22	80W	1760
2	**TUBE**	102	40W	4080
3	**PROJECTOR**	1	150W	150
4	**AC**	5	1000W	5000
5	**INVERTER**	2	200W	400
7	**PC**	31	25W	775
11	**PRINTER**	5	20W	100
12	**COOLER**	2	750W	1500
13	**WATER PURIFIER**	2	10W	20
18	**EXHAUST FAN**	8	50W	400
19	**PHOTOSTAT M/C**	1	1500W	1500
20	**TABLE FAN**	20	81W	1620

- DETAILS OF TOTAL CONNECTED LOAD : A BLOCK

SL NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	**FAN**	39	80W	3120
2	**TUBE**	56	60W	3360
3	**PC**	8	25W	200
4	**COOLER**	1	750W	750
5	**CFL**	4	11W	44

Table 11: A BLOCK connected load

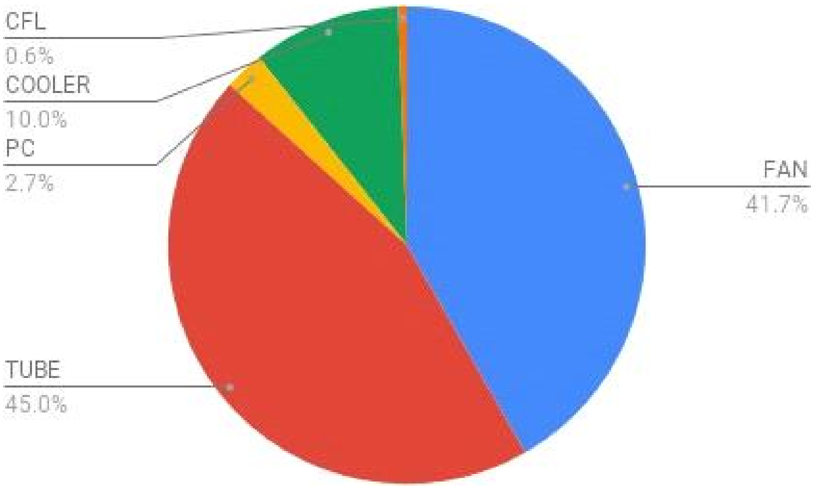

Fig 12: A BLOCK connected load distribution

- DETAILS OF TOTAL CONNECTED LOAD : SIBERIA HOSTEL

SL NO	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	FAN	67	80 W	5360 W
2	TUBE	122	40 W	4880 W
3	COOLER	3	750 W	2250 W
4	WATER PURIFIER	3	10 W	30 W
5	FRIDGE	1	100 W	100 W
6	EXHAUST FAN	5	50 W	250 W
7	GRINDER	1	370 W	370 W
8	STABILISER	1	3 KVA	3 KVA
9	MIXER	1	750 W	750 W
10	TV	1	145 W	145 W
11	LED LAMP	1	5 W	5 W

Table 12: SIBERIA HOSTEL connected load

- CONSOLIDATED LOAD DETAILS

SL NO:	TYPE OF LOAD	TOTAL NUMBER	RATING OF LOAD	TOTAL LOAD
1	FAN	858	80 W	68640
2	TUBE	1862	40 W	74480
3	PROJECTOR	50	150 W	7500
4	AC	98	300 W	29400
5	INVERTER	82	200 W	16400
6	PC	379	250 W	94750
7	PRINTER	31	20 W	620
8	COOLER	21	750 W	15750
9	WATER PURIFIER	11	10 W	110
10	FRIDGE	7	100 W	700
11	EXHAUST FAN	59	50 W	2950
12	PHOTOSTAT M/C	18	1500 W	27000
13	TABLE FAN	56	81 W	4536
15	UPS	3	536 W	1608
17	INDUCTION COOKER	3	1000 W	3000
18	CFL	6	11 W	66
20	GRINDER	2	370 W	740
21	MIXER	2	750 W	1500
22	TV	2	145 W	290
24	PUMP	1 4 1 1 1 1	10 HP 2 HP 1.5 HP 3 HP 1 HP 5 HP	21252.45

Table 13: Consolidated connected load

- ESTIMATED ENERGY CONSUMPTION

Based on the values of the connected load taken, annual energy consumption was calculated using assumed working hours for each loads. Since SOE is an educational institute the operating hours for class room and office buildings are assumed to be regular office hours, while for the labs and workshops the hours are taken appropriately according to their daily usage. For the hostels the after-college hours were taken as operating hours. It fell somewhat in line with the annual energy consumption calculated from KSEB electricity bills.

SL. NO	TYPE OF LOAD	CALCULATED ENERGY CONSUMPTION
1	FAN	82368
2	TUBE	74480
3	PROJECTOR	3000
4	AC	44100
5	INVERTER	6560
6	PC	75800
7	PRINTER	279
8	COOLER	22050
9	WATER PURIFIER	154
10	FRIDGE	1120
11	EXHAUST FAN	1180
12	PHOTOSTAT M/C	10800
13	TABLE FAN	3629
14	STABILIZER	29
15	UPS	1930
16	AMPLIFIER	21
17	INDUCTION COOKER	1200
18	CFL	79
19	GRINDER	296
20	MIXER	750
21	TV	290
22	PUMP	12751.5
	TOTAL	342866.5

Table 14: Estimated energy consumption

ENERGY SAVING OPPORTUNITIES

Based on the analysis of the power consumption data, certain steps have been recommended for improving energy efficiency of the campus. Complete cost analysis of implementation of recommended measures has been performed wherever necessary. Also, a number of general measures for energy efficiency have been listed. Described below are some important recommendations for better energy efficiency:

- **REPLACING ELECTRONIC BALLAST WITH LED TUBES**

Dominant light source at most places in the campus is traditional 40W FTLs with LED tubes which consumes 14 – 16W in addition to the 40W. As per our data collection, the campus has in total 1862 FTLs. If these FTLs are replaced by LED Tubes, 25-30W power can be saved per FTL.

Cost Analysis of Replacing Electronic Ballast [Choke] FTL with LED

- Total No. of Electronic Ballast[Choke] FTLs in Campus = 1862
- Average Power of Electronic Ballast[Choke] FTL = 40 W
- Average Power of LED = 18 W
- Power saved per LED Tubes = 22W
- Total Power saving = (1862*22) = 40.964 kW
- Average Use of LED Tubes per year = 200*5 = 1000hrs
- Total Energy saved per year = 40.964kw * 1000 =40964kWh
- Saving in Rs. Per year = 40964kwh * 8 = Rs. 327712 /-
- Average Cost of Replacing each FTL = Rs.500 /-
- Total Cost of Replacing all Electronic Ballast FTLs = 1862*500 = Rs. 931000/-
- Capital Cost Recovery time =(931000/327712) = 2.84yrs

Hence, the capital cost recovery time for replacing all Electronic Ballast FTLs of the campus is around 2.84years

• REPLACING RESISTANCE REGULATOR OF FANS BY ELECTRONIC REGULATORS:

Most of the buildings in campus are very old and so are the fans. Most of the fans here have resistance regulators. According to the data collected, there are a total of 512 fans with resistance regulator while number of fans with electronic regulator is only 290. A saving of 5-10W per fan can be obtained by replacing resistance regulators by electronic regulators.

Cost Analysis of Replacing Resistance regulators with Electronic regulators

- Total No. of resistance regulated fans in Campus = 420
- Average Power saved per fan = 8W
- Total Power saving = 420*8 = 3360W
- Average Use of fans per year = 200*6h = 1200hrs
- Total Energy saved per year = 1200*3360 = 4032kWH
- Saving in Rs. Per year = 4032* 8 = Rs. 32256/-
- Average Cost of Replacing per fan = Rs. 150/-
- Total Cost of Replacing all resistance regulated fans = 420 *150 = Rs. 63000/-
- Capital Cost Recovery time = 63000/32256 = 1.95yrs

Hence, the capital cost recovery time for replacing all resistance regulated fans of the campus is around 2 years.

• THERMOSTAT

AC thermostat is the device that controls the air conditioner units. It uses to turn the heater or AC unit ON and OFF. Reducing your thermostat three to four degrees will save you about 10% on your summer cooling bills. This is based upon a rule of thumb that you save approximately three percent for every degree warmer you set your thermostat.

Cost Analysis of installing at AC's in the campus with thermostats

- Number of ACs=98
- Rating of each AC=300 W
- Total number of hours of use(annually)=300*6
- Total power consumption(per year)=300*98*250*6=44100 KWH

- Savings=10% of total power consumption=10% *44100=4410
- Hence ,total savings in rupees=4410*8=35280
- Total installation cost of one thermostat=2000
- Total thermostats=40
- Therefore, total cost of installing thermostats=2000*40=80000
- Payback Period=80000/35280=2.26 years

Hence, the capital cost recovery time for installing at AC's in the campus with thermostats is around 2.26 years.

- **REPLACING FANS IN HOSTELS WITH GORILLA(BLDC) FANS**

The main difference between BLDC and ordinary DC fans is the commutation method. A commutation is basically the technique of changing the direction of current in the motor for the rotational movement. In a BLDC motor, as there are no brushes so the commutation is done by the driving algorithm in the Electronics. The main advantage is that over a period of time, due to mechanical contact in a brushed motor the commutators can undergo wear and tear, this thing is eliminated in BLDC Motor making the motor more rugged for long-term use.

Cost benefit analysis of replacing normal fans with gorilla fans was done for the entire SOE, but the payback period was more than four years. So, the decision was made just to replace fans in the hostels where the usage is much more.

Cost Analysis of replacing normal fans with Gorilla fans

- Total number of fans=200
- Total days of use=300
- Rating of regular fan=80W
- Rating of gorilla fan=28W
- Number of hours of use(annually)=300*15=4500
- Total savings=(80-28)*4500*200=46800
- Therefore total savings in rupees=46800*8=374400
- Cost per gorilla fan=320
- Total cost=3200*200=640000

- Payback period=640000/374400=1.7 years

Hence, the capital cost recovery of replacing normal fans with Gorilla fans is around 1.7 years.

- **AIR CONDITIONER**

Limiting the usage of ACs -assuming the AC is switched on for 3 hours during each of morning and evening sessions, total usage would amount to 6 hours. We could limit this usage to about 5 hours by switching off ACs prior to leaving the room. This will not affect the comfort level of consumer because the cooling effect of ACs will be prevalent for half an hour after being switched off. Timers can be pre-set in order to turn off ACs.

- Rating of each ACs=300W
- Number of ACs=98
- Total power savings=300*98*1*200=5880 KWH
- Total savings(In rupees)=5880*8=47040

A saving of 47040 Rs. can be made annually just by turning of the AC half an hour prior to leaving the room.

- **SMART POWER STRIP FOR COMPUTERS**

A smart power strip (also called a smart power bar) looks similar to a traditional power bar, however circuitry is designed to monitor and control power to each electrical outlet in the strip to improve energy efficiency and prevent household electronics from wasting power. Experts say standby power consumption is ap proximately 10 percent of your total energy consumption.

- Total number of PCs in campus that can use smart power strip=320
- Rating of each PC=300 W
- Annual hours of usage=4*200=800
- Total power consumption=76800 KWH
- Saving by using a smart power strip =10% of total
- Hence, power saved=7680
- Savings in rupees=7680*8=61440
- Cost of a smart power strip=2500
- Hence, total number of smart power strips needed=320/4=80(approx.)

- Total cost=2500*80=200000 rupees
- Therefore payback period=200000/61440=3.25 years (approx.)

Hence, the capital cost recovery of installing smart power strips for PC's is around 3.25 years.

- **SOLAR STREET LIGHTS**

A suggestion was made to separate external lighting from the grid and to replace it with solar power street lights. Having solar power street lights has the following advantages:

- Money & Energy saving:

After initial cost the solar energy is completely free and after installing solar street light system the customer can use it without any monthly bills. That will surely reduce the overall cost and save a lot of money and energy.

- Environment friendly:

Our solar street light uses solar energy to operate. Solar energy is completely free of pollutions and does not emit any hazardous gases. So using it is cost effective as well as environment friendly choice for us.

- Independent operation:

Solar street light operates independently and does not required power supply from external sources. This makes solar street light uses the energy generated through solar panel installed on top of the solar street light. This is the main reason that solar street light can be installed at outskirt areas where no grid electricity is available.

- Low or almost no maintenance:

Our solar street light does not require any maintenance. They operate silently, have no moving parts, do not release offensive smells and do not require you to add any fuel. More solar panels can easily be added in the future when your family's needs grow.

- Automatic operation:

These lights are designed for automatic operation. It means there is no need to switch solar street light on/off manually. Solar street lights have inbuilt light sensors and they get switched on/off automatically in day/night.

Solar street lighting is a very promising street lighting option that is coming up these days. Using solar one can completely avoid using electricity from grid for a few months in a year.

- Number of external lights present in the campus=22
- 13 of which are 90w rated and the rest 9 are 45w rated.

- Assuming they work for 12 hrs per day for 365 days in a year, Total power consumption=12*365*(13*90+45*9)=1575*12*365=6898.6KWh

- Assuming a charge of Rs 8 per unit ,total charge in a year=Rs 55188.

Replacing 90w CFL with 50w LED and 45w CFL with 27w LED

- Cost of installation of one solar street lighting system(50W LED)=Rs 20000(including labour cost)

- Cost of installation of one solar street lighting system(27W LED)=Rs 15000(including labour cost)

- Total Cost of installation=13*20000+9*15000=Rs 395000

- Therefore payback period =7.15 years

- From then onwards, energy saved per year =6898.6KWh

- Savings in rupees per year=Rs 55188

Incandescent Watts	CFL Watts	LED Watts	Lumens (Brightness)
40	8 – 12	6 – 9	400 – 500
60	13 – 18	8 – 12.5	650 – 900
75-100	18 – 22	13+	1100 – 1750
100	23 -30	16 – 20	1800+

Table 15: Comparison of lumen output of different types of bulbs

- **REPLACING REPAIRED FANS WITH LOWER RATED FANS**

- Number of fans repaired once = 346
- Number of fans repaired twice = 58
- Fans repaired once have a rating of 96 W

- Fans repaired twice have a rating of 112 W
- Replace each fan by 50 W

∴Average power saved for replacing fan repaired once = 96-50 = 46 W

∴Average power saved for replacing fan repaired twice = 112-50 =62 W

Total Power Saving = 46*346+62*58 = 19512 W

- Average use of fans per year = 200*6 = 1200 hrs
- Total energy saved per year = 1200*19512 = 23414.4 KWh
- Saving in Rs per year = Rs 1600
- Total cost of replacing fans = 404*1600 = Rs 646400
- Capital Cost Recovery time = 646400/183715.2 = 3.45 years.

Hence, the capital recovery cost of replacing previously repaired fans with new fans of lower rating is around 3.45 years.

- ### OVERALL COST BENEFIT ANALYSIS

Overall cost benefit analysis can be found out by considering each of the cost incurred of the proposed energy saving measures and their respective calculated savings.

- Total expenditure of proposed energy saving measures= 2955400 Rs
- Total savings per year = 1117355 Rs
- Total energy savings(in units)= 140081 KWh
- Total payback period= 2955400/1117355 = 2.64 years

Total cost incurred by the aforementioned energy saving mentioned will have a payback period of 2.64 years.

POWER QUALITY STUDY

In AC power supply systems, current waveform is distorted and harmonics are created due to usage of non-linear loads that reduces the quality of power. That causes enormous fault occurrence and monetary losses toward power supply system. Harmonics effect in AC power system is increasing day by day. Harmonics due to personal computers loads has particular attention to power quality (PQ) because personal computers are frequently concentrated in a massive group and produces harmonics. A. Personal Computers(PC's) Personal computers are non-linear loads to AC system. Switch Mode Power Supply (SMPS) used in computers generate harmonics. For nonlinear load, non-linear flow of current is created because of dc link capacitor in power supply.

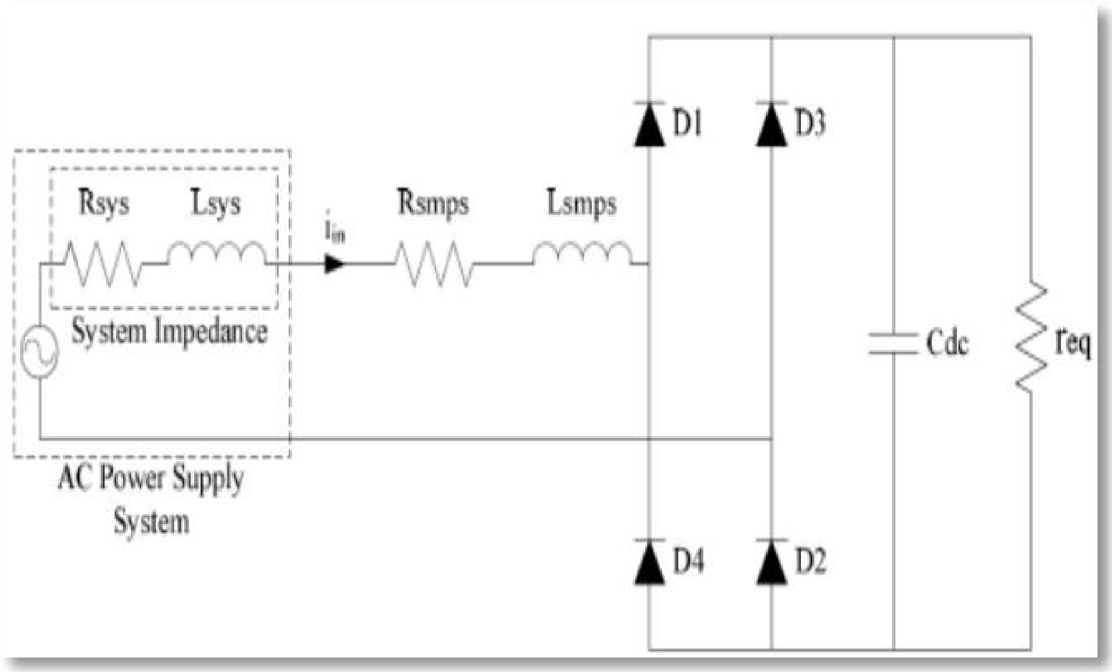

Fig 13: Equivalent SMPS circuit model of PC

TABLE 16: PQA MEASURED RESULTS

No of PC's	Input supply voltage	Input supply current (ampere)	PF	DPF	Apparent Power	Active Power	Reactive Power	Crest Factor for current	Crest factor for voltage
1	209.5	0.87	-0.77	-1	183	-140	118	2.2	1.4
24	140.4	22.22	-0.80	-0.99	4.24k	-3.41k	2.52k	2.0	1.3

TABLE 17: PQA MEASURED RESULTS OF CURRENT THD,VOLTAGE THD

No of PC's	3rd Harmonic	5th Harmonic	7th Harmonic	9th Harmonic	11th Harmonic	13th Harmonic	15th Harmonic	Current THD	Voltage THD
1	57.2	28.3	8.6	11.3	8.6	9.5	5.4	66.3	1.6
24	51.3	10.6	9.0	5.8	2.5	3.7	0.4	55.8	4.3

TABLE 18: CIRCUIT PARAMETERS USED FOR SIMULATION OF EQUIVALENT COMPUTER POWER SUPPLY

Voltage(Supply)	220V	C	100*(10^-6)F
Current(Supply)	10.65	R	25 ohm
Frequency	50Hz	Voltage(f)	0.8V
R(Sys)	1 ohm	H	3rd,5th,7th,9th
L	1mh		

- METHODOLOGY

Harmonic distortion depends upon electronic elements used in appliance's circuitry. Numbers of nonlinear residential loads are increasing day by day; therefore harmonics caused by these loads cannot be neglected. There are many techniques to reduce harmonics but economic and maintenance points of view there have necessity to select best compensation method. The design attempts to comply with the IEEE Standard 519- 1992 recommended harmonic limits applied to the current harmonic limits.

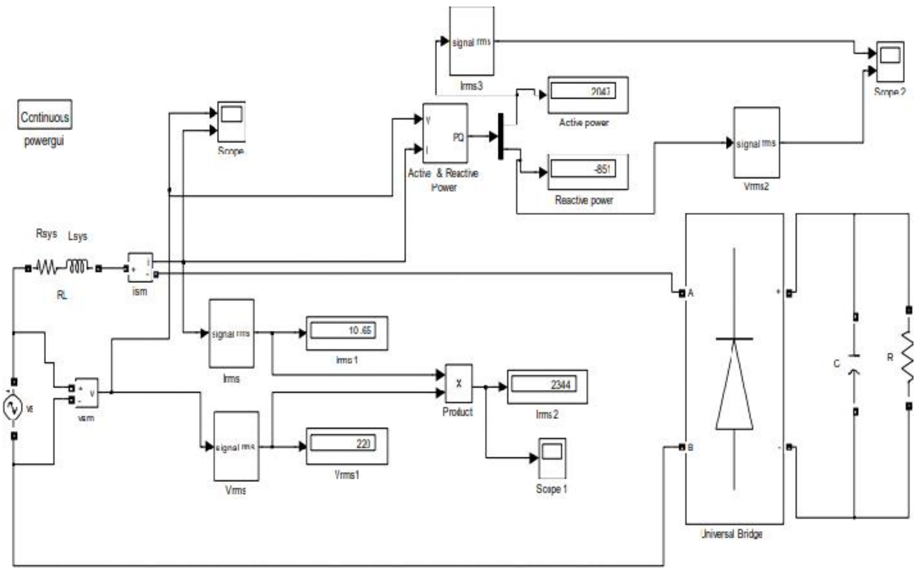

Fig 14:Simulation of proposed model for passive filter design.

Fig 15: Simulation of equivalent SM.

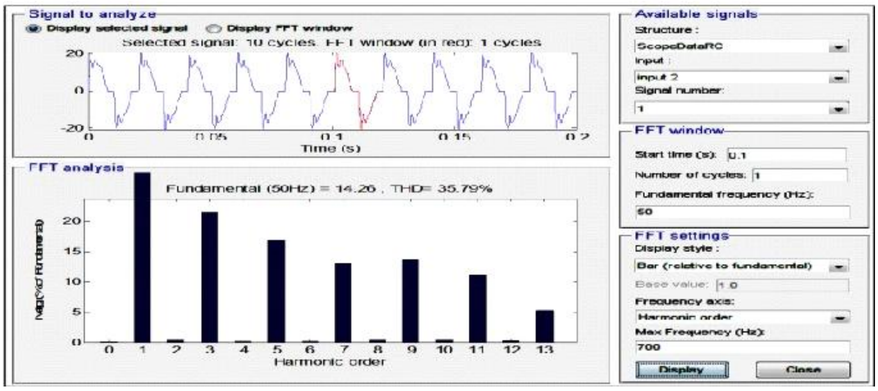

Fig 16: Input supply current without passive filter.

- SIMULATION OF EQUIVALENT SMPS OF PC

The parameters used for this system are given in Table III and equivalent SMPS of PC is simulated using MATLAB software by Simulink library as shown above. The 3rd, 5th, 7th , 9th and 11th harmonic component are high in magnitudes. So these harmonic components are to be mitigating during this research work. Fig. 16 shows the supply current prior to installation of passive filter, the current and voltage harmonic distortion (THD i and THD v) are found to be 35.79 % and 0.38 % respectively. So IEEE limits for THD i distortion limits are violated while THD v is found under standard limit.

<u>Design of Single-Tuned Passive Filter</u>
Quantities required for the filter design:

- Non active power N in VAR
- Supply frequency f in Hz
- Supply voltage (rms) Vs in volts
- Harmonic order h Number
- Quality Factor Q l.

Steps to calculate values of C, L and R for single tuned filter.
$Xc=(Vs2/N)*(h2/(h2-1))$
$C=1/(2*pi*f*X c)$
$X_L=X c/h2$
$L=Xl/(2*pi*f)$
$R=Xl/Q l$

Here to avoid from using a trial-and-error approach for single tune filter design, non-active power is considered as design parameter and proposed MATLAB/Simulink model for doing this calculation and various power obtained from this proposed model is written as shown in Table 19.

TABLE 19.:VARIOUS POWERS OBTAINED WITH PROPOSED MODEL

S(VA)	P(W)	Q(VAR)
2344	2047	-851

Now we can use below equation to computes the nonactive power needs in Var as follows:
N=√Q2+H2
N=1141.89 VAR
Now we can calculate values of required passive harmonic component filter as follows. For 3rd Harmonic filter

Xc =47.69ohm
C=66.79μF

X_L=5.29 ohm
L=16.8 mH
R=0.1058ohm

Similarly follows the same steps ,in this paper four single tuned passive filter has been designed such as 3rd,5th,7th and 9th and the values of all passive tuned filter can be found out.

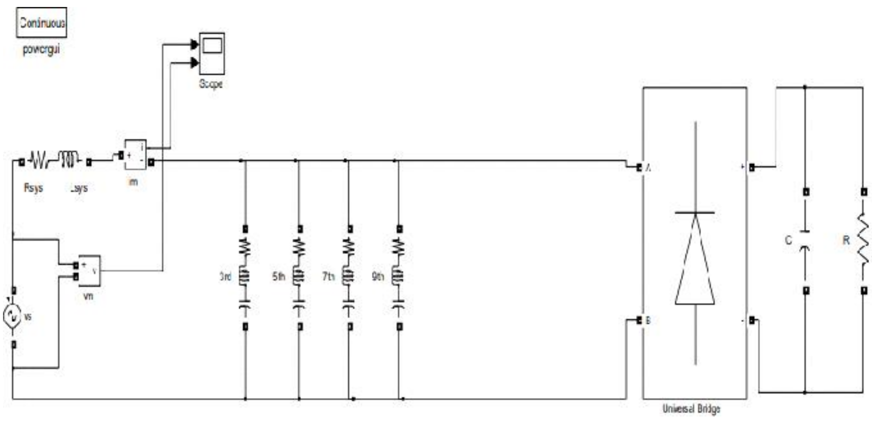

Fig 17: Simulation model of equivalent computer power supply using 3rd,5th,7th and 9th harmonic filter.

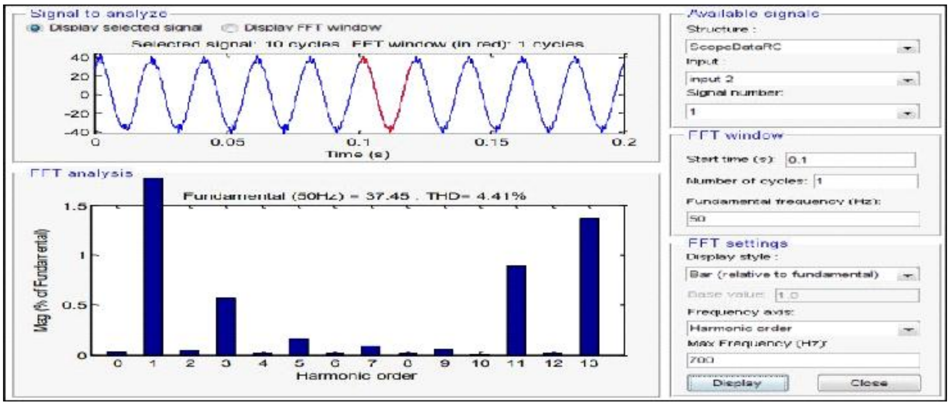

Fig 18:Input supply voltage with passive filter

Fig. 17 shows simulation model of equivalent computer power supply using designed filters. Fig 18 show source current after passive filter installation. Current THD was reduced to 4.41% from 35.79 % after passive filters installation according to IEEE limit. It can be noticed that before compensation, the input supply current is not sinusoidal (distorted) with rms. (root mean square) value of 14.26 ampere. The input source current after compensation by passive filter becomes nearly sinusoidal from the distorted wave. After compensation the source current becomes sinusoidal with rms value of 37.45 and in phase with the supply voltage.

The harmonic distortion depends upon electronic elements used in appliances circuitry. Numbers of nonlinear residential loads are increasing day by day; therefore harmonics caused by these loads cannot be neglected. Produced harmonics due to residential loads should be minimized. There are many techniques to reduce harmonics but economic and maintenance points of view there have necessity to select best compensation method. Design of passive harmonic filters by using non active power can be the better and simple solution and cost effective systems. By means of the simulation of proposed design method of passive filters showed good results for harmonic reduction with profit of upgrade of power factor too.

RECOMMENDATIONS FOR IMPROVED ENERGYEFFICIENCY

The following conservation measures are suggested to be implement for energy conservation to various loads:

- FANS

  - Replace all resistance regulators with electronic regulators.
  - Minimising repair in fans:
  - During data collection repaired fans have been found to consume high power.
  - It has been found that the fans repaired once consumes 20%more avg consumption in the fans repaired twice consume 40%more avg consumption.

- AIR CONDITIONER

  - Replacing life expired inefficient AC units with energy efficient 5 star rated AC units
  - Adjusting thermostat setting by 3 degree higher level to keep room temperatures at optimum condition of 25-26 degree.
  - Switching on the AC before 15 mins of leaving the AC space.

Reducing the heat gain in AC spaces will reduce the energy used for cooling, and Heat gain can be reduced by using the following measures:

- Improve building fabric.
- Shield the building with shaded trees.
- Reduce lighting whenever possible.
- Block unneeded windows.
- Control air leakage out of the facility.
- Upgrading of wall insulation is difficult and expensive because of original construction techniques or because activities inside the building would be disrupted.
- New insulator roof membrane can be covered with reflecting silver coloured polymer paint to help minimise heat transmission.

- Standard triple glazing to windows adds extra air space, hence insulation.
- Glass coating reduces heat emissivity and reflection
- Low emissivity coating reduces heat through the glass and reflection.
- Low emissivity reduces radiant heat through the glass and achieves same insulation as triple glazing.

Reducing air leaks can improve the efficiency of the AC and this can be made sure using the following measures:

- Examine all openings for cracks that allow air to leak in and out of the building.
- Door seals to be provided
- Most efficient door is an unglazed insulated door with double stripping.
- Proper maintenance and cleaning of AC's is required at regular intervals.

- COMPUTERS
  - Configure your monitor to turn off after 10 minutes of inactivity, your hardware to turn off 20 minutes after your inactivity. Place your PC in a standby mode when you leave office for more than 2hrs.
  - Do not use screensaver as energy saver as they cause monitor to continue operating at full power.
  - Do not turn on your comp in the morning until you actually need it.
  - There is a common misconception that pc's and monitors purchased with energy star logo are efficient, in reality they are built in energy conservation features but PC can't take full advantage of it.

- PUMPS
  - Use level controllers for tank filling.
  - Shut down pumps when not required.
  - Maintain clearance tolerance at pump impellers.
  - Check and adjust drivers regularly for belt tension and coupling alignment.

- Clean pump impellers and repair or replace if corroded.
- Implement a program of regular inspection and preventive maintenance to minimise pump failures.
- Install variable speed drive to address demand for liquid flow with flexibility.

- USE OF MASTER SWITCH ON EACH FLOOR
    - Installation of master switch can make it easy for a person to switch off all appliances of a room in case someone forgets to switch off while leaving the room.

- ELECTRICAL DISTRIBUTION
    - Load balance to reduce neutral current.
    - Reduce supply voltage to match rated voltage of equipment with transformer tap settings.

- UPS SYSTEMS
    - Optimising the number of ups by disconnecting additional ups and improving load and existing working ups.

Dr.G.Madhu
Professor
Division of Safety and Fire Engineering
School of Engineering

Dr.P.G Latha
Associate Professor
Division of Electrical and Electronics Engineering
School of Engineering

Dr.James Varghese
Associate Professor
Division of Mechanical Engineering
School of Engineering

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY