ENERGY AUDIT

Conducted at

REVA UNIVERSITY,
KATTIGENAHALLI CAMPUS, BANGALORE

REVA UNIVERSITY
Bengaluru, India

REPORT NO.: REVA/EEE/EA/03/2019

Audit Period : July 2018 - June 2019

Study conducted by

School of Electrical & Electronics Engineering,
REVA University, Kattigenahalli, Yelahanka,
Bangalore - 560064

Project Summary

1.	Title:	Energy Audit at REVA University, Kattigenahalli Campus, Bangalore
2.	Sponsoring agency:	REVA University, Bangalore
3.	Contact Person	Mr. Shivaraj, Maintenance Engineer
4.	Energy Audit Conducted by	Dr. Rajashekar P. Mandi, Director, School of EEE, Certified Energy Auditor (EA-3246), E-mail: dir.eee@reva.edu.in Ph: 9448465065
5.	Energy Audit team members	Shri. B.S. Shivaraj, Electrical Engineer Prof. Adithya Ballaji, Asst. Professor Prof. Burri Ankaiah., Asst. Professor, Prof. Sujo Oommen, Asst. Professor Prof. Pavan B., Asst. Professor
8.	Objectives:	➢ Conserve the energy at REVA University ➢ Reduce the energy losses thereby saving the energy cost
9.	Scope of work:	➢ Study of energy consumption and maximum demand variation pattern ➢ Re-organisation of electrical system ➢ Performance evaluation of electrical system including power factor, demand, etc. ➢ Performance evaluation of lighting system ➢ Performance evaluation of DG sets & Air-conditioners ➢ Performance evaluation of water pumping system. ➢ Computing the energy index as per ECBC codes and suggestion for reducing the energy consumption.
10.	Report No.:	REVA/EEE/EA/03/2019
11.	Energy Audit period	July 2018 – Jun 2019
12.	Date of issue of report:	June 2019
13.	Signature of Certified Energy Auditor	

ACKNOWLEDGEMENT

The Energy audit team is thankful to Hon'ble Chancellor Dr. P. Shyama Raju and the Management of REVA University, Bangalore to take up the energy audit activities at REVA University Kattigenahalli Campus.

We are thankful to Dr. S.Y. Kulkarni, Vice Chancellor, Dr. P. Dhanamjaya, Registrar, Deans, Directors of all Schools, coordinators from all schools and the staff of electrical maintenance department for their excellent co-operation, valuable help and arrangements made during the conduct of the energy audit study.

EXECUTIVE SUMMARY

The detailed Energy audit study is conducted at REVA University, Bangalore for the period of July 2018 to June 2019. The electrical energy from grid was varying between 188.2 MWh/month to 265 MWh/month. The average monthly energy consumption is reduced from 242 MWh/month to 233 MWh/month and the reduction is 3.7% of total energy consumption due to the implementation of energy conservation measures compared to previous year.

The total energy consumption (grid+DG) for period during energy audit study was varying between 200 MWh/month (July 2018) to 291.5 MWh/month (March 2019). The monthly average total energy consumption is reduced from 253.1 MWh/month to 248.1 MWh/month compared to previous year. The reduction is about 2.1% of total energy consumption. The total energy consumption from grid during the academic year 2018-19 is 27,96,140 kWh/y, energy generation by DG set is 1,81,270 kWh/y and the total energy consumption at REVA University is 29,77,410 kWh/y. The total built area is 1,46,548 m^2. The energy performance index (EPI) for total REVA University campus is 20.32 kWh/m^2-year which is reduced from 21.59 kWh/y compared to previous year. The overall EPI is lower than the EPI specified by Energy Conservation Building Code (ECBC) 2006 of 120 kWh/m^2-year.

The recorded MD during the energy audit period was varying between 675 kVA to 725 kVA. The recorded MD during July 2018 is reduced to 675 kVA due to vacation for academics at REVA University but the minimum chargeable MD is 1003 kVA because the power is taken through open access where the minimum chargeable MD will be for 1003 kVA. The monthly average power factor is varying between 0.90 and 0.96. The power factor is good because of addition of lighting load and also installation of automatic power factor controller at main incoming.

The variation of energy cost during the energy audit period was in the range of Rs. 14.7 lakhs/month to Rs. 23.1 lakhs/month. The average monthly total energy cost is reduced from Rs. 21.8 lakhs/month to Rs. 20.4 lakhs/month compared to

previous year. The energy cost is reduced may be due to implementation of energy conservation measures and also due to purchasing the energy from renewable energy through open access. The reduction in cost is by about 6.4 %. The average energy rate during energy audit period was varying between Rs. 8.34 to 9.35 per kWh. The energy rate has decreased after Dec. 2017 due to change of category of service connection. Again the average energy rate is increased to Rs. 8.49 per kWh due to increase of contract demand.

The major energy is being used at Hostel panel 1 (Boys Hostel A, B & C, Girls hostel 2, Library, Guest house and faculty & staff Quarters) is 82.7 MWh/month (35.5% of total energy consumption) and followed by the Boys D hostel, Girls hostel 1 and STP feeder energy consumption is 50.1 MWh/month (21.7%). The total energy used by hostels, guest house, quarters, water pumping, STP & library is 59.4%. The energy used for academics is 41.6% of total energy consumption.

The major energy is used for lighting system i.e., 19.1% of total energy in which 9.3% is used for hostel lighting. The next major energy consuming facility is lab equipment which forms about 18.7%. The energy used for computers & peripherals is 17.7%. The energy used for air-conditioning (AC) system is 14.7%. The energy used for comfort air fans is about 13.5% including hostel. The energy shared for faculty & staff quarters is 7.6% of total energy consumption. The energy used for water pumping system is 2.0% and for STP plant is 1.3%. The energy loss in transformer is computed as 1.7% and distribution loss is 3.7% of total energy consumption.

There are two distribution transformers Tr. 1 of 500 kVA & Tr. 2 of 1000 kVA to step down high voltage of 11 kV to 433 V at main incoming. The energy loss in transformer is computed as 4.0 MWh/month that forms 1.7% of total energy input. The power factor on transformer secondary is good in the range of 0.91 to 0.96 due to use of automatic power factor correction (APFC) panel. The load of transformer 1 is varying between 20.2 to 61.3% and transformer 2 is in the range of 3.8 to 23.3%. All day efficiency of Tr.1 is 98.4% which is slightly better than that of Tr. 2 of 97.6%. The diverting of all the total loads on to Tr. 2 (1000 kVA) during

day time between 08:00 to 17:00 hours and during evening hours between 17:00 to next day 08:00 hours will reduce the *energy consumption by 3,045 kWh/month*.

There are two DG sets of 500 kVA to provide the back up power during grid power failure. The load factors of DG sets are in the range of 46.4 to 51.2% and the Specific energy generation (SEG) of DG sets is normal in the range of 2.95 to 2.99 kWh/l.

There are about 19 numbers of underground sump pumps to lift the water from sump to overhead tank and these pumps are installed with auto controllers. There are about 8 numbers of borewell pumps to lift the water from ground to underground sumps. These pumps are being operated manually. The load factors of these pumps are in the range of 69.3 to 87.6% and are normal. The water pump – motors can be overhauled at regular intervals to enhance the energy efficiency of water pumps which will save the energy consumption.

There are about 2,230 computer systems and 145 printers of different sizes. The power consumption for the system varies between 355 to 415 W. The power used by printers varies between 280 to 950 W but the power is varying widely. In many labs the systems are put OFF after the completion of labs but few places it was observed that systems were put ON in energy saving mode. But in energy saving mode, the processor will be working that consume the power of about 150 to 200 W. It is suggested to put OFF the systems whenever they are not required.

The specific cooling capacity of air-conditioning system varies between 1167 to 1718 TR/ft^2 which is slightly higher than the normal specific air-conditioning system of 1000 TR/ft^2. The average specific energy consumption (SEC) for air-conditioning units of different size varies between 1.23 to 1.73 kW/TR (the average SEC is 1.35 kW/TR). At few labs and seminar halls, it was observed that the room temperature is being maintained at 21 – 23 ^{o}C which should be maintained above 25^{o}C (human comfortable) which will reduce the energy consumption by 3% per degree of room temperature. The anticipated *energy saving is 455 kWh/month*.

The relative humidity in the air-conditioning room is being maintained in the range of 40 to 58 % and is good.

At Administrative block 55 kW solar power plant is installed to provide the power supply to loads at administrative block. The 55 kW solar power plant generates energy in the range of 5,273 to 6,811 kWh/month during the audit period. The energy generation by inverters is reduced over the period of time due to degradation of PV panel and the degradation rate is 8.2 % for inverter 1, 15.4 % for inverter 2, 18.2% for inverter 3 and 6.6% for inverter 4. The total energy generation by solar PV plant is reduced by 12.5% during last 4 years due to degradation of PV panels and the degradation rate is very high. The overall specific energy generation or yield is reduced from 4.15 kWh/kW-day to 3.63 kWh/kW-day. The present yield is very less compared to the normal acceptable value of 5.0 kWh/kW-day. This solar PV power plant reduced the CO_2 emission in the range of 76.6 t/y to 87.5 t/y (average of 2.91% of total CO_2 emission).

About 80,000 LPD solar hot water system is installed to provide the hot water to students residing at hostels. The specific hot water is varying between 18.3 to 28.0 and the water temperature varies between 45 to 60^{o}C. The nominal Specific hot water requirement is 25 LPD/student at a temperature of 60 ^{o}C. The installation of solar hot water system had reduced the electrical energy consumption (if hot water is provided through electric heating) by about 48,000 kWh/month and the reduction of CO_2 emission is about 50.4 t/month which is a very good initiation of energy conservation measures.

At Sir CV Raman block Amphi theatre roof, the transparent polycarbonate sheets are installed for the approximate area of 1025 m^2. This had allowed very good natural light during day hours which had reduced the average electrical energy of 490 kWh/month which is commendable. Similarly at Vivekananda block Rangasthala roof is also provided with transparent polycarbonate sheets for the approximate area of 900 m^2. This had allowed very good natural light during day hours and had reduced the average electrical energy of 430 kWh/month.

The energy used for lighting system is 44.6 MWh/month that forms 19.1% of total energy consumption. The energy used for comfort air fans is 31.5 MWh/month that forms 13.5% and for other end use & lab equipment is 43.5 MWh/month that forms 18.7% of total energy consumption. The illumination level is good because many rooms, natural light is available and is being used appropriately. At rooms and labs, about 2664 numbers of 36W T8 fluorescent lamps (TFL) are installed, if these T8 lamps are replaced by 18W LED lamps will reduce the total energy consumption by 7,033 kWh/month. The anticipated investment is Rs. 10.66 lakhs and the simple payback period is 20 months.

In order to conserve the energy consumption at Hostel blocks, at each room one number of the 36W T8 TFL lamp were already replaced with 18W LED lamp. This had reduced the total energy consumption for 3360 number of lamps by 15,120 kWh/month with an investment of Rs. 12.10 lakhs and the payback period was 10 month which is a very good payback period.

At present the installation of renewable energy system had reduced the electrical energy consumption of 54 MWh/month that forms 19.2% of total energy consumption and reduced the CO_2 emission of 56.7 t/month.

Summary of Recommendations
Immediate term measures

Sl. No.	Recommendations	Anticipated energy savings, kWh/month / Rs.	Anticipated investment, Rs.	Payback period, months
01	Transformer management	3045 kWh/month	-	-
02	Optimizing the room temperature in AC rooms	455 kWh/month	-	-
Total		**3500 kWh/month**	**-**	**-**

Medium term measures

Sl. No.	Recommendations	Anticipated energy savings, kWh/month	Anticipated investment, Rs. in lakhs	Payback period, months
01	Replacement of 36W T8 lamps by 18W LED lamps	7033 kWh/month	10.66	20
Total		**7033 kWh/month**	**10.66**	**20**

Long term measures

Sl. No.	Recommendations	Anticipated energy savings, kWh/month	Anticipated investment, Rs. in lakhs	Payback period, months
02	Installation of energy management system	[a]	10	-
Total		**[a]**	**10**	**-**

[a] intangible savings

CONTENT

1.0 INTRODUCTION

The use of electrical energy generated through fossil fuel based power plants cause global warming and also leads to air pollution due to release of large amount of CO_2 into the atmosphere. Thus, conservation of energy is the essential tool to control the pollution and also for energy security in India. Since India has adopted central power generation and transmission & distribution of power through lengthy lines, cause huge energy loss. Therefore, saving one unit of electrical power at end-use is equivalent generation of two units of power. This necessitates conducting of energy audits and implementation of energy conservation measures in Institutes, industries, buildings, etc. The REVA University is committed in conserving the energy and also help the nation in controlling the air pollution as well as global warming. This section introduces the REVA University, scope of the work and electrical distribution system.

1.1 REVA University

REVA University has been established under the REVA University Act, 2012. The University is located in Bengaluru on a sprawling green campus, spread over 45 acres of land, built with the state-of-the-art infrastructure creating an environment conducive for higher learning and research.

The founders of REVA University believe in the motto' Knowledge is Power'. Driven with a philanthropic vision and a missionary zeal, the campus is built to transform students into outstanding citizens. The University prides itself in contributing to every student's holistic development. The University currently offers 24 Full-time Post Graduate Programs, 5 Part-time Post Graduate programs, 21 Graduate programs, several Certificate/Diploma and Post graduate Diploma programs in Engineering, Architecture, Science & Technology, Commerce, Management Studies, Law, Arts & Humanities and Performing Arts. Above All, the University facilitates Research leading to Doctoral Degrees in all disciplines. The programs offered by REVA University are well planned and designed based on in depth analysis and research will emphasis on knowledge assimilation, practical

applications, hands-on training, global and Industrial relevance and their social significance.

REVA University believes in preparing students through the Choice Based Credit System (CBCS) and Continuous Assessment and Grading Pattern (CAGP) of education. The CBCS & CAGP pattern of education has been introduced in all programs to facilitate students to opt for subjects of their choice in addition to the core subjects of the study and prepare them with required skills. It also provides opportunities for students to earn more credits and there by acquired additional Proficiency Certificates and Diplomas.

The University is located at Bangalore on the way to Bangalore International Airport from city at distance of about 15 km from city. The campus comprises of 4 Hostel blocks for boys & 2 hostel blocks for ladies with all basic amenities. A good number of faculty quarters provide ample opportunity to draw upon benefits of corporate life.

The main energy source is electrical energy and is presently being tapped at 11 kV feeder. The 11 kV is stepped down to 0.433 kV by using 500 kVA and 1000 kVA transformers. To provide the back up power supply during grid power failure, two numbers of 500 kVA DG sets are installed. All the Hostels are provided with grid power as well as DG set power supply.

1.2 Scope of work

The detailed scopes of energy audit at REVA University are:

1. Study on present energy consumption and maximum demand pattern
2. Study on use of renewable energy system
3. Study on Existing Electrical Network i.e., voltage profile, power factor variation
4. Electrical Motors and Drives (Above 5 kW)
5. Air Conditioning System

6. Water Pumping System
7. Diesel Generating Sets
8. Lighting Levels
9. Re-organization of the Electrical Network

1.2.1 Existing Electrical Network

(a) *Transformer Performance Evaluation:* Load Cycle Analysis, Determination of Peak Load, Efficiency, Strategy for optimum loading and minimization of transformer losses.

(b) *Power factor Management: S*tudy of Power factor at different locations and schemes for improvement

(c) *Distribution Network Evaluation:* Determination of peak load carried by cables and conductors, studies on energy losses, strategy for optimal loading and future expansion

(d) Voltage Profile Analysis: Analysis of incoming voltage conditions at different locations and schemes for improvement.

1.2.2 Electrical Motors and Drives (Above 5 kW)

(a) Analysis of loading conditions, load pattern, operating parameters such as kW, kVA, power factor, voltage, current and frequency

(b) Suggestions for proper sizing, energy efficient motors and other measures.

1.2.3 Air conditioning System

(a) Measurement of power consumption and estimation of specific power.

(b) Energy efficiency measurement

(c) AHU performance evaluation

(d) Energy Conservation Measures

1.2.4 Water Pumping System

(a) Measurement of Water flow rate

(b) Measurement of delivery pattern
(c) Analysis of Pumps, Motors, Drives, Flow Control System employed
(d) Efficiency computation
(e) Prevention of operational failures
(f) Energy Conservation Measures

1.2.5 Diesel Generator Sets

(a) Performance Evaluation
(b) Analysis of loading pattern
(c) Specific energy consumption determination
(d) Schemes for optimal operation

1.2.6 Lighting Levels

(a) Illumination level measurement at different locations
(b) Optimum lighting scheme
(c) energy conservation measures

2.0 EXPERIMENTAL WORK

The energy audit field work was carried out through the year from July 2018 to June 2019. The field work consists of:

- Measurement of voltage, current, power factor, power, energy, voltage & current harmonics at all the transformers and DG sets.
- The lighting level measurements were taken for all the labs, class rooms, faculty rooms, guest house, etc.
- The discharge pressure and water flow measurements were carried out for water pumps.
- Performance test on DG sets

3.0 OBSERVATIONS, STUDY RESULTS AND DISCUSSION

The detailed observations and results are discussed in detail below:

3.1 Overall Energy Consumption

The energy consumption at REVA University is given in Figure 1 and the total energy consists from two sources i.e., grid energy which is being purchased from renewable energy source through open access and the energy from DG sets for back up power. The grid energy is varying between 100.8 MWh/month (Jan. 2015) and 284.7 MWh/month (March 2017). During the energy audit period for the year 2018-19, the energy consumption was varying between 188.2 MWh/month (July 2018) to 265.0 MWh/month (March 2019). The average monthly energy consumption is reduced from 242 MWh/month to 233 MWh/month and the reduction is 3.7% of total energy consumption due to the implementation of energy conservation measures compared to previous year. The energy consumption was less 194.8 MWh/month and 220 MWh/month respectively for the months of Jan 2019 & June 2019 due to semester end vacation. The energy consumption was peak of about 265 MWh/month during the month of March 2019. The deviation between maximum to minimum energy consumption value is 30.1 % and is normal.

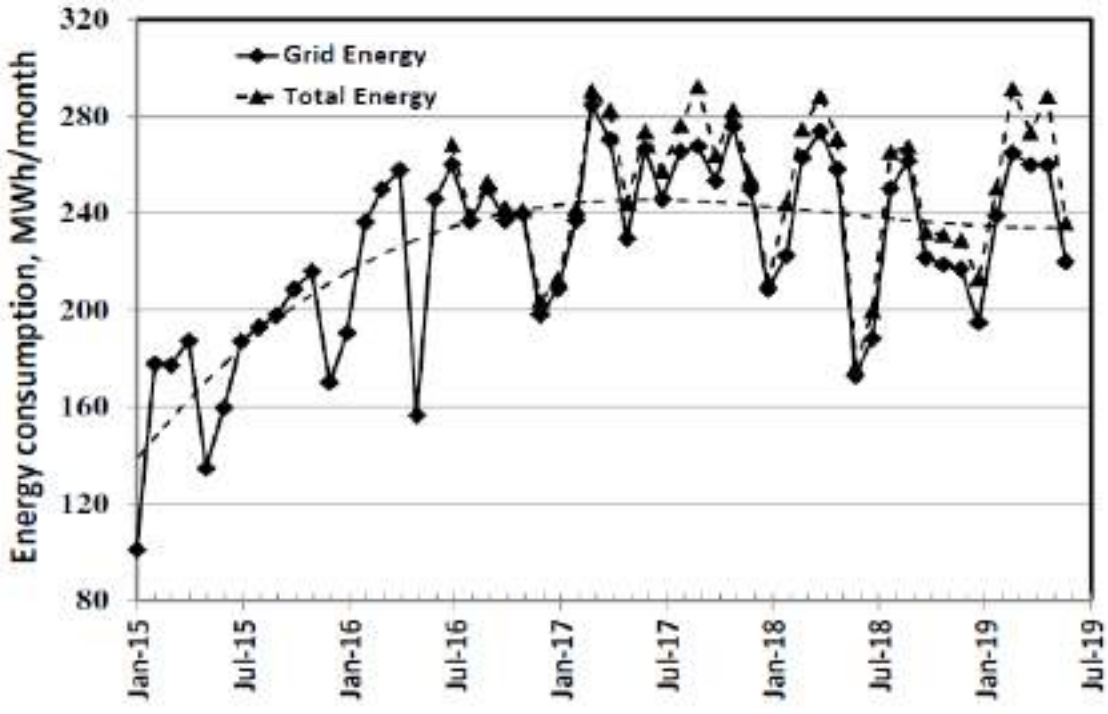

Figure 1: Variation of energy consumption.

Figure 2 gives the variation of total energy generation by DG sets and its share. The energy generation by DG sets is varying between 1.6 MWh/month (Nov. 2016) to 28.4 MWh/month (May 2019). The energy generation during the period of audit is varying between 11.4 MWh/month to 28.4 MWh/month. During May 2019, the energy generation was more due to more power cut. The share of energy used by DG set is varying between 4.5 to 9.8% which is normal.

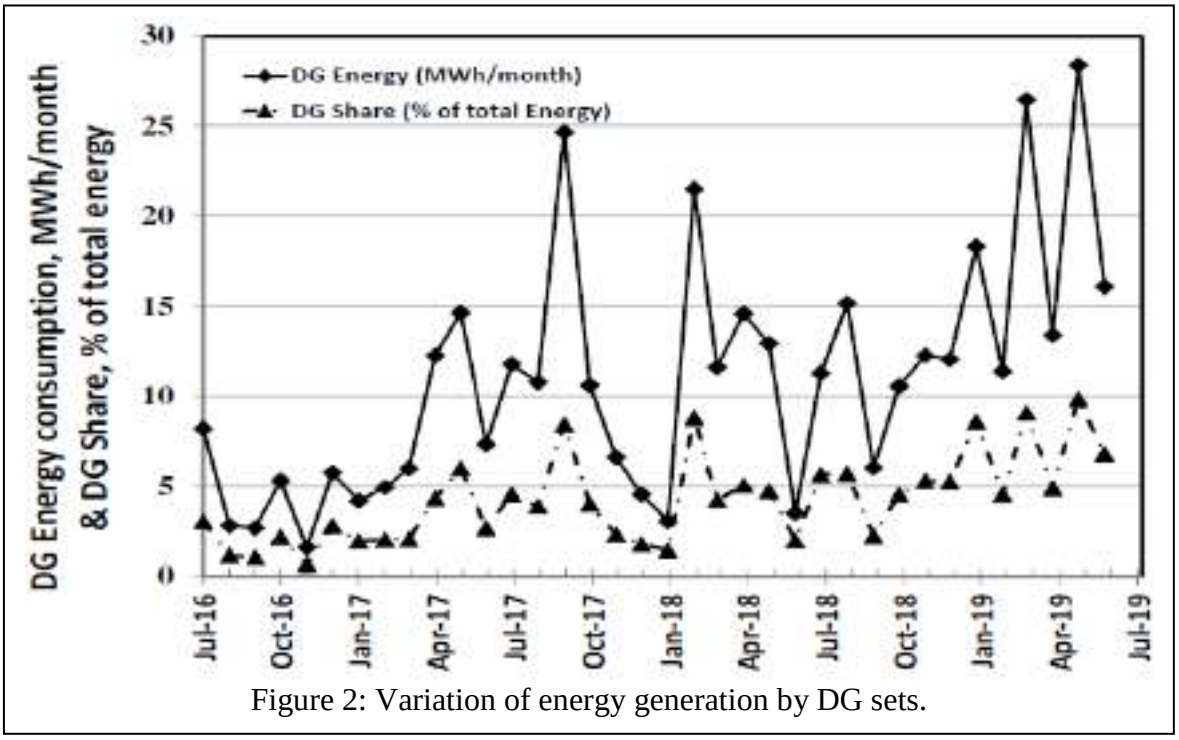

Figure 2: Variation of energy generation by DG sets.

The total energy consumption (grid + DG) for period during energy audit study is varying between 200 MWh/month (July 2018) to 291.5 MWh/month (March 2019). It can also be seen from the above Figure that the monthly average total energy consumption is reduced from 253.1 MWh/month to 248.1 MWh/month. The reduction is about 2.1% of total energy consumption. The total energy consumption from grid during the academic year 2018-19 is 27,96,140 kWh/y, energy generation by DG set is 1,81,270 kWh/y and the total energy consumption at REVA University is 29,77,410 kWh/y. The total built up area is 1,46,548 m^2. The energy performance index (EPI) for total REVA University campus is 20.32 kWh/m^2-year which is reduced from 21.59 kWh/y compared previous year. The overall EPI is lower than the EPI specified by Energy Conservation Building Code (ECBC) 2006 of 120 kWh/m^2-year.

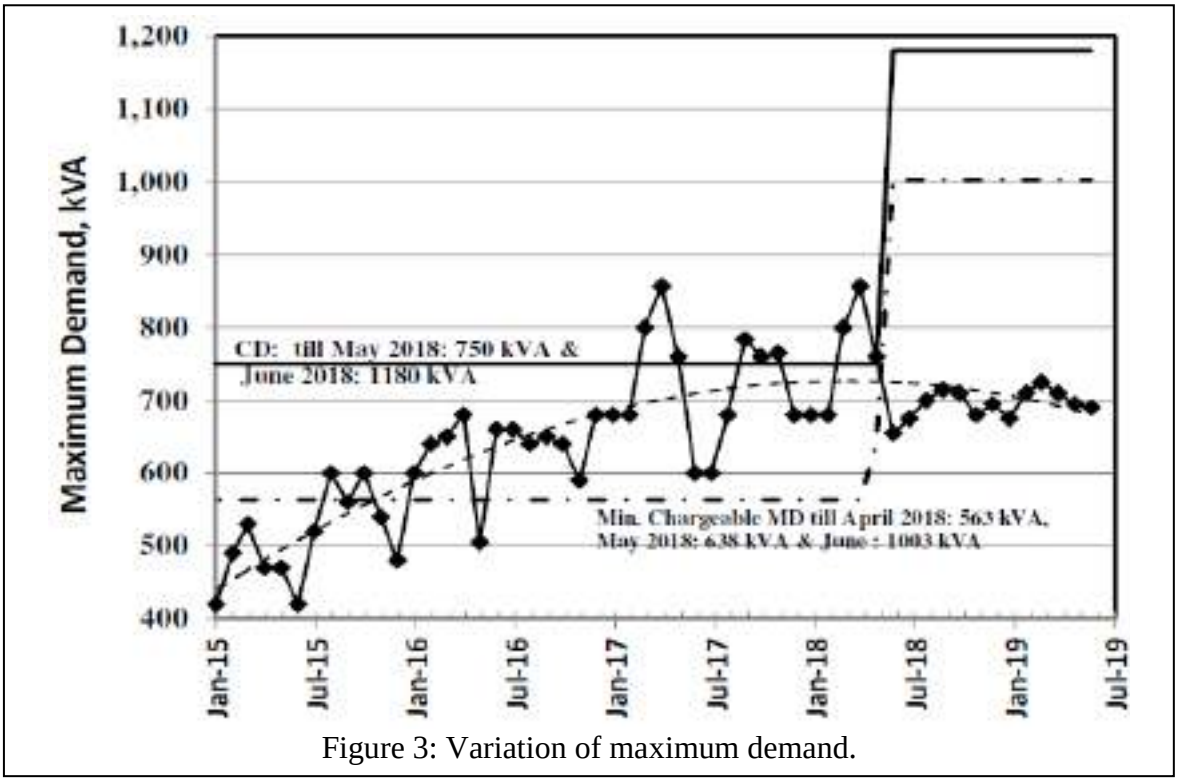

Figure 3: Variation of maximum demand.

Figure 3 gives the variation of recorded maximum demand (MD) and is varying between 410 kVA (Jan. 2015) and 856 kVA (April 2018). The recorded MD during the energy audit period was varying between 675 to 725 kVA. The recorded MD during July 2018 is reduced to 675 kVA due to vacation for academics at REVA University but the minimum chargeable MD is 1003 kVA because the power is taken through open access where the minimum chargeable MD will be for 1003 kVA.

Figure 4 shows the variation of monthly average power factor and is varying between 0.90 and 0.96. The power factor is good because of addition of lighting load and also installation of automatic power factor controller at main incoming.

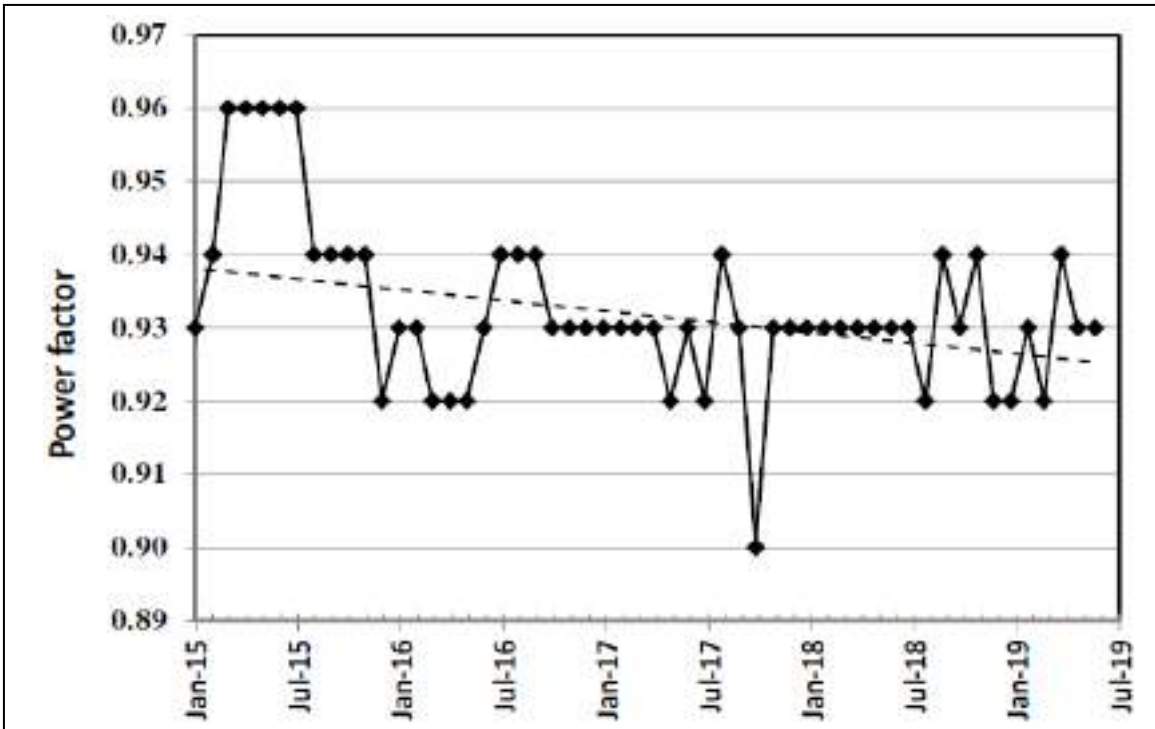

Figure 4: Variation of power factor.

The variation of energy cost is given in Figure 5 and is varying between Rs. 11.5 lakhs/month (Jan. 2015) to 27.2 lakhs/month (Sept. 2017). The energy cost variation during the energy audit period was in the range of Rs. 14.7 lakhs/month to Rs. 23.1 lakhs/month. The average monthly total energy cost is reduced from Rs. 21.8 lakhs/month to Rs. 20.4 lakhs/month. The energy cost is reduced may be due to implementation of energy conservation measures and also due to purchasing the energy from renewable energy through open access. The reduction in cost is by about 6.4 %.

Figure 6 shows the variation of average energy rate (including demand & energy charges). The energy rate during energy audit period was in the range of Rs. 8.34 to 9.35 per kWh. It can be seen from the figure that the energy rate has decreased after Dec. 2017 due to change of category of service connection. Again the average energy rate is increased to Rs. 8.49 per kWh due to increase of contract demand. Figure 7 shows the variation of energy rate with energy consumption. It

can be seen from the Figure that as the energy consumption increases the energy rate decreases.

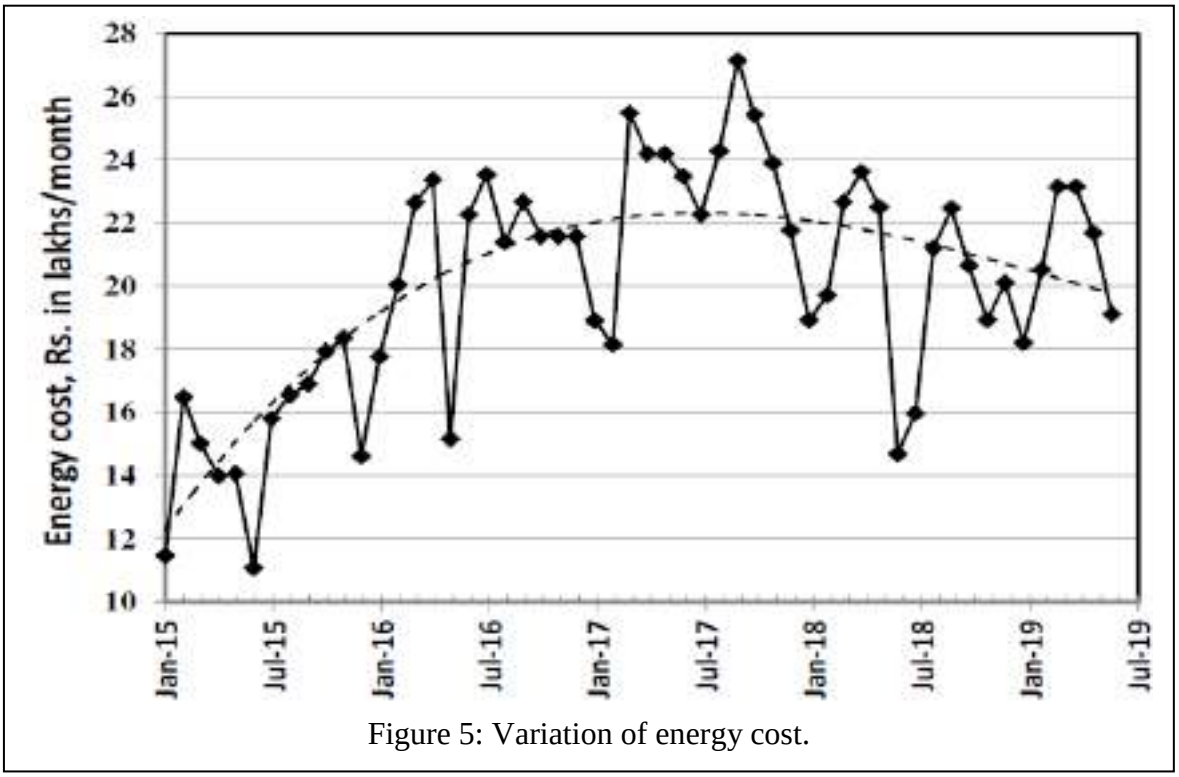

Figure 5: Variation of energy cost.

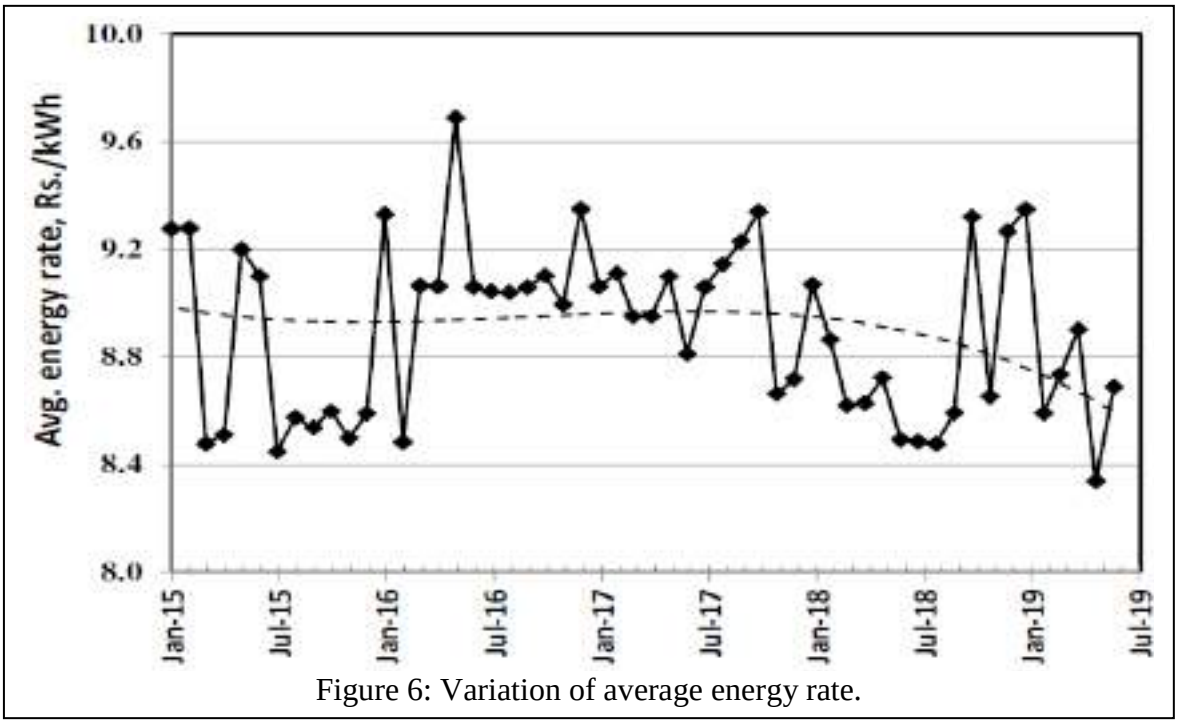

Figure 6: Variation of average energy rate.

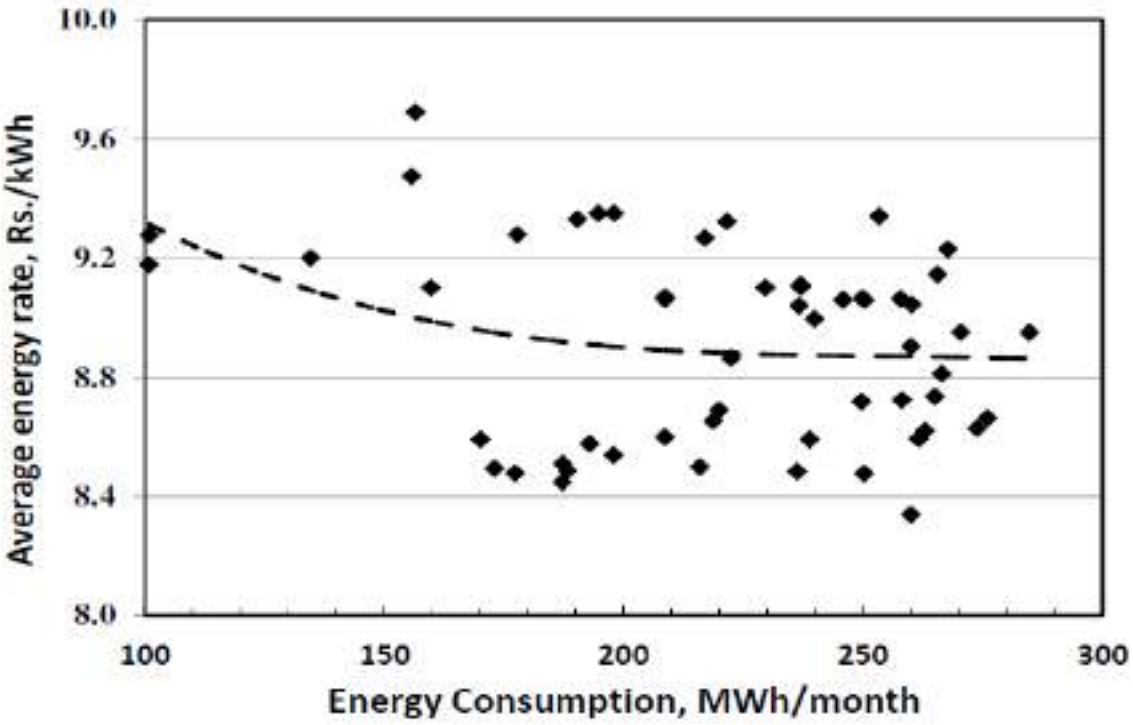

Figure 7: Variation of average energy rate with energy generation.

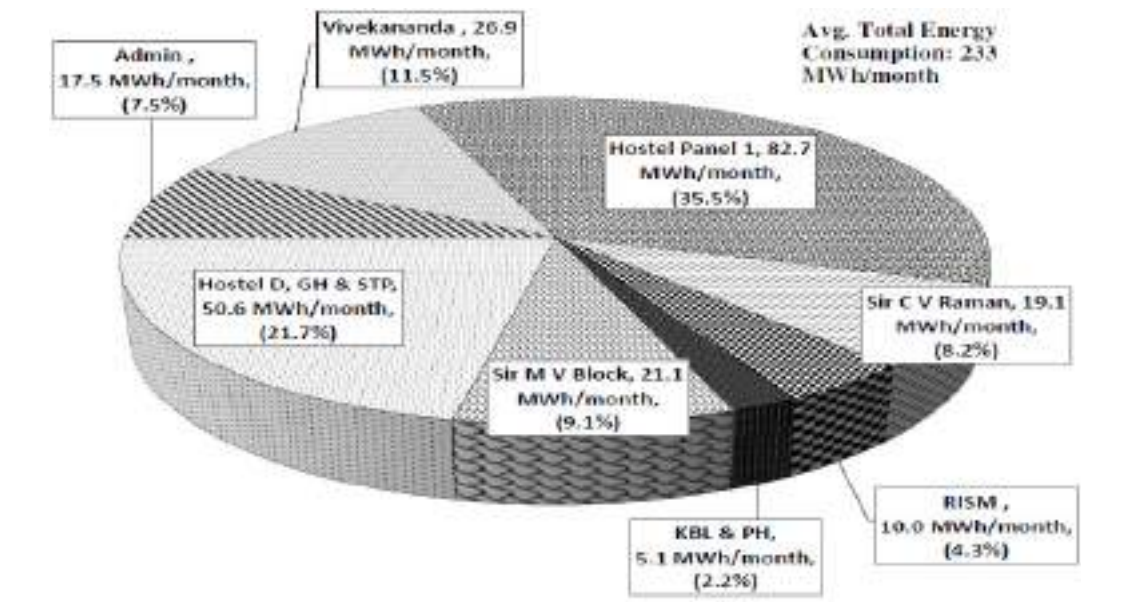

Figure 8: Energy consumption by different blocks.

Figure 8 gives the energy consumption by different academic & non-academic blocks / feeders. The major energy is used at Hostel panel 1 (Boys Hostel A, B &

C, Girls hostel 2, Library, Guest house and faculty & staff Quarters) is 82.7 MWh/month (35.5% of total energy consumption) and followed by the Boys D hostel, Girls hostel 1 and STP feeder energy consumption is 50.1 MWh/month (21.7%). The total energy used by hostels, guest house, quarters, water pumping, STP & library is 59.4%. The energy used for academics is 41.6% of total energy consumption.

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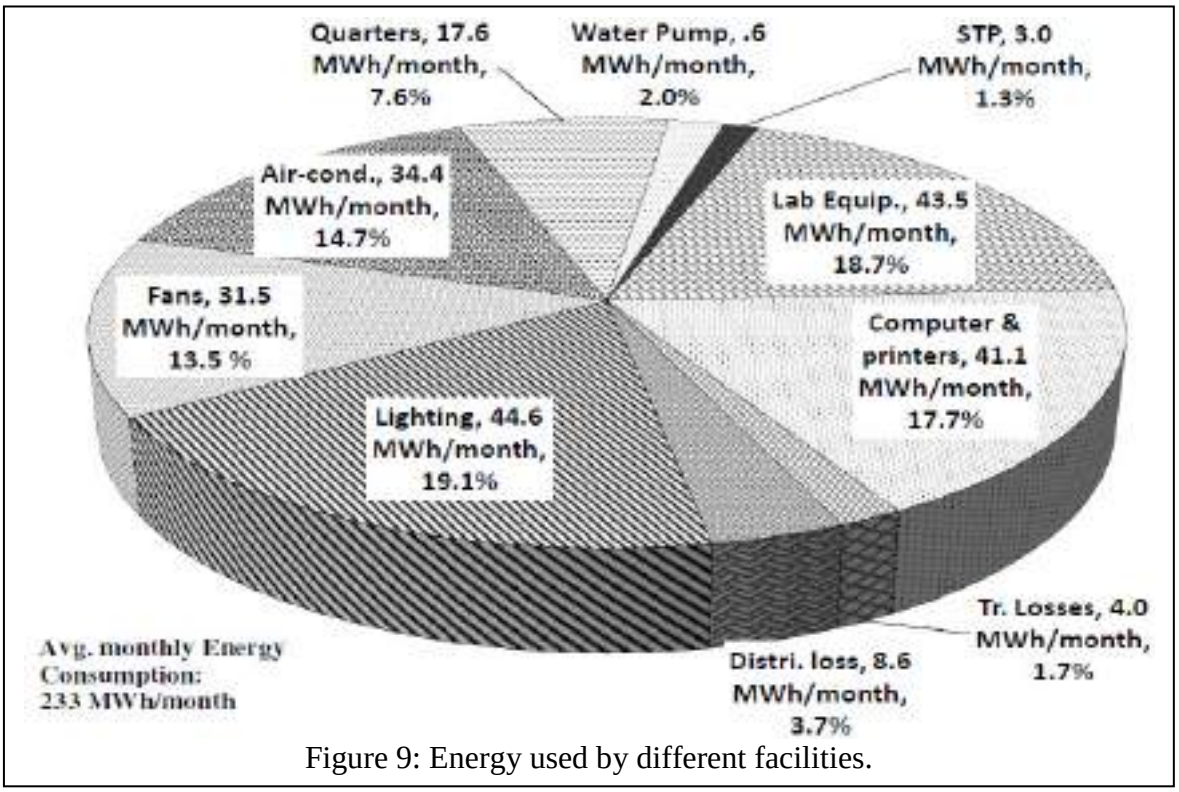

Figure 9: Energy used by different facilities.

Figure 9 gives the energy consumption by different facilities / components. The major energy is being used for lighting system i.e., 19.1% of total energy in which 9.3% is used for hostel lighting. The lighting energy consumption at hostel rooms is reduced by replacing of T8 fluorescent lamps of 36 W by 18 W LED lamps in all hostel rooms. The next major energy consuming facility is lab equipment which forms about 18.7%. The energy used for computers & peripherals is 17.7%. The energy used for air-conditioning (AC) system is 14.7%. The energy used for comfort air fans is about 13.5% including hostel. The energy shared for faculty & staff quarters is 7.6% of total energy consumption. The energy used for water

pumping system is 2.0% and for STP plant is 1.3%. The energy loss in transformer is computed as 1.7% and distribution loss is 3.7% of total energy consumption

3.2 Electrical distribution system

Figures 10 to 12 give the schematic of the electrical distribution system at REVA University. The 11 kV incoming is tapped from BESCOM at main entrance sub-station. 11 kV Vacuum Circuit Breaker (VCB) is installed along with metering cubicle. The 11 kV is connected to incoming of two Distribution transformers Tr.1 of 500 kVA and Tr. 2 of 1000 kVA where 11 kV is stepped down to 433 V. The secondary of Tr.1 is connected to LT panel 1 and the secondary of Tr. 2 is connected to LT panel 2. The bus-coupler is connected between two LT panels. DG set 1 of 500 kVA is connected to LT panel 1 whereas DG set 2 of 500 kVA is connected to LT panel 2 through change over switch to provide the power supply to entire REVA university campus.

At LT panel 1, there are seven outgoing feeders, three of them are spare feeders, one feeder is connected to Administrative block through 400A air circuit breaker (ACB), one feeder is feeding power to Vivekananda block through 800A ACB and another feeder is feeding power to main hostel panel through 800A ACB. The Hostel feeder is re-distributed to boys hostel A, boys hostel B, boys hostel C, Library, faculty & staff quarters, girls hostel 2 and guest house sub feeders. All these feeders are provided with 400A ACBs except guest house feeder of 250A ACB.

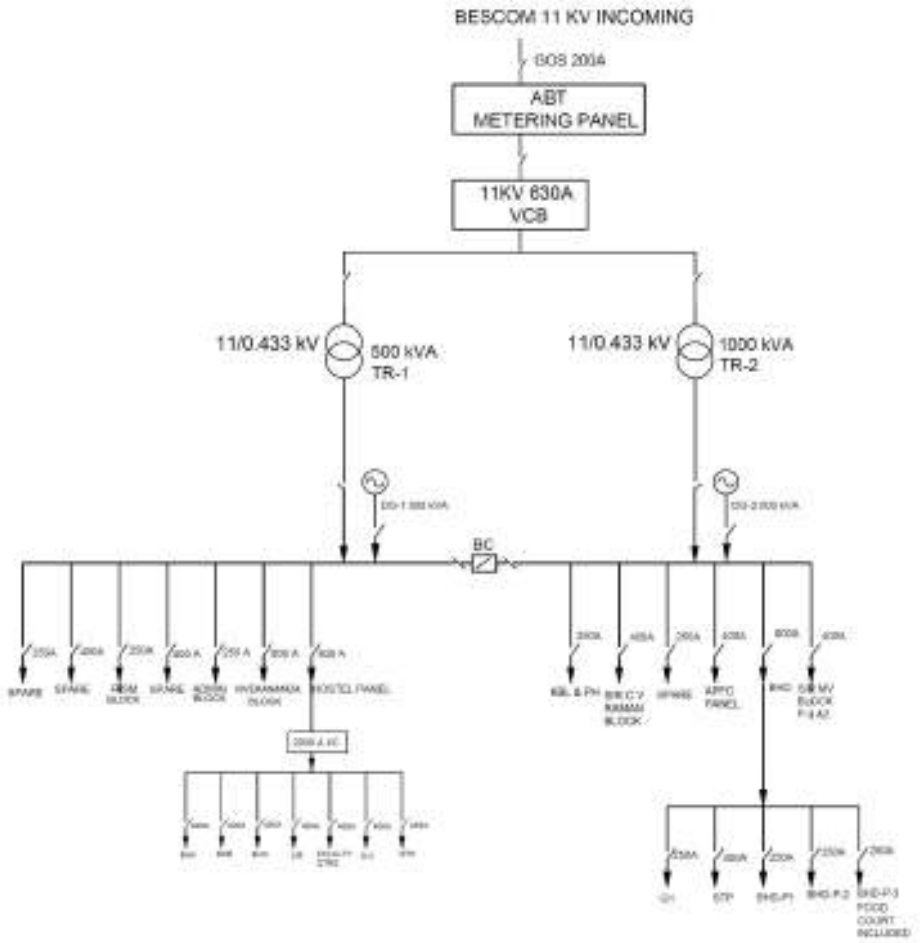

Figure 10: Single line diagram of main incomer from grid & LT distribution.

At LT panel 2, there are six outgoing feeders, one of them is spare feeder, one feeder is connected to Karnataka Bank & pump house through 250A air circuit breaker (ACB), one feeder is feeding power to Sir C V Raman block through 400A ACB, one feeder is connected automatic power factor controller panel of 250 kVAR capacitor banks through 400A ACB, one feeder is connected to Sir M. Visvesvaraya block through 400A ACB and another feeder is feeding power to boys hostel D block panel through 800A ACB. The boys hostel D feeder is re-distributed to girls hostel 1, STP, boys hostel D-P1, boys hostel D-P2, boys hostel D-P3 and food court. All these feeders are provided with 250A ACBs except STP feeder of 400A ACB.

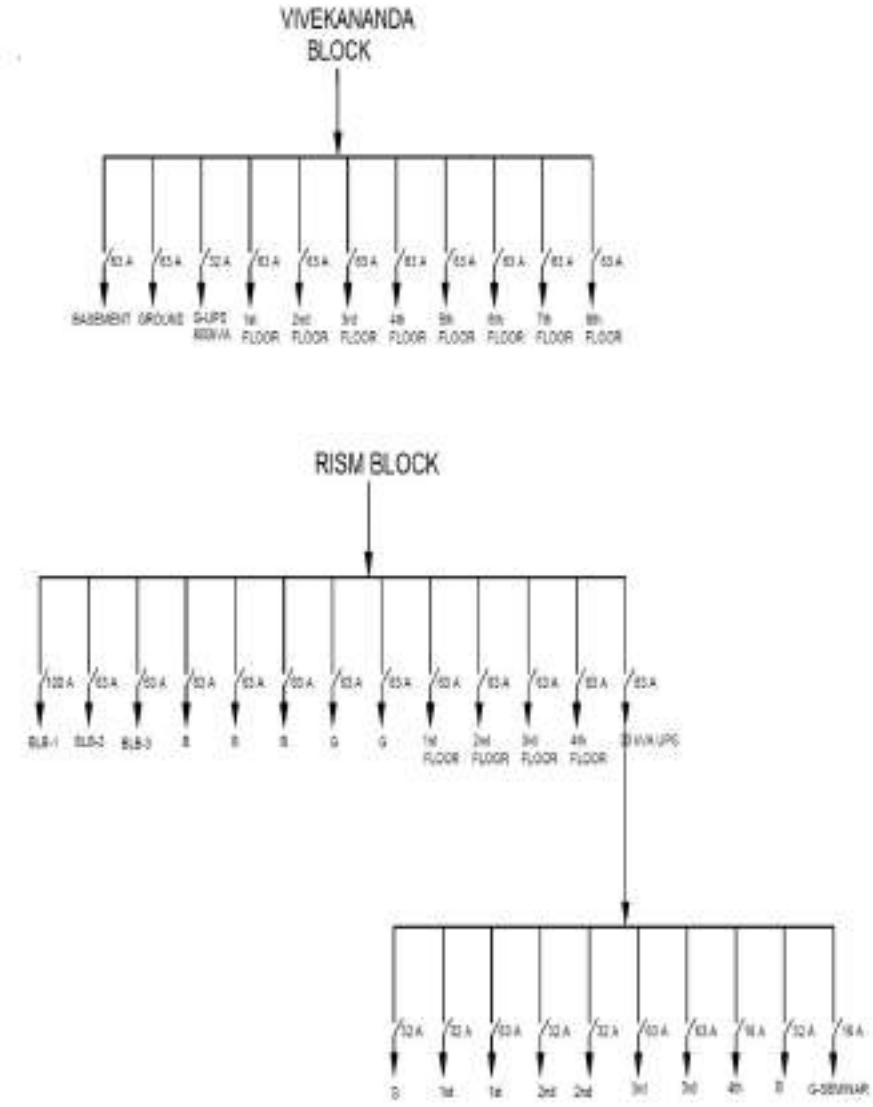

Figure 11: Electrical distribution at Vivekananda & RISM Blocks.

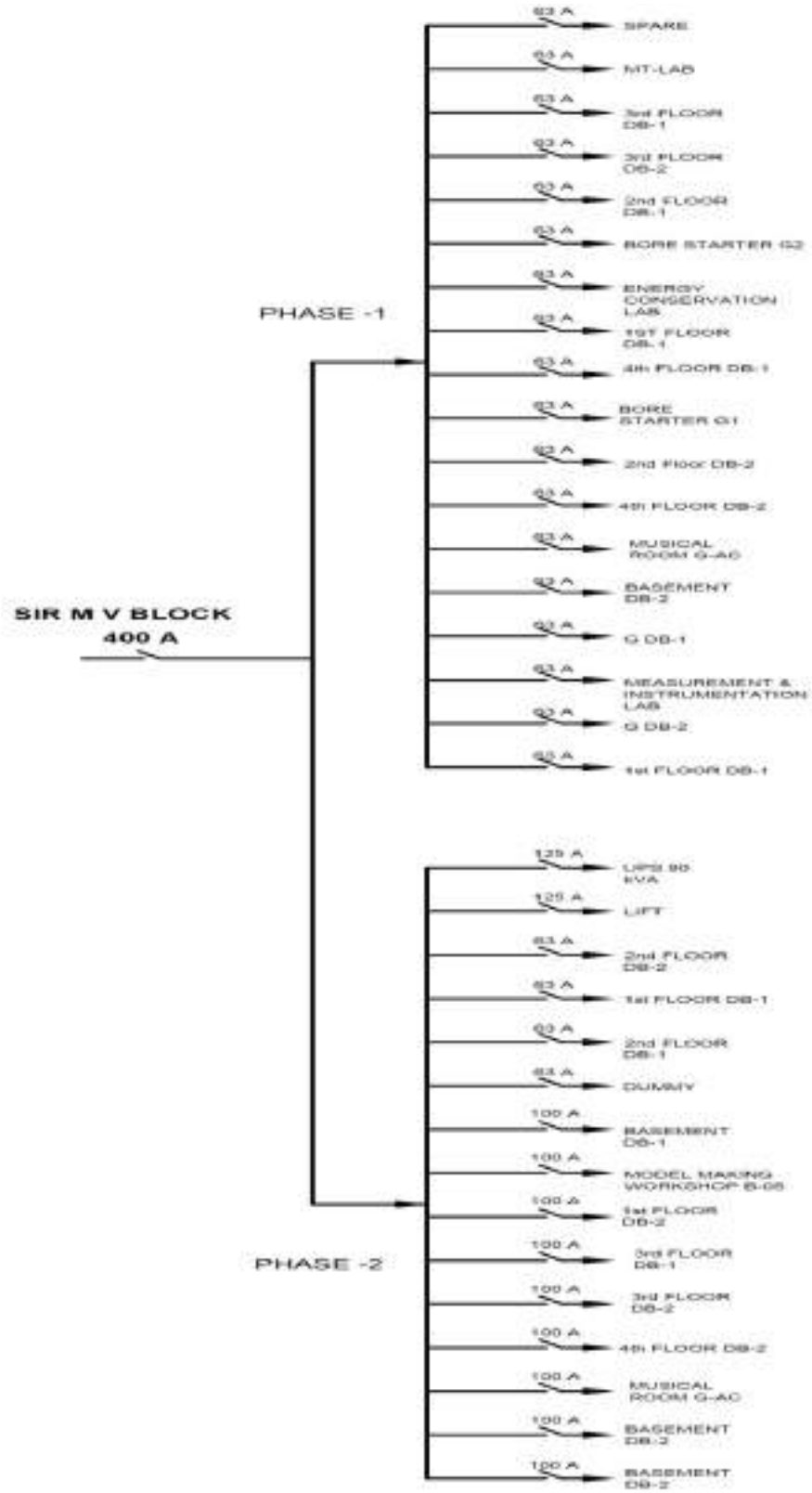

Figure 12: Electrical distribution at Sir MV Block.

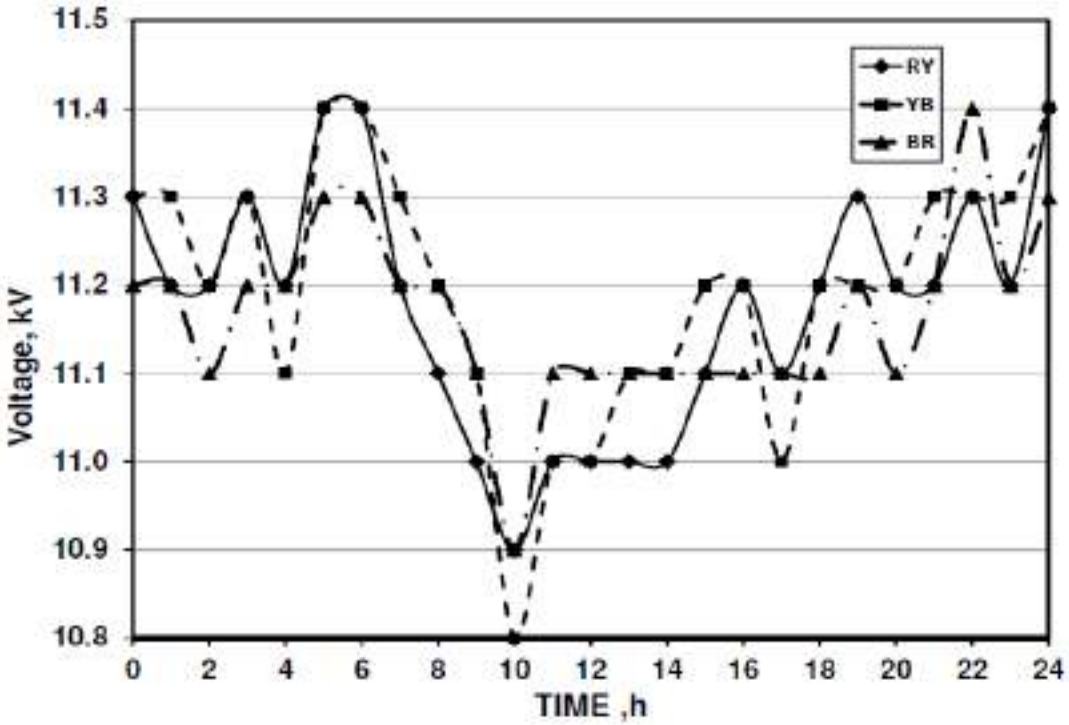

Figure 13: Variation of voltage at main incomer from BESCOM.

Figure 13 gives the variation of incoming voltage on 11 kV side on a typical day and is varying between 10.8 to 11.4 kV (-1.8% to +3.6%). The voltage variation is within the limit specified by the IE rule 1956, Rule No. 54, the voltage limits allowed is +6% & -9%. The voltage unbalance between 3-phases is computed at main incoming feeder and is presented in Figure 14. The voltage unbalance between 3-phases is varying between 0.59 to 0.61 % and is also lower than the International standards EN-50160 < 2% for LV & MV system and < 1% for HV system.

Figure 15 shows the variation of measured current at main incoming 11 kV feeder and is varying between 6.7 to 30.3 A. The load unbalance between 3-phases is computed for the incoming feeder and is given in Figure 16. The load unbalance between 3-phases is varying between 1.82 to 7.36% and is also normal. The capacity reduction of transformers due to load unbalance is about 11%.

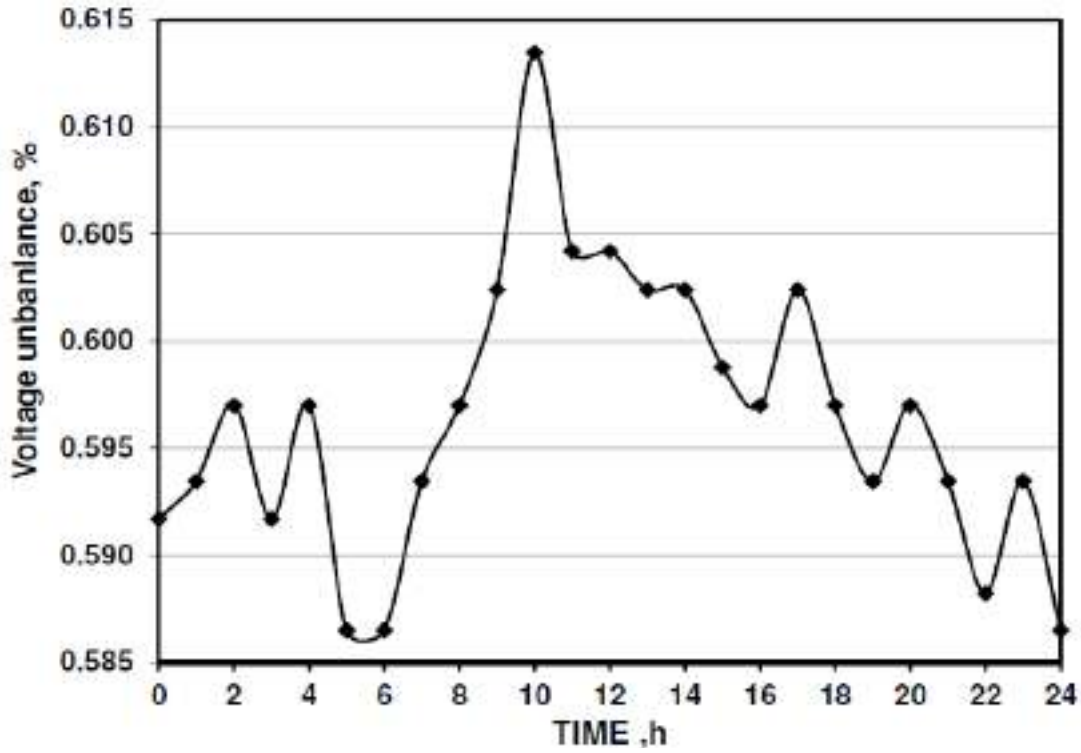

Figure 14: Variation of voltage unbalance at main incomer from BESCOM.

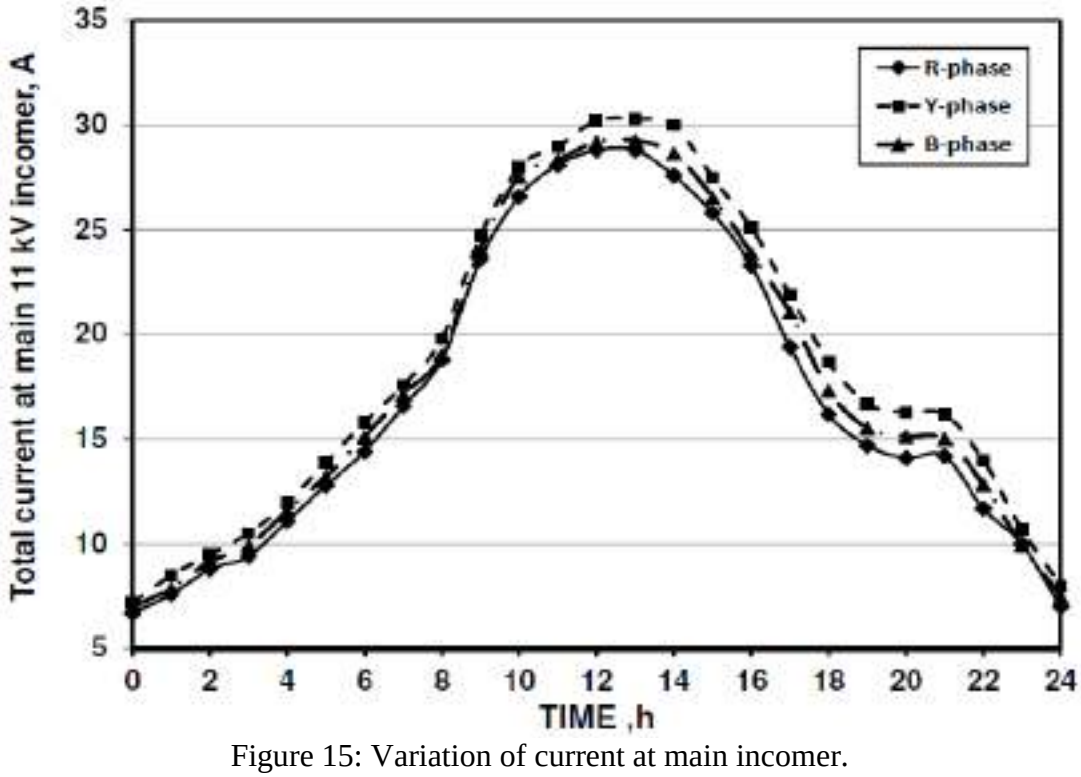

Figure 15: Variation of current at main incomer.

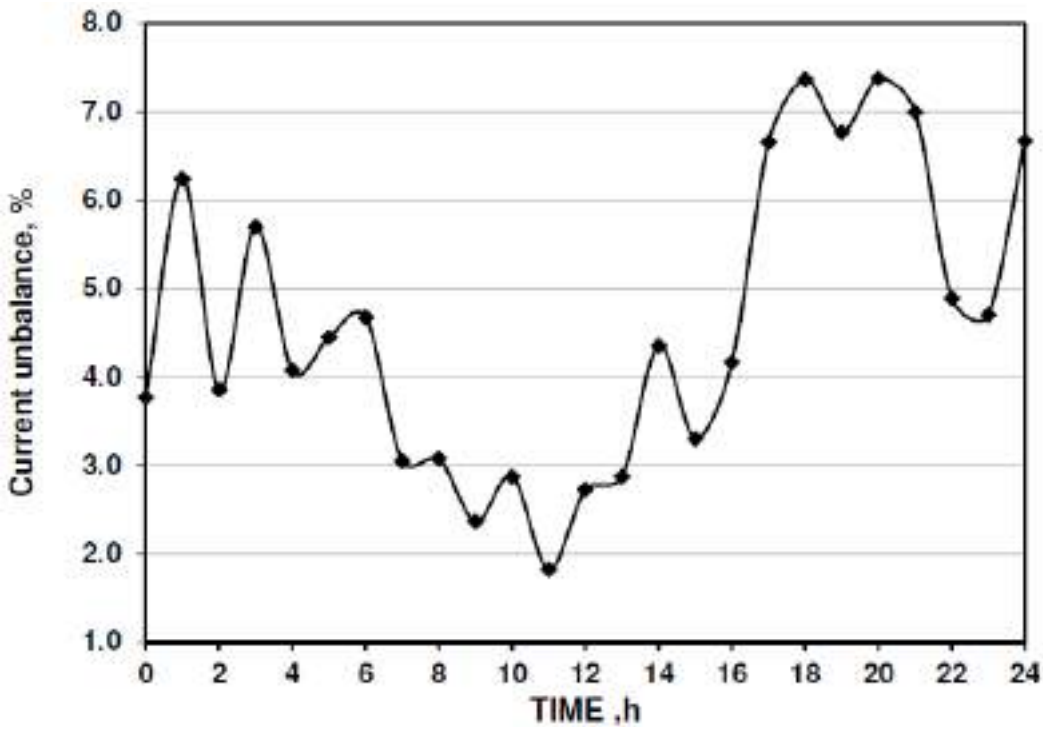

Figure 16: Variation of current unbalance at main incomer.

To provide the power supply to RISM block, the underground cable of 3½ core aluminium PVC 400 mm^2 is laid from main sub-station and connected through the 250 A air circuit breaker. The peak current through the feeder is 65 A and the circuit breaker loading is 26% which is good. The cable conductor loading is 13.9% which is less. The circuit breaker and cable loading is good. Figure 17 gives the variation of power at RISM feeder for a typical and is varying between 2.6 to 42.1 kW (8.0% of peak demand). The peak power is during 10:00 to 17:00 hours. The computed monthly average energy consumption is 10.0 MWh/month that forms about 4.3% of total energy consumption. The built area is 4,704 m^2 and the energy performance index (EPI) is 25.5 kWh/m^2-year which is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006. The EPI is reduced from 26.1 to 25.5 kWh/m^2-year compared to last year due to implementation of energy conservation measures.

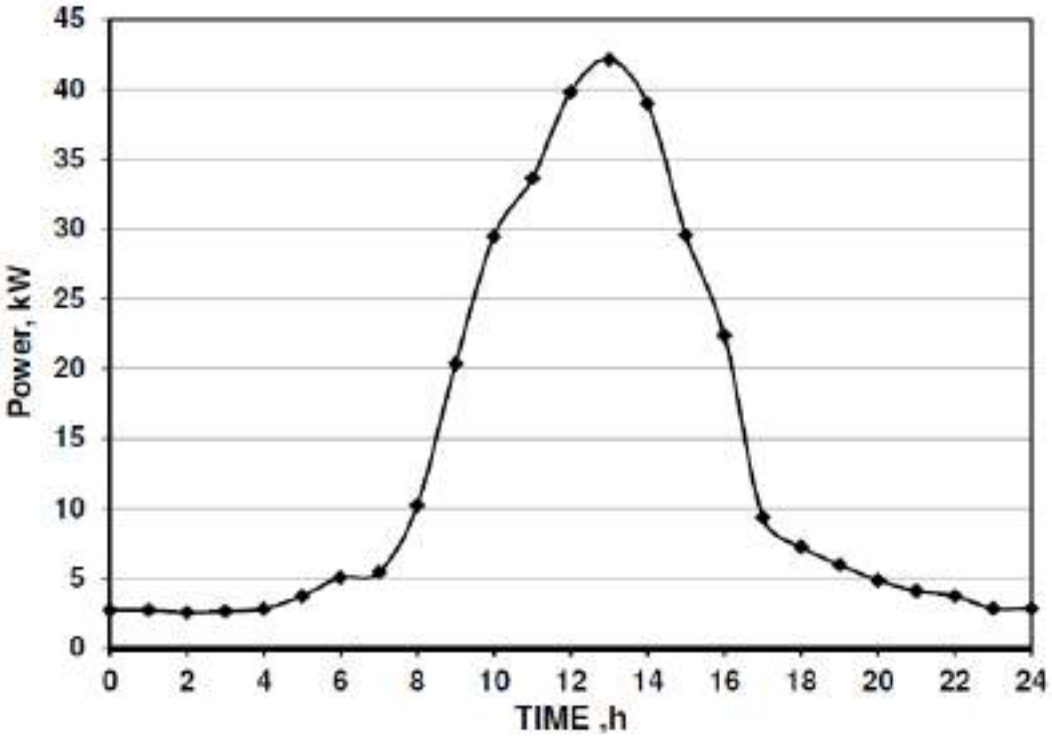

Figure 17: Variation of power at RISM feeder.

At Administration block, the power is fed by using the underground cable of 3½ core aluminium PVC 400 mm^2 from main sub-station and connected through the 250 A air circuit breaker. The peak current through the feeder is 101A and the circuit breaker loading is 40.4%. The cable conductor loading is 21.6%. The circuit breaker and cable loading is good. Figure 18 gives the variation of power at Administrative block feeder for a typical day and is varying between 3.3 to 65.1 kW (12.6% of peak demand). The peak power is during 10:00 to 17:00 hours. The computed monthly average energy consumption is 17.5 MWh/month that forms about 7.5% of total energy consumption. The built area is 6,836 m^2 and the energy performance index (EPI) is 30.7 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006. The EPI is reduced from 31.0 to 30.7 kWh/m^2-year compared to previous year due to implementation of energy conservation measures.

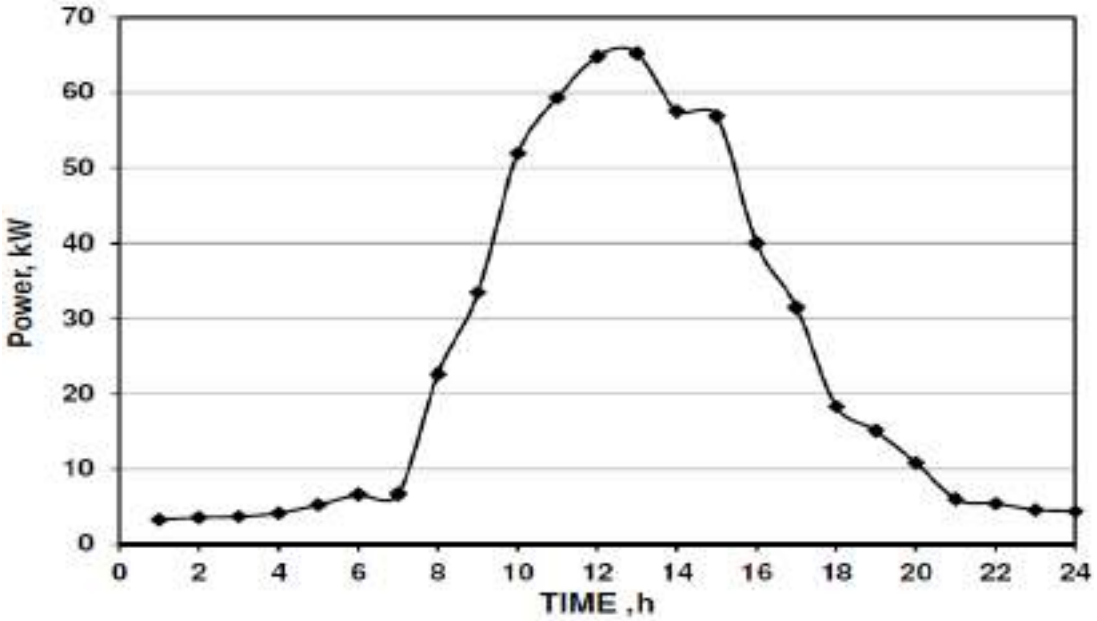

Figure 18: Variation of power at Administration block feeder.

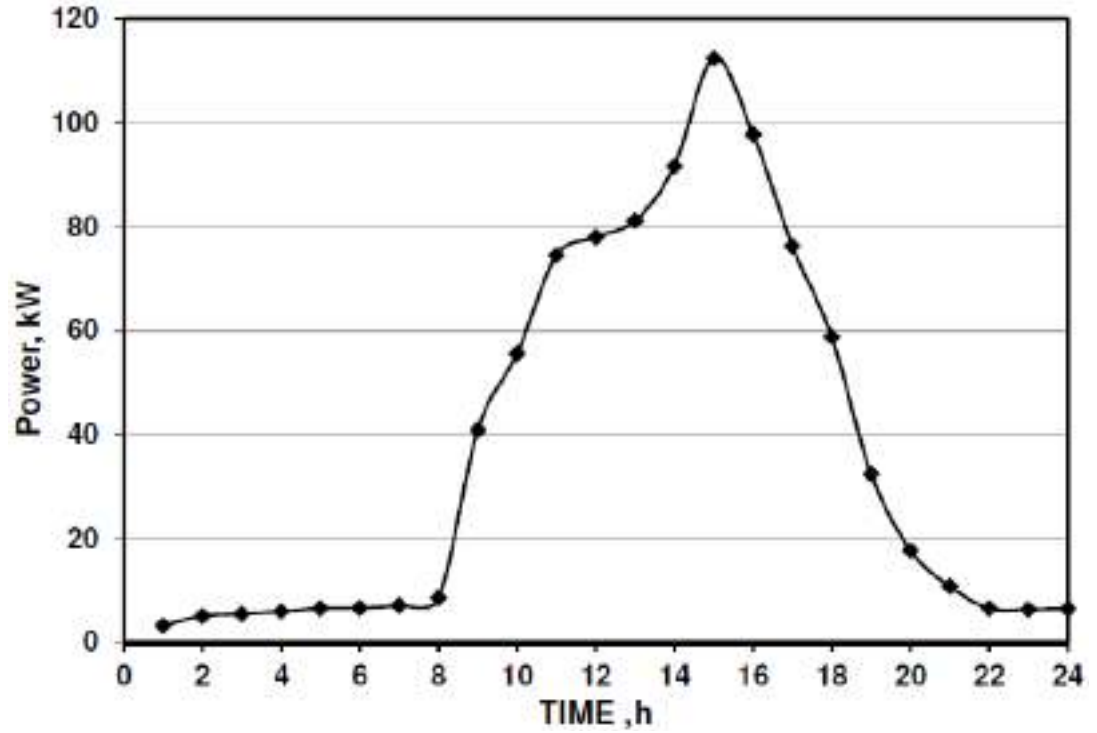

Figure 19: Variation of power at Vivekananda block feeder.

At Vivekananda Block, the power is supplied through underground cable of 3½ core aluminium PVC 400 mm^2 and terminated at main panel by using ACB of 800 A. The peak current through the feeder is 174A and the circuit breaker loading is 21.8%. The cable conductor loading is 36.8%. The circuit breaker and cable loading is good. Figure 19 gives the variation of power at Vivekananda block feeder for a typical day and is varying between 3.3 to 112.5 kW (22.2% of peak demand). The peak power is during 10:00 to 17:00 hours. The computed monthly average energy consumption is 26.9 MWh/month that forms about 11.6% of total energy consumption. The built area is 28,372 m^2 and the energy performance index (EPI) is 11.4 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2 as per ECBC code 2006. The EPI is reduced from 13.7 to 11.4 kWh/m^2-year compared to previous year due to implementation of energy conservation measures.

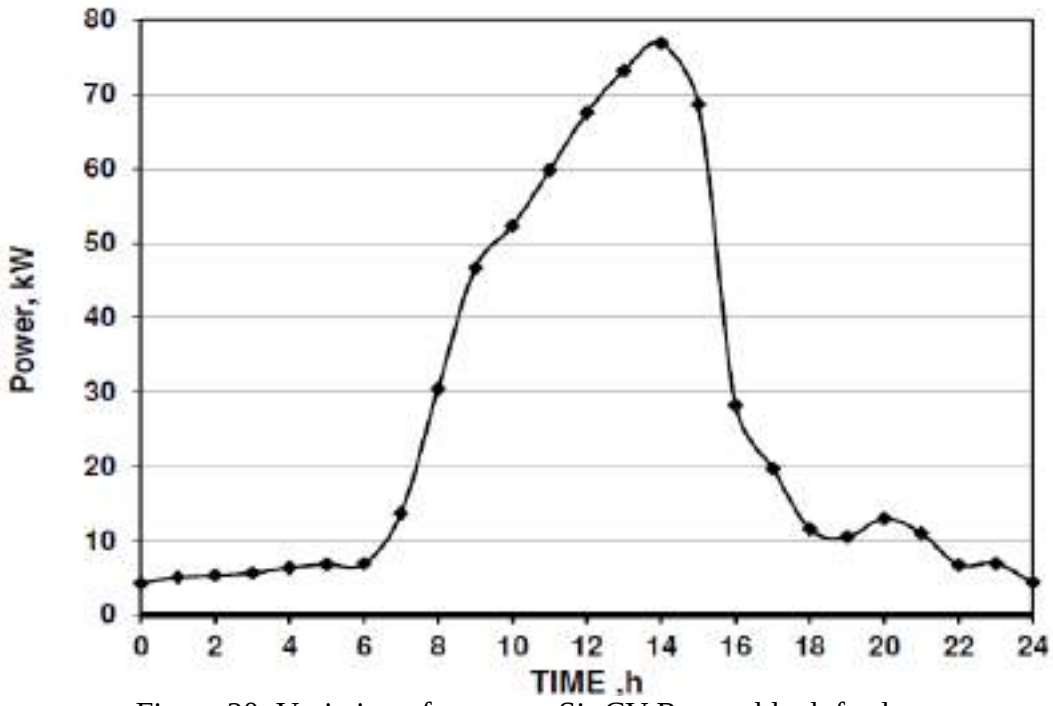

Figure 20: Variation of power at Sir CV Raman block feeder.

At Sir C.V. Raman Block, the power is fed through 3½ core aluminium PVC 400 mm^2 cable and is terminated at main panel by using 400 A air circuit breaker. The peak current through the feeder is 119A and the circuit breaker loading is 29.8%.

The cable conductor loading is 25.5%. The circuit breaker and cable loading is good. Figure 20 gives the variation of power at Sir C V Raman Block feeder for a typical day and is varying between 4.3 to 76.9 kW (15.2% of peak demand). The peak power is during 08:00 to 16:00 hours. The computed monthly average energy consumption is 19.1 MWh/day that forms about 8.2% of total energy consumption. The built area is 17,785 m^2 and the energy performance index (EPI) is 15.65 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006. The EPI is reduced from 15.7 to 12.9 kWh/m^2-year due to implementation of energy conservation measures

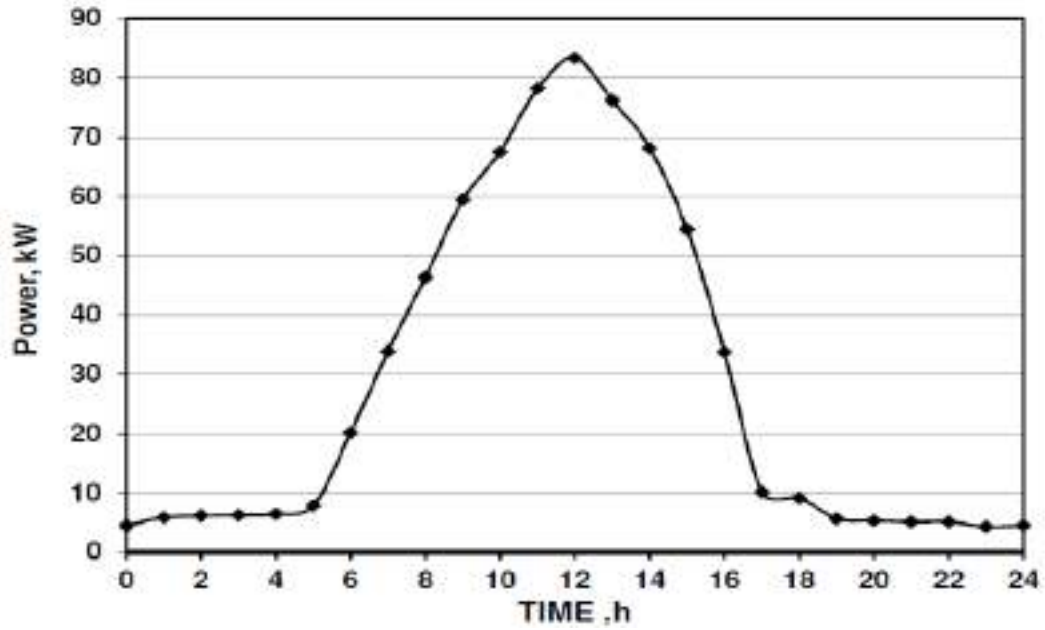

Figure 21: Variation of power at Sir M Visvesvaraya block feeder.

At Sir M. Visvesaraya Block, the electric power is fed through 3½ core aluminium PVC 400 mm^2 cable and is connected by 400 A air circuit breaker at main panel. The peak current through the feeder is 129A and the circuit breaker loading is 32.2%. The cable conductor loading is 27.6%. The circuit breaker and cable loading is good. Figure 21 gives the variation of power at Sir M Visvesvaraya Block feeder for a typical day and is varying between 4.5 to 83.3 kW (16.1% of peak demand). The peak power is during 09:00 to 16:00 hours. The computed monthly average energy consumption is 21.1 MWh/month that forms about 9.1% of total

energy consumption. The built area is 18,218 m^2 and the energy performance index (EPI) is 13.9 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006. The EPI is reduced from 15.1 to 13.9 kWh/m^2-year compared previous year due to implementation of energy conservation measures.

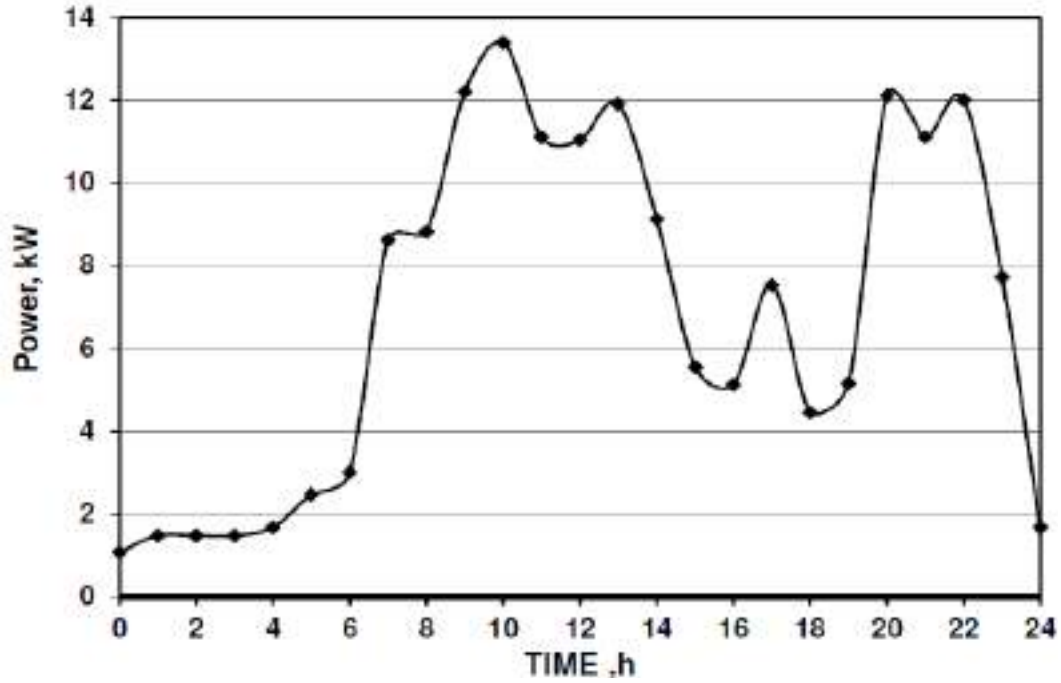

Figure 22: Variation of power at KBL & pump house feeder.

At KBL & pump house, the power is supplied through 250A air circuit breaker and 3½ core aluminium PVC 50 mm^2 cable. The peak current through the feeder is 21A and the circuit breaker loading is 8.4%. The cable conductor loading is 15.7%. The circuit breaker and cable loading is less than the allowable limit of 50%. Figure 22 gives the variation of power at KBL & pump house feeder for a typical day and is varying between 1.1 – 13.4 kW (2.9% of peak demand). The peak power is during 07:00 to 14:00 hours and 20:00 to 22:00 hours. The computed monthly average energy consumption is 5.1 MWh/month that forms about 2.2% of total energy consumption. The built area is 440 m^2 and the energy performance index (EPI) is 139.0 kWh/m^2-year and is higher than the EPI of 120 kWh/m^2-year as per ECBC code 2006 because this feeder consists of concentrated loads like water pumps.

At the Hostel panel 1, the power is supplied through two parallel runs of 3½ core aluminium PVC 400 mm^2 cables and ACB of 800 A. The peak current through the feeder is 241A and the circuit breaker loading is 30.1%. The cable conductor loading is 25.8%. The circuit breaker and cable loading is good. Figure 23 gives the variation of power at Hostel Panel 1 feeder for a typical day and is varying between 74.8 – 156.2 kW (51.8% of peak demand). The peak power is during 06:00 to 09:00 and 16:00 to 22:00 hours. The computed monthly average energy consumption is 82.7 MWh/month that forms about 35.5% of total energy consumption. The built area is 42,918 m^2 and the energy performance index (EPI) is 23.1 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006. The EPI is reduced from 27.1 to 23.1 kWh/m^2-year compared to previous year due to implementation of energy conservation measures.

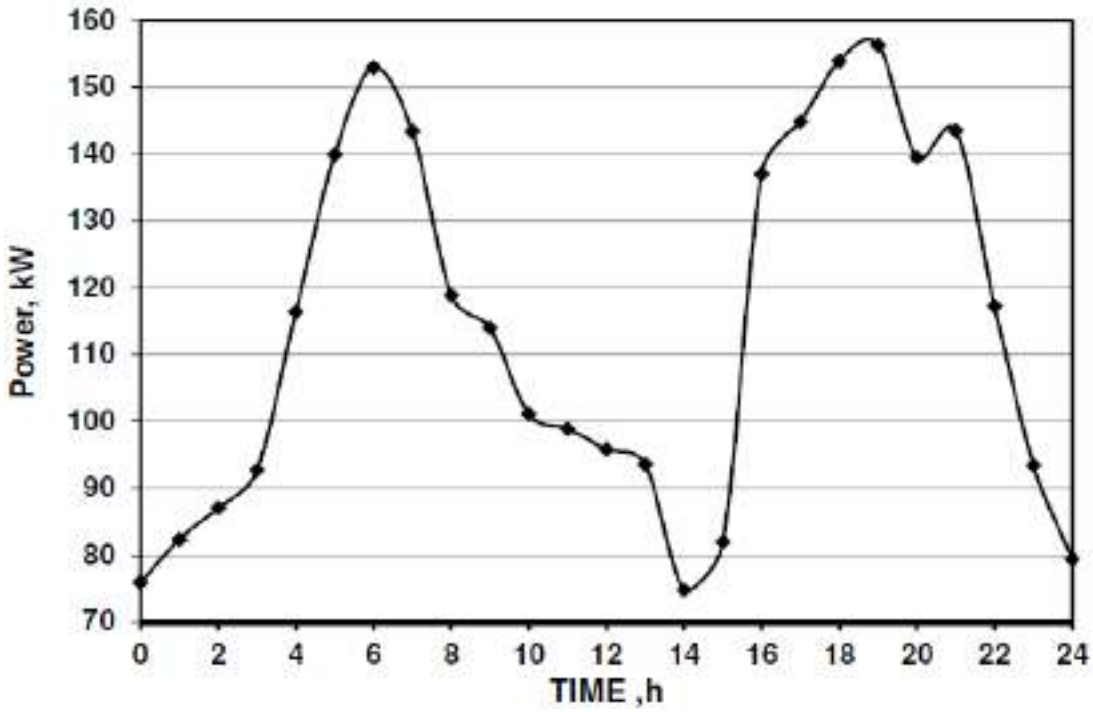

Figure 23: Variation of power at Hostel panel 1 feeder.

At Boys Hostel D, girls hostel 1, guest house & STP, the power is supplied through 3½ core aluminium PVC 400 mm^2 and ACB of 800 A. The peak current through the feeder is 150A and the circuit breaker loading is 18.8%. The cable conductor

loading is 31.0%. The circuit breaker and cable loading is good. Figure 24 gives the variation of power at Boys Hostel D, girls hostel 1, guest house & STP feeder for a typical day and is varying between 31.9 – 96.7 kW (22.4% of peak demand). The peak power is during 04:00 to 22:00 hours. The computed monthly average energy consumption is 50.6 MWh/month that forms about 21.7% of total energy consumption. The built area is 28,010 m^2 and the energy performance index (EPI) is 21.7 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006. The EPI is reduced from 23.5 to 21.7 kWh/m^2-year compared to previous year due to implementation of energy conservation measures

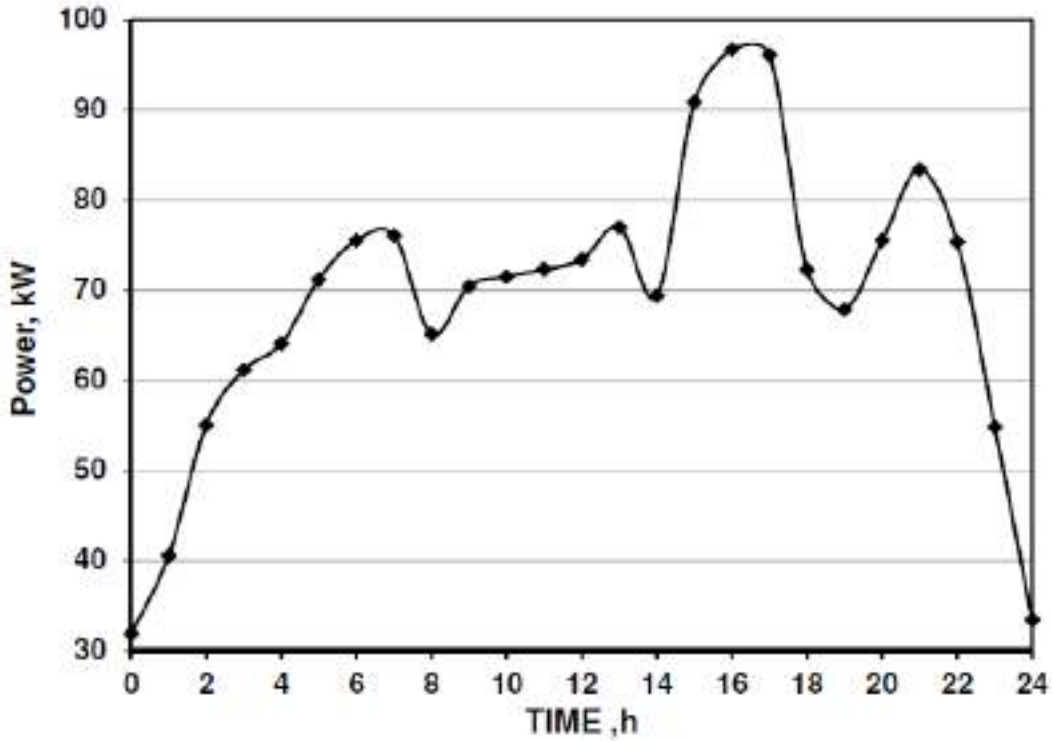

Figure 24: Variation of power at Boys Hostel D block panel feeder.

3.3 Transformers

There are two distribution transformers to step down high voltage of 11 kV to 433 V at main incoming. The average monthly energy loss in transformer is computed as 4.0 MWh/month that forms 1.7% of total energy input. Both transformers are provided with on load tap changers (OLTC) to maintain the secondary voltage. The

transformer OLTCs are working properly and the secondary voltage is fixed as 415 V as standard voltage for the distribution which is suitable for operation of equipment even though the transformer secondary is designed as 433 V. OLTCs are adjusting the secondary voltage in the range of 403 to 425 V (-2.9% to +2.4%).

Figures 25 and 26 give the variation of voltage at both transformer secondary. The voltage at Tr. 1 secondary is varying between 410.1 to 430.1 V (-1.2 to +3.6%) on a typical day whereas at Tr.2 is varying in the range of 411.2 to 431.1 V (-0.9 to +3.9%). The voltage variation is quite good. The voltage unbalance between 3-phases (Figure 27) is varying between 0.17 to 0.60% at Tr.1 and at Tr.2 is in the range of 0.12 to 0.63% which is also well below the range specified by EN-50160 & IEC 1000-3-6 standard (allowed limit of <2% of LV & MV and <1% for HV system). The unbalanced voltage at motor terminals will create negative sequence torque and cause heating of motor winding & core.

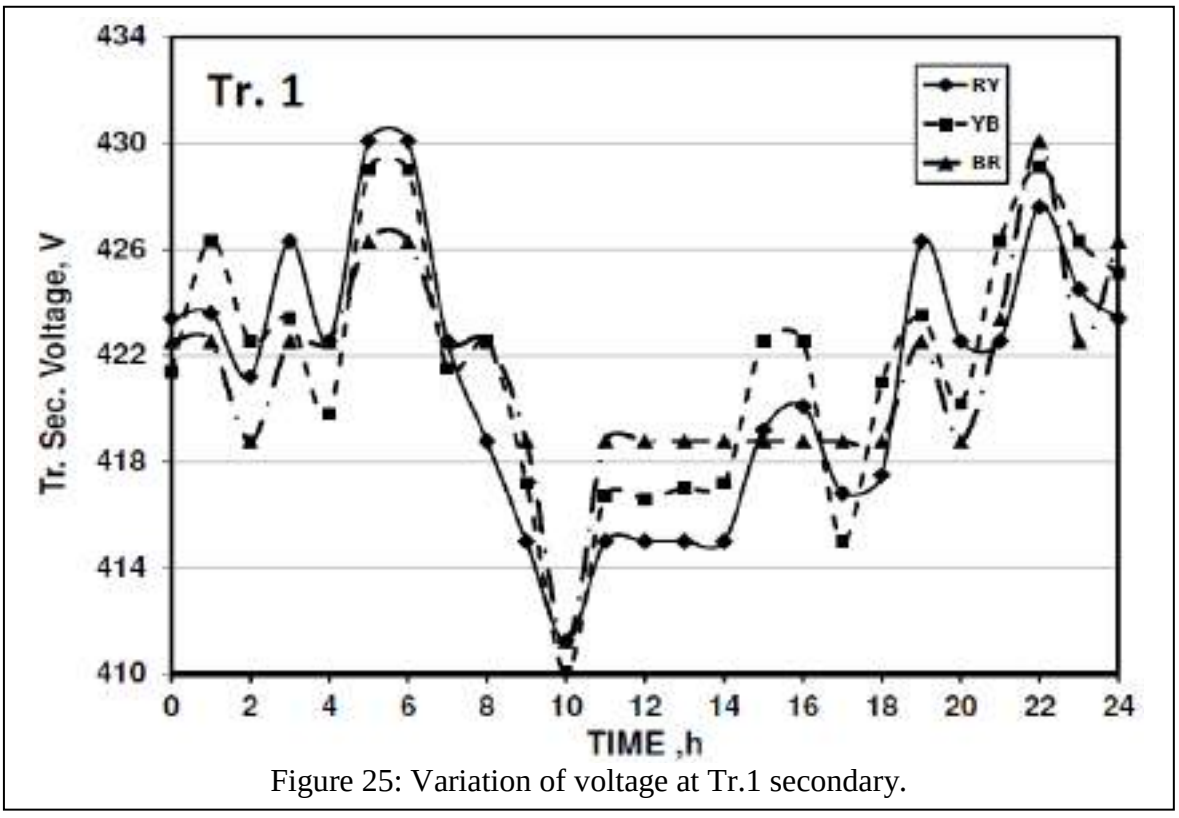

Figure 25: Variation of voltage at Tr.1 secondary.

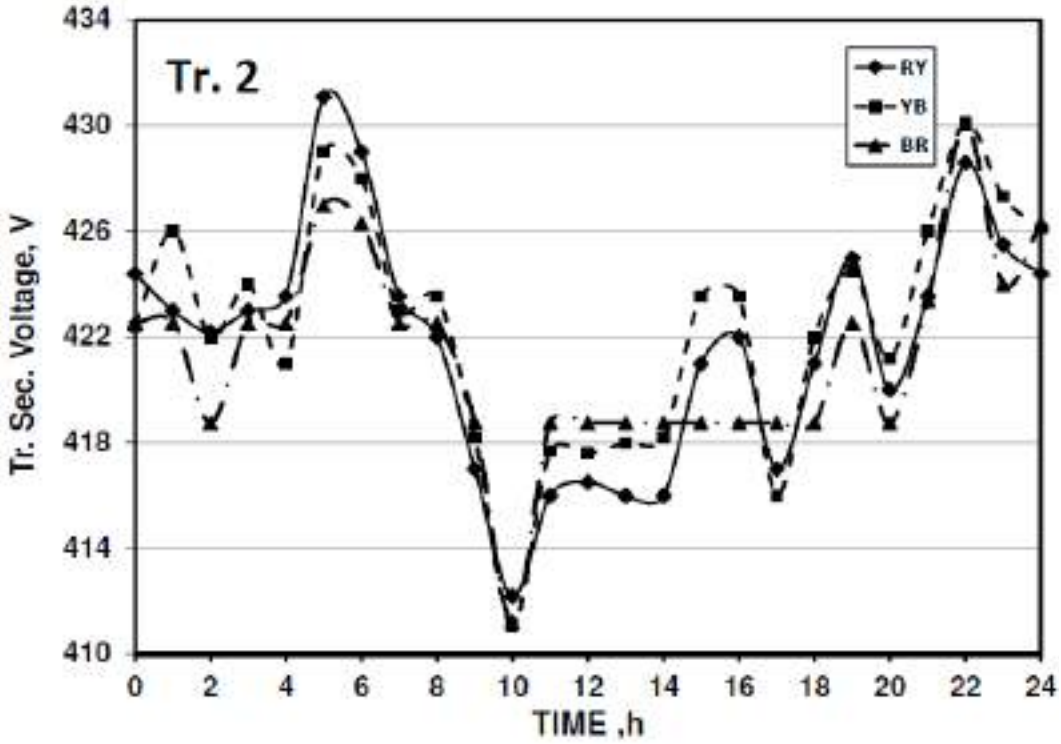

Figure 26: Variation of voltage at Tr.2 secondary.

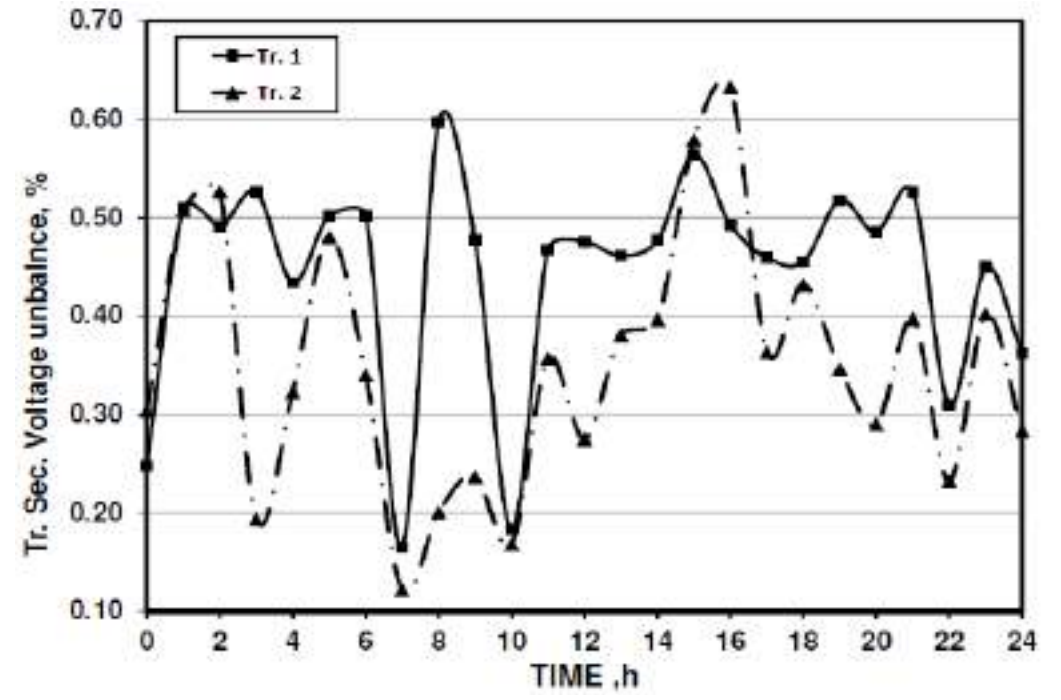

Figure 27: Variation of voltage unbalance at Tr.1 & Tr.2 secondary.

Figures 28 and 29 give the variation of load factor of transformers Tr.1 & Tr.2 on a typical day with bus coupler OFF position. It can be seen from the figure that the loading on transformer 1 is slightly on higher side in the range of 20.2 to 61.3% because generally distribution transformers are designed with maximum efficiency (where core losses equal the winding losses) in the load factor range of 40 to 55%. The transformers are generally designed based on the all day efficiency of transformers. The load factor of transformer 2 is slightly on lower side in the range of 3.8 to 23.3%. The all day efficiency of transformer 1 is 98.4% which is slightly better than that of transformer 2 of 97.6% because the load on Tr. 2 is less.

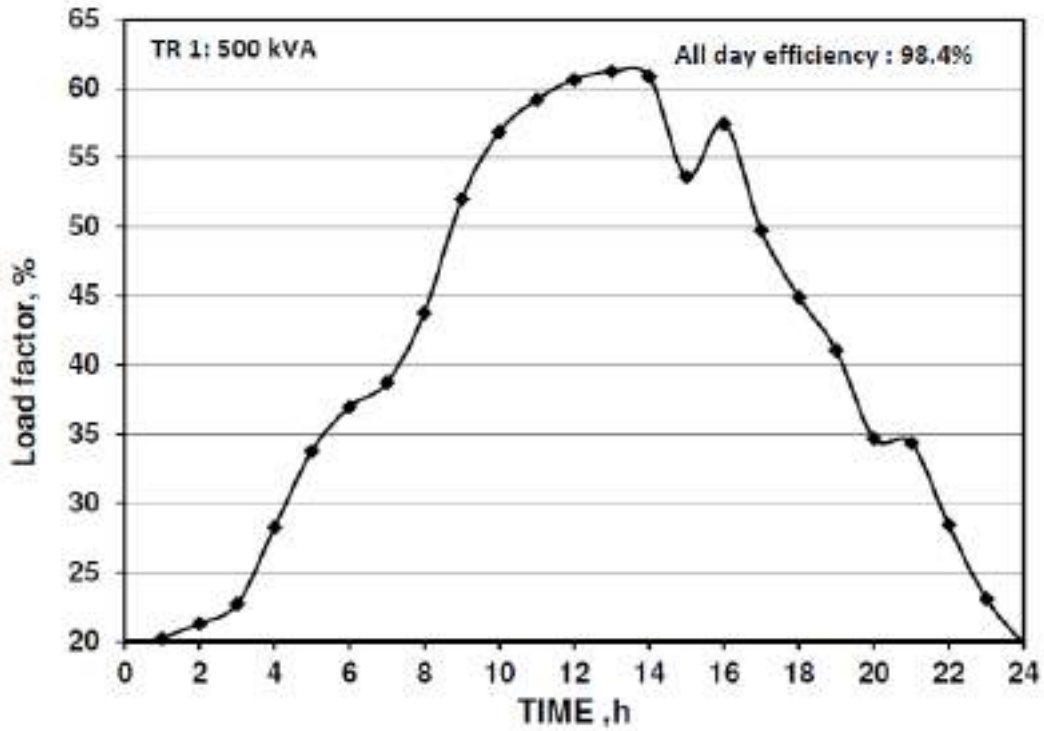

Figure 28: Variation of load factor of Tr.1.

The power factor on transformer secondary is good in the range of 0.91 to 0.94 due to use of automatic power factor controller (APFC) panel. The transformer winding temperature of Tr.1 is varying between 32.4 to 56.7 ^{o}C and at Tr. 2 is recorded in the range of 31.3 to 54.7 ^{o}C which is well within the limit of 55^{o}C above ambient temperature. Similarly the transformer oil temperature is measured in the

range of 31.1 to 51.2 ^{o}C at Tr.1 and 30.1 to 50.4 ^{o}C at Tr. 2 which is lower than the limit of 50 ^{o}C above ambient temperature.

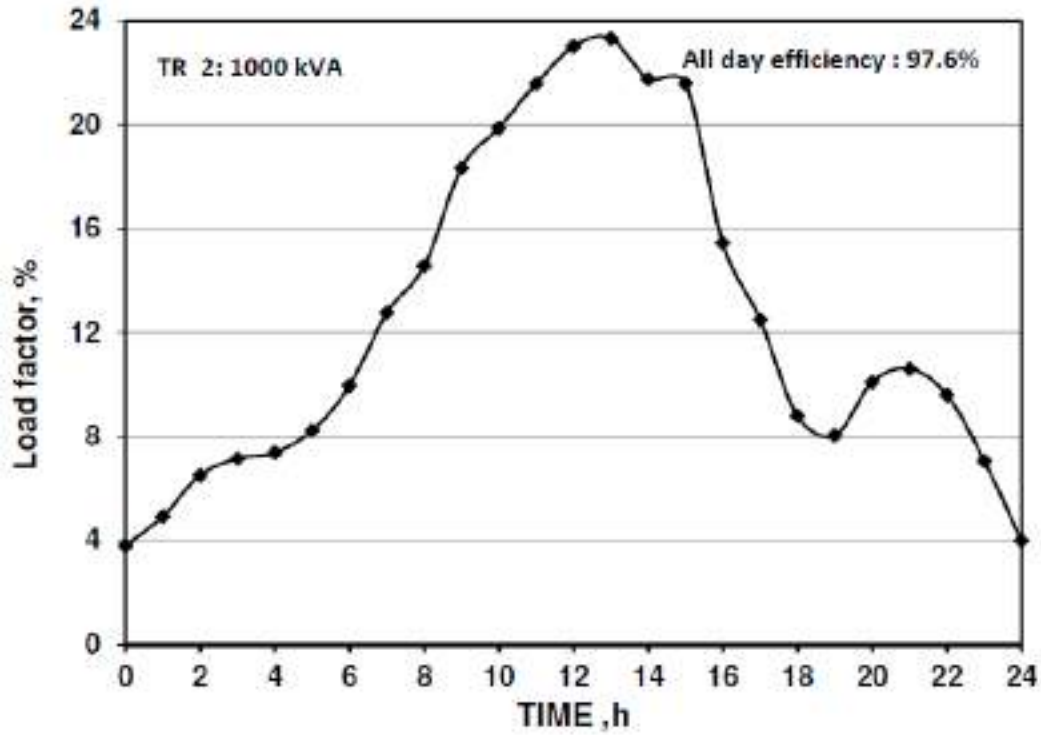

Figure 30: Variation of load factor of Tr.2.

Recommendations: It is suggested to divert all the loads on to Tr. 2 (1000 kVA) during day time between 08:00 to 17:00 hours and during evening hours between 17:00 to next day 08:00 hours, the Tr. 1 can be charged with full load. The implementation of this suggestion will change the load factor of Tr.1 in the range of 12.6 to 38.3% (refer Figure 31) and that of Tr. 2 will be in the range of 23.6 to 38.3%. This will reduce the ***energy consumption by 3,045 kWh/month***.

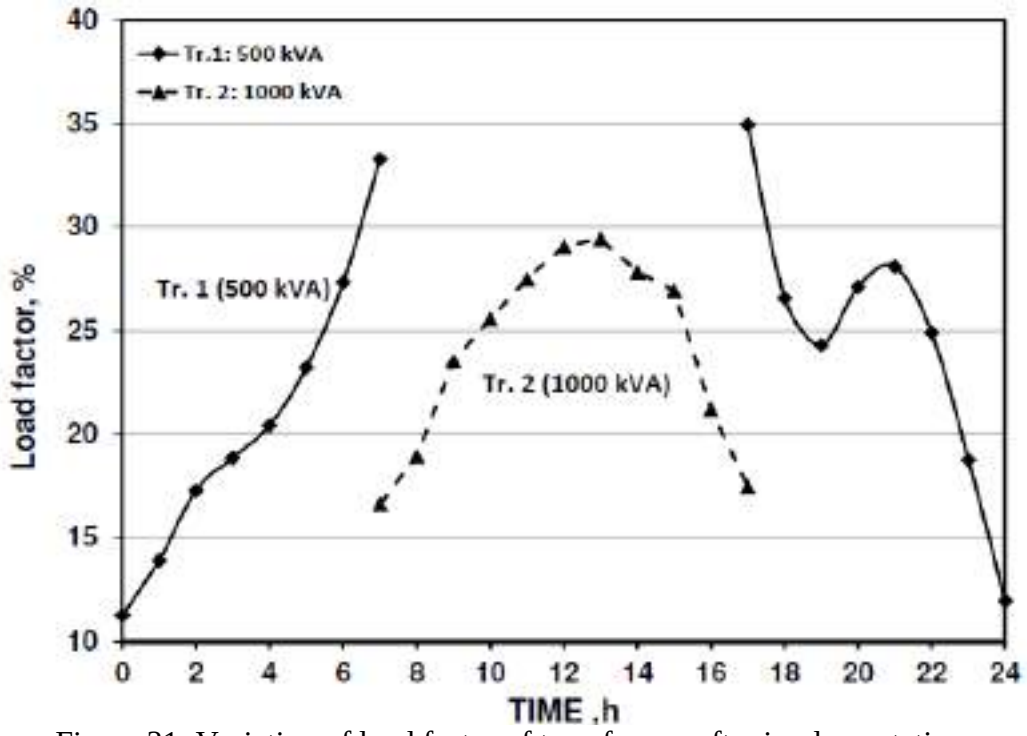

Figure 31: Variation of load factor of transformer after implementation.

3.4 Power factor management

It can be seen from the Figure 4 that the average power factor at main incoming is varying between 0.90 to 0.94 and is good. The automatic power factor controller (APFC) panel with capacitor banks of four numbers of 50 kVAR and two numbers of 25 kVAR are installed at main incoming panel to maintain the power factor near unity. Generally one number of 50 kVAR and one number of 25 kVAR capacitor banks will be in service through APFC panel to improve the power factor. The APFC panel is maintaining the power factor in the range of 0.91 to 0.97 at LT panels.

3.5 Diesel generator (DG) sets

In order to provide the back-up power supply during grid power supply failure, there are two DG sets of 500 kVA are connected at two LT panels. Both DG sets are provided with auto close panels. DG sets provide the power supply to entire University including Hostel and quarters during the grid power failure. Figure 32

gives the monthly energy generation by DG sets. The monthly energy generation by DG set 1 during the energy audit study is varying between 3,104 to 17,024 kWh/month whereas the energy generation by DG set 2 is in the range of 2,922 to 12,337 kWh/month. The total monthly energy generation by DG sets is varying between 6,026 to 28,362 kWh/month that forms 2.25 to 9.84% of total energy consumption which is less.

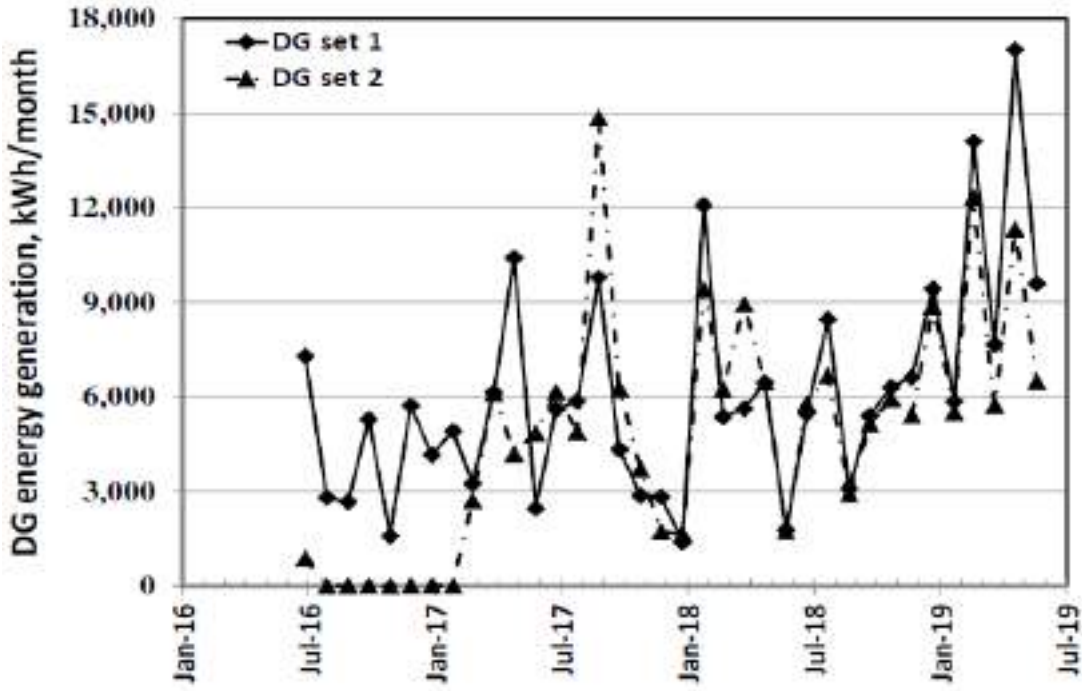

Figure 32: Variation of monthly energy generation by DG sets.

Table 1 gives the performance results of DG sets. The observations and recommendations for energy conservation measures are:

1. The load factor of DG set 1 and 2 (based on average power) are in the range of 46.4 & 50.3 % but based on peak phase current the load factor of these DG sets are in the range of 46.4 & 51.2 %. The loading of DG sets is on lower side.
2. The Specific energy generation (SEG) of DG 1 is 2.95 kWh/l whereas SEG of DG 2 is 2.99 kWh/l which is slightly low. The SEG of both DG sets are

slightly on lower side may be due to lower loading during the performance tests conducted during energy audit study.

Table 1: Performance results of DG sets.

Sl. No.	Particulars	Unit	DG Set 1	DG Set 2
1	Rating	kVA	500	500
2	Measured RY voltage	V	411.3	415.1
3	Measured YB voltage	V	412.1	413.9
4	Measured BR voltage	V	410.9	414.0
5	Measured Current R phase	A	329	333
6	Measured Current Y phase	A	321	338
7	Measured Current B phase	A	326	349
8	Power factor R	-	0.93	0.92
9	Power factor Y	-	0.93	0.94
10	Power factor B	-	0.94	0.93
11	Power	kW	216.4	233.8
12	Load Factor based on average load	%	***46.4***	***50.3***
13	Load Factor based on peak phase current	%	***47.3***	***51.2***
14	Energy generation	kWh/h	172.8	151.2
15	Oil Consumption	l/h	58.6	50.5
16	Specific Energy Generation	***kWh/l***	***2.95***	***2.99***
17	Specific Oil Consumption	l/kWh	0.34	0.33
18	Radiator outlet air temperature	^{o}C	58-63	51-65
19	Radiator inlet air temperature	^{o}C	36-45	32-43
20	Exhaust gas temperature	^{o}C	140-262	117-217
21	Alternator body temperature	^{o}C	45-66	41-57

3.6 Water pumping system

The water is received through water tankers from outside to various sumps and also from borewells inside the campus. The average water received through tankers is about 7.5 to 8.0 lakh litres per day. The energy used for water pumping system is 4.6 MWh/month that forms 2.0% of total energy consumption.

Table 2: Performance results of water pumps

Sl. No.	Particulars	Rating, kW	Avg. Voltage, V	Avg.Current, A	Power factor	Power, kW	Load factor, %	Control
1	A Block UG S. pump 1	5.5	415.2	7.0	0.86	4.33	78.7	auto
2	A Block UG S. pump 2	7.5	412.8	10.5	0.89	6.68	89.1	auto
3	A Block UG S. pump 3	3.7	415.2	5.2	0.85	3.18	85.9	auto
4	A Block UG S. pump 4	3.7	412.4	5.0	0.86	3.07	83.0	auto
5	A Block UG S. pump 5	5.5	415.1	7.6	0.85	4.64	84.4	auto
6	B Block UG S. pump 1	5.5	413.1	6.5	0.82	3.81	69.3	auto
7	B Block UG S. pump 2	3.7	414.5	5.1	0.86	3.15	85.1	auto
8	B Block UG S. pump 3	5.5	416.2	7.8	0.86	4.84	87.9	auto
9	C Block UG S. pump 1	5.5	413.8	7.2	0.81	4.18	76.0	auto
10	C Block UG S. pump 2	5.5	411.1	7.4	0.84	4.43	80.5	auto
11	C Block UG S. pump 3	3.7	415.2	5.1	0.84	3.08	83.3	auto
12	G1 Block UG S. pump 1	5.5	414.8	7.8	0.86	4.82	87.6	auto
13	Adm.Block UG S. pump 1	3.7	412.3	5.5	0.82	3.22	87.0	auto
14	Adm.Block UG S. pump 2	3.7	415.2	5.6	0.81	3.26	88.2	auto
15	V. Block UG S. pump 1	1.5	414.9	2.2	0.83	1.31	87.5	auto
16	V. Block UG S. pump 2	1.5	413.3	2.1	0.81	1.22	81.2	auto
17	V. Block UG S. pump 3	1.5	412.3	2.2	0.8	1.26	83.8	auto
18	V. Block UG S. pump 4	1.5	414.2	2.1	0.82	1.24	82.4	auto
19	PH UG S. pump	5.5	414.1	6.9	0.87	4.31	78.3	auto
20	Playground B. pump 1	5.5	410.6	6.5	0.84	3.88	70.6	Manual
21	Playground B. pump 2	3.7	411.2	4.9	0.87	3.04	82.1	Manual
22	GH Borewell pump	3.7	415.2	5.0	0.82	2.95	79.7	Manual
23	RISM B. pump	3.7	412.3	5.0	0.83	2.96	80.1	Manual
24	MV Block B. pump 1	3.7	414.1	4.9	0.84	2.95	79.8	Manual
25	MV Block B. pump 2	5.5	409.2	7.1	0.85	4.28	77.8	Manual
26	Hostel B Block B. pump	3.7	411.1	5.2	0.81	3.00	81.1	Manual
27	Girls Kitchen B. pump	3.7	413.2	4.9	0.83	2.91	78.7	Manual

Table 2 gives the performance results of water pumps used for lifting the water from ground and also from sump to overhead tanks. The observations from the study are as follows:

a) There are about 8 numbers of borewell pumps (3.7 kW – 6 Nos. & 5.5 kW – 2 Nos.) to lift the water from ground to sump and are operated manually for about 2 – 3 hours/day.

b) The load factor of these borewell pump motors is varying in the range of 70.6 to 82.1% and the water pump moor loading is normal.

c) There are about 19 numbers of sump pumps to lift the water from sump to overhead tanks. For all these pumps, automatic controllers are installed.

d) At Pump house, 5.5 kW water pump is installed and its load factor is 78.3% which is normal.
e) At A Block hostel, 7.5 kW – 1 No., 5.5 kW – 2 Nos. & 3.7 kW – 2 Nos. water pumps are installed and their load factor of motors is varying between 78.7 – 89.1% which is normal.
f) At B Block hostel, 5.5 kW – 2 Nos. & 3.7 kW – 1 Nos. water pumps are installed and their load factor of motors is varying between 69.3 – 87.9% which is normal.
g) At UG sump at C Block hostel, 5.5 kW – 2 Nos. & 3.7 kW – 1 Nos. water pumps are installed and their load factor of motors is varying between 76.0 – 83.3% which is normal.
h) At G1 Block hostel, 5.5 kW water pump is installed and its load factor of motors is 87.6% which is normal.
i) At Admin Block, two numbers of 3.7 kW water pumps are installed and their load factor of motors is varying between 87.0 to 88.2% which is normal.
j) At Vivekananda Block, four numbers of 1.5 kW water pumps are installed and their load factor of motors is varying between 81.2 – 87.5% which is normal.
k) At few places, the gland seal leakage was observed which needs to arrested by replacing the gland seals.
l) The water pump – motors can be overhauled at regular intervals to enhance the energy efficiency of water pumps which will save the energy consumption.

3.7 UPS and Computers & peripherals

The monthly average energy used for computers and peripherals is 41.1 MWh/month that forms about 17.6% of total energy consumption. All these computers are powered through uninterrupted power supply (UPS). The energy consumption at UPS is about 32.6 MWh/month that forms 14.0% of total energy consumption. The UPS details are:

a) At Sir C.V. Raman Block, two numbers of 80 kVA UPS are installed, their load factor is varying between 56.2 to 61.5% and loading of UPS is normal.
b) At Sir M Visvesvaraya Block, one number of 60 kVA & another of 80 kVA UPS are installed, their load factor is varying between 49.8 to 52.1% and UPS loading is normal.
c) At Swami Vivekanand Block, two numbers of 80 kVA UPS are installed, their load factor is varying between 51.8 to 63.2% and UPS loading is normal.
d) At Library, one number of 60 kVA UPS is installed, its load factor is varying between 41.8 to 55.3% and UPS loading is normal.
e) At RISM block, one number of 30 kVA UPS is installed, its load factor is varying between 43.5 to 57.8% and UPS loading is normal.
f) At Administration Block, one number of 80 kVA & another of 40 kVA UPS are installed, their load factor is varying between 41.3 to 62.3% and UPS loading is normal.

There are about 2,230 computer systems and 145 printers of different sizes. The power consumption for the system varies between 355 to 415 W. The power used by printers varies between 280 to 950 W but the power is varying widely. In many labs the systems are put OFF after the completion of labs but few places it was observed that systems were put ON in energy saving mode. But in energy saving mode, the processor will be working that consume the power of about 150 to 200 W. It is suggested to put OFF the systems whenever they are not required.

3.8 Air-conditioning system

The monthly average energy used for Air-conditioning system is 34.4 MWh/month that forms about 14.7% of total energy consumption. The total installed cooling capacity of air-conditioning units in REVA University Kattigenahalli campus is 545.1 TR. Depending on the specific requirement for various applications like laboratories, seminar halls, discussion rooms, board rooms and officials' cabins, split air-conditioners, cassette units, package and Ceiling Suspended Units (CSU)

are installed of different ratings. The running hours of each AC units vary depending on the requirement.

a) Kalpana Chawla Seminar Hall: 2TR (split) – 5 Nos.
b) C.N.R. Rao seminar hall: 2TR (split) – 4 Nos.
c) C.V. Raman Block GF: 1.5TR (split) – 4 Nos., 2TR (split) – 8 Nos., 1TR (split) – 1 No. & 3TR (split) – 3 Nos.
d) C.V. Raman Block FF: 1.5TR (split) – 1 No., 2TR (cassette) – 6 Nos. & 7.5TR (CSU) – 4 Nos.
e) C.V. Raman Block SF: 2TR (split) – 4 Nos., 3TR (split) – 1 No., 2.5TR (split) – 1 No. & 1.5TR (split) – 1 No.
f) C.V. Raman Block third floor (Auditorium): 8.5TR (CSU) – 1 No., 11TR (package) – 2 Nos. & 11TR (CSU) – 5 Nos.
g) RISM: 2TR (split) – 4 Nos., 2.5TR (split) – 1 No. & 1TR (split) – 1 No.
h) Sir M.V. Block: 1.5TR (split) – 1 No. & 2TR (split) – 5 Nos.
i) Library: 5.5TR (CSU) – 3 Nos., 2TR (split) – 1 No. & 12TR (package) – 5 Nos.
j) Admin Block basement: 7.5TR (CSU) – 3 Nos., 11TR (CSU) – 1 No. & 2TR (split) – 6 Nos.
k) Admin Block GF: 1.5TR (split) – 2 No.
l) Admin Block 5^{th} floor: 7.5TR (CSU) – 3 Nos., 11TR (CSU) – 1 No., 10TR (CSU) – 1 Nos., & 12.5TR (CSU) – 2 No.
m) Admin Block 6^{th} floor: 2TR (cassette) – 16 Nos. & 1TR (cassette) – 2 Nos.
n) Vivekananda Block: 2.5TR (cassette) – 5 Nos., 3TR (cassette) – 2 Nos. & 2TR (split) – 7 Nos.
o) Vivekananda Block 7^{th} floor seminar hall: 3TR (cassette) – 4 Nos.
p) Vivekananda Block GF & FF: 2.5TR (split) – 3 Nos., 3TR (split) – 4 Nos., 3TR (cassette) – 1 No., 0.8TR (split) – 4 Nos., 1TR (split) – 8 Nos., 1.5TR (split) – 3 Nos., 2.5TR (cassette) – 4 Nos. & 2.0TR (cassette) – 2 Nos.

The specific cooling capacity of air-conditioning system varies between 1167 to 1718 TR/ft^2 which is slightly higher than the normal specific air-conditioning system

of 1000 TR/ft^2. The average specific energy consumption (SEC) for air-conditioning units of different size varies between 1.23 to 1.73 kW/TR (the average SEC is 1.35 kW/TR). At few labs and seminar halls, it was observed that the room temperature is being maintained at 21 – 23 ^oC which should be maintained above 25^oC (human comfortable) which will reduce the energy consumption by 3% per degree of room temperature. The anticipated ***energy saving is 455 kWh/month***. The relative humidity in the air-conditioning room is being maintained in the range of 40 to 58 % and is good.

3.9 Renewable energy Systems

3.9.1 Present 55 kW Solar PV power plant

At Administrative block 55 kW solar power plant is installed to provide the power supply to loads at administrative block. There are four inverters of 15 kVA each and 220 Numbers of 250 W_p each solar photovoltaic panels are installed.

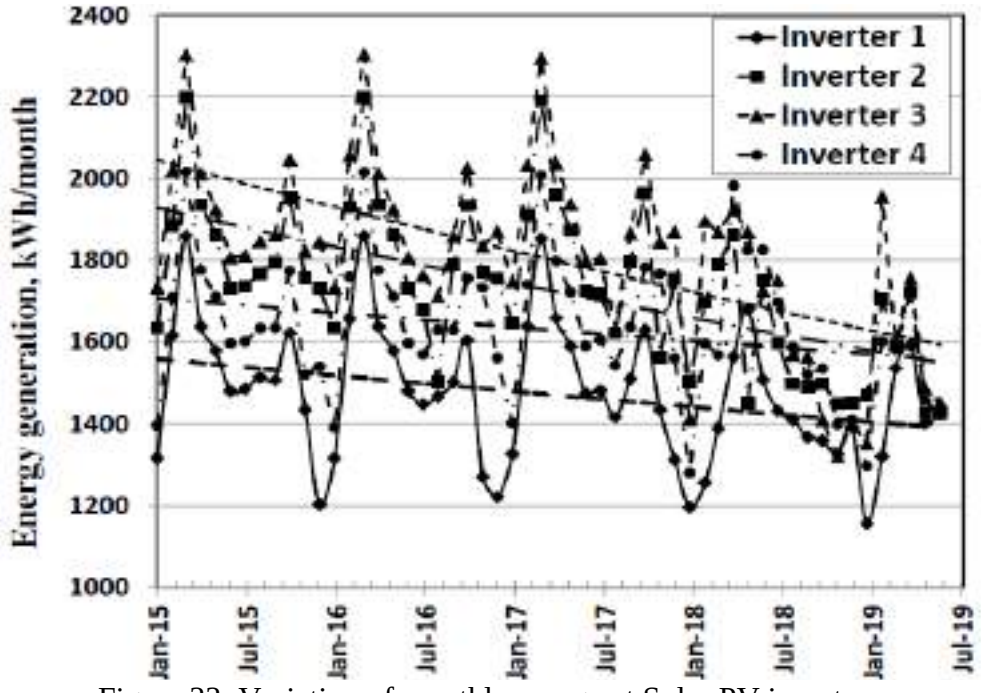

Figure 33: Variation of monthly energy at Solar PV inverters.

Figure 33 shows the variation of energy at inverters and the energy generation during the audit period are:

a) Inverter 1: 1156 to 1592 kWh/month

b) Inverter 2: 1425 to 1751 kWh/month
c) Inverter 3: 1321 to 1956 kWh/month
d) Inverter 4: 1296 to 1826 kWh/month

It can be seen from the Figure that the energy generation by inverters is reduced over the period of time due to degradation of PV panel and the degradation rate is 8.2 % for inverter 1, 15.4 % for inverter 2, 18.2% for inverter 3 and 6.6% for inverter 4. The performance of PV panels connected with inverters 2 & 3 is poor where the degradation rate is very high.

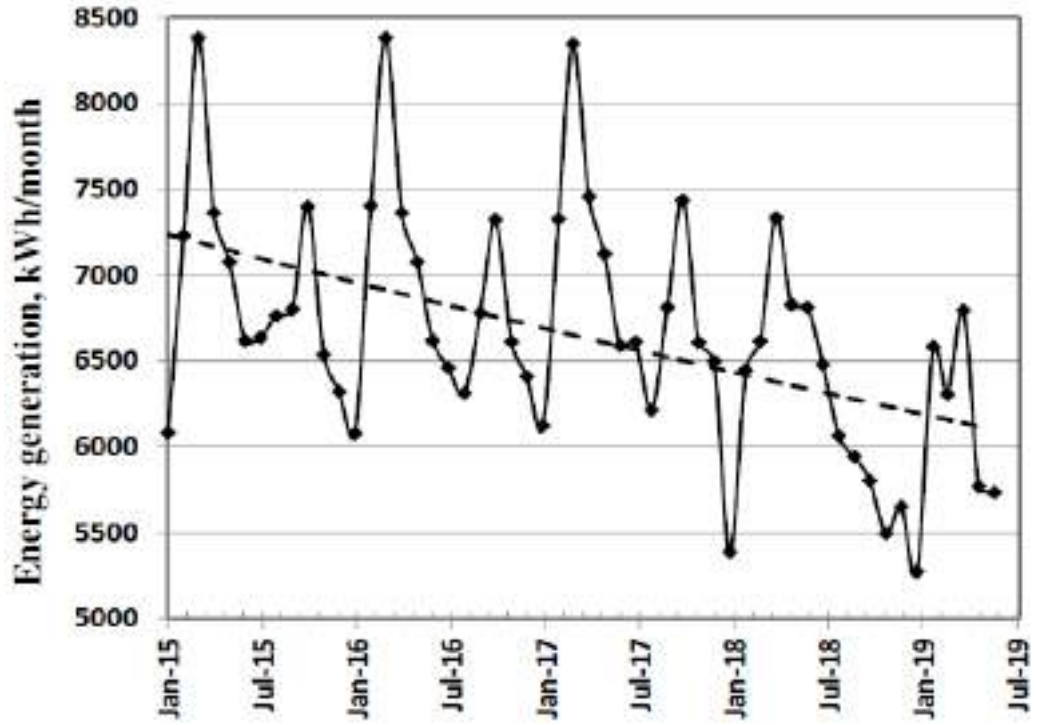

Figure 34: Variation of total energy generation by 55 kW Solar PV power plant.

The energy generation is less during Jan. month and is high during March month. Figure 34 gives the variation of monthly total energy generation by solar PV power plant for last five years. The generation varies between 5,273 to 6,811 kWh/month during the energy audit period. The annual solar energy generation and its share are:

a) Year 2015-16: 83,367 kWh/y (3.97% of total energy consumption)
b) Year 2016-17: 82,883 kWh/y (2.97% of total energy consumption)

c) Year 2017-18: 79,376 kWh/y (2.73% of total energy consumption)
d) Year 2018-19: 72,970 kWh/y (2.67% of total energy consumption)

It can be seen from the Figure that the total energy generation by solar PV plant is reduced by 12.5% during last 4 years due to degradation of PV panels and the degradation rate is very high. The overall specific energy generation or yield is reduced from 4.15 kWh/kW-day to 3.63 kWh/kW-day. The present yield is very less compared to the normal acceptable value of 5.0 kWh/kW-day. This solar PV power plant reduced the CO_2 emission in the range of 76.6 t/y to 87.5 t/y (average of 2.91% of total CO_2 emission).

3.9.2 Solar hot water system

At REVA University Kattigenahalli campus, the solar hot water systems are installed to provide the hot water to students residing at hostels. The total solar hot water capacity of 80,000 litres/day (LPD) for the total student strength of 3293 with specific hot water of 24.3 LPD/student.

a) Boys Hostel A block: 10,000 LPD, students: 395 Nos. : Specific water: 25.3 LPD/student
b) Boys Hostel B block: 10,000 LPD, students: 373 Nos. : Specific water: 26.8 LPD/student
c) Boys Hostel C block: 10,000 LPD, students: 547 Nos. : Specific water: 18.3 LPD/student
d) Boys Hostel D block: 30,000 LPD, students: 1070 Nos. : Specific water: 28.0 LPD/student
e) Girl Hostel G1: 10,000 LPD, students: 443 Nos. : Specific water: 22.5 LPD/student
f) Girl Hostel G2: 10,000 LPD, students: 467 Nos. : Specific water: 21.4 LPD/student

The specific hot water used is varying between 18.3 to 28.0 and the water temperature varies between 45 to 60^{o}C. The nominal Specific hot water

requirement is 25 LPD/student at a temperature of 60 ^{o}C. The installation of solar hot water system had reduced the electrical energy consumption (if hot water is provided through electric heating) by about 48,000 kWh/month and the reduction of CO_2 emission is about 50.4 t/month which is a very good initiation of energy conservation measures.

The total energy consumption through renewable energy systems is 54 MWh/month that forms 19.2% of total energy consumption.

3.10 Lighting System

The monthly average energy is used for lighting system is 44.6 MWh/month that forms 19.1% of total energy consumption. The energy consumption for lighting system is reduced from 57.7 MWh/month to 44.6 MWh/month compared to previous year due to implementation of energy conservation measures (reduction of 22.7% of lighting energy). Since all the hostel blocks are included in total energy consumption, the major energy share for lighting is from hostel blocks. Tables 3 to 8 give the number of light fittings, fans, measured lighting levels and the details of other major equipments. The energy used for comfort air fans is 31.5 MWh/month that forms 13.5% of total energy consumption. The energy consumption for fans is reduced from 36.9 MWh/month to 31.5 MWh/month compared to previous year due to implementation of energy conservation measures (reduction of 14.6% of fan energy). The energy used for other end use & lab equipment is 43.5 MWh/month that forms 18.7% of total energy consumption. Table 9 gives the recommended lighting level for various tasks as per **IS:3646-1966 Standards**. The observations and suggestions for energy conservation measures are as follows:

1. In the Sir CV Raman block Amphi theatre roof is provided with transparent polycarbonate sheets for the approximate area of 1025 m^2. This had allowed very good natural light during day hours. This had reduced the average electrical energy of 490 kWh/month which is commendable.

2. Similarly at Vivekananda block Rangasthala roof is provided with transparent polycarbonate sheets for the approximate area of 900 m^2. This had allowed very good natural light during day hours and had reduced the average electrical energy of 430 kWh/month.
3. The energy used for lighting in class rooms is very less because of good amount of natural light is available in all blocks. The window curtains are used are of light colours.
4. The wall paints in all class room is of light colour whose reflectance factor is good (refer Table 11).

Table 3: Lighting level measurement at Vivekananda Block

Particulars	**Light fitting**			**Fans, (60 W)**	**Illumination level, lumens/m^2 (lux)**	**Remarks / Other equipment**
	LED (18W)	**TFL (36W)**	**CFL (15W)**			
Rooms	323	101	184	534	173, 120,166, 215, 182, 148	
DBMS Project Lab	1	1			188, 134, 187, 239, 216, 179	2 TV, 1 Biometric, 5 Purifiers
OOPS Lab	2	1			287, 175, 167, 261, 211, 207	
DBMS Lab	4	8			128, 108, 123, 187, 178, 201	
WEB Lab	2	2			138, 142, 178, 165, 178, 145	
Staff Room		108	7	132	185, 176, 208, 175, 224, 176,	Projector, PC
Corridors	72	85			184, 178, 203, 309, 115, 202,	16 Purifiers,7 Projectors, 2 Coffee Machines,2 Vending Machines
Computer Lab	2	2			212, 187, 145, 166, 167, 204,	
CCP Lab	2	2			115,105,67,178, 126, 134, 108	
Research Centre			8	3	128, 123, 176, 175, 187, 165	
Programming Lab		6			117, 207, 189, 209, 278, 203	2 Projector

5. At Vivekananda block (Table 3), at class rooms about 323 numbers of 18W LED lamps, 101 numbers of T8 TFL and 184 numbers of 15W CFL are installed. The illumination level is varying between 129 to 234 lumens/m^2 and is normal. It was also observed that good natural light. There are 534 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18W LED lamps which will reduce the

energy consumption by 266 kWh/month. The anticipated investment is Rs. 0.40 lakhs and the payback period is 20 months.

6. At Vivekananda block other labs and rooms, about 85 numbers of 18W LED lamps, 215 numbers of 36W T8 TFL, 15 numbers of 5W CFL and 293 numbers of 28W CFL are installed. The illumination level is varying between 114 to 329 lumens/m^2 and is normal. It was also observed that good natural light. There are 135 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18W LED lamps which will reduce the ***energy consumption by 567 kWh/month***. The anticipated investment is Rs. 0.86 lakhs and the payback period is 20 months.

Table 4: Lighting level measurement at Sir M Visvesvaraya Block

Particulars	**Light fitting**			**Fans, (60 W)**	**Illumination level, lumens/m^2 (lux)**	**Remarks / Other equipment**
	LED (18W)	**TFL (36 W)**	**CFL (5 W)**			
Rooms	66	512	18	606	201, 211, 156, 178, 165, 145	
HOD & staff room			28		189, 109, 96, 156, 208, 218	
corridor	12	74			55,85,67,108, 116, 124, 108	
Wash rooms		37	74		78, 118, 131, 157, 148, 211	
exam control room	2	2		4	110, 211,107, 109, 114, 145	
CAD hall 1,2,3	12	10		26	211, 201, 178, 234, 217, 210	Projector, PC
Material science lab		8		12	178, 156, 208, 207, 134, 187	
Fluid mechanics lab		18		20	156, 176, 207, 211, 208, 165	
Machine shop		18		20	144, 85, 200, 178, 165, 118	
Skill development center		11		10	168, 133, 156, 175, 137, 195	
Measurement and instruments		4		4	118, 132, 168, 163, 171, 165	
Manufacturing technology lab		8		4	187, 155, 167, 201, 211, 209	
Energy conversion lab		8		8	205, 176, 208, 175, 204, 176	
HMT lab		5		6	167, 207, 189, 209, 218, 209	
Design lab		7		6	178, 134, 187, 239, 256, 179	
CAED Lab and Auto CADD lab		18		13	134, 178, 203, 309, 115, 207	Projector
CAMA, CIM, Automation lab		9		6	112, 167, 145, 156, 187, 204	Projector, PC
Physics Lab 1 & 2		8		10	213, 150,156, 205, 182, 178	

7. At Visvesvaraya block (Table 4), at class rooms about 66 numbers of 18W LED lamps, 512 numbers of 36W tubular fluorescent lamps (TFL) i.e., T8 and 18 numbers of 5W compact fluorescent lamps (CFL) are installed. The illumination level is varying between 145 to 233 lumens/m^2 and is normal. It was also observed that good natural light. There are 606 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18 W LED lamps which will reduce the ***energy consumption by 1,352 kWh/month***. The anticipated investment is Rs. 2.05 lakhs and the payback period is 20 months.
8. At Visvesvaraya block other labs and rooms, about 26 numbers of 18W LED lamps, 238 numbers of 36W T8 TFL and 102 numbers of 5W CFL are installed. The illumination level is varying between 117 to 283 lumens/m^2 and is normal. It was also observed that good natural light. There are 149 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18W LED lamps which will reduce the ***energy consumption by 628 kWh/month***. The anticipated investment is Rs. 0.95 lakhs and the payback period is 20 months.
9. At Administrative block (Table 5), at class rooms about 106 numbers of T8 TFL and 298 numbers of 15W CFL are installed. The illumination level is varying between 141 to 322 lumens/m^2 and is normal. It was also observed that good natural light. There are 127 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18W LED lamps which will reduce the ***energy consumption by 280 kWh/month***. The anticipated investment is Rs. 0.43 lakhs and the payback period is 20 months.
10. At Administrative block, other labs and rooms, 106 numbers of 36W T8 TFL, 196 numbers of 15W CFL and 293 numbers of 28W CFL are installed. The illumination level is varying between 88 to 224 lumens/m^2 and is normal. It was also observed that good natural light. There are 31 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18W LED lamps which will reduce the

energy consumption by 280 kWh/month. The anticipated investment is Rs. 0.43 lakhs and the payback period is 20 months.

Table 5: Lighting level measurement at Admin Block

Particulars	**Light fitting**			**Fans, (60 W)**	**Illumination level, lumens/m^2 (lux)**	**Remarks / Other equipment**
	TFL (36 W)	**CFL**				
		(15W)	**(28W)**			
Rooms	106	298		127	231, 241, 198, 234, 227, 210	
Corridor	57	163	158	2	115, 106, 208, 125, 214, 156	2 TV, 1 Biometric, 5 Purifiers
Washrooms	24			8	123,175, 137,158, 126, 144	
Auditing Office	6				180, 211 , 157, 109, 114, 155	
VC Visitor Lounge			7		108, 122, 178, 165, 178, 146	
ERP & HR Office			35		134, 185, 200, 178, 165, 111	Projector, PC
HR Interview Room			26		119, 109, 96, 196, 208, 218	
Admission and public relations	4		5	7	152, 117, 155, 136, 197, 224	
Office of the administration & establishment	4			5	157, 115, 177, 281, 211, 209	
Registrar office			4	2	118, 163, 176, 165, 187, 163	
Conference hall and Board room		33	6		187, 207, 109, 229, 258, 219	2 Projector
Accounts office	5			5	134, 185, 200, 178, 165, 111	
university office			1		109, 129, 76, 126, 168, 138	
Advisor			9	1	128, 188, 193, 157, 168, 201	
Vice chancellor			11		222, 214, 187, 203, 198, 108	1 TV
Chancellor office	3		31		148, 174, 127, 289, 256, 139	1 TV
Pantry	3			1	124, 168, 223, 319, 125, 217	2 Purifiers

11. At RISM block (Table 6), at class rooms about 214 numbers of T8 TFL are installed. The illumination level is varying between 145 to 233 lumens/m^2 and is normal. It was also observed that good natural light. There are 140 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18W LED lamps which will reduce the ***energy consumption by 565 kWh/month***. The anticipated investment is Rs. 0.86 lakhs and the payback period is 20 months.

Table 6: Lighting level measurement at Science Block (RISM Block)

Particulars	Light fitting		Fans, (60 W)	Illumination level, lumens/m^2 (lux)	Remarks / Other equipment
	TFL (36 W)	CFL (5 W)			
Rooms	214		140	165, 123, 145, 167, 204, 211, 213, 156,156, 205, 182, 178	
Principal ,Admin office	3	8	3	156, 188, 213, 249,213,209	
Exam control room and pantry	4	2	4	128, 142, 168, 175, 198, 195	Vending machine
Corridor	94	2		109, 178, 196, 156, 218, 207	
Wash rooms	21		2	147, 217, 165, 169, 178, 176,	
Seminar halls		12		168, 194, 167, 209, 226, 189,	Projector
Sports room	18		9	115, 186, 218, 156, 214, 216 165, 217,	
Chemistry lab 1,2,3,4,5,6	34		28	126, 178, 234, 178, 218,234, 195, 278, 312, 234, 267, 167	Conductivity meter, ,temp controller, colorimeter, spectro photo meter, Chemical analyser, UV visible spectroscope, Shaker's incubator, Hot air incubator, Deep freezer
Physics Lab 1 ,2,3	14		9	137, 177, 167, 231, 216, 189,	Digital inverter, Hot air oven, ultrasonicator, Quartz furnace, signal generators, Fermi energy set up, Michelson Intereferometer
Plant tissue culture lab	15			168, 133, 186, 185, 197, 145	Silica beed sterilizer, Laminar air flow
Biology lab, Genetic Lab	16		6	145,125,167,178, 186, 154	Hot air incubator, AC, Potarymictrotome
Basic Material lab	46		16	164, 185, 209, 178, 175, 118	Two span simply supported beem,,Venture flame and OGEE wier

12. At RISM block other labs and rooms, 301 numbers of 36W T8 TFL and 30 numbers of 5W CFL are installed. The illumination level is varying between 145 to 226 lumens/m^2 and is normal. It was also observed that good natural light. There are 97 numbers of comfort air fans are installed in labs.

Recommendations: It is suggested to replace T8 lamps by 18W LED lamps which will reduce the ***energy consumption by 795 kWh/month***. The anticipated investment is Rs. 1.20 lakhs and the payback period is 20 months.

13. At Sir C.V. Raman block class rooms (Table 7), about 24 numbers of LED lamps, about 653 numbers of T8 TFL, 66 numbers of 8W CFL, 14 numbers of 12W CFL and 102 numbers of 36W CFL are installed. The illumination level is varying between 146 to 295 lumens/m^2 and is normal. It was also observed that good natural light. There are 401 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18W LED lamps which will reduce the ***energy consumption by 1,724 kWh/month***. The anticipated investment is Rs. 2.62 lakhs and the payback period is 20 months.

Table 7: Lighting level measurement at C.V. Raman Block (Main Block)

Particulars	**Light fitting**							**Fans, (60 W)**	**Illumination level, lumens/m^2 (lux)**	**Remarks / Other equipment**
	LED (18 W)	**TFL**	**CFL**			**Focus Lights**				
			8 W	**12 W**	**36W**	**22 W**	**50 W**			
Rooms	24	653	66	14	102			401	224, 178, 203, 319, 115, 207	6 Projectors
Labs	12	79			22			22	147, 207, 189, 209, 218, 209	4 Exhaust Fans
Corridor	24	58		4	22		4	16	107, 217,148, 126, 134, 108	4 Purifiers,1 TV, 3 Biometric Machines
Washrooms		16							98, 108, 183, 167, 118, 201,	3 Exhaust Fans
Training rooms	10	20						12	195, 176, 208, 175, 264, 176,	2 Projectors
Seminar halls and Board rooms		32	51	41	46				218, 184, 187, 239, 256, 179,	2 Projectors
Office (Principal, GM, DGM,)		13						8	183, 160,136, 285, 182, 178	
Amphitheatre					4	1	1		232, 157, 145, 156, 187, 204,	
Main gate dome						15			217, 155, 167, 271, 211, 209,	
Pantry									118, 153, 136, 115, 127, 145	2 Exhaust Fans

14. At Sir C.V. Raman block other labs and rooms, about 46 numbers of LED lamps, 218 numbers of T8 TFL, 51 numbers of 8W CFL, 45 numbers of 12W CFL, 94 numbers of 36W CFL, 16 numbers of 22W focus lights (halogen) and 5 numbers of 50W of focus lights (halogen) lamps are installed. The illumination level is varying between 105 to 315 lumens/m^2 and is normal. It was also observed that good natural light. There are 58 numbers of comfort air fans are installed in labs. **Recommendations:** It is suggested to replace T8 lamps by 18W LED lamps which will reduce the energy consumption by 576 kWh/month. The anticipated investment is Rs. 0.88 lakhs and the payback period is 20 months.
15. In order to conserve the energy consumption at Hostel blocks, at each room one number of 36W T8 TFL lamp was replaced with 18W LED lamp. This had reduced the total energy consumption for 3360 numbers of lamps by 15,120 kWh/month with an investment of Rs. 12.10 lakhs and the payback period was 10 month which is a very good payback period.

Table 8: Lighting level measurement at Hostel Blocks

Particulars	**Light fitting**		**Fans, (60 W)**	**Illumination level, lumens/m^2 (lux)**	**Remarks / Other equipment**
	CFL (5 W)	**LED (18W)**			
A block	488	136	128	157, 207, 189, 209, 218, 209	1 Camera,1Vending Machine, 7 Purifiers
B Block	486	136	128	128, 134, 187, 219, 256, 179	1 Camera,1Vending Machine, 7 Purifiers
C block	476	136	128	144,105,67,178, 156, 134, 108	1 Camera,1Vending Machine, 7 Purifiers
D block	640	620	260	131, 108, 123, 167, 178, 201,	1 Camera,1Vending Machine, 4 Purifiers
Girls hostel 1	623	235	185	142, 160,156, 215, 182, 118	1 Camera,2Vending Machine, 2Purifiers
Girls hostel 2	320	150	120	232, 136, 211, 165, 204, 176	1 Camera,2Vending Machine, 2 Purifiers
Corridors		325		176, 63, 156, 181, 177, 93, 55	

16. At Boys Hostel block A, B & C, 128 numbers of 18W LED lamps and 512 numbers of 5W CFL lamps are installed. The illumination level is varying between 128 to 208 lumens/m^2 and is normal. There are 128 numbers of comfort air fans are installed in labs.

17. At Boys Hostel block D, 520 numbers of 18W LED lamps and 780 numbers of 5W CFL lamps are installed. The illumination level is varying between 108 to 201 lumens/m^2 and is normal. There are 260 numbers of comfort air fans are installed in labs.
18. At Girls Hostel 1, 185 numbers of 18W LED lamps and 683 numbers of 5W CFL lamps are installed. The illumination level is varying between 163 to 231 lumens/m^2 and is normal. There are 128 numbers of comfort air fans are installed in labs.
19. At Girls Hostel 2, 120 numbers of 18W LED lamps and 360 numbers of 5W CFL lamps are installed. The illumination level is varying between 144 to 216 lumens/m^2 and is normal. There are 120 numbers of comfort air fans are installed in labs.

Table 9: Recommended illumination level for various purposes in industrial buildings as per **IS:3646-1966.**

Sl. No.	**Industrial building and process**	**Illumination level, lumen/m^2**
	1.0 Office buildings	
(a)	Entrance halls and Reception areas	150
(b)	Conference rooms, executive offices	300
(c)	General offices	300
(d)	Drawing offices (i) General (ii) Tracings	 300 450
(e)	Corridors and lifts cars	70
(f)	Stairs	100
(g)	Lift landing	150
	2.0 Laboratory and test rooms	
(a)	Electrical & instrument laboratories	450
(b)	Central laboratories, balance rooms	300
	3.0 Machine and fitting shops	
(a)	Rough bench and machine works	150
(b)	Medium bench and machine works, ordinary automatic machines, rough grinding, medium grinding, fine buffing, etc..	300
(c)	Fine bench and machine work, fine automatic machines, medium grinding fine buffing and polishing, etc..	700
4.0	**Entrance, corridors, stairs**	100
5.0	**Exist roads, car parks, internal factory & road**	20
6.0	**Canteens**	150
7.0	**Cloak rooms**	100

Table 10: Reflection factors of different materials.

Sl No.	Material	Reflection factor, %	Sl No.	Material	Reflection factor, %
01	White plaster	90.95	13	Light grey	66
02	White paper	80	14	Primrose yellow	65
03	Silvered mirrors	70.85	15	Pale pink	51
04	Chromium plate	65	16	Light green	45
05	Polished Aluminium	62	17	Pale blue	44
06	Lime stone	35 - 38	18	Medium grey	42
07	Polished marble	30 - 70	19	Sky blue	34
08	Tracing cloth	30	20	Olive green	21
09	Grey cement	20 - 30	21	Medium brown	17
10	Granite	20 - 25	22	Cardinal red	19
11	Red brick	10 - 15	23	Dark grey	17
12	Black paper	5			

3.11 Energy Management System

The energy consumption and the electrical distribution system had increased over the period of time. The electrical distribution system had become complex. In order to monitor, maintain and control the electrical distribution system at REVA University, it suggested to install the Energy Management System (EMS). The following measures to be implemented:

1) Installation of energy metering system at all hostel blocks, all buildings floor wise, water pump houses and street lights to monitor the energy consumption.
2) The master control room where all the energy consumption details are collected through online.
3) Collect the occupancy level in hostel and computing the specific energy consumption (SEC). Remedial measures for higher SEC.
4) Monitoring the load on all feeders and shifting of loads from overloaded feeders through remote.
5) Monitoring the voltage profile at farthest end use equipments.

6) Monitoring the reactive power all the major feeders and management of reactive power in auto.

The anticipated investment for energy management system is Rs. 10.0 lakhs.

4.0 CONCLUSIONS

The main conclusions from the study are as follows:

1. The electrical distribution system is well maintained.
2. The energy from grid is varying between 188.2 to 265 MWh/month. The average monthly energy consumption is reduced from 242 MWh/month to 233 MWh/month and the reduction is 3.7% of total energy consumption due to the implementation of energy conservation measures compared to previous year.
3. The total energy consumption (grid+DG) for period during energy audit study is varying between 200 MWh/month (July 2018) to 291.5 MWh/month (March 2019). The monthly average total energy consumption is reduced from 253.1 MWh/month to 248.1 MWh/month compared to previous year. The reduction is about 2.1% of total energy consumption. The total energy consumption from grid during the academic year 2018-19 is 27,96,140 kWh/y, energy generation by DG set is 1,81,270 kWh/y and the total energy consumption at REVA University is 29,77,410 kWh/y. The total built area is 1,46,548 m^2. The energy performance index (EPI) for total REVA University campus is 20.32 kWh/m^2-year which is reduced from 21.59 kWh/y compared previous year. The overall EPI is lower than the EPI specified by Energy Conservation Building Code (ECBC) 2006 of 120 kWh/m^2-year.
4. The load of transformer 1 is varying between 20.2 to 61.3% and transformer 2 is in the range of 3.8 to 23.3%. All day efficiency of Tr.1 is 98.4% which is slightly better than that of Tr. 2 of 97.6%. The diverting of all the total loads on to Tr. 2 (1000 kVA) during day time between 08:00 to 17:00 hours and

during evening hours between 17:00 to next day 08:00 hours will reduce the *energy consumption by 3,045 kWh/month*.

5. The load factor of DG sets are in the range of 46.4 to 51.2% and the Specific energy generation (SEG) of DG sets is normal in the range of 2.95 to 2.99 kWh/l.
6. There are about 19 numbers of underground sump pumps to lift the water from sump to overhead tank and these pumps are installed with auto controllers. There are about 8 numbers of borewell pumps to lift the water from ground to underground sumps. These pumps are being operated manually. The load factors of these pump motors are in the range of 69.3 to 87.6% and are normal. The water pump – motors can be overhauled at regular intervals to enhance the energy efficiency of water pumps which will save the energy consumption.
7. There are about 2,230 computer systems and 145 printers of different sizes. The power consumption for the system varies between 355 to 415 W. The power used by printers varies between 280 to 950 W but the power is varying widely. In many labs the systems are put OFF after the completion of labs but few places it was observed that systems were put ON in energy saving mode. But in energy saving mode, the processor will be working that consume the power of about 150 to 200 W. It is suggested to put OFF the systems whenever they are not required.
8. The specific cooling capacity of air-conditioning system varies between 1167 to 1718 TR/ft^2 which is slightly higher than the normal specific air-conditioning system of 1000 TR/ft^2. The average specific energy consumption (SEC) for air-conditioning units of different size varies between 1.23 to 1.73 kW/TR (the average SEC is 1.35 kW/TR). At few labs and seminar halls, it was observed that the room temperature is being maintained between 21 – 23 ^oC which should be maintained above 25^oC (human comfortable) that will reduce the energy consumption by 3% per degree of room temperature. The anticipated *energy saving is 455*

kWh/month. The relative humidity in the air-conditioning room is being maintained in the range of 40 to 58 % and is good.

9. The 55 kW solar power plant generates energy in the range of 5,273 to 6,811 kWh/month during the audit period. The energy generation by inverters is reduced over the period of time due to degradation of PV panel and the degradation rate is 8.2 % for inverter 1, 15.4 % for inverter 2, 18.2% for inverter 3 and 6.6% for inverter 4. The total energy generation by solar PV plant is reduced by 12.5% during last 4 years due to degradation of PV panels and the degradation rate is very high. The overall specific energy generation or yield is reduced from 4.15 kWh/kW-day to 3.63 kWh/kW-day. The present yield is very less compared to the normal acceptable value of 5.0 kWh/kW-day. This solar PV power plant reduced the CO_2 emission in the range of 76.6 t/y to 87.5 t/y (average of 2.91% of total CO_2 emission).
10. The specific hot water is varying between 18.3 to 28.0 and the water temperature varies between 45 to 60^{o}C. The nominal Specific hot water requirement is 25 LPD/student at a temperature of 60 ^{o}C. The installation of solar hot water system had reduced the electrical energy consumption (if hot water is provided through electric heating) by about 48,000 kWh/month and the reduction of CO_2 emission is about 50.4 t/month which is a very good initiation of energy conservation measures.
11. The energy used for lighting system is 44.6 MWh/month that forms 19.1% of total energy consumption.
12. The energy used for comfort air fans is 31.5 MWh/month that forms 13.5% and for other end use & lab equipment is 43.5 MWh/month that forms 18.7% of total energy consumption.
13. The illumination level is good because at many rooms, natural light is available and is being used appropriately. At rooms and labs, about 2664 numbers of 36W T8 fluorescent lamps (TFL) are installed, if these T8 lamps are replaced by 18W LED lamps will reduce the total energy consumption by 7,033 kWh/month. The anticipated investment is Rs. 10.66 lakhs and the simple payback period is 20 months.

14. In order to conserve the energy consumption at Hostel blocks, at each room one number of the 36W T8 TFL lamp were already replaced with 18W LED lamp. This had reduced the total energy consumption for 3360 number of lamps by 15,120 kWh/month with an investment of Rs. 12.10 lakhs and the payback period was 10 month which is a very good payback period.
15. At present the installation of renewable energy system had reduced the electrical energy consumption of 54 MWh/month that forms 19.2% of total energy consumption and reduced the CO_2 emission of 56.7 t/month.

Annexure I

Table 11: Maintenance schedule for transformers up to 1000 kVA.

Sl. No.	Frequency of inspection	Inspection	Inspection details	Action to be taken
01	Hourly	Load (current), temperature, voltage	Check against rated values	Start if fans are necessary to maintain the temperature
02	Daily	De-hydrating breather	Check that air passage are clear and colour of active agent	If silica gel is pink, change or may be activated for use again
03	Monthly	Oil level in transformer	Check transformer oil level	If low, top up with dry oil, examine transformer for leaks.
04	Quarterly	Bushings	Examine for cracks & dirt deposits	Clean or replace
05	Half yearly	No conservator	Check for moisture cover	Improve ventilation, check oil
06	Yearly	Oil in transformer	Check for dielectric strength, water content, acidity & sludge.	If the dielectric strength is less than 30 kV/2.5 mm gap replace the oil. Acidity & sludge is more, filter the oil.
		Earth resistance	-	Restore the earth resistance below 0.2 Ω
		Relays, alarms, their circuits, etc..	Examine relay & alarm contacts, their operation, fuses, etc.. Check relay accuracy etc..	Clean the components and replace contacts & fuses if necessary. Change the setting if necessary
07	Bi-annually	non conservator transformer	Internal instruction above core	Filter oil regardless of condition
08	5 yearly	-	Overall inspection. Lifting of core & coil.	Wash by hosing down with clean dry oil.

Table 12: Some of trouble shooting of distribution transformers

Symptoms	Causes	Suggestions
Temperature rise beyond permissible	Overload or low power factor	Reduce load, increase PF or augment capacity
	Oil-level below radiator tubes	Stop oil leakages and fill oil to proper level
	Oil jellied	If insulation not damaged, refill with fresh oil after flushing the tank.
	Unbalanced load	Check load-currents and redistribute single phase loads.
Bushing flashover	Lightning	Check lightning arrestor connections, lugs, grounding, etc.
	Dirty Bushings	Clean porcelains and check sources of dirt.
Occurrence of explosions in Transformer tank	Short circuited HV windings	If moisture is present, dehydrate the oil.
	Short circuited HV & LV windings	Find out cause of insulation failure owing to overloading, oscillating current, unstable voltage or lightning discharge and replace faulty section of windings
Noisy Transformer	Loose core and /or tie-bolts.	Check loose or broken connections and tighten loose clamp bolts, nuts and replace missing ones.
	Extremely low oil level exposing live parts.	Check cause, repair or replace damaged parts, refill to proper level.
Leaks	Cracks, holes, loose bolts, imperfect welds, and poor gasket installation.	Repair or replace damaged parts.
Rust and paint	Whether, polluted or salty atmosphere, overloads	Clean surfaces, repaint with proper paints and sufficient coatings.
Sludging	Overheating or wrong varnishing	Remove cause and clean out
Tank corroded	Acidity in oil	Test oil and treat it.
Low dielectric strength, dirt, moisture, etc..	Sludge or carbon	Filter and heat or change the transformer oil to get required values.

Annexure II

BUREAU OF ENERGY EFFICIENCY

Examination Registration No. : EA-3246 Serial Number 1557

Certificate Registration No. : 1557

Certificate For Certified Energy Manager

This is to certify that Mr./Mrs./Ms. Rajashekar P. Mandi Son/Daughter of Mr./Mrs. Parappa M Mandi who has passed the National Examination for certification of energy manager held in the month of May 2005 is qualified as certified energy manager subject to the provisions of Bureau of Energy Efficiency (Certification Procedures for Energy Managers) Regulations, 2010.

This certificate shall be valid for five years with effect from the date of award of this certificate and shall be renewable subject to attending the prescribed refresher training course once in every five years.

His/Her name has been entered in the Register of certified energy manager at Serial Number 1557 being maintained by the Bureau of Energy Efficiency under the aforesaid regulations.

Mr./Mrs./Ms. Rajashekar P. Mandi is deemed to have qualified for appointment or designation as energy manager under clause (*l*) of Section 14 of the Energy Conservation Act, 2001 (Act No.52 of 2001).

Given under the seal of the Bureau of Energy Efficiency, this 7th day of February 2013

Secretary
Bureau of Energy Efficiency
New Delhi

Dates of attending the refresher course	Secretary's signature	Dates of attending the refresher course	Secretary's signature