REVA UNIVERSITY
Bengaluru, India

ENERGY AUDIT

Conducted at

REVA University,
Kattigenahalli Campus,
Yelahanka, Bangalore

REPORT NO.: REVA/EEE/EA/02/2020

Audit Period : July 2019 - May 2020

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, Yelahanka, 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 Prof. Manish Bharath, 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/02/2020
11.	Energy Audit period	July 2019 – May 2020
12.	Date of issue of report:	May 2020
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. Surendra Rao Shankapal, Pro-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 REVA University is strongly believe in conserving the energy will reduce the global warming which is taken up as a part of Jagruthi 2 and therefore REVA University is committed to conserve the energy. Also REVA University had taken up series of training program one energy conservation for staff, faculties and students. Two numbers of social outreach programs are conducted at at villages to gives the awareness of energy conservation involving the students.

The detailed Energy audit study is conducted at REVA University, Bangalore for the period of July 2019 to May 2020. The electrical energy from grid was varying between 217.9 to 278.1 MWh/month till Feb. 2020. Then it was reduced to 113.7 MWh/month during May 2020 due to lock down. The average monthly energy consumption is reduced from 233 MWh/month to 218.6 MWh/month and the reduction is 6.2% 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 is varying between 245.16 MWh/month (Dec. 2019) to 287.73 MWh/month (Sept. 2019) till Feb. 2020. Then the University was locked down due to Covid-19 and the energy consumption was reduced to 120.42 MWh/month during May 2020. The annual total energy consumption is initially increased from 2509.68 MWh/y during 2015-16 to 2994.85 MWh/month during 2016-17 (increase of 19.3%), followed a marginal increase of 3.3% to the year 2017-18. Then the energy consumption started decreasing by 3.7% and 8.5% (extrapolated for 12 months) respectively for the year 2018-19 & 2019-20 due to implementation of energy conservation measures. The energy performance index (EPI) for total REVA University campus is 18.6 kWh/m^2-year which is reduced from 20.32 kWh/y compared previous year (reduction of 8.5%) which is very good. The overall EPI is lower than the EPI

specified by Energy Conservation Building Code (ECBC) 2006 of 120 kWh/m^2-year.

The maximum demand is recorded in Tri-vector meter installed at main incoming 11 kV grid feeders. The recorded MD during the energy audit period was varying between 645 kVA (Feb. 2020) to 690 kVA (Sept. 2020) till Feb. 2020. 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 energy cost variation during the energy audit period was in the range of Rs. 18.59 lakhs/month (Feb. 2020) to Rs. 25.10 lakhs/month (Sept. 2019) upto Feb. 2020 and energy cost was reduced to Rs. 10.21 lakhs/month during May 2020 due to lock down. The average monthly total energy cost is reduced from Rs. 24.52 lakhs/month to Rs. 21.21 lakhs/month compared to previous year (reduction of 13.5%). The energy rate during energy audit period was in the range of Rs. 8.44 to 9.23 per kWh. The average energy rate is reduced from Rs. 8.78 per kWh to Rs. 8.10 per kWh compared to previous year (reduction of 7.7%). .

The major energy is used at Hostel panel 1 is 77.9 MWh/month (35.6% of total energy consumption) and followed by the Boys D hostel, Girls hostel 1 and STP feeder energy consumption is 48.3 MWh/month (22.1%). The total energy used by hostels, guest house, quarters, water pumping, STP & library is 57.7%. The energy used for academics is 42.3% of total energy consumption.

The major energy is being used for lighting system i.e., 18.9% of total energy followed by lab equipment which forms about 18.1% computers & peripherals 16.8%, air-conditioning (AC) system 14.7%, comfort air fans 13.4% including hostel, faculty & staff quarters 8.1%, water pumping system 2.0% and STP plant 1.4%.

.

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 1.8% of total energy input. The power factor on transformer secondary is good in the range of 0.91 to 0.94 due to use of automatic power factor correction (APFC) panel. The load of transformer 1 is varying between 17.4 to 61.9% and transformer 2 is in the range of 4.6 to 23.4%. All day efficiency of Tr.1 is 98.2% which is slightly better than that of Tr. 2 of 97.5%. 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 2,425 kWh/month*.

There are two DG sets of 500 kVA to provide the back up power during grid power failure. The load factor of DG set 1 and 2 (based on average power) are in the range of 33.9 & 41.5 % but based on peak phase current the load factor of these DG sets are in the range of 35.4 & 41.6 %. The loading of DG sets is on lower side.The Specific energy generation (SEG) of DG 1 is 2.91 kWh/l whereas SEG of DG 2 is 2.93 kWh/l which is slightly low compared to optimal value of 3.0 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 borewell pump motors are in the range of 63.39 to 82.24% and are normal. The load factor of sump pump motors are in the range of 63.2 to 82.6% and are normal. The overall pump efficiency of sump pumps are in the range of 44.9 to 6.6% and few pumps efficiencies are on lower side due to pump internal leakages.

The specific cooling capacity of air-conditioning system varies between 1147 to 1738 TR/ft^2 which is slightly. At few labs and seminar halls, the room temperature is being maintained at 21 – 23 ^oC which should be maintained above 25^oC which will reduce the energy consumption by 3% per degree of room temperature. The anticipated *energy saving is 413 kWh/month*.

The 55 kW solar power plant generates energy in the range of 5,165 to 6,645 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 is reduced from 4.15 kWh/kW-day to 3.42 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 72.0 t/y to 87.5 t/y (average of 2.91% of total CO_2 emission).

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.

The energy used for lighting system is 41.3 MWh/month that forms 18.9% of total energy consumption. The energy used for comfort air fans is 29.4 MWh/month that forms 13.% and for other end use & lab equipment is 39.6 MWh/month that forms 18.1% of total energy consumption.

In the Sir CV Raman block Amphi theatre and at Vivekananda block Rangasthala roofs are provided with transparent polycarbonate sheets which has allowed the natural light during day hours and reduced the energy consumption by 920 kWh/month.

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 Academic buildings and corridors, T8 lamps are replaced with 18W LED lamps which had reduced the energy consumption by 293 kWh/month. The illumination level is good because at many rooms, natural light is available and is being used appropriately. At rooms and labs, about 2485 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 6,560 kWh/month. The anticipated investment is Rs. 9.94 lakhs and the simple payback period is 20 months.

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 Implementation of few tangible energy conservation measures

Sl. No.	Implemented measures	Energy saving achieved, kWh/month
01	Installation of transparent polycarbonate sheets at Amphi theatre & Rangasthala	920
02	Replacement of T8 lamps by 18 W LED lamps at Hostel rooms	15,120
03	Replacement of T8 lamps by 18 W LED lamps at Academic blocks	293
04	Installation of solar hot water system at Hostel	48,000
Total		**64,333**

Summary of Recommendations
Immediate term measures

Sl. No.	Recommendations	Anticipated energy savings, kWh/month / Rs.	Anticipated investment, Rs.	Payback period, months
01	Transformer management	2425 kWh/month	-	-
02	Optimizing the room temperature in AC rooms	413 kWh/month	-	-
Total		**2,838 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	6,560 kWh/month	9.94	20
Total		**6,560 kWh/month**	**9.94**	**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 present installed capacity in India is about 359 GW and about 60% of the total electrical energy is being generated using coal. This energy releases of 2.0 Million tonne of CO_2 per year into atmosphere. 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 feeders. 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 2019 to May 2020. 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 electrical energy is taken from ***M/s. Avaada Non-conventional Energy Pvt. Ltd***. through open access though the BESCOM 11 kV grid. The 11 kV is stepped down to 433 V through two distribution transformers of 500 kVA & 1000 kVA. The energy consumption and maximum demanded is recorded at main incomer on 11 kV side (at point of common coupling (PCC)) through Tri-vector meter (Figure 1). The monthly energy consumption for past 5 years is given in Figure 2. During the energy audit study period, the grid energy import varies between 217.9 to 278.1 MWh/month till Feb. 2020. Then the University was locked down due to Covid-19 and energy import was reduced to 113.7 MWh/month during May 2020.

Figure 1: View of Metering system.

There are two DG sets of 500 kVA to provide the backup power during the grid power failure. Figure 3 gives the variation of total energy generation by DG sets and their energy share. The energy generation by DG sets during energy audit period is varying between 4.86 MWh/month (Dec. 2019) to 12.73 MWh/month (Sept. 2019). During Sept. 2019, the energy generation was more due to more power cut. The share of energy used by DG set is varying between 1.7 to 4.4% which is normal. Figure 4 gives the bar chart of annual energy generation by DG sets during last four years and is varying between 75.69 MWh/year to 181.27

MWh/month. The share of energy generation by DG set is varying between 2.5 to 6.4%. During the period of energy audit study the energy used by DG set energy generation is reduced from 6.4 % to 3.7 % of total energy consumption compared to previous year.

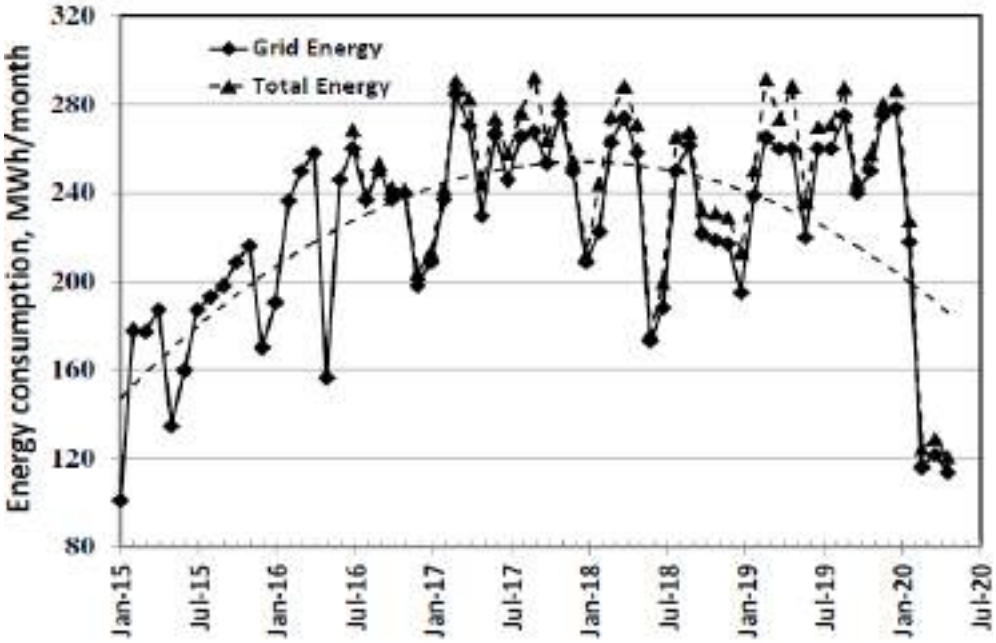

Figure 2: Variation of energy consumption.

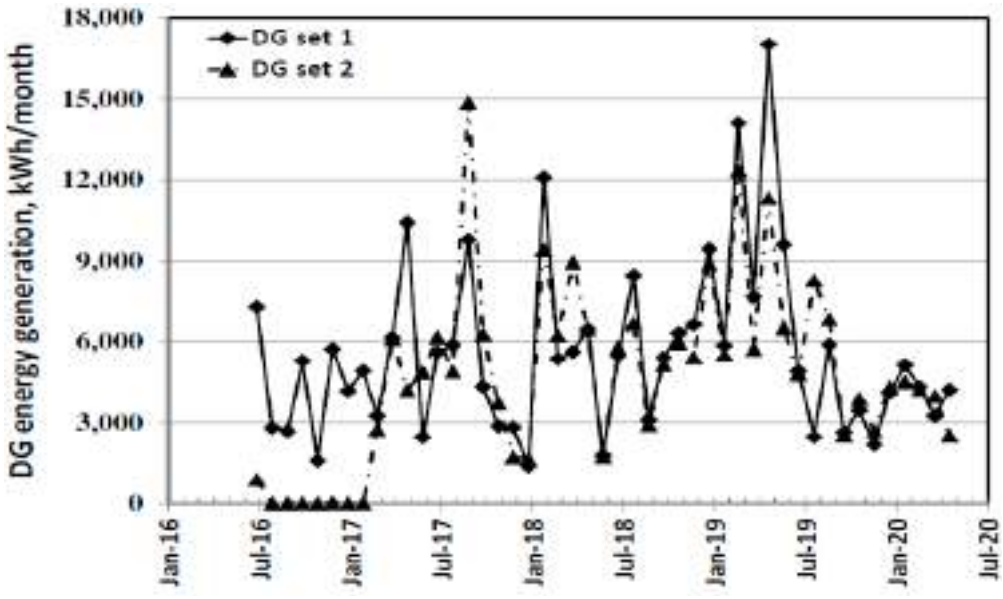

Figure 3: Variation of energy generation by DG sets.

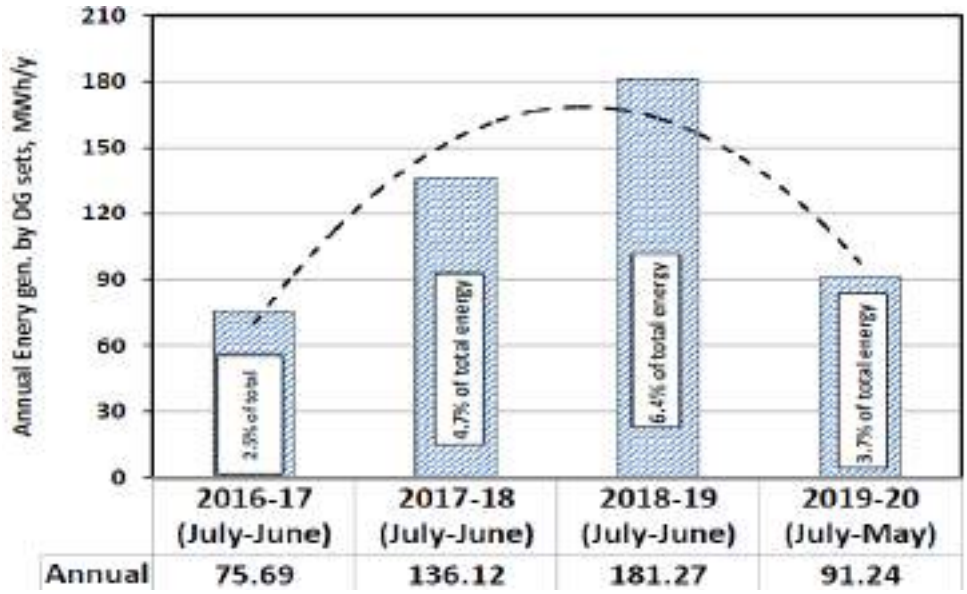

Figure 4: Annual energy generation by DG sets & their share.

The total energy consumption (grid + DG) for period during energy audit study is varying between 245.16 MWh/month (Dec. 2019) to 287.73 MWh/month (Sept. 2019) till Feb. 2020. Then the University was locked down due to Covid-19 and the energy consumption was reduced to 120.42 MWh/month during May 2020. Figure 5 shows the bar chart of annual total energy consumption for previous 5 years. The total energy consumption is initially increased from 2509.68 MWh/y during 2015-16 to 2994.85 MWh/month during 2016-17 (increase of 19.3%), followed a marginal increase of 3.3% to the year 2017-18. Then the energy consumption started decreasing by 3.7% and 8.5% (extrapolated for 12 months) respectively for the year 2018-19 & 2019-20 due to implementation of energy conservation measures.

The total energy consumption from grid & DG set is 2498.6 MWh/month for the period upto May 2020 and the annual energy consumption is extrapolated for 12 months and is 2725.68 MWh/month during the academic year 2019-20. The total built up area is 1,46,548 m^2. The energy performance index (EPI) for total REVA University campus is 18.6 kWh/m^2-year which is reduced from 20.32 kWh/y compared previous year (reduction of 8.5%) which is very good. The overall EPI is

lower than the EPI specified by Energy Conservation Building Code (ECBC) 2006 of 120 kWh/m^2-year.

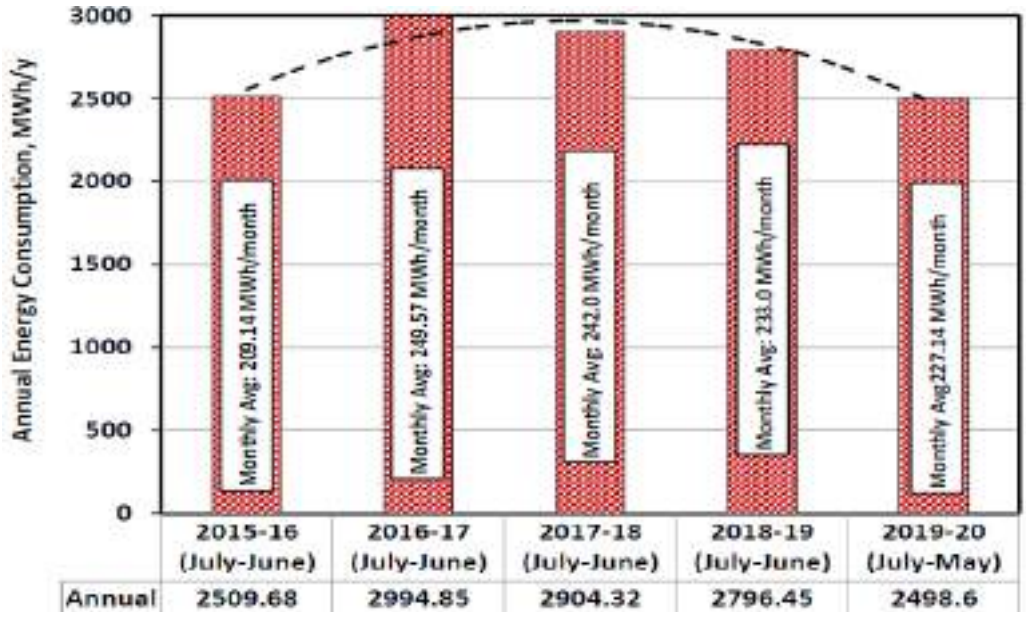

Figure 5: Annual energy consumption for last 5 years.

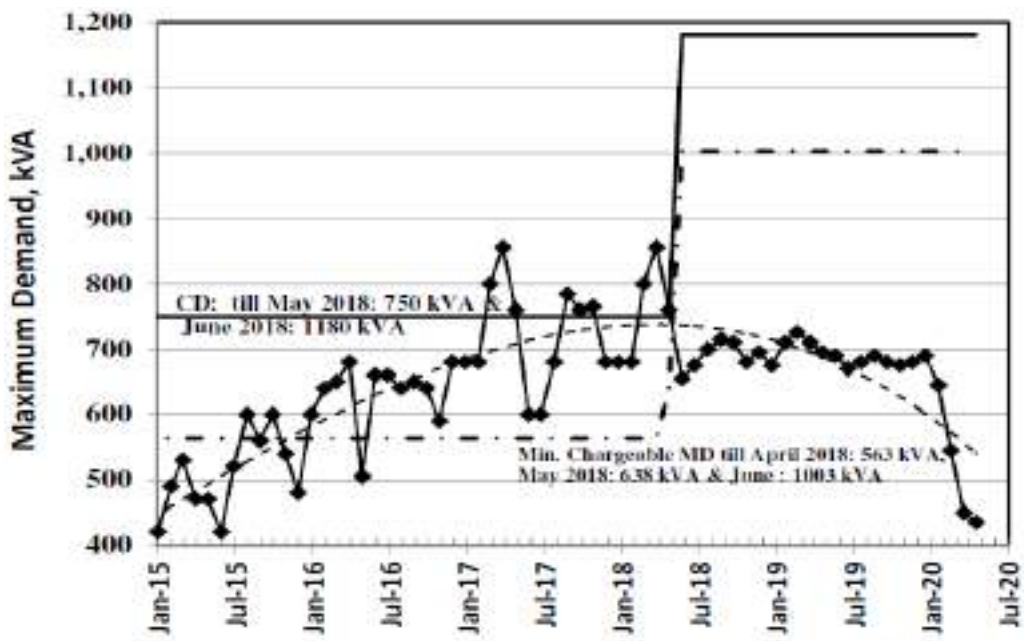

Figure 6: Variation of maximum demand.

The maximum demand is recorded in Tri-vector meter installed at main incoming 11 kV grid feeders. Figure 6 gives the variation of recorded maximum demand

(MD) for last 5 years. The recorded MD during the energy audit period was varying between 645 kVA (Feb. 2020) to 690 kVA (Sept. 2020) till Feb. 2020. Then the University was locked down due to Covid-19 and the maximum demand was reduced to 435 kVA during May 2020. 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 7 shows the variation of monthly average power factor and is varying between 0.93 and 0.94 during energy audit period. The power factor is good because of addition of lighting load and also installation of automatic power factor controller at main incoming.

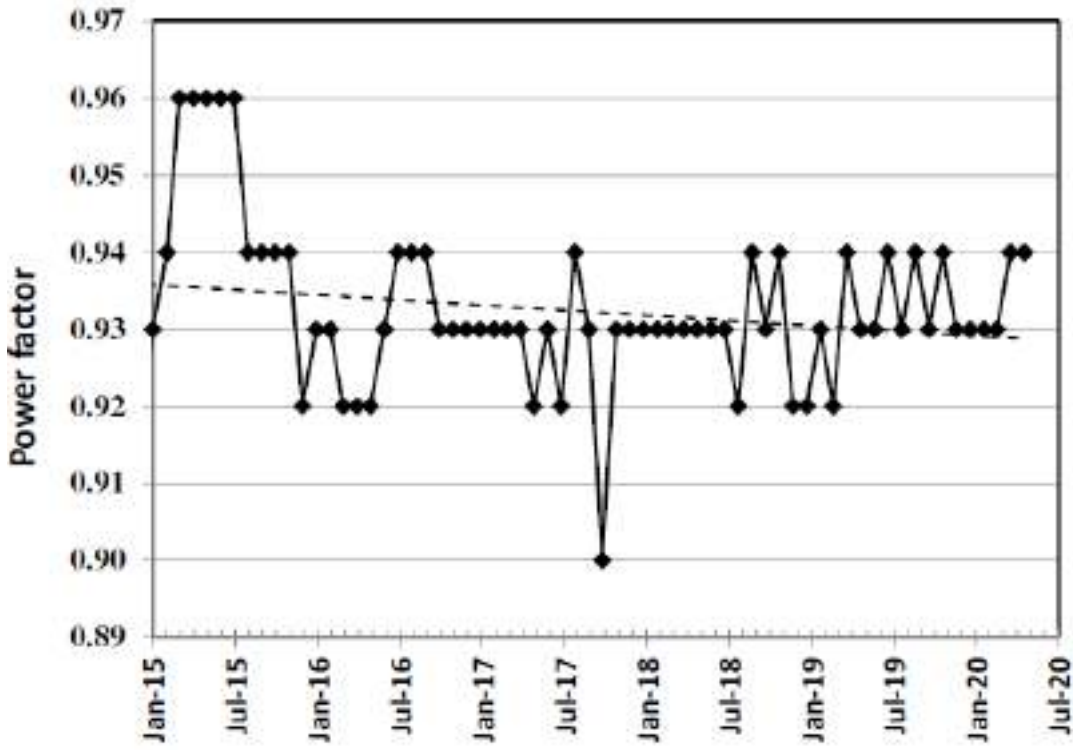

Figure 7: Variation of power factor.

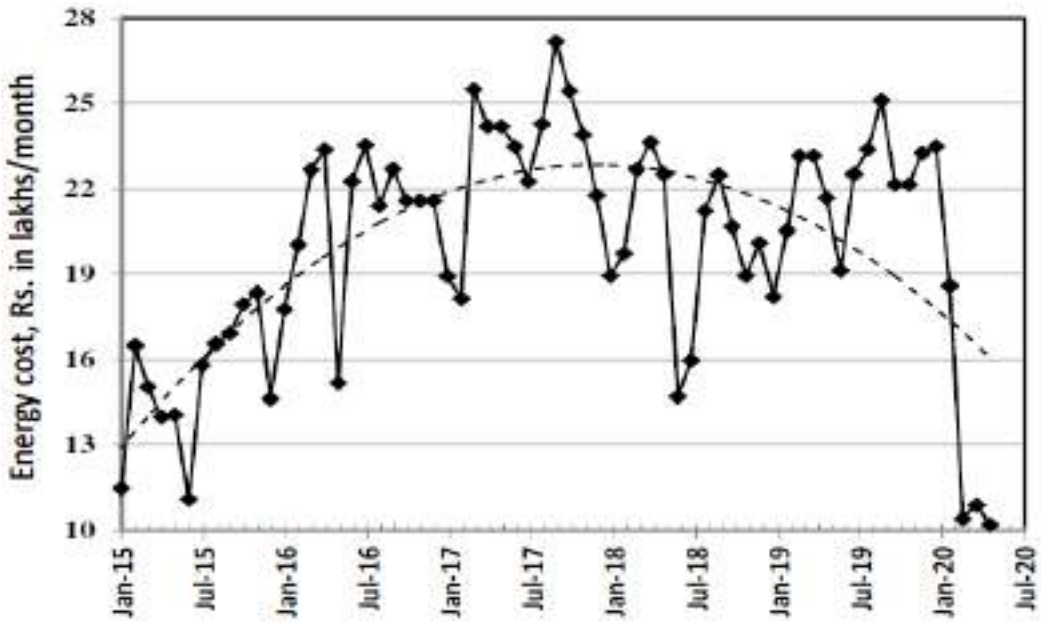

Figure 8: Variation of energy cost.

The variation of energy cost is given in Figure 8 for last 5 years. The energy cost variation during the energy audit period was in the range of Rs. 18.59 lakhs/month (Feb. 2020) to Rs. 25.10 lakhs/month (Sept. 2019) upto Feb. 2020. Then the University was locked down due to Covid-19 and energy cost was reduced to Rs. 10.21 lakhs/month during May 2020. The average monthly total energy cost is reduced from Rs. 24.52 lakhs/month to Rs. 21.21 lakhs/month compared to previous year (reduction of 13.5%). 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 energy rate is computed by using the ratio of total energy cost including MD chares to the total energy consumption. Figure 9 shows the variation of average energy rate (including demand & energy charges). The energy rate during energy audit period was in the range of Rs. 8.44 to 9.23 per kWh. The average energy rate is reduced from Rs. 8.78 per kWh to Rs. 8.10 per kWh compared to previous year (reduction of 7.7%). Figure 10 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.

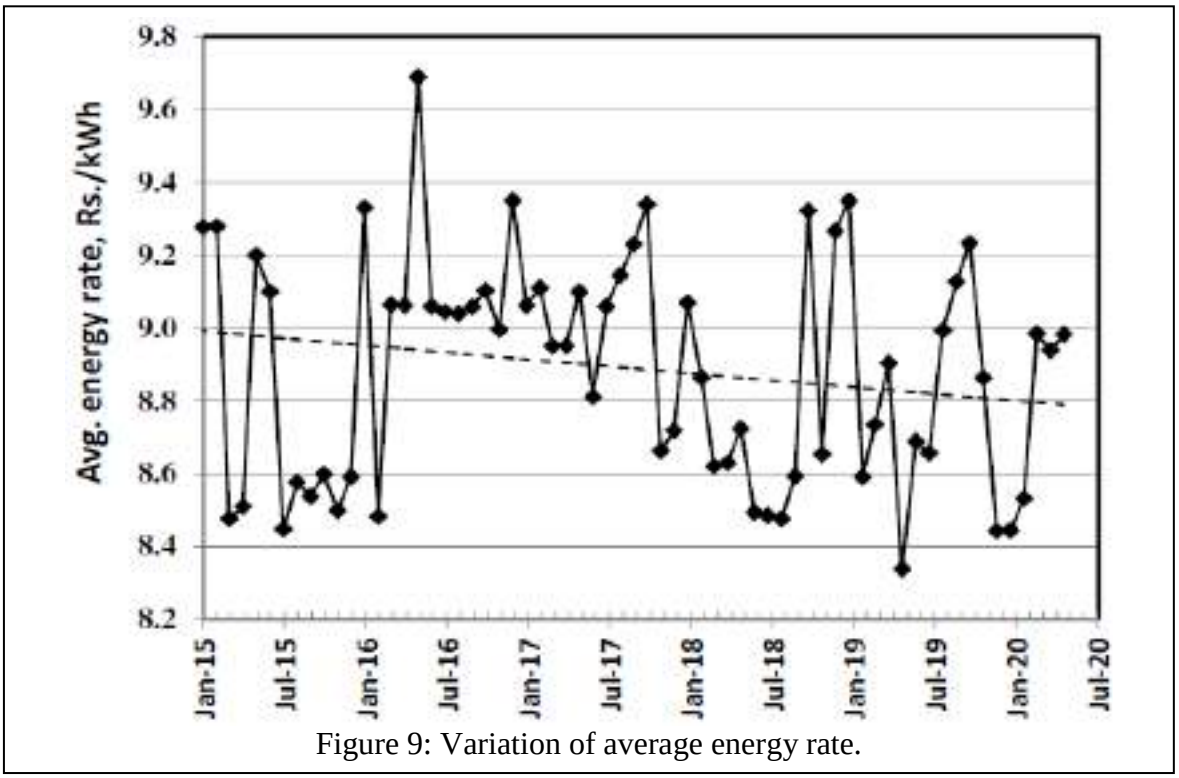

Figure 9: Variation of average energy rate.

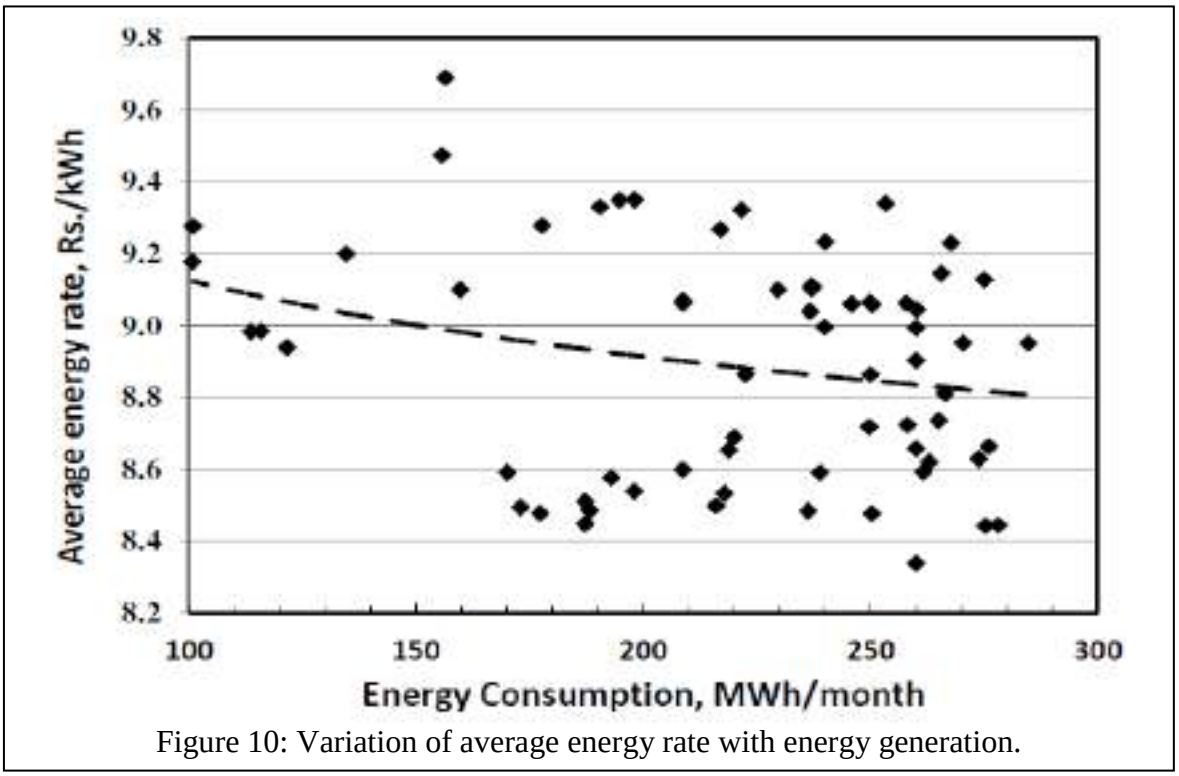

Figure 10: Variation of average energy rate with energy generation.

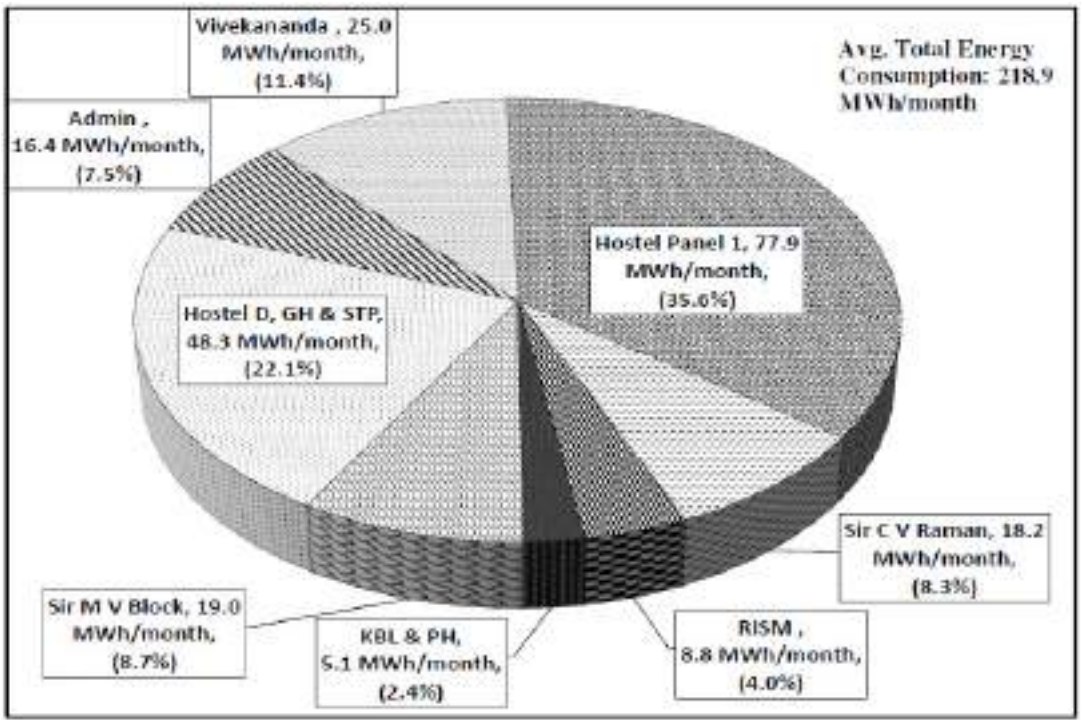

Figure 11: Energy consumption by different blocks.

Figure 11 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 77.9 MWh/month (35.6% of total energy consumption) and followed by the Boys D hostel, Girls hostel 1 and STP feeder energy consumption is 48.3 MWh/month (22.1%). The total energy used by hostels, guest house, quarters, water pumping, STP & library is 57.7%. The energy used for academics is 42.3% of total energy consumption.

Figure 12 gives the energy consumption by different facilities / components. The major energy is being used for lighting system i.e., 18.9% of total energy in which 9.5% 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 18.1%. The energy used for computers & peripherals is 16.8%. The energy used for air-conditioning (AC) system is increased from 14.7% (previous

year) to 15.7% due to addition of air-conditioning at Kuvempu auditorium. The energy used for comfort air fans is about 13.4% including hostel. The energy shared for faculty & staff quarters is 8.1% of total energy consumption. The energy used for water pumping system is 2.0% and for STP plant is 1.4%. The energy loss in transformer is computed as 1.8% and distribution loss is 3.8% of total energy consumption

.

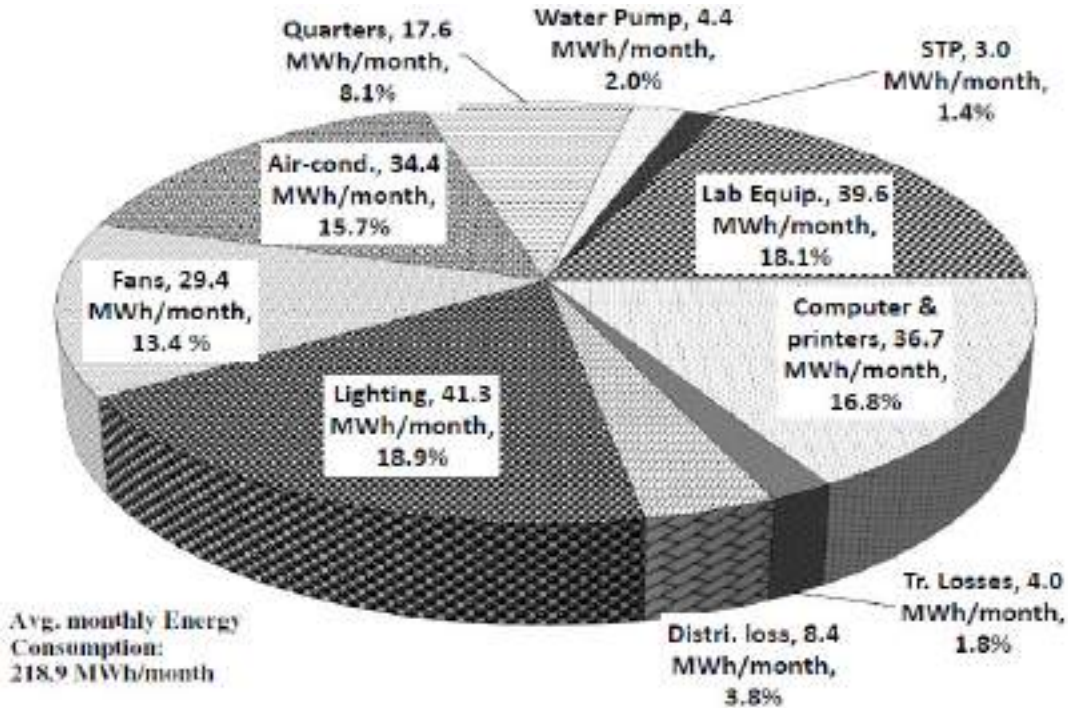

Figure 12: Energy used by different facilities.

3.2 Electrical distribution system

Figures 13 to 15 give the schematic of the electrical distribution system at REVA University. The 11 kV incoming is tapped from BESCOM grid is connected to the Tri-vector metering cubicle. 630 A 11 kV Vacuum Circuit Breaker (VCB) is installed along with metering cubicle. The 11 kV is connected to Primary side 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 through 3 parallel runs of 3½ core 400 sq. mm aluminium armoured cables for both transformers. 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 & necessary protection to provide the power supply to entire REVA University campus.

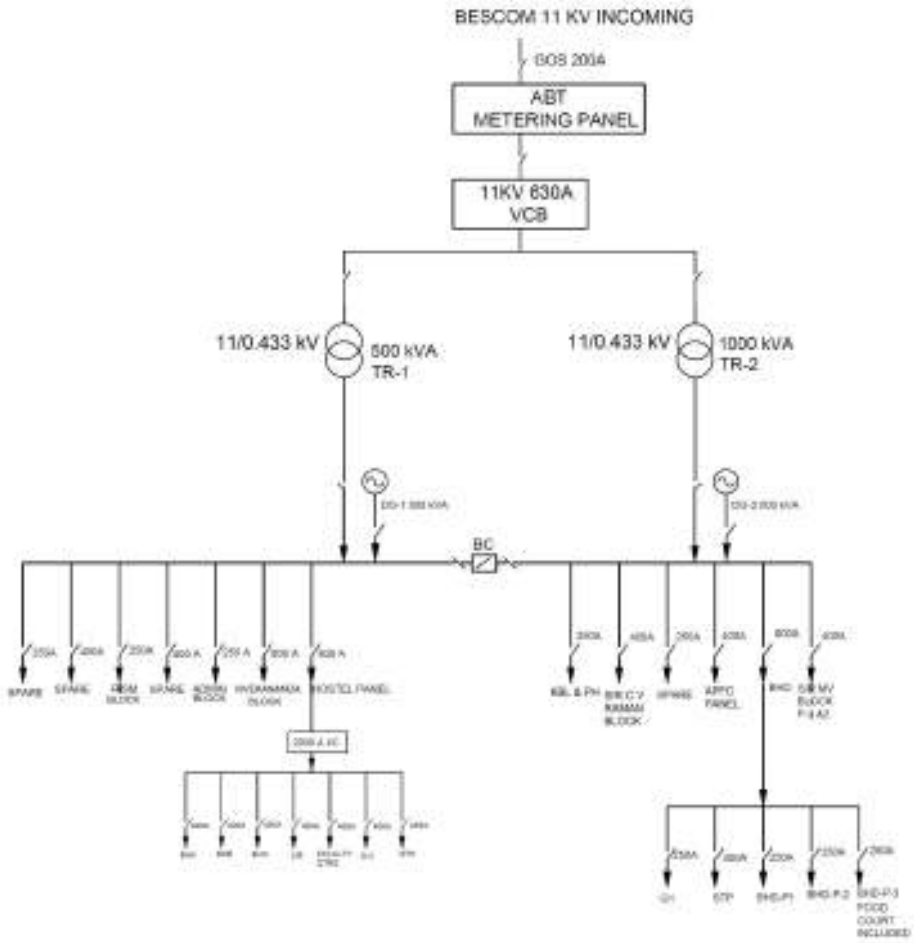

Figure 13: Single line diagram of main incomer from grid & LT distribution.

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.

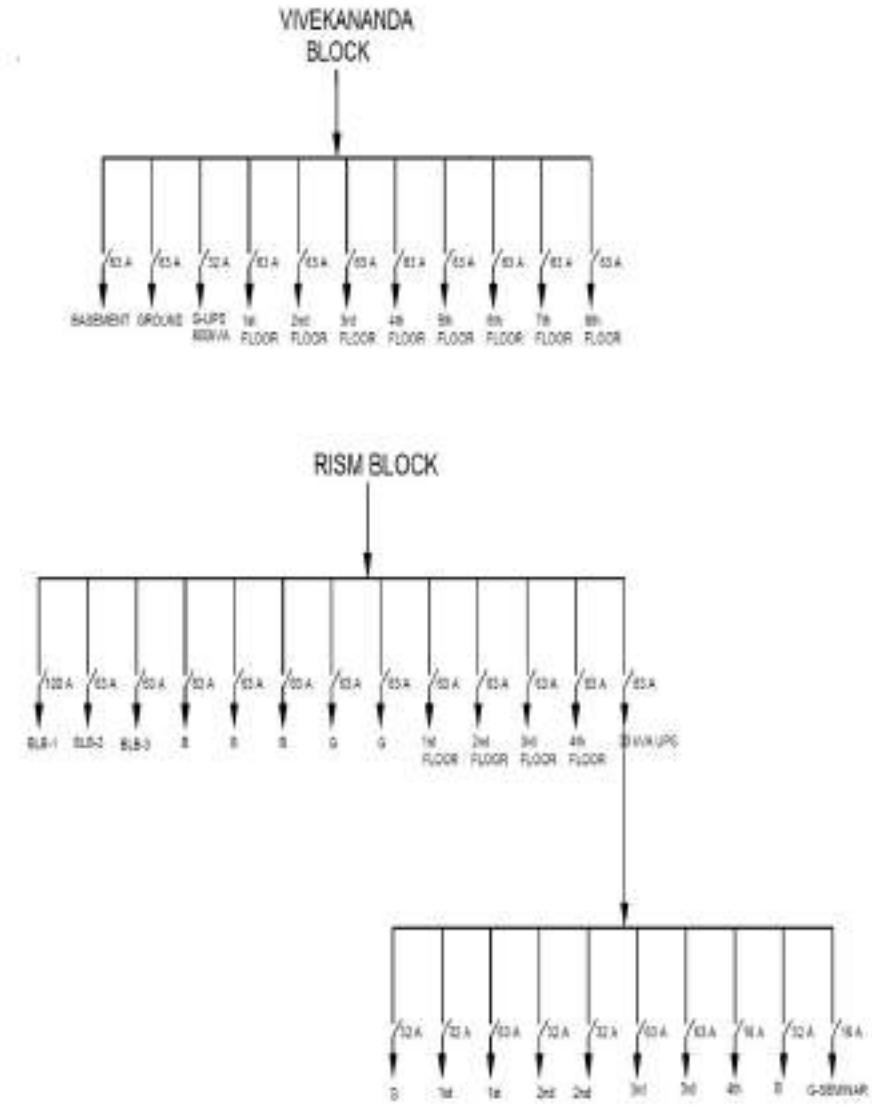

Figure 14: Electrical distribution at Vivekananda & RISM Blocks.

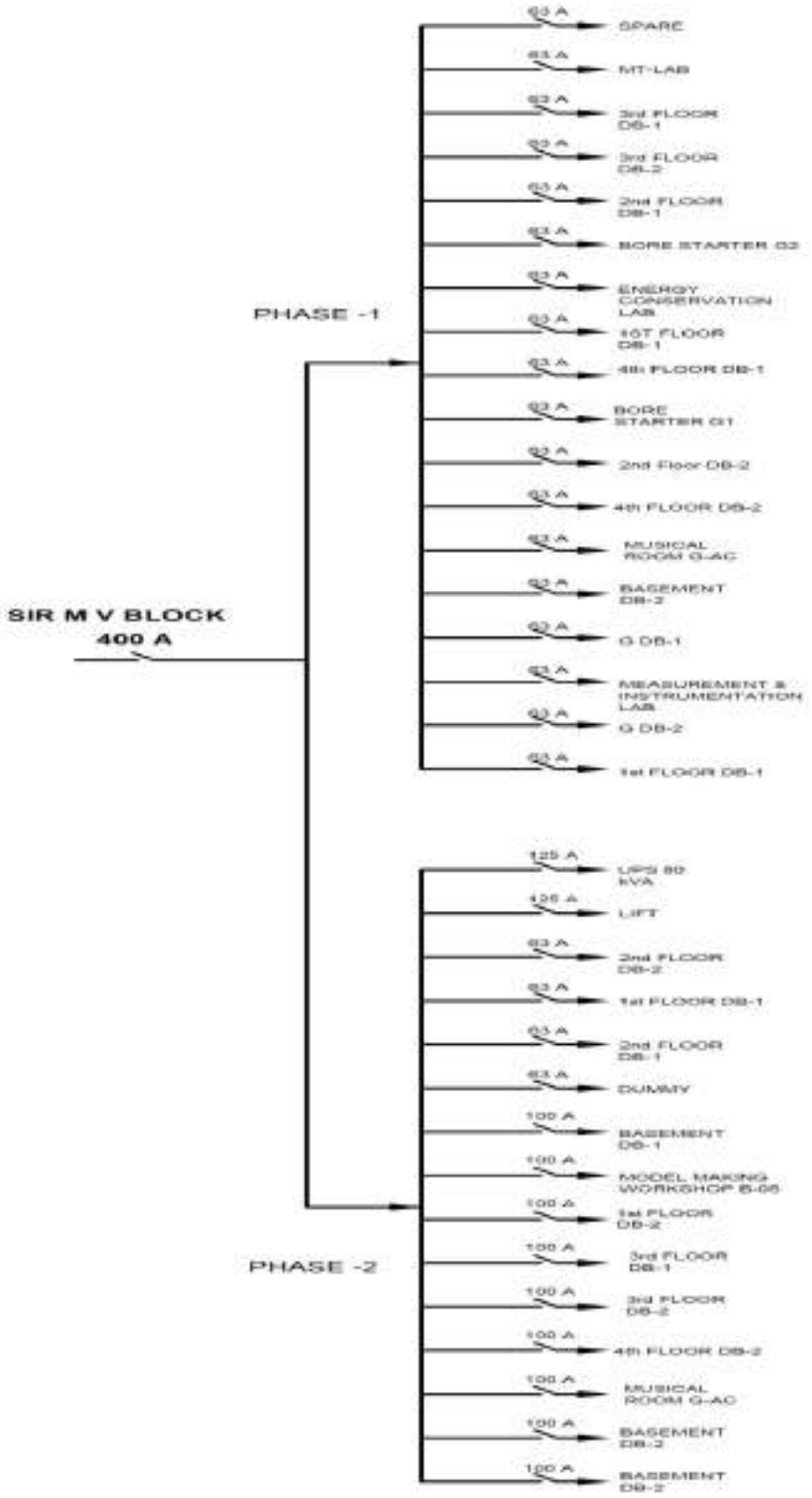

Figure 15: Electrical distribution at Sir MV Block.

Figure 16: View of main LT panel.

Figure 16 shows the view of LT panels. 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.

All these breakers are provided with overload protection relay, the outgoing cables are taken from top of the panels with proper cable glands. All these cable gland and panel boards are provided with two earths. All the cable end terminations are made with appropriate copper lugs and insulation tapes. All 3-phase markings like R-phase, Y-phase & B-phase are made properly. The end terminations are quite good and the voltage drop across end terminations at outgoing feeders is very less in the range of 2 to 25 mV and the end-termination loss is very less and there is no heat generation in panel boards. The ACB male and female contacts are also inspected, there is no carbon formation and pitting on the contacts, but as a good

maintenance practice at least once in year, the contacts have to be cleaned and end terminations have to be tightened.

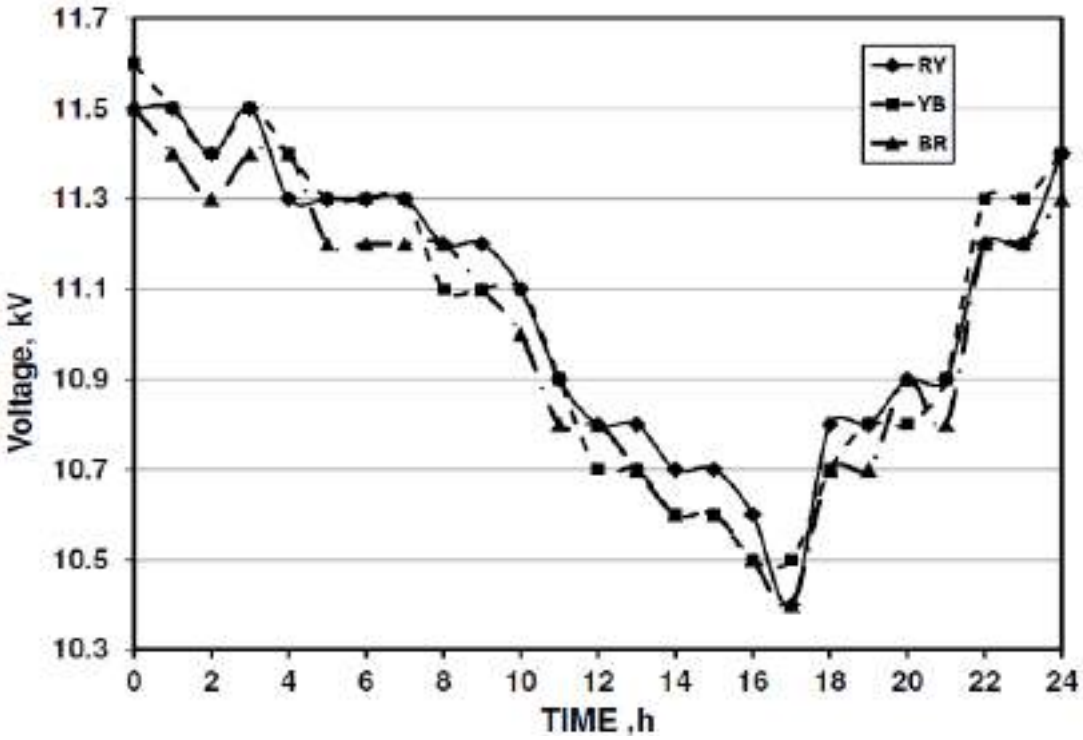

Figure 17: Variation of voltage at main incomer from grid.

The voltage at incomer side is measured for a typical day and the values are plotted in Figure 17. The voltage is varying between 10.4 to 11.6 kV (-5.4% to +5.4%). 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 18. The voltage unbalance between 3-phases is varying between 0.58 to 0.64 % and is also lower than the International standards EN-50160 < 2% for LV & MV system and < 1% for HV system.

Figure 19 shows the variation of measured current at main incoming 11 kV feeder and is varying between 6.4 to 28.6 A. The load unbalance between 3-phases is computed for the incoming feeder and is given in Figure 20. The load unbalance between 3-phases is varying between 2.6 to 6.3% and is also normal.

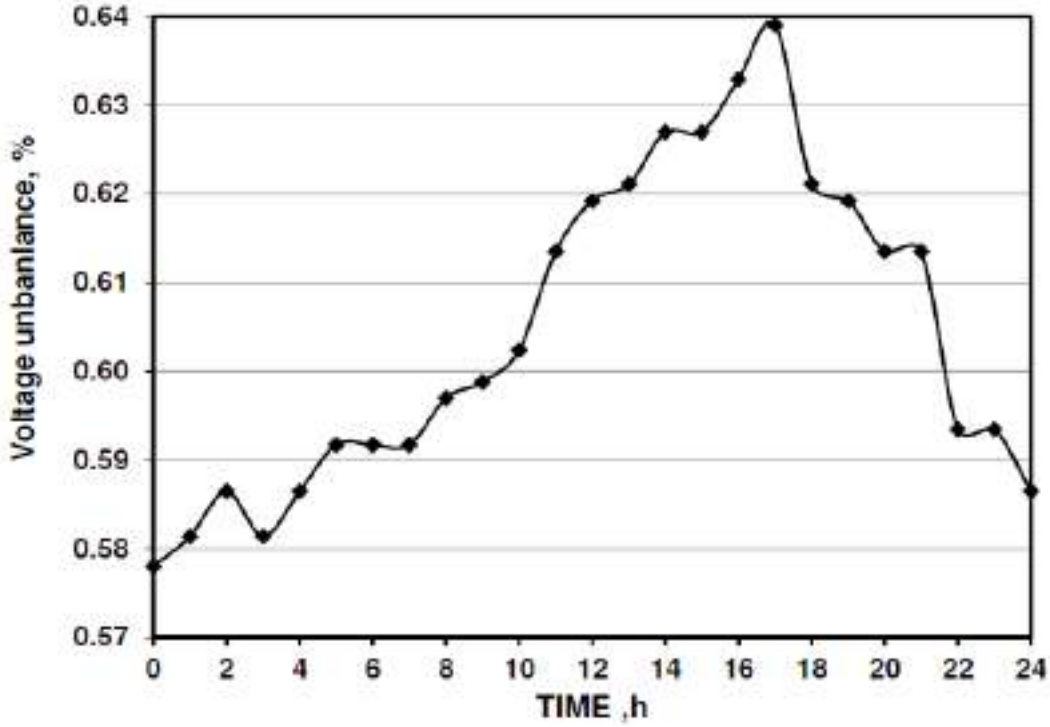

Figure 18: Variation of voltage unbalance at main incomer from grid.

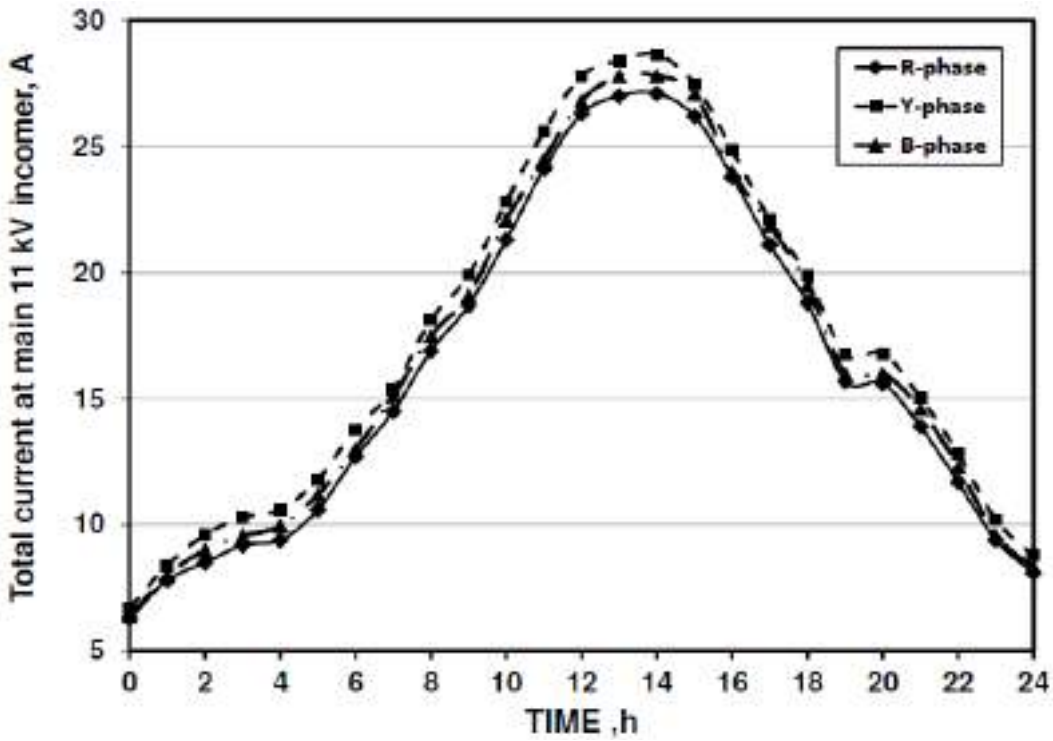

Figure 19: Variation of current at 11 kV main incomer.

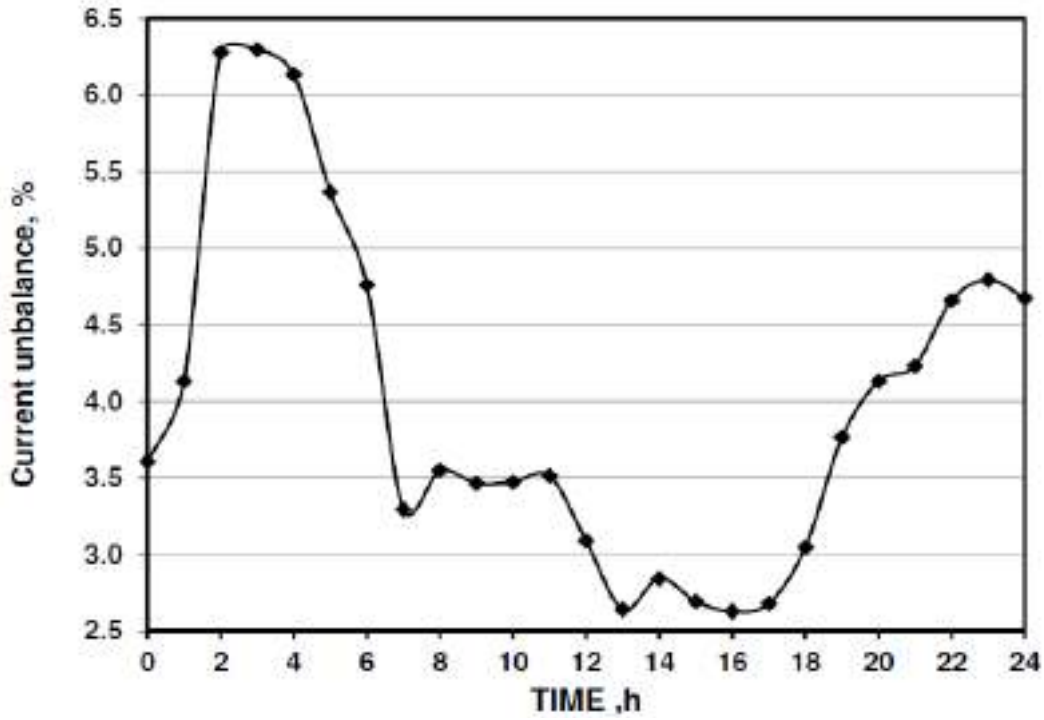

Figure 20: Variation of current unbalance at 11 kV main incomer.

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 at both ends. The peak current through the feeder is 59 A and the circuit breaker loading is 24% which is good. The cable conductor loading is 15.4% which is less. The voltage drop across the joints at both ends is varying between 41 to 65 mV and the average estimated joint loss is 19 W which is less. The circuit breaker and cable loading is good. Figure 21 gives the variation of power at RISM feeder for a typical and is varying between 2.6 to 39.0 kW (7.9% of peak demand). The peak power is during 10:00 to 17:00 hours. The computed monthly average energy consumption is 8.8 MWh/month that forms about 4.0% of total energy consumption. The average monthly energy consumption of RISM block is reduced from 10 MWh/month to 8.0 MWh/month compared to previous year (reduction of 20%) may be due to implementation of energy conservation measures and also lock down for a period of 4 months. The built area is 4,704 m^2 and the energy performance index (EPI) is 22.4 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

22.4 to 17.0 kWh/m^2-year compared to last year due to implementation of energy conservation measures.

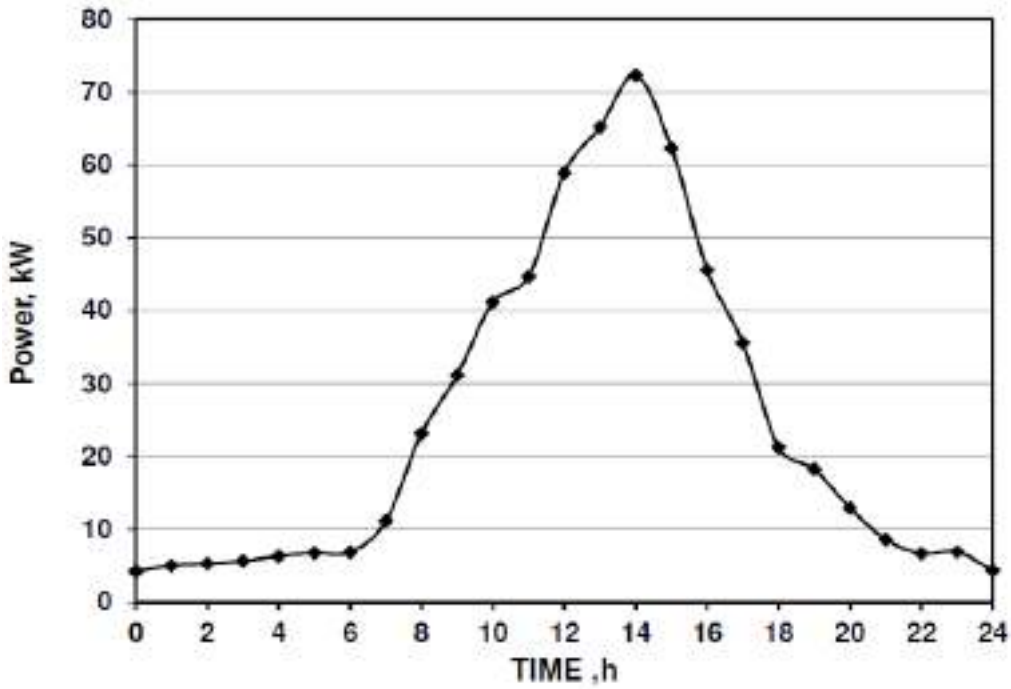

Figure 21: Power variation at RISM feeder.

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 at both ends. The peak current through the feeder is 93A and the circuit breaker loading is 37.2%. The cable conductor loading is 24.3%. The voltage drop across the joints at both ends is varying between 37 to 85 mV and the average estimated joint loss is 34 W which is less. The circuit breaker and cable loading is good. Figure 22 gives the variation of power at Administrative block feeder for a typical day and is varying between 3.6 to 62.1 kW (12.5% of peak demand). The peak power is during 10:00 to 17:00 hours. The computed monthly average energy consumption is 16.4 MWh/month that forms about 7.5% of total energy consumption. The average monthly energy consumption of Administrative block is reduced from 17.5 MWh/month to 16.4 MWh/month compared to previous year (reduction of 6.3%) may be due to implementation of energy conservation measures and also lock down for a period of 4 months. The built area is 6,836 m^2 and the energy performance index (EPI) is 28.8 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 30.7 to 28.8 kWh/m^2-year compared to previous year due to implementation of energy conservation measures.

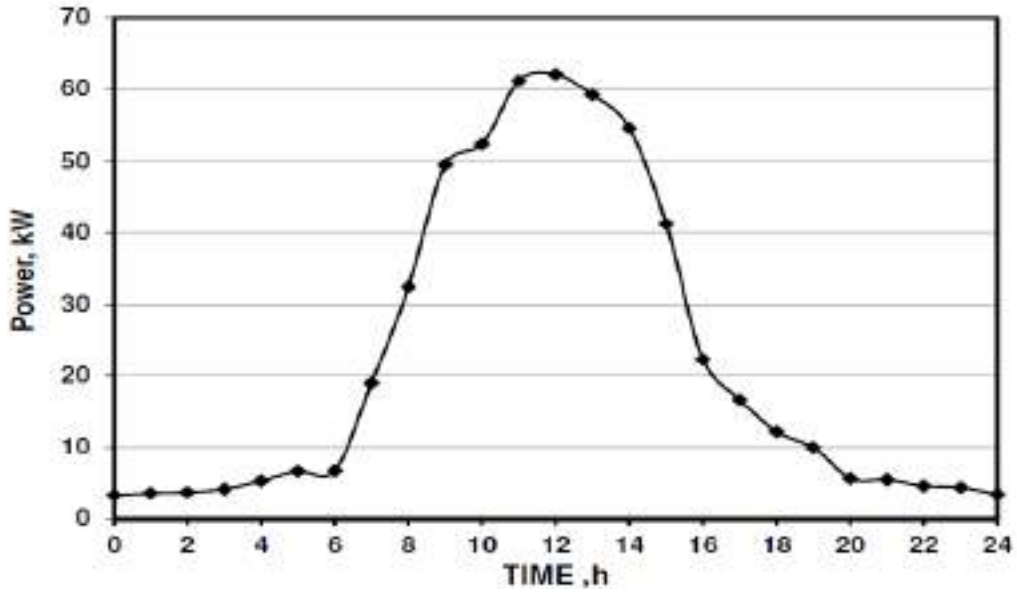

Figure 22: Power variation at Administration block feeder.

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 147A and the circuit breaker loading is 18.4%. The cable conductor loading is 38.4%. The circuit breaker and cable loading is good. The voltage drop across the joints at both ends is varying between 23 to 67 mV and the average estimated joint loss is 40 W which is less. Figure 23 gives the variation of power at Vivekananda block feeder for a typical day and is varying between 3.3 to 98.2 kW (19.8% of peak demand). The peak power is during 10:00 to 17:00 hours. The computed monthly average energy consumption is 25.0 MWh/month that forms about 11.5% of total energy consumption. The average monthly energy consumption of Vivekananda block is reduced from 26.9 MWh/month to 25.0 MWh/month compared to previous year (reduction of 7.1%) may be due to implementation of energy conservation measures and also lock down for a period of 4 months. The built area is 28,372 m^2 and the energy performance index (EPI) is 10.6 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 11.4 to 10.6 kWh/m^2-year compared to previous year due to implementation of energy conservation measures.

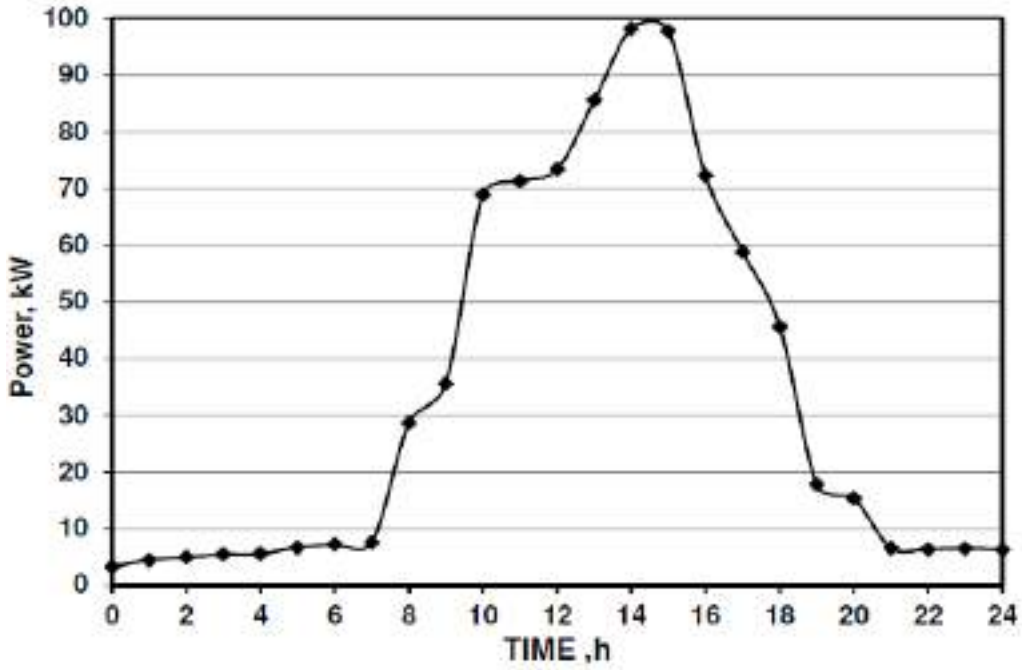

Figure 23: Power variation at Vivekananda block feeder.

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 at both ends. The peak current through the feeder is 108A and the circuit breaker loading is 27.0%. The voltage drop across the joints at both ends is varying between 19 to 56 mV and the average estimated joint loss is 40 W which is less. The cable conductor loading is 28.2%. The circuit breaker and cable loading is good. Figure 24 gives the variation of power at Sir C V Raman Block feeder for a typical day and is varying between 4.3 to 72.3 kW (14.6% of peak demand). The peak power is during 08:00 to 16:00 hours. The computed monthly average energy consumption is 18.2 19.1 MWh/day that forms about 8.3% of total energy consumption. The average monthly energy consumption of Sir C V Raman block is reduced from 19.1 MWh/month to 18.2 MWh/month compared to previous year (reduction of 4.7%) may be due to implementation of energy conservation

measures and also lock down for a period of 4 months. The built area is 17,785 m^2 and the energy performance index (EPI) is 12.3 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 12.9 to 12.3 kWh/m^2-year due to implementation of energy conservation measures

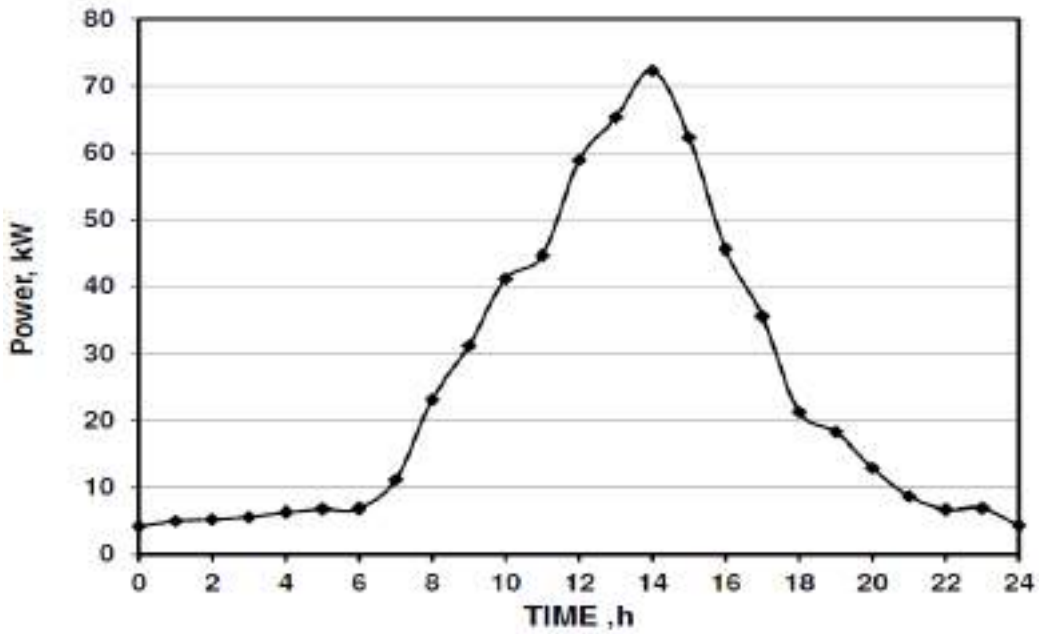

Figure 24: Power variation at Sir CV Raman block feeder.

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 at both ends. The peak current through the feeder is 118A and the circuit breaker loading is 29.5%. The voltage drop across the joints at both ends is varying between 39 to 79 mV and the average estimated joint loss is 42 W which is less. The cable conductor loading is 30.8%. The circuit breaker and cable loading is good. Figure 25 gives the variation of power at Sir M Visvesvaraya Block feeder for a typical day and is varying between 4.5 to 78.6 kW (15.8% of peak demand). The peak power is during 09:00 to 16:00 hours. The computed monthly average energy consumption is 19.0 MWh/month that forms about 8.7% of total energy consumption. The average monthly energy consumption of Sir M Visvesvaraya block is reduced from 21.1 MWh/month to 19.0 MWh/month compared to previous

year (reduction of 9.9%) may be due to implementation of energy conservation measures and also lock down for a period of 4 months. 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 12.5 13.9 to 12.5 kWh/m^2-year compared previous year due to implementation of energy conservation measures.

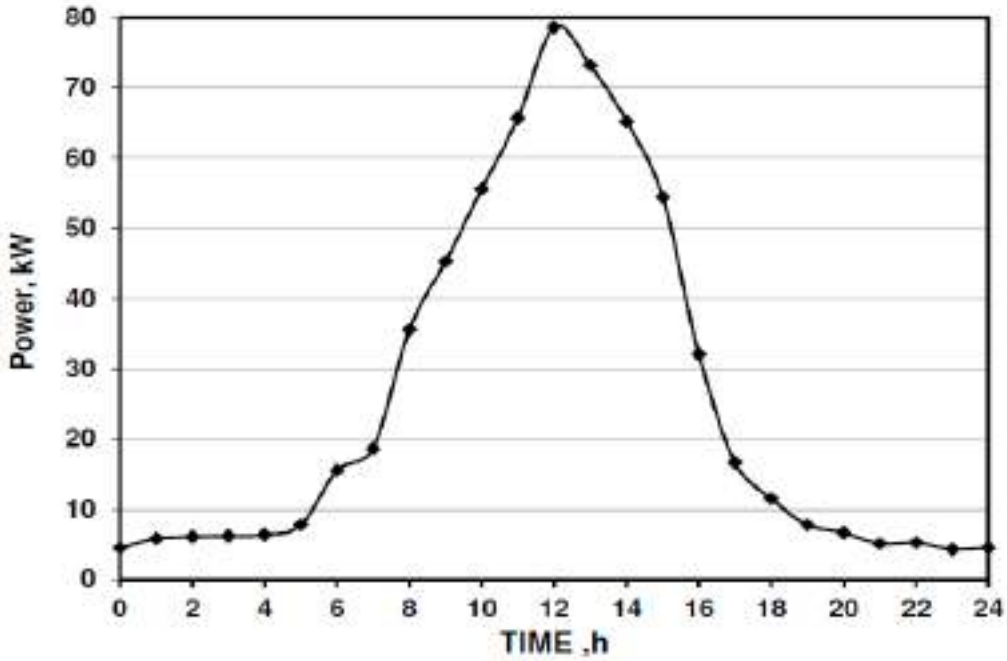

Figure 25: Power variation at Sir M Visvesvaraya block feeder.

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 20A and the circuit breaker loading is 8.0%. The voltage drop across the joints at both ends is varying between 23 to 45 mV and the average estimated joint loss is 5 W which is less. The cable conductor loading is 18.2%. The circuit breaker and cable loading is less than the allowable limit of 50%. Figure 26 gives the variation of power at KBL & pump house feeder for a typical day and is varying between 1.1 – 13.5 kW (2.7% 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 2.4% 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.

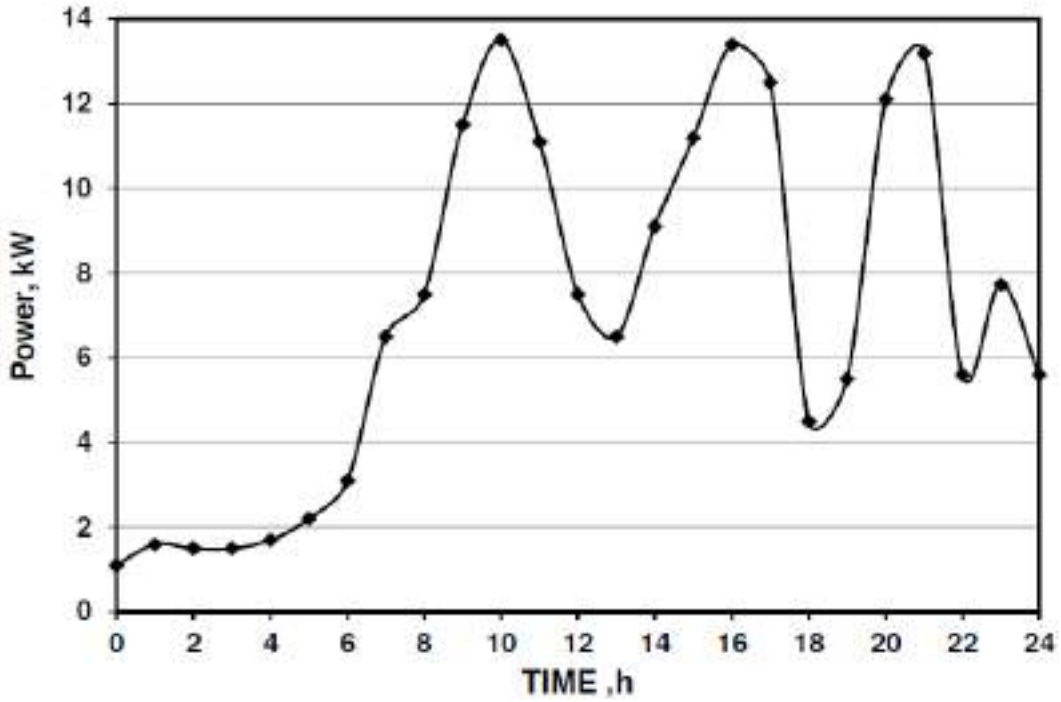

Figure 26: Power variation at KBL & pump house feeder.

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 218A and the circuit breaker loading is 27.3%. The cable conductor loading is 28.5%. The voltage drop across the joints at both ends is varying between 43 to 78 mV and the average estimated joint loss is 158 W which is less. The circuit breaker and cable loading is good. Figure 27 gives the variation of power at Hostel Panel 1 feeder for a typical day and is varying between 65.7 – 145.3 kW (29.3% 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 77.9 MWh/month that forms about 35.6% of total energy consumption. The average monthly energy consumption of Hostel panel 1 is reduced from 82.7 MWh/month

to 77.9 MWh/month compared to previous year (reduction of 5.8%) may be due to implementation of energy conservation measures and also lock down for a period of 4 months. The built area is 42,918 m^2 and the energy performance index (EPI) is 21.8 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 23.1 to 21.8 kWh/m^2-year compared to previous year due to implementation of energy conservation measures.

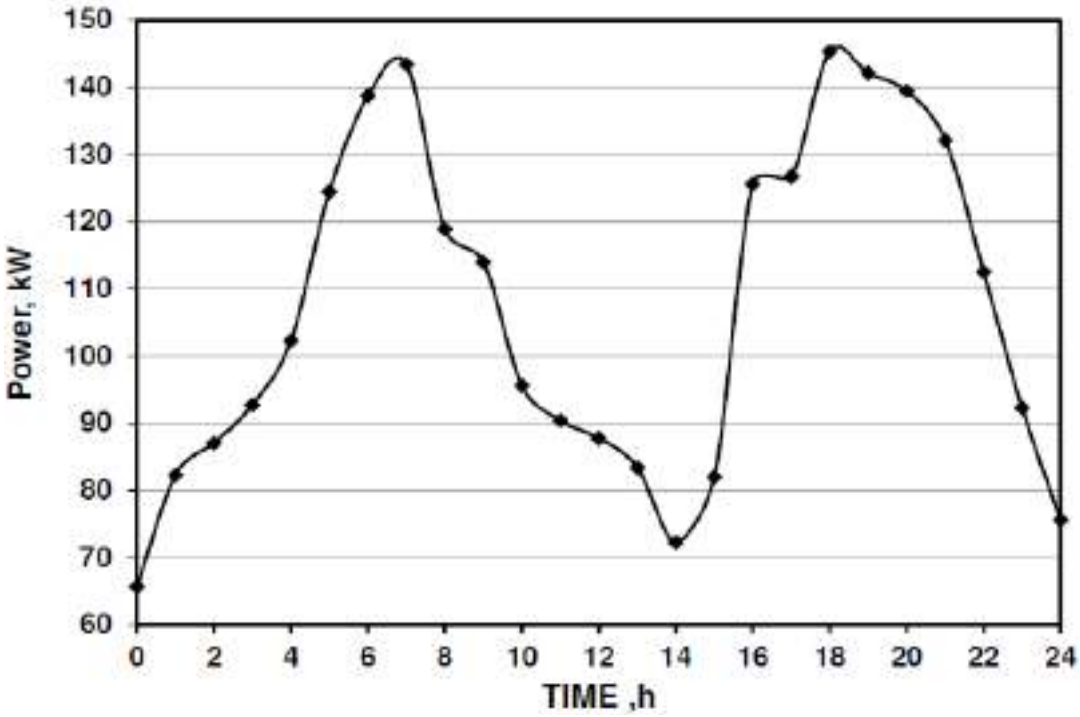

Figure 27: Power variation at Hostel panel 1 feeder.

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 voltage drop across the joints at both ends is varying between 35 to 87 mV and the average estimated joint loss is 55 W which is less. The circuit breaker and cable loading is good. Figure 28 gives the variation of power at Boys Hostel D, girls hostel 1, guest house & STP feeder for a typical day and is varying between 35.6 – 87.5 kW (17.6% of peak demand). The peak power is during 04:00 to 22:00 hours. The computed monthly average energy

consumption is 48.3 MWh/month that forms about 22.1% of total energy consumption. The average monthly energy consumption of Hostel panel 1 is reduced from 50.6 MWh/month to 48.3 MWh/month compared to previous year (reduction of 4.5%) may be due to implementation of energy conservation measures and also lock down for a period of 4 months. 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 almost same as previous year.

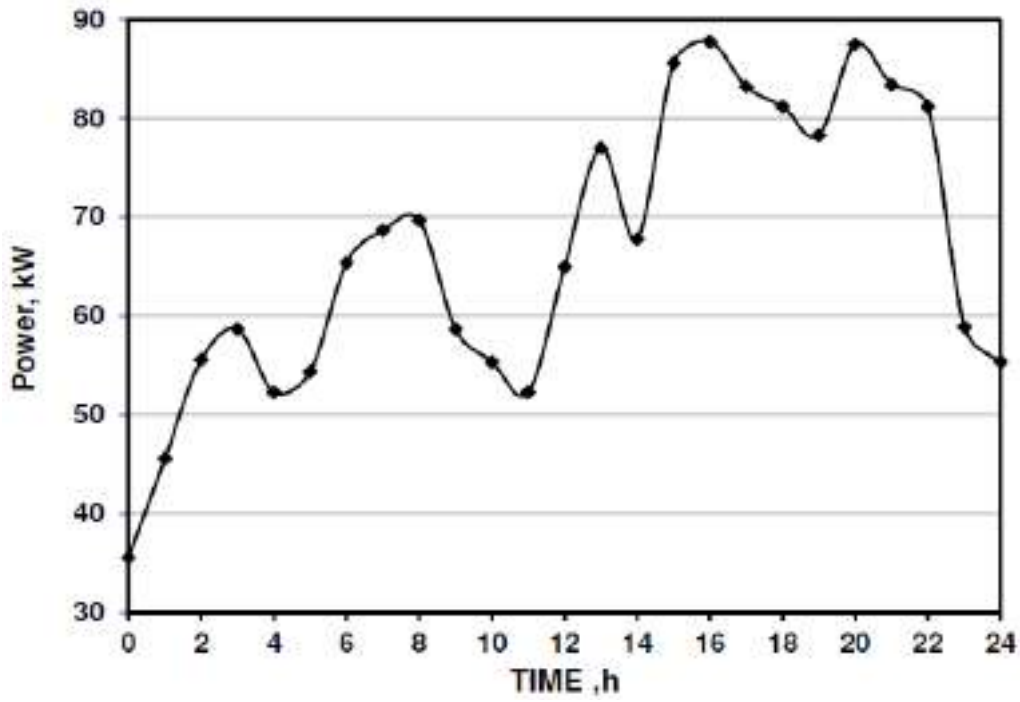

Figure 28: Power variation at Boys Hostel D block panel feeder.

3.3 Transformers

There are two distribution transformers to step down high voltage of 11 kV to 433 V at main incoming. Figures 29 & 30 show the view of Tr.1. & Tr. 2 respectively. Figures 31 presents the transformer sub-station & yard. The average monthly energy loss in transformer is computed as 4.0 MWh/month that forms 1.8% of total energy input. Both transformers are provided with on load tap changers (OLTC) to

maintain the secondary voltage o nearly constant to the standard voltage of 415 V. Figure 32 shows the variation of transformer taps to adjust the secondary voltage on a typical day. The OLTC centre tap is at 5th tap. During off-peak (night) hours the tap position is on lower side in the range of 1 to 5 and try to maintain the secondary voltage nearly constant for the higher primary voltage. During day hours the tap position varies between 6 to 14 (higher side) to maintain the secondary voltage where the primary voltage is lower than the rated voltage of 11 kV. The operation of OLTC is in auto mode and is working satisfactorily.

Figure 29: View of main Tr.1 (500 kVA)

Figure 30: View of main Tr. 2 (1000 kVA)

Figure 31: View of sub-station & transformer yard.

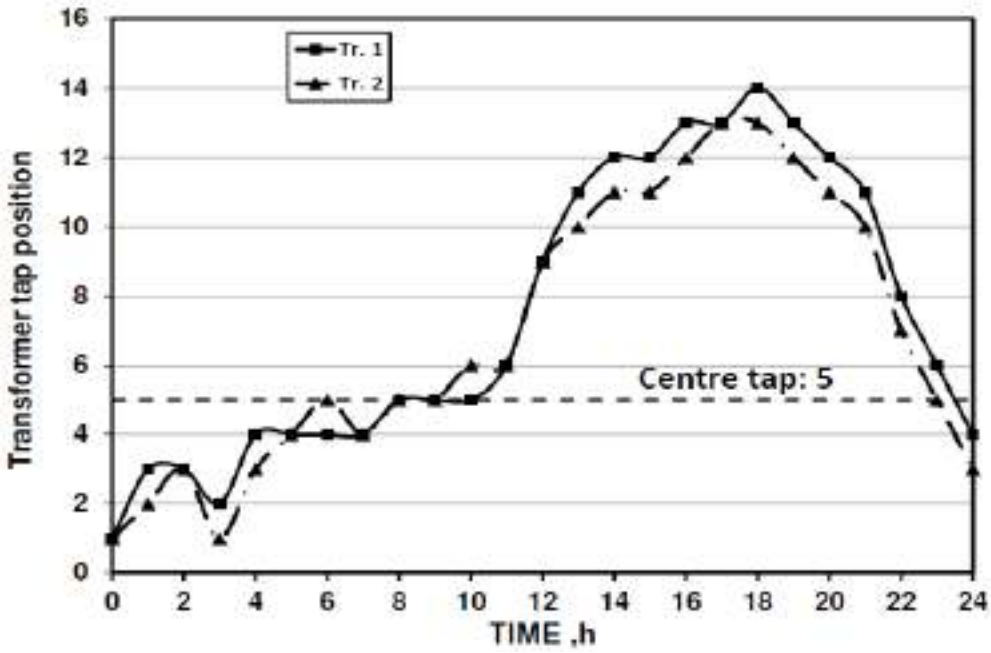

Figure 32: Transformer tap position

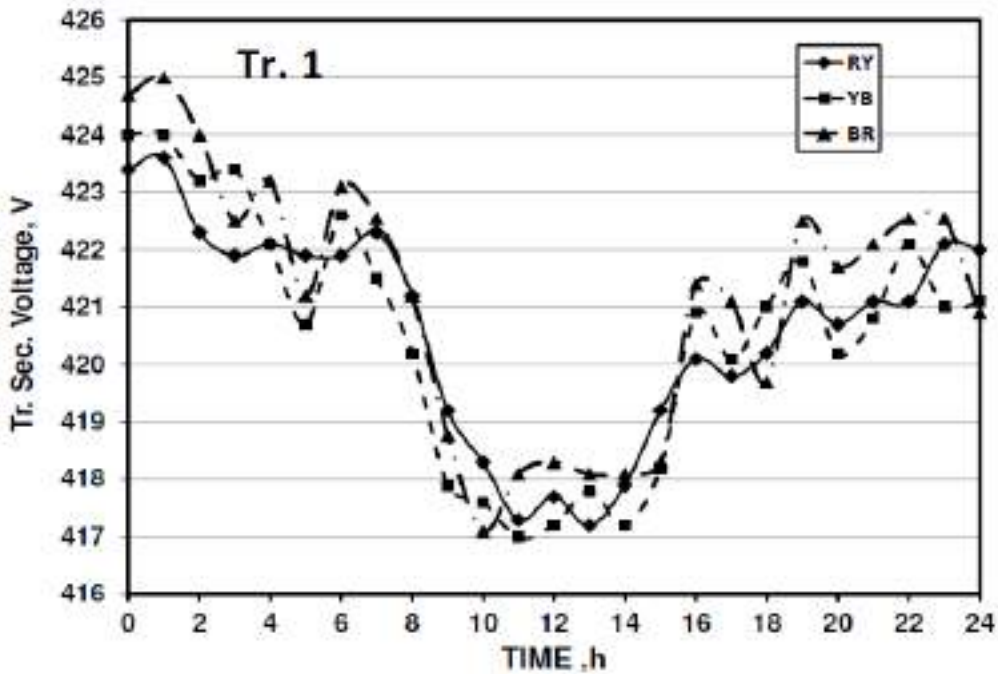

Figure 33: Secondary voltage variation at Tr.1.

Figures 33 and 34 give the variation of voltage at transformer secondary of Tr.1 & Tr.2 respectively. The voltage at Tr. 1 secondary is varying between 417 to 425 V (+0.5 to +2.4%) on a typical day whereas at Tr.2 is varying in the range of 417.2 to 425.2 V (+0.5 to +2.5%). The voltage variation is quite good. The voltage

unbalance between 3-phases (Figure 27) is varying between 0.12 to 0.20% at Tr.1 and at Tr.2 is in the range of 0.15 to 0.19% 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.

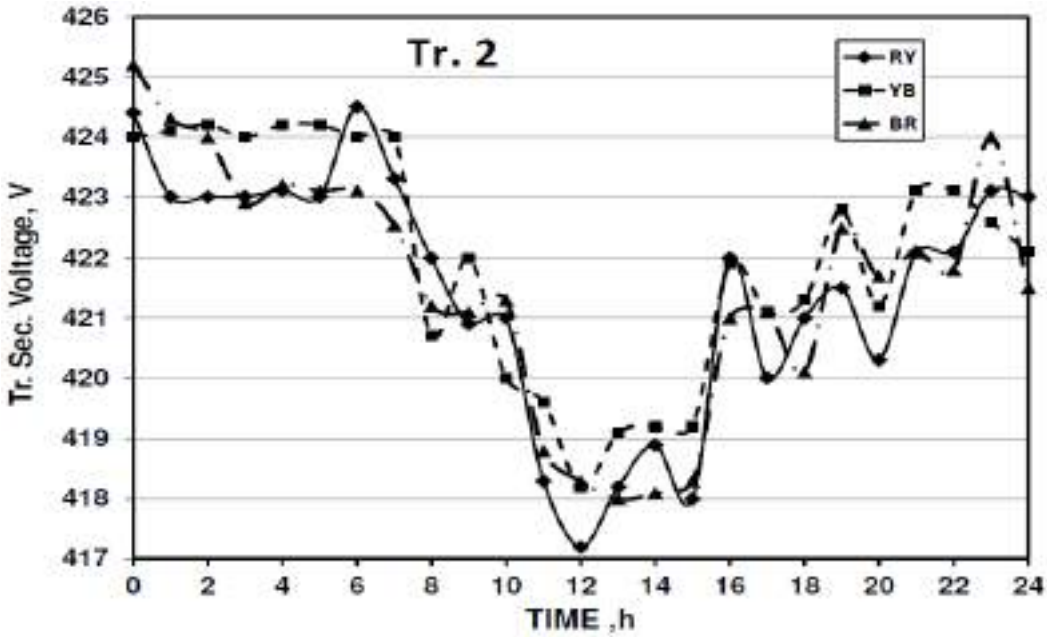

Figure 34: Secondary voltage variation at Tr.2.

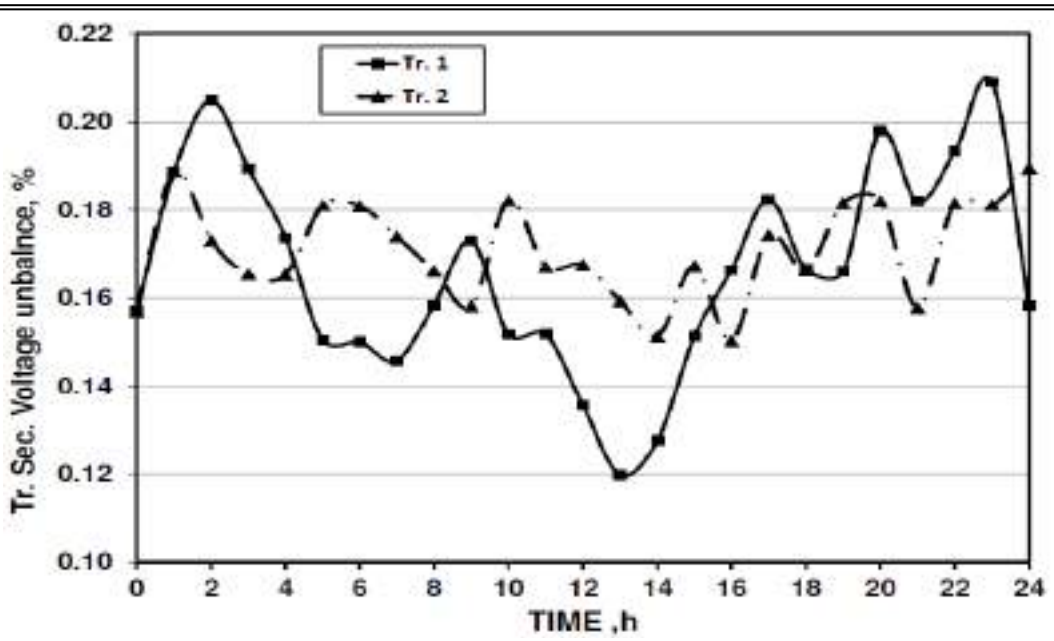

Figure 35: Voltage unbalance between 3-phases at Transformer secondary.

Figures 36 and 37 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 17.4 to 61.9% 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 4.6 to 23.4%. The all day efficiency of transformer 1 is 98.2% which is slightly better than that of transformer 2 of 97.5% because the load on Tr. 2 is less.

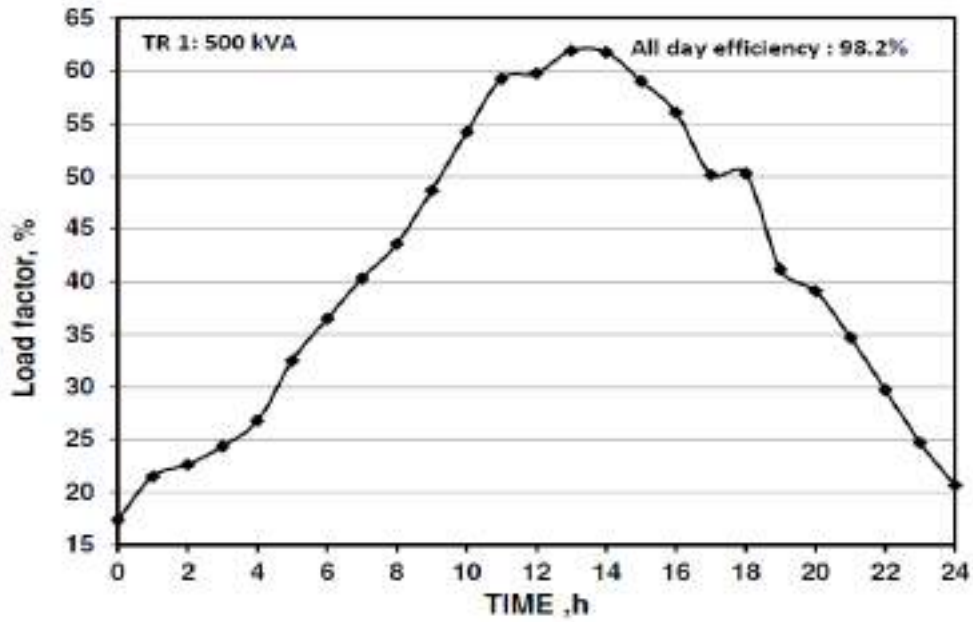

Figure 36: Variation of load factor of 500 kVA Tr.1.

The power factor on transformer secondary is good in the range of 0.91 to 0.93 due to use of automatic power factor controller (APFC) panel. The transformer winding temperature of Tr.1 is varying between 31.8 to 55.3 ^{o}C and at Tr. 2 is recorded in the range of 30.8 to 53.9 ^{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 30.1 to 50.2 ^{o}C at Tr.1 and 29.1 to 49.4 ^{o}C at Tr. 2 which is lower than the limit of 50 ^{o}C above ambient temperature.

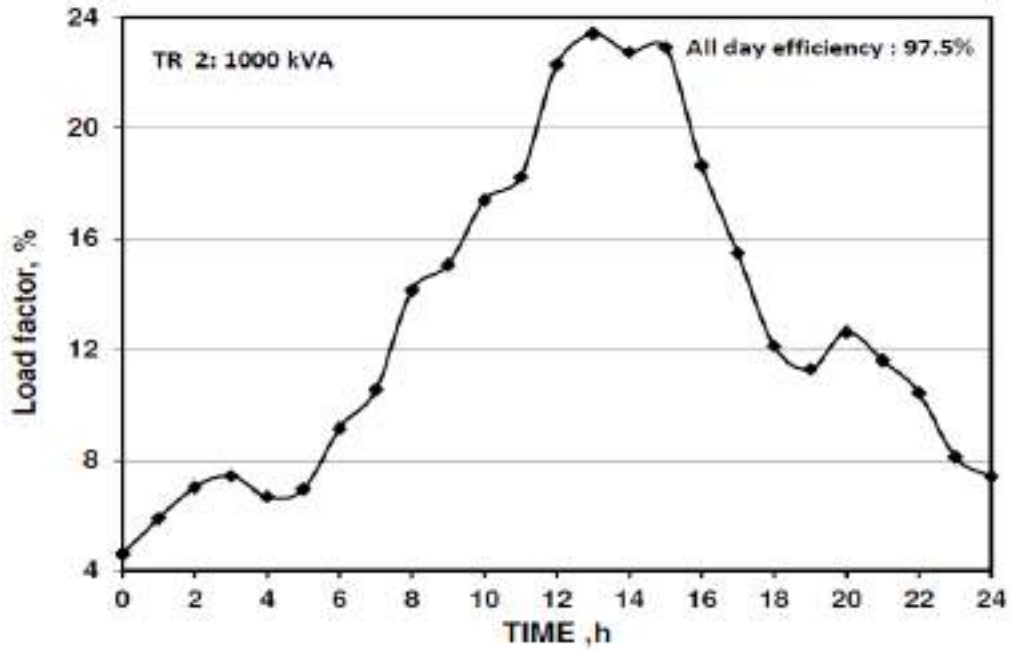

Figure 37: Variation of load factor of 1000 kVA Tr.2.

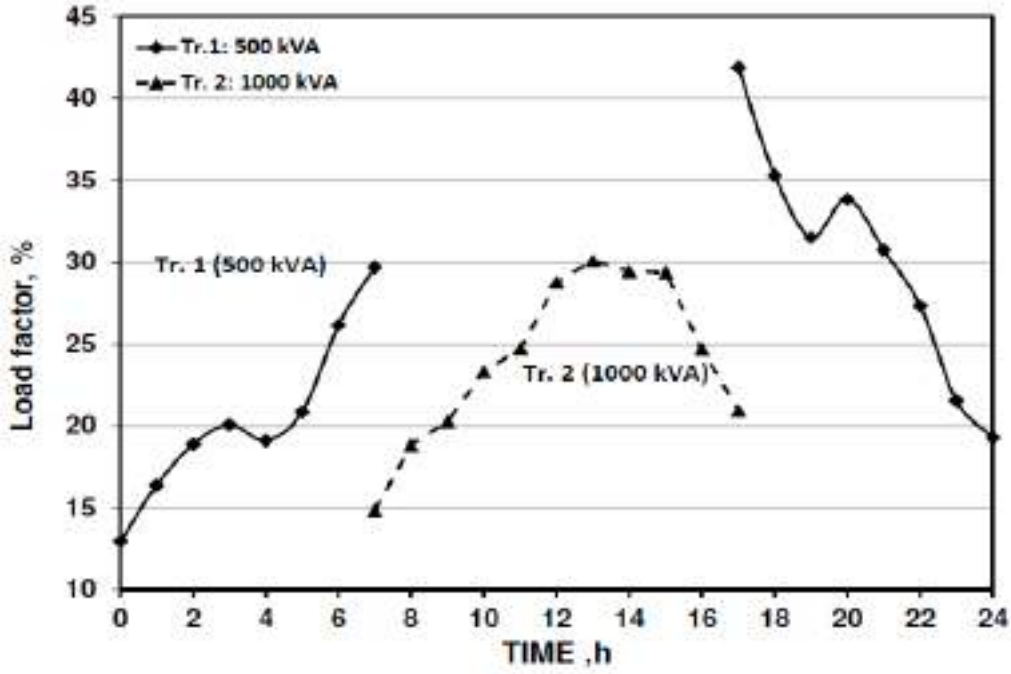

Figure 38: Variation of load factor of transformer after implementation.

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

13.0 to 41.9% (refer Figure 38) and that of Tr. 2 will be in the range of 14.8 to 30.1%. This will reduce the ***energy consumption by 2,425 kWh/month***.

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 0.93 and is good. Figure 39 shows the view of APFC panel included at main panel. 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 0.96 at LT panels.

Figure 39: View of APFC panel included in main panel.

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. Figure 40 gives the view of DG sets installed at REVA campus. DG sets provide the power supply to entire University including

Hostel and quarters during the grid power failure. Figure 41 gives the monthly energy generation by DG sets. The monthly energy generation by DG set 1 during the energy audit study is varying between 2,178 to 5,123 kWh/month whereas the energy generation by DG set 2 is in the range of 2,520 to 8,280 kWh/month. The total monthly energy generation by DG sets is varying between 4,856 to 12,728 kWh/month that forms 1.73 to 6.87% of total energy consumption which is less. The annual average energy used from DG set is reduced from 6.4% to 3.7% compared to previous year.

Figure 40: View of DG sets at REVA Campus

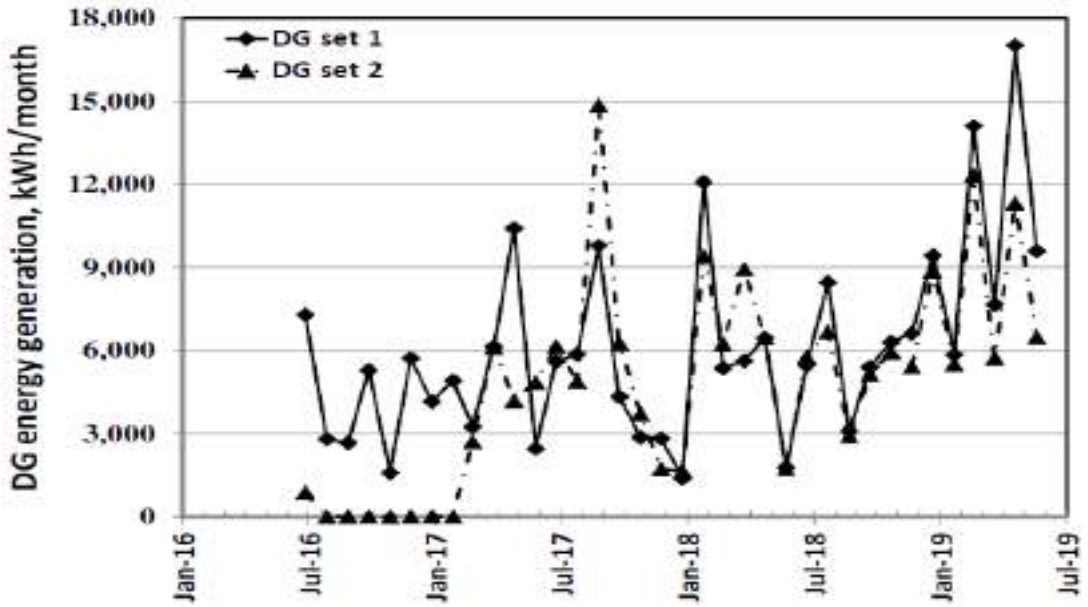

Figure 41: Variation of monthly energy generation by DG sets.

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 33.9 & 41.5 % but based on peak phase current the load factor of these DG sets are in the range of 35.4 & 41.6 %. The loading of DG sets is on lower side.
2. The Specific energy generation (SEG) of DG 1 is 2.91 kWh/l whereas SEG of DG 2 is 2.93 kWh/l which is slightly low compared to optimal value of 3.0 kWh/l. 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.
3. The DG set oil is cooled by forced air through fans over the radiator. The air inlet temperature at radiator is in the range of 33 to 45 ^{o}C and is quite good, this indicates the atmospheric ambient temperature. The ambient temperature is high, the performance of DG set will degrade.

4. The air temperature at radiator outlet is varying between 53 – 69 ^{o}C and is also quite good with rise in peak temperature is about 24 ^{o}C.
5. The alternator body temperature is varying between 42 to 64 ^{o}C and is very less compared to the optimal value of about 110 ^{o}C.
6. The flue gas exhaust temperature is varying between 122 to 255 ^{o}C. The waste heat recovery system may be introduced at DG set exhaust but the usage rate of DG set is very less i.e., average of 30 minutes/day and it is not economically viable.

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	421.3	420.1
3	Measured YB voltage	V	421.1	420.9
4	Measured BR voltage	V	421.8	421.2
5	Measured Current R phase	A	231.5	289.3
6	Measured Current Y phase	A	245.9	285.1
7	Measured Current B phase	A	219.8	280.2
8	Power factor R	-	0.94	0.93
9	Power factor Y	-	0.94	0.94
10	Power factor B	-	0.95	0.93
11	Power	kW	159.4	193.1
12	Load Factor based on average load	%	***33.9***	***41.5***
13	Load Factor based on peak phase current	%	***35.4***	***41.6***
14	Energy generation	kWh/h	135.5	158.3
15	Oil Consumption	l/h	46.5	54.0
16	Specific Energy Generation	***kWh/l***	***2.91***	***2.93***
17	Specific Oil Consumption	l/kWh	0.34	0.34
18	Radiator outlet air temperature	^{o}C	53-61	53-69
19	Radiator inlet air temperature	^{o}C	35-43	33-45
20	Exhaust gas temperature	^{o}C	139-255	122-221
21	Alternator body temperature	^{o}C	42-63	43-64

3.6 Water pumping system

The water is received through water tankers from outside to various sumps and also from borewells inside the campus. Figure 42 shows the view of pump house. 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 4.4 MWh/month that forms 2.0% of total energy consumption.

Figure 42: View of water pump house..

The performance tests are conducted on water pumps. Table 2 gives the electrical parameters of water pumps used for lifting the water from ground and also from sump to overhead tanks. Table 3 shows the overall performance of water pumps. 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 63.39 to 82.24% 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 69.8% which is normal. The overall efficiency of pump is 57.6% and is also normal.
e) At Vivekananda Block, four numbers of 1.5 kW water pumps are installed and their load factor of motors is varying between 75.5 to 82.6% which is normal. The overall efficiency of pumps is varying between 44.9 to 53.9%

and is on lower side may be due to ageing of pumps. It is suggested to overall the pumps.

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	RISM B. pump	3.7	421.3	4.8	0.81	2.84	76.68	Manual
2	Hostel B Block B. pump	3.7	420.1	5.1	0.82	3.04	82.24	Manual
3	Girls Kitchen B. pump	3.7	415.6	4.2	0.87	2.63	71.09	Manual
4	Playground B. pump 1	5.5	412.3	6.1	0.81	3.53	64.15	Manual
5	Playground B. pump 2	3.7	418.7	4.2	0.77	2.35	63.39	Manual
6	GH Borewell pump	3.7	416.7	4.5	0.78	2.53	68.47	Manual
7	MV Block B. pump 1	3.7	412.3	4.2	0.78	2.34	63.23	Manual
8	MV Block B. pump 2	5.5	412.3	7.2	0.81	4.16	75.72	Manual
9	PH UG S. pump	5.5	415.6	6.5	0.82	3.84	69.76	auto
10	V. Block UG S. pump 1	1.5	417.8	2.0	0.81	1.17	78.15	auto
11	V. Block UG S. pump 2	1.5	416.7	2.2	0.78	1.24	82.57	auto
12	V. Block UG S. pump 3	1.5	421.3	2.1	0.77	1.18	78.66	auto
13	V. Block UG S. pump 4	1.5	412.6	2.2	0.72	1.13	75.47	auto
14	Adm.Block UG S. pump 1	3.7	417.6	5.1	0.78	2.88	77.76	auto
15	Adm.Block UG S. pump 2	3.7	415.2	5.2	0.71	2.66	71.76	auto
16	G1 Block UG S. pump 1	5.5	418.7	7.4	0.81	4.35	79.03	auto
17	C Block UG S. pump 1	5.5	415.6	7.1	0.83	4.24	77.13	auto
18	C Block UG S. pump 2	5.5	413.5	7.3	0.81	4.23	77.00	auto
19	C Block UG S. pump 3	3.7	423.1	4.8	0.81	2.85	77.01	auto
20	B Block UG S. pump 1	5.5	416.7	6.1	0.79	3.48	63.24	auto
21	B Block UG S. pump 2	3.7	416.7	4.7	0.81	2.75	74.26	auto
22	B Block UG S. pump 3	5.5	416.2	7.1	0.82	4.20	76.31	auto
23	A Block UG S. pump 1	5.5	415.9	76.6	0.80	4.38	79.63	auto
24	A Block UG S. pump 2	7.5	414.5	10.1	0.81	5.87	78.31	auto
25	A Block UG S. pump 3	3.7	412.5	5.1	0.82	2.99	80.75	auto
26	A Block UG S. pump 4	3.7	414.6	4.7	0.81	2.73	73.89	auto
27	A Block UG S. pump 5	5.5	411.2	7.1	0.82	4.15	75.39	auto

f) At Admin Block, two numbers of 3.7 kW water pumps are installed and their load factor of motors is varying between 71.8 to 77.8% which is normal. The overall efficiency of pumps is varying between 61.3 to 64.6% and is normal.

g) At G1 Block hostel, 5.5 kW water pump is installed and its load factor of motors is 79.0% which is normal. The overall efficiency of pump is 54.7% and is on lower side may be due to ageing of pump. It is suggested to overall the pump.

Table 3: Performance results of water pumps

Sl. No.	Particulars	Rating, kW	Power input, kW	Head, m	Flow, l/s	Power output, kW	Efficiency, %
1	PH UG S. pump	5.5	3.84	23	9.8	2.21	57.58
2	V. Block UG S. pump 1	1.5	1.17	27	2.2	0.58	49.80
3	V. Block UG S. pump 2	1.5	1.24	27	2.1	0.56	44.86
4	V. Block UG S. pump 3	1.5	1.18	27	2.2	0.58	49.38
5	V. Block UG S. pump 4	1.5	1.13	27	2.3	0.61	53.91
6	Adm. Block UG S. pump 1	3.7	2.88	24	7.5	1.77	61.31
7	Adm. Block UG S. pump 2	3.7	2.66	24	7.3	1.72	64.61
8	G1 Block UG S. pump 1	5.5	4.35	24	10.1	2.38	54.67
9	C Block UG S. pump 1	5.5	4.24	19	13.2	2.46	58.03
10	C Block UG S. pump 2	5.5	4.23	19	14.1	2.63	62.13
11	C Block UG S. pump 3	3.7	2.85	19	7.8	1.45	51.01
12	B Block UG S. pump 1	5.5	3.48	20	10.5	2.06	59.20
13	B Block UG S. pump 2	3.7	2.75	20	8.1	1.59	57.79
14	B Block UG S. pump 3	5.5	4.20	20	11.9	2.33	55.59
15	A Block UG S. pump 1	5.5	4.38	22	12.1	2.61	59.62
16	A Block UG S. pump 2	7.5	5.87	22	16.4	3.54	60.30
17	A Block UG S. pump 3	3.7	2.99	22	8.1	1.75	58.47
18	A Block UG S. pump 4	3.7	2.73	22	7.9	1.70	62.45
19	A Block UG S. pump 5	5.5	4.15	22	11.7	2.53	60.85

h) 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 77.0 to 79.0% which is normal. The overall efficiency of pumps is varying between 51.0 to 62.1% and is on lower side may be due to ageing of pumps. It is suggested to overall the pumps.

i) 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 63.2 to 76.3% which is normal. The overall efficiency of pumps is varying between 55.6 to 59.2% and is on lower side may be due to ageing of pumps. It is suggested to overall the pumps.

j) 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 73.9 – 80.8% which is normal. The overall efficiency of pumps is varying between 58.5 to 62.5% and is on 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 36.7 MWh/month that forms about 16.8% of total energy consumption. All these computers are powered through uninterrupted power supply (UPS). The energy consumption at UPS is about 28.6 MWh/month that forms 13.1% 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 54.2 to 60.9% 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 48.2 to 52.9% and UPS loading is normal.
c) At Swami Vivekanand Block, two numbers of 80 kVA UPS are installed, their load factor is varying between 47.8 to 61.2% and UPS loading is normal.
d) At Library, one number of 60 kVA UPS is installed, its load factor is varying between 44.8 to 57.3% and UPS loading is normal.
e) At RISM block, one number of 30 kVA UPS is installed, its load factor is varying between 41.5 to 52.8% 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 37.3 to 61.3% 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 345 to 409 W. The power used

by printers varies between 286 to 940 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 15.7% 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 5th floor: 7.5TR (CSU) – 3 Nos., 11TR (CSU) – 1 No., 10TR (CSU) – 1 Nos., & 12.5TR (CSU) – 2 No.
m) Admin Block 6th 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 7th 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 1147 to 1738 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 413 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 (Figure 43). There are four inverters of 15 kVA each and 220 Numbers of 250 W_p each solar photovoltaic panels are installed.

Figure 43: View of 55 kW Solar PV Power Plant.

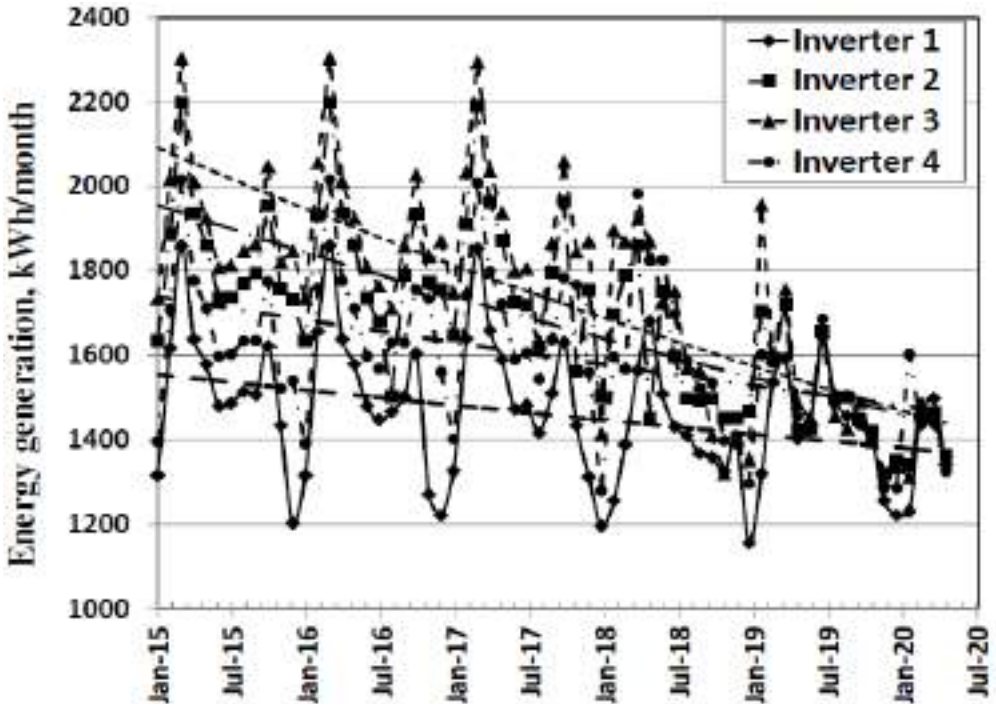

Figure 44: Variation of monthly energy at Solar PV inverters.

Figure 44 shows the variation of energy at inverters and the energy generation during the audit period are:

a) Inverter 1: 1221 to 1642 kWh/month
b) Inverter 2: 1321 to 1659 kWh/month
c) Inverter 3: 1302 to 1658 kWh/month
d) Inverter 4: 1286 to 1686 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.

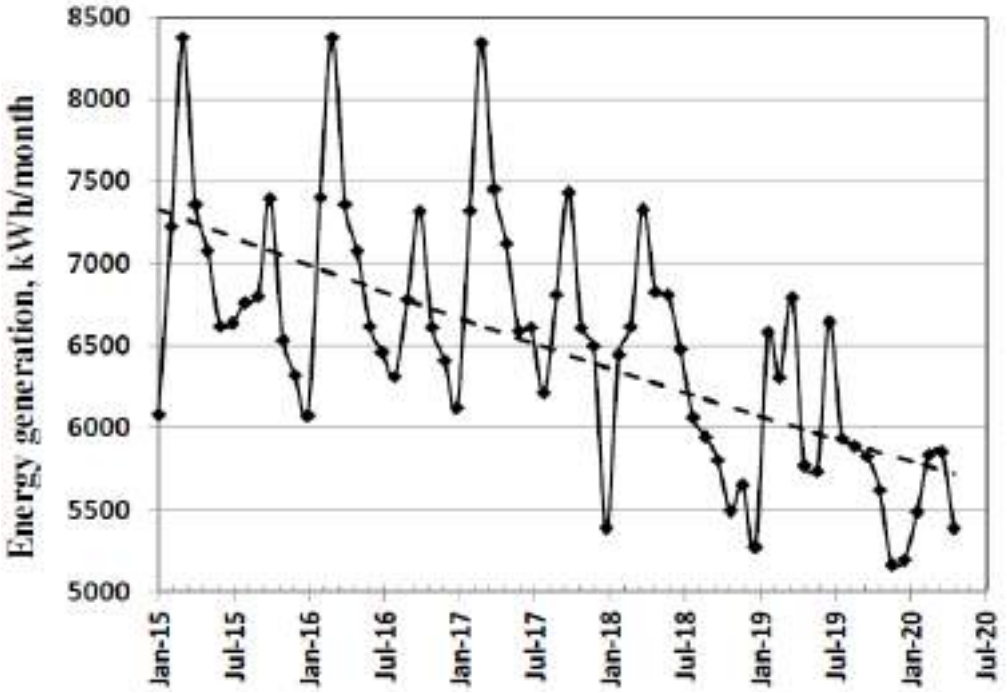

Figure 45: Variation of total energy generation by 55 kW Solar PV power plant.

The energy generation is less during Jan. month and is high during March month. Figure 45 gives the variation of monthly total energy generation by solar PV power plant for last five years. The generation varies between 5,165 to 6,645 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)
e) Year 2019-20 (till May): 68,574 kWh/y (2.61% of total energy consumption)

It can be seen from the Figure that the total energy generation by solar PV plant is reduced by 10.3% during last 5 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 3.42 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 72.0 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 (Figure 46). 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.

Figure 46: View of Solar water heater system installed at REVA Campus.

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 41.3 MWh/month that forms 18.9% of total energy consumption. The energy consumption for lighting system is reduced from 44.6 MWh/month to 41.3 MWh/month compared to previous year due to implementation of energy conservation measures (reduction of 7.4% 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 4 to 9 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 29.4 MWh/month that forms 13.4% of total energy consumption. The energy consumption for fans is reduced from 31.5 MWh/month to 29.4 MWh/month compared to previous year due to implementation of energy conservation measures (reduction of 6.7% of fan

energy). The energy used for other end use & lab equipment is 39.6 MWh/month that forms 18.1% of total energy consumption. Table 10 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. At CV Raman block, 25 numbers of T8 lamps are replaced with 18W LED lamps, this had reduced the energy consumption by 66 KWh/month.
4. At Sir M.V. block, 31 numbers of T8 lamps are replaced with 18W LED lamps, this had reduced the energy consumption by 82 KWh/month.
5. At Vivekananda block, 41 numbers of T8 lamps are replaced with 18W LED lamps, this had reduced the energy consumption by 108 KWh/month.
6. At RISM block, 14 numbers of T8 lamps are replaced with 18W LED lamps, this had reduced the energy consumption by 37 KWh/month.
7. 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.
8. The wall paints in all class room is of light colour whose reflectance factor is good (refer Table 11).
9. At Vivekananda block (Table 4), at class rooms about 101 numbers of 18W LED lamps, 101 numbers of T8 TFL and 184 numbers of 15W CFL are installed. The illumination level is varying between 119 to 257 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 267 kWh/month***. The anticipated investment is Rs. 0.40 lakhs and the payback period is 20 months.

Table 4: 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	184, 178, 203, 309, 115, 202,	
DBMS Project Lab	1	1			212, 187, 145, 166, 167, 204	2 TV, 1 Biometric, 5 Purifiers
OOPS Lab	2	1			117, 207, 189, 209, 278, 203	
DBMS Lab	4	8			128, 108, 123, 187, 178, 201	
WEB Lab	2	2			115,105,67,178, 126, 134, 108	
Staff Room		108	7	132	185, 176, 208, 175, 224, 176,	Projector, PC
Corridors	113	46			184, 178, 203, 309, 115, 202,	16 Purifiers,7 Projectors, 2 Coffee Machines,2 Vending Machines
Computer Lab	2	2			173, 120,166, 215, 182, 148,	
CCP Lab	2	2			138, 142, 178, 165, 178, 145	
Research Centre			8	3	128, 123, 176, 175, 187, 165	
Programming Lab		6			287, 175, 167, 261, 211, 207	2 Projector

10. At Vivekananda block other labs and rooms, about 176 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 128 to 361 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 465 kWh/month***. The anticipated investment is Rs. 0.70 lakhs and the payback period is 20 months.

Table 5: 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	168, 133, 156, 175, 137, 195	
HOD & staff room			28		134, 178, 203, 309, 115, 207	
corridor	43	43			59,65,97,118, 116, 124, 108	
Wash rooms		37	74		68, 108, 121, 167, 128, 211	
exam control room	2	2		4	167, 207, 189, 209, 218, 209	
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	201, 211, 156, 178, 165, 145	
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	110, 211,107, 109, 114, 145	
Design lab		7		6	178, 134, 187, 239, 256, 179	
CAED Lab and Auto CADD lab		18		13	189, 109, 96, 156, 208, 218	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	

11. At Visvesvaraya block (Table 5), 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 156 to 238 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.
12. At Visvesvaraya block other labs and rooms, about 26 numbers of 18W LED lamps, 214 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 565 kWh/month***. The anticipated investment is Rs. 0.86 lakhs and the payback period is 20 months.

Table 6: Lighting level measurement at Admin Block

Particulars	**Light fitting**				**Fans, (60 W)**	**Illumination level, lumens/m^2 (lux)**	**Remarks / Other equipment**
	LED (18W)	**TFL (36 W)**	**CFL**				
			(15W)	**(28W)**			
Rooms	12	94	298		127	241, 198, 234, 227, 210	
Corridor	10	47	163	158	2	106, 208, 125, 214, 156	2 TV, 1 Biometric, 5 Purifiers
Washrooms		24			8	175, 137,158, 126, 144	
Auditing Office		6				211 , 157, 109, 114, 155	
VC Visitor Lounge				6		122, 178, 165, 178, 146	
ERP & HR Office				31		185, 200, 178, 165, 111	Projector, PC
HR Interview Room				31		109, 96, 196, 208, 218	
Admission and public relations		4		4	7	117, 155, 136, 197, 224	
Office of the administration & establishment		4			5	115, 177, 281, 211, 209	
Registrar office				6	2	163, 176, 165, 187, 163	
Conference hall and Board room			33	6		207, 109, 229, 258, 219	2 Projector
Accounts office		5			5	185, 200, 178, 165, 111	
university office				2		129, 76, 126, 168, 138	
Advisor				9	1	188, 193, 157, 168, 201	
Vice chancellor				11		214, 187, 203, 198, 108	1 TV
Chancellor office		3		26		174, 127, 289, 256, 139	1 TV
Pantry		3			1	168, 223, 319, 125, 217	2 Purifiers

13. At Administrative block (Table 6), at class rooms about 12 numbers of LED lamps, about 94 numbers of T8 TFL and 298 numbers of 15W CFL are installed. The illumination level is varying between 153 to 302 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 248 kWh/month. The anticipated investment is Rs. 0.38 lakhs and the payback period is 20 months.

Table 7: Lighting level measurement at Science Block (RISM 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	20	194		140	123, 145, 167, 204	
Principal ,Admin office		3	8	3	188, 213,249,213, 209,213,189	
Exam control room and pantry		4	2	4	142, 168, 175, 198, 195,106,189.178	Vending machine
Corridor	26	78	2		109, 178, 196, 156	
Wash rooms		21		2	147, 217, 165, 169	
Seminar halls			12		168, 194, 167, 209	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 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, Potarymictrotome
Basic Material lab		46		16	164, 185, 209, 178, 175, 118	Two span simply supported beem,,
Geo technical engineering lab		31		20	98, 108, 87, 97, 78, 111	Unconfines compression tester, Butimen stripping

14. At Administrative block, other labs and rooms, about 12 numbers of LED lamps, 96 numbers of 36W T8 TFL, 196 numbers of 15W CFL and 293 numbers of 28W CFL are installed. The illumination level is varying between 112 to 284 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 253 kWh/month***. The anticipated investment is Rs. 0.39 lakhs and the payback period is 20 months.
15. At RISM block (Table 7), at class rooms about 20 numbers of LED lamps, about 194 numbers of T8 TFL are installed. The illumination level is varying between 116 to 212 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 512 kWh/month***. The anticipated investment is Rs. 0.78 lakhs and the payback period is 20 months.
16. At RISM block other labs and rooms, about 26 numbers of LED lamps, 280 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 739 kWh/month***. The anticipated investment is Rs. 1.12 lakhs and the payback period is 20 months.
17. At Sir C.V. Raman block class rooms (Table 8), about 57 numbers of LED lamps, about 620 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 167 to 312 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 1,639 kWh/month***. The anticipated investment is Rs. 2.48 lakhs and the payback period is 20 months.

Table 8: 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	57	620	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	44	38		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

18) At Sir C.V. Raman block other labs and rooms, about 66 numbers of LED lamps, 198 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 523 kWh/month***. The anticipated investment is Rs. 0.79 lakhs and the payback period is 20 months.

19) 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 9: 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	137, 227, 179, 219, 228, 239	1 Camera,1Vending Machine, 7 Purifiers
B Block	486	136	128	108, 144, 157, 209, 251, 165	1 Camera,1Vending Machine, 7 Purifiers
C block	476	136	128	154,135,167,158, 136, 164, 158	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	182, 140,196, 205, 172, 138	1 Camera,2Vending Machine, 2Purifiers
Girls hostel 2	320	150	120	222, 146, 241, 215, 224, 196	1 Camera,2Vending Machine, 2 Purifiers
Corridors		325		116, 63,156, 181, 107, 103, 155	

20) 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.
21) 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.
22) 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.
23) 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 10: 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

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.

Table 11: 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 Aluminum	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			

4.0 CONCLUSIONS

The main conclusions from the study are as follows:

1. The operation and maintenance of electrical system is quite good.
2. The grid energy import varies between 217.9 to 278.1 MWh/month till Feb. 2020. Then it was reduced to 113.7 MWh/month during May 2020 due to lock down.
3. The energy generation by DG sets is varying between 4.86 to 12.73 MWh/month that forms variation of 1.7 to 4.4% which is normal.

4. The annual energy generation by DG sets during last four years and is varying between 75.69 MWh/year to 181.27 MWh/month. DG set energy generation is reduced from 6.4 % to 3.7 % of total energy consumption compared to previous year.
5. The monthly average total energy consumption is reduced from 253.1 MWh/month to 248.1 MWh/month compared to previous year (reduction of 2.1% of total energy consumption).
6. 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.
7. The recorded MD 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. The monthly average power factor is varying between 0.90 and 0.96.
8. The average monthly total energy cost is reduced from Rs. 21.8 lakhs/month to Rs. 20.4 lakhs/month compared to previous year.
9. The energy rate is decreased from Rs. 8.78 per kWh to Rs. 8.10 per kWh compared to previous year (reduction of 7.7%)
10. The major energy is being used at Hostel panel 1 of 77.9 MWh/month (35.6% of total energy consumption) and followed by the Boys D hostel, Girls hostel 1 and STP feeder energy consumption is 48.3 MWh/month (22.1%).
11. Lighting consume major energy by about 18.9%, followed by lab equipment 18.1%, computers & peripherals 16.8%, air-conditioning (AC) system 14.7% comfort air fans 13.4% faculty & staff quarters 8.1%, water pumping system is 2.0% and STP plant 1.4%.
12. The load of transformer 1 is varying between 17.4 to 61.9% and transformer 2 is in the range of 4.6 to 23.4%.. All day efficiency of Tr.1 is 98.2% which is slightly better than that of Tr. 2 of 97.5%. 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 2,425 kWh/month*.

13. The load factor of DG set 1 and 2 (based on average power) are in the range of 33.9 & 41.5 % but based on peak phase current the load factor of these DG sets are in the range of 35.4 & 41.6 %. The loading of DG sets is on lower side.
14. The Specific energy generation (SEG) of DG 1 is 2.91 kWh/l whereas SEG of DG 2 is 2.93 kWh/l which is slightly low compared to optimal value of 3.0 kWh/l.
15. The load factors of borewell pump motors are in the range of 63.39 to 82.24% and are normal. The load factor of sump pump motors are in the range of 63.2 to 82.6% and are normal. The overall pump efficiency of sump pumps are in the range of 44.9 to 6.6% and few pumps efficiencies are on lower side due to pump internal leakages.
16. The specific cooling capacity of air-conditioning system varies between 1147 to 1738 TR/ft^2 which is slightly. At few labs and seminar halls, the room temperature is being maintained at 21 – 23 ^oC which should be maintained above 25^oC which will reduce the energy consumption by 3% per degree of room temperature. The anticipated *energy saving is 413 kWh/month*.
17. The 55 kW solar power plant generates energy in the range of 5,165 to 6,645 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 is reduced from 4.15 kWh/kW-day to 3.42 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 72.0 t/y to 87.5 t/y (average of 2.91% of total CO_2 emission).

18. 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.
19. The energy used for lighting system is 41.3 MWh/month that forms 18.9% of total energy consumption.
20. The energy used for comfort air fans is 29.4 MWh/month that forms 13.% and for other end use & lab equipment is 39.6 MWh/month that forms 18.1% of total energy consumption.
21. In the Sir CV Raman block Amphi theatre and at Vivekananda block Rangasthala roofs are provided with transparent polycarbonate sheets which has allowed the natural light during day hours and reduced the energy consumption by 920 kWh/month.
22. 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.
23. At Academic buildings and corridors, T8 lamps are replaced with 18W LED lamps which had reduced the energy consumption by 293 kWh/month
24. The illumination level is good because at many rooms, natural light is available and is being used appropriately. At rooms and labs, about 2485 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 6,560 kWh/month. The anticipated investment is Rs. 9.94 lakhs and the simple payback period is 20 months.

25. 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

Annexure III

Social outreach program on creating awareness on energy conservation and use of renewable energy at Chikkasanne Village on 06-11-2019

At School of EEE, about 44 numbers of students of 3rd sem, 5th sem & 7th sem have visited the Chikkasanne village along with 3 faculties on 06-11-2019 to study the electrical distribution system, electrical safety, energy usage pattern, water consumption, water pumping system, etc. Dr. Rajashekar P. Mandi, Director, School EEE have addressed the students, Govt. Primary School children and villagers about the necessity of energy conservation to reduce the carbon emission, use of solar energy for lighting as well as for hot water system. The Director also explained the students about the electrical distribution system in individual house, school, streetlights and also distribution transformers. Also narrated about the electrical safety being maintained for residences, school & street lights. Dr. Divakar B.P., Dean (R&I) also addressed the students and villagers and highlighted about the use of renewable energy system for street lights, maintaining the cleanliness of the environment, avoiding use of plastic to protect the mother earth. Then all the students have visited all the individual houses, collected the information like number of light points used, type of lamp, numbers of other electrical gadgets like iron box, fans, TV, Radio, water heaters, etc. Also checked the electrical wiring whether they are using proper sockets & plugs, if they have not used plugs & sockets, our students have suggested to use plugs & sockets to avoid loose connection that may cause fire accident and also cause excessive energy loss. Students also suggested to use solar water heater for water heating applications that will save electrical energy considerably. They suggested the villagers to go for solar water pumping system where they get subsidy from MNRE, New Delhi.

Finally the students have distributed about 80 numbers of LED bulbs to villagers on free of cost to motivate the villagers for conserving the energy that reduce the electricity bill for them and also reduce the carbon emission.

Finally the students have conducted some fun games to the children to motivate them do well in their studies and come to REVA University for higher study.

The Principal of the Chikkasanne school also addressed the villagers and appreciated the work done by REVA University students for the Nobel cause. Finally the Chikkasanne Gram Panchayat President also praised our students and the effort put by the REVA University in publicizing the energy conservation and use of renewable energy system for villagers.


REVA