ENERGY AUDIT

Conducted at

REVA UNIVERSITY,
KATTIGENAHALLI CAMPUS, BANGALORE

REVA UNIVERSITY
Bengaluru, India

REPORT NO.: REVA/EEE/EA/01/2018

Audit Period : July 2017 - June 2018

Study conducted by

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

Project Summary

1.	Title:	Energy Audit at REVA University, Kattigenahalli Campus, Bangalore
2.	Sponsoring agency:	REVA University, Bangalore
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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/01/2018
11.	Energy Audit period	July 2017 – Jun 2018
12.	Date of issue of report:	July 2018
13.	Signature of Certified Energy Auditor	

ACKNOWLEDGEMENT

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

EXECUTIVE SUMMARY

The detailed Energy audit study is conducted at REVA University, Bangalore. The energy consumption is reduced to 173 MWh/month during June 2018 due to vacation for the academics at University. The energy generation by DG sets is varying between 1.6 and 24.7 MWh/month and the share of DG energy is in the range of 0.6 to 8.8%. The total energy consumption (BESCOM+DG) is varying between 203.8 and 292.3 MWh/month. The total energy consumption is increasing due to addition of loads and also construction work activities. The total energy consumption during 2017 is 31,63,318 kWh/y which is taken as base energy consumption for energy audit study. The total built area is 1,46,548 m^2. The energy performance index (EPI) for total REVA University campus is 21.59 kWh/m^2-year which is lower than the EPI specified by Energy Conservation Building Code (ECBC) 2006 of 120 kWh/m^2-year.

The recorded maximum demand (MD) is varying between 410 kVA and 856 kVA. The recorded MD during June 2018 is reduced to 422 kVA due to vacation for academics at REVA University but the minimum chargeable MD is 1003 kVA (the additional MD charges due to increase of CD is Rs. 73,000 per month). The contract demand is 750 kVA and the minimum chargeable demand (75% of CD) is 563 kVA till April 2018, during May it is raised to 638 kVA (85% of CD) and from June 2018 onwards the CD is raised to 1180 kVA for which the minimum chargeable MD is 1003 kVA (85% of CD). The contract demand can be reduced to 1000 kVA that reduce the minimum chargeable MD to 850 kVA which will ***reduce the MD charges by Rs. 30,600 per month***.

The average power factor is varying between 0.90 and 0.96 and is good. The energy cost is varying between Rs. 8.5 lakhs/month to 27.2 lakhs/month. From Dec. 2017 onwards, the energy cost had decreased to Rs. 16.9 lakhs/month due to change of category from commercial (HT2a) to educational institute (HT 2c) for service connection. The energy rate is varying between Rs. 7.56 and 9.89 per kWh. The energy rate has decreased after Dec. 2017 due to change of category of

service connection. Again the average energy rate is increased to Rs. 8.49 per kWh due to increase of contract demand.

The total energy used by hostels, guest house, quarters, STP & library is 57.6%. The energy used for academics is 42.4% of total energy consumption. About 20.4% of total energy consumption is used for lighting system followed by lab equipment of 18.8%. The energy used for computers & peripherals is 17.8%, for air-conditioning (AC) system is 14.1% (AC at Kuvempu auditorium is not included), for comfort air fans is about 13.1% including hostel, for faculty & staff quarters is 6.6%, for water pumping system is 2.0% and for STP plant is 1.2%. The energy loss in transformer is computed as 1.8% and distribution loss is 4.1% of total energy consumption.

There two distribution transformers Tr. 1 of 500 kVA & Tr. 2 of 1000 kVA are used to step down high voltage of 11 kV to 433 V at main incoming. The energy loss in transformer is computed as 5,190 kWh/month that forms 0.17% of total energy input. The power factor on transformer secondary is good in the range of 0.91 to 0.96 due to use of automatic power factor correction (APFC) panel. The transformer winding and oil temperature are normal in the range of 30.1 to 67.3 ^{o}C. The loading on Tr.1 1 is slightly on higher side in the range of 21.8 to 87.9% whereas that Tr. 2 is slightly on lower side in the range of 4.1 to 30.0% but on this transformer the newly renovated Kuvempu auditorium is connected whose load of about 120 – 130 kW will get added. The all day efficiency of Tr.1 is 98.34% which is slightly better than that of Tr. 2 of 97.88%. The diverting of all the total loads on to Tr. 2 (1000 kVA) during day time between 08:00 to 17:00 hours and during evening hours between 17:00 to next day 08:00 hours will reduce the ***energy consumption by 3,045 kWh/month***.

The load factor of DG sets are in the range of 31.8 to 48.1% and the Specific energy generation (SEG) of DG sets in normal in the range of 2.80 to 3.04 kWh/l. The energy used for computers and peripherals is 1679.2 kWh/day that forms about 17.8% of total energy consumption. There are about 2,196 systems and 134 printers of different sizes.

The energy used for Air-conditioning system is 1328.4 kWh/day that forms about 14.1% of total energy consumption. The total installed capacity of air-conditioning units is 517.1 TR. The specific air-conditioning system varies between 1231 to 1698 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 1.25 to 1.67 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 22 – 23 ^{o}C which should be maintained above 25^{o}C which will reduce the energy consumption by 3% per degree of room temperature. The anticipated ***energy saving is 400 kWh/month***.

At Administrative block 55 kW solar power plant is installed to provide the power supply to loads at administrative block. ***The generation by solar PV power plant varies between 6076 to 8411 kWh/month that forms 2.78% during 2018 to 4.08% during 2015***. The average specific energy generation by solar PV power plant is slightly lower in the range of 4.12 kWh/kW-day to 4.14 kWh/kW-day.

About 80,000 LPD solar hot water system is are installed to provide the hot water to students residing at hostels. The average specific hot water is 24.3 LPD/student. 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 56, 411 kWh/month that forms 21.4% of total energy consumption.

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

approximate area of 900 m^2. This had allowed very good natural light during day hours and had reduced the average electrical energy of 430 kWh/month.

The major energy is being used for lighting system of 1923.1 kWh/day that forms 20.4% of total energy consumption. The energy used for comfort air fans is 1230 kWh/day that forms 13.1% and for other end use & lab equipment is 1769.6 kWh/day that forms 18.8% of total energy consumption. The illumination level is good because many room natural light is available and is being used appropriately. At rooms and labs, about 2946 numbers of 36W T8 fluorescent lamps (TFL) are installed, if these T8 lamps are replaced by 18W LED lamps will reduce the ***total energy consumption by 7,070 kWh/month***. The anticipated investment is Rs. 10.61 lakhs and the simple payback period is 18 months. Putting off of dome lights during 11:00 PM to 5:30 AM will reduce the energy consumption by 231 kWh/month.

In order to conserve the energy consumption at Hostel blocks, at each room one number of the 36W T8 TFL lamp was 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.

The installation of 500 kW solar power plant will reduce the energy consumption by 8,52,000 kWh/y with an investment of Rs. 195 lakhs will be paid back in 47 months. This reduces the CO_2 emission by 895 t/y.

The implementation of energy conservation measures at REVA University Kattigenahalli campus and installation of 500 kW solar PV Power plant will reduce the ***energy consumption by 81,746 kWh/month (31.0 % of total energy input)***. This will reduce the CO_2 emission by 85.8 t/month.

Summary of Recommendations
Immediate term measures

Sl. No.	Recommendations	Anticipated energy savings, kWh/month / Rs.	Anticipated investment, Rs.	Payback period, months
01	Reducing the Contract demand to 1000 kVA	Rs.30,600	-	-
02	Transformer management	3045 kWh/month	-	-
03	Optimizing the room temperature in AC rooms	400 kWh/month	-	-
04	Putting off of dome lights between 11:00 PM to 5:30 AM	231 kWh/month	-	-
Total		**3676 kWh/month Rs. 30,600**	**-**	**-**

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	7070 kWh/month	10.61	18
Total		**7070 kWh/month**	**10.61**	**18**

Long term measures

Sl. No.	Recommendations	Anticipated energy savings, kWh/month	Anticipated investment, Rs. in lakhs	Payback period, months
01	Installation of 500 kW grid interactive solar PV power plant	71,000	195	47
02	Installation of energy management system	[a]	10	-
Total		**71,000**	**205**	**49**

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1.0 INTRODUCTION

This section introduces the REVA University, scope of the work and electrical distribution system.

1.1 REVA University

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

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

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

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

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

1.2 Scope of work

The detailed scope 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 between ***01-07-2018 to 20-07-2018***. 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

Figure 1 gives the variation of monthly energy consumption at REVA University from Nov. 2014 to June 2018. The BESCOM incoming energy consumption is varying between 100.8 MWh/month (Jan. 2015) and 284.7 MWh/month (March 2017). The energy consumption is reduced to 173 MWh/month during June 2018 due to vacation for the academics at University. The deviation between maximum to minimum value is 84.1 % and is high.

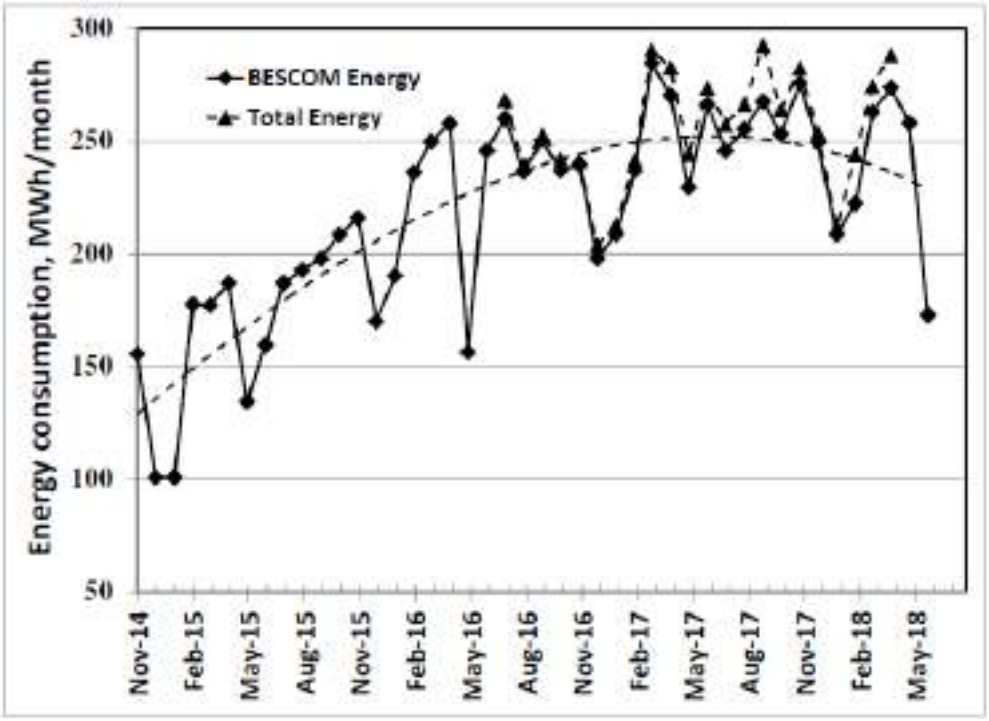

Figure 1: Variation of energy consumption.

Figure 2 gives the variation of total energy generation by DG sets and its share. The energy generation by DG sets is varying between 1.6 MWh/month (Nov. 2016) to 24.7 MWh/month (Sept. 2017) and the share of DG energy is in the range of 0.6 to 8.8%. The average DG set energy share is 3.74% which is very less. Only during Sep. 2017 the energy generation by DG is high due to more BESCOM power failure. The total energy consumption (BESCOM+DG) (for period between July 2016 to April 2018) is varying between 203.8 MWh/month (Dec. 2016) to 292.3 MWh/month (Nov. 2017). It can also be seen from the above Figure that the total energy consumption is increasing may be due to addition of loads. The energy consumption is low during Jan. & June months because of vacation for the academics and is high during April & Aug. Months. The total energy consumption from BESCOM during the year 2017 is 29,93,440 kWh/y, energy generation by DG set during 2017 is 1,17,164 kWh/y and the total energy consumption at REVA University is 31,63,318 kWh/y. The total built area is 1,46,548 m^2. The energy performance index (EPI) for total REVA University campus is 21.59 kWh/m^2-year

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

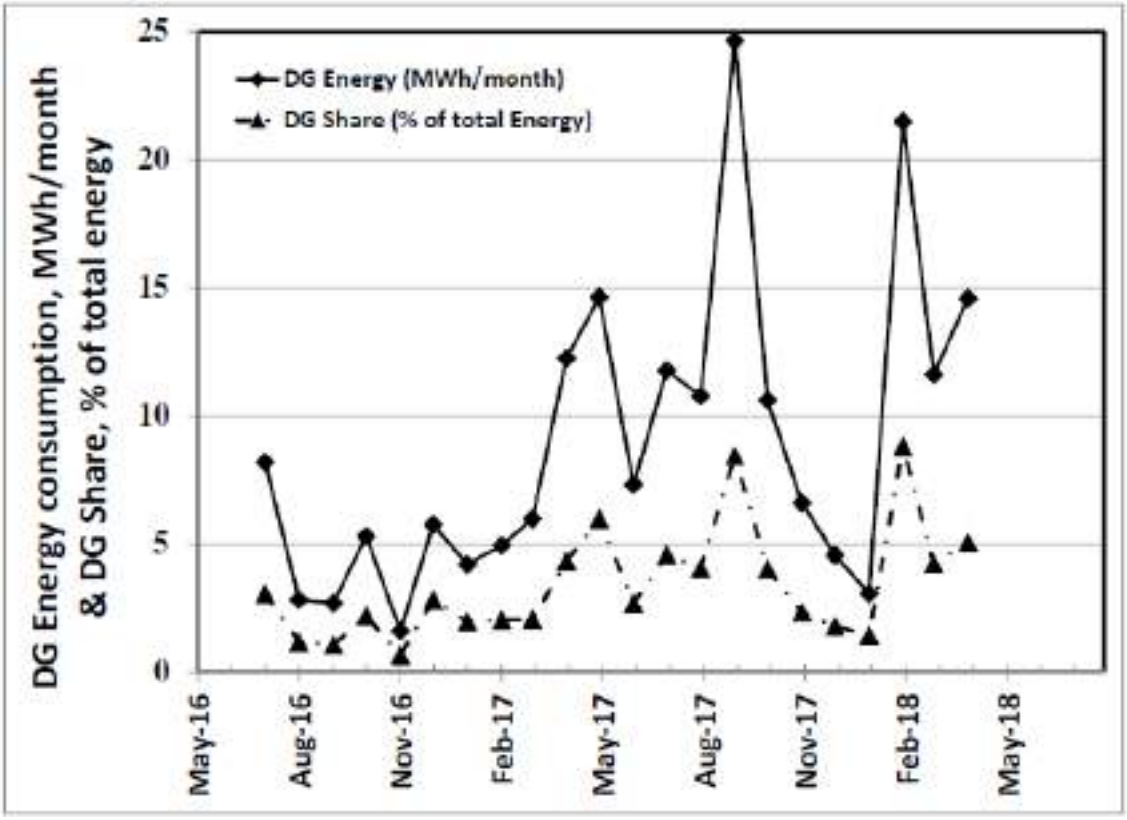

Figure 2: Variation of energy generation by DG sets.

Figure 3 gives the variation of recorded maximum demand (MD) is varying between 410 kVA (Nov. 2014) and 856 kVA (April 2018). The recorded MD during June 2018 is reduced to 422 kVA due to vacation for academics at REVA University but the minimum chargeable MD is 1003 kVA (the additional MD charges due to increase of CD is Rs. 73,000 per month). The deviation between maximum to minimum value is 71.2 % and is also on higher side due to increasing connected load. The recorded maximum demand also increased due to construction work. The contract demand is 750 kVA and the minimum chargeable demand (75% of CD) is 563 kVA till April 2018, during May it is raised to 638 kVA (85% of CD) and from June 2018 onwards the CD is raised to 1180 kVA for which the minimum chargeable MD is 1003 kVA (85% of CD). The recorded maximum demand was more than contract demand from March 2017 onwards due to construction work. The contract demand can be reduced to 1000 kVA that reduce

the minimum chargeable MD to 850 kVA which will ***reduce the MD charges by Rs. 30,600 per month***.

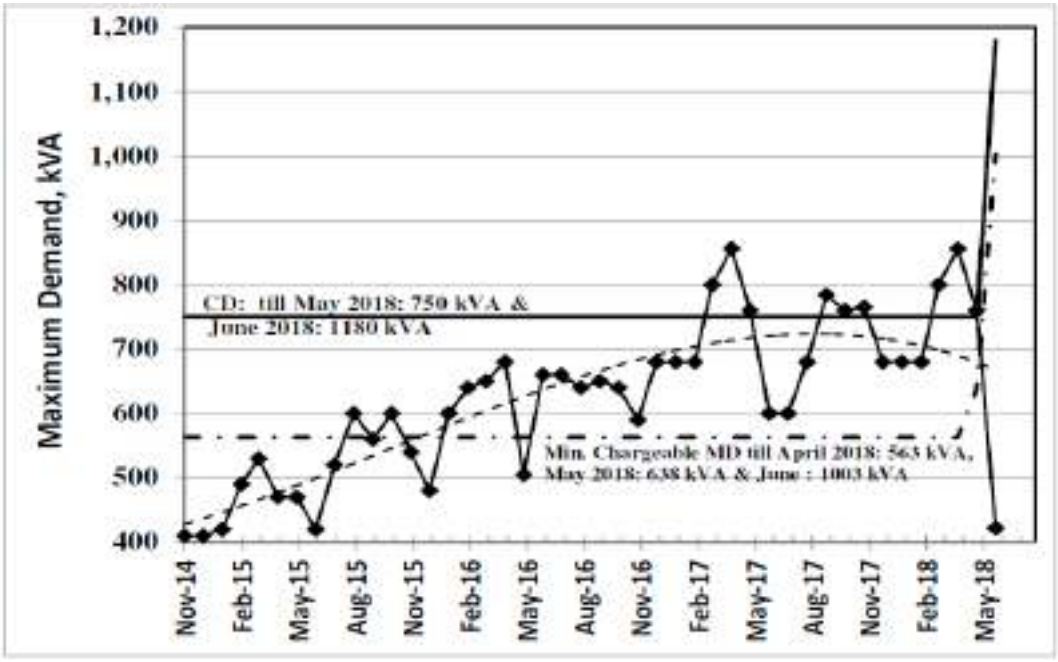

Figure 3: Variation of maximum demand.

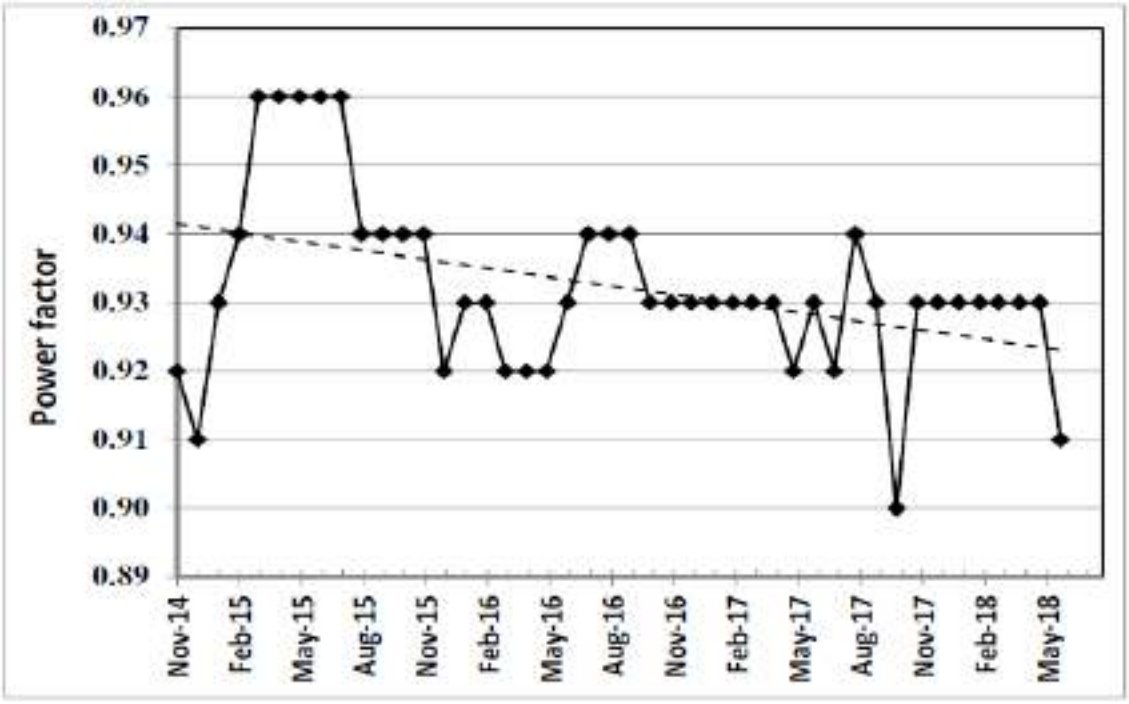

Figure 4: Variation of power factor.

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

Figure 5 gives the variation energy cost and is varying between Rs. 8.5 lakhs/month (Dec. 2014) to 27.2 lakhs/month (Sept. 2017). From Dec. 2017 onwards, the energy cost had decreased to Rs. 16.9 lakhs/month due to change of category from commercial (HT2a) to educational institute (HT 2c) for service connection. Figure 6 shows the variation of average energy rate (including demand & energy charges). The energy rate is varying between Rs. 7.56 to 9.89 per kWh. It can be seen from the figure that the energy rate has decreased after Dec. 2017 due to change of category of service connection. Again the average energy rate is increased to Rs. 8.49 per kWh due to increase of contract demand.

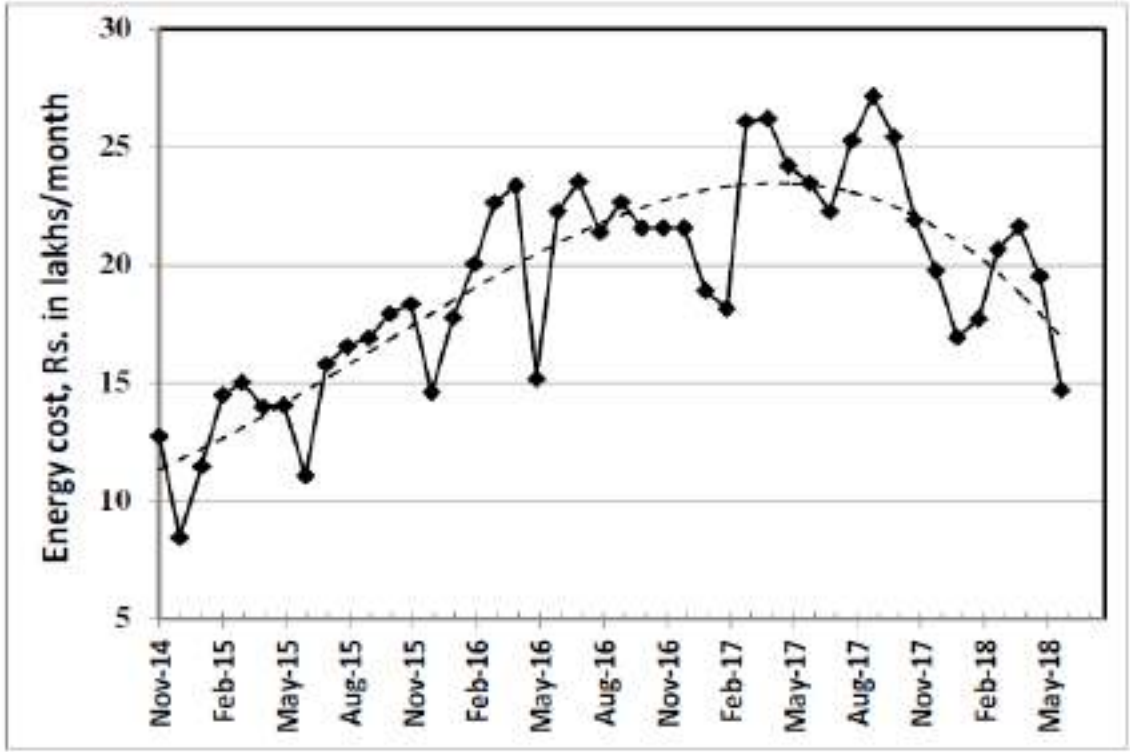

Figure 5: Variation of energy cost.

Figure 7 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 36.8% of

total energy consumption and followed by the Boys D hostel, Girls hostel 1 and STP feeder energy consumption is 20.8%. The total energy used by hostels, guest house, quarters, STP & library is 57.6%. The energy used for academics is 42.4% of total energy consumption.

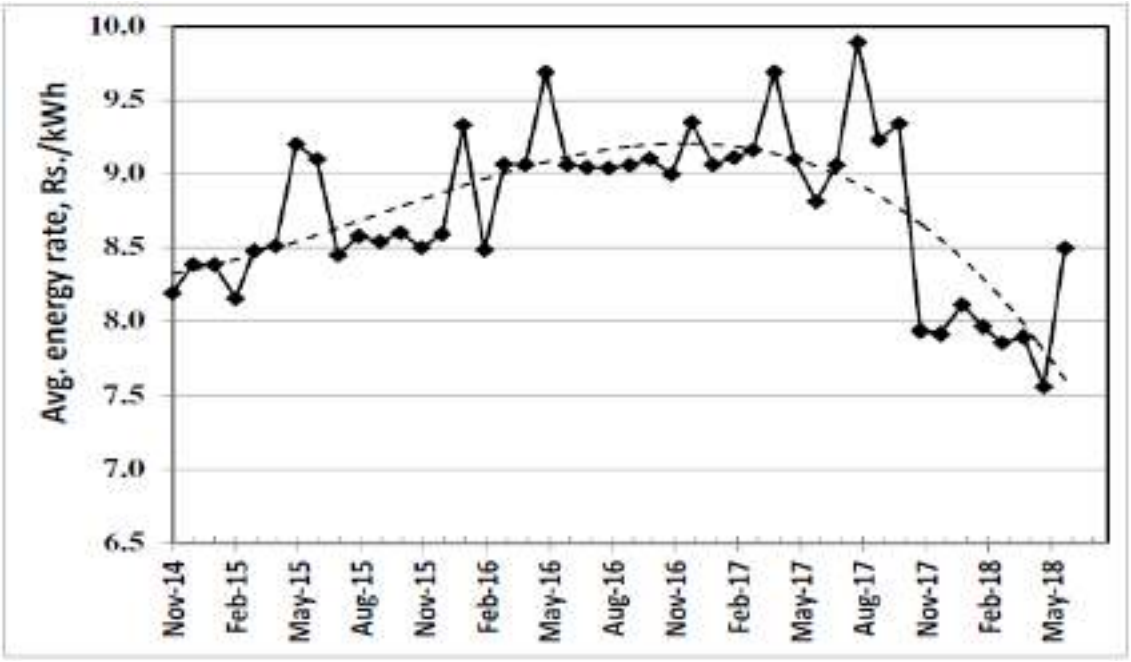

Figure 6: Variation of average energy rate.

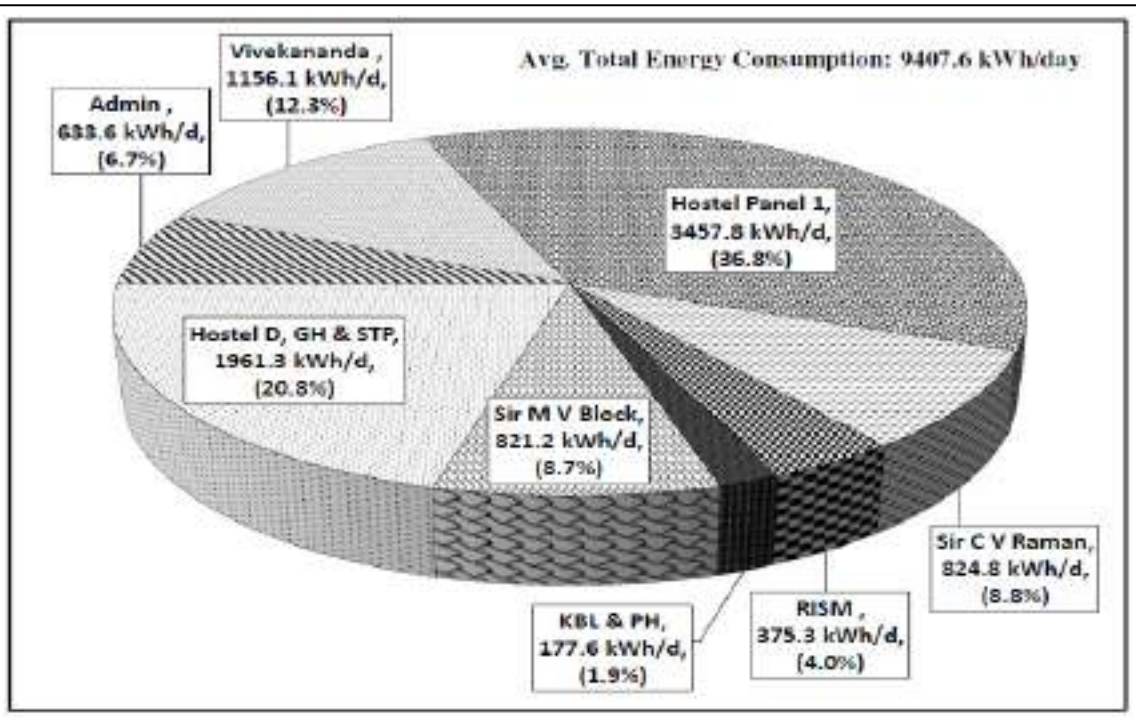

Figure 7: Energy consumption by different blocks.

Figure 8 gives the energy consumption by different facilities / components. The major energy is used for lighting system i.e., 20.8% of total energy in which 9.1% 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 18.8%. The energy used for computers & peripherals is 17.8%. The energy used for air-conditioning (AC) system is 14.1% (AC at Kuvempu auditorium is not included). The energy used for comfort air fans is about 13.1% including hostel. The energy shared for faculty & staff quarters is 6.6% of total energy consumption. The energy used for water pumping system is 2.0% and for STP plant is 1.2%. The energy loss in transformer is computed as 1.8% and distribution loss is 4.1% of total energy consumption.

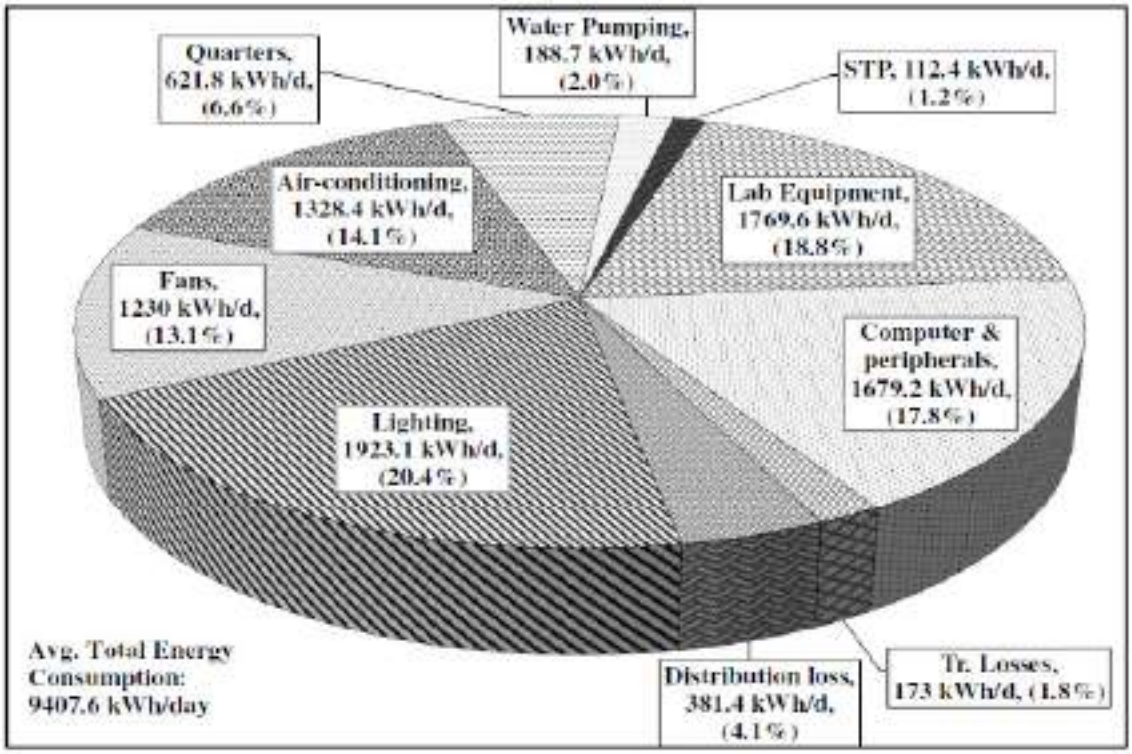

Figure 8: Energy used by different facilities.

3.2 Electrical distribution system

Figure 9 gives the view of LT incoming panel. Figures 10 to 12 give the schematic of the electrical distribution system at REVA University. The 11 kV incoming is tapped from BESCOM at main entrance sub-station. 11 kV Vacuum Circuit Breaker (VCB) is installed along with metering cubicle. The 11 kV is connected to incoming of two Distribution transformers Tr.1 of 500 kVA and Tr. 2 of 1000 kVA where 11 kV is stepped down to 433 V. The secondary of Tr.1 is connected to LT panel 1 and the secondary of Tr. 2 is connected to LT panel 2. The bus-coupler is connected between two LT panels. DG set 1 of 500 kVA is connected to LT panel 1 whereas DG set 2 of 500 kVA is connected to LT panel 2 through change over switch to provide the power supply to entire REVA university campus.

Figure 9: View of Electrical main LT incomer panels.

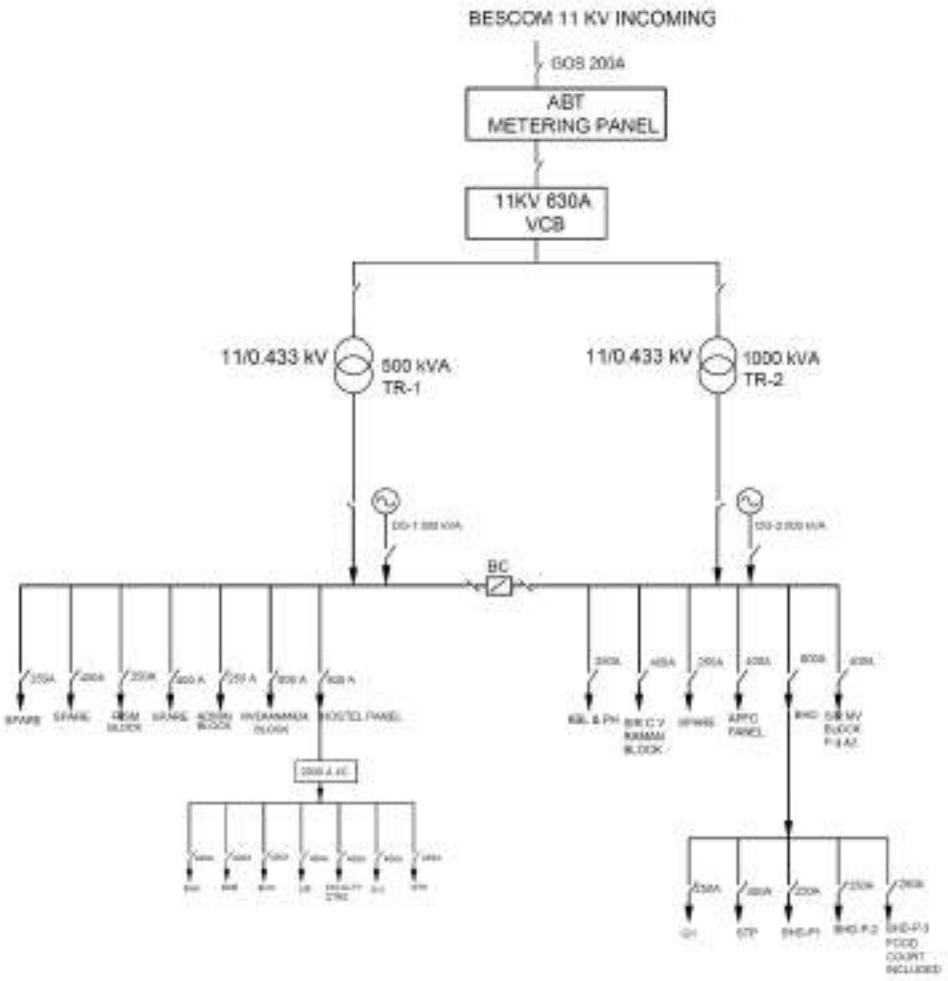

Figure 10: Single line diagram of main incomer from BESCOM & LT distribution.

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.

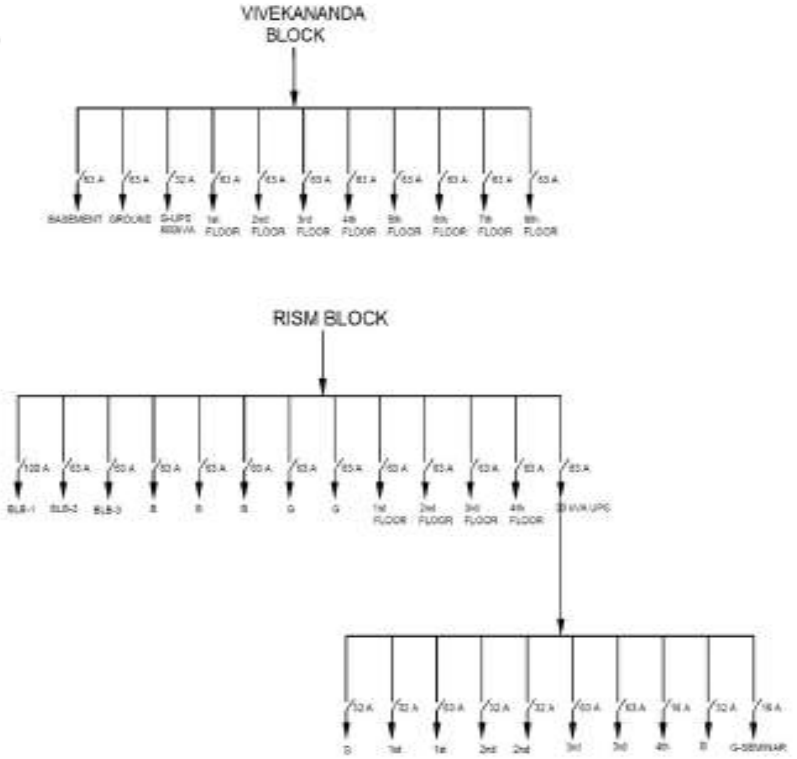

Figure 11: Electrical distribution at Vivekananda & RISM Blocks.

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

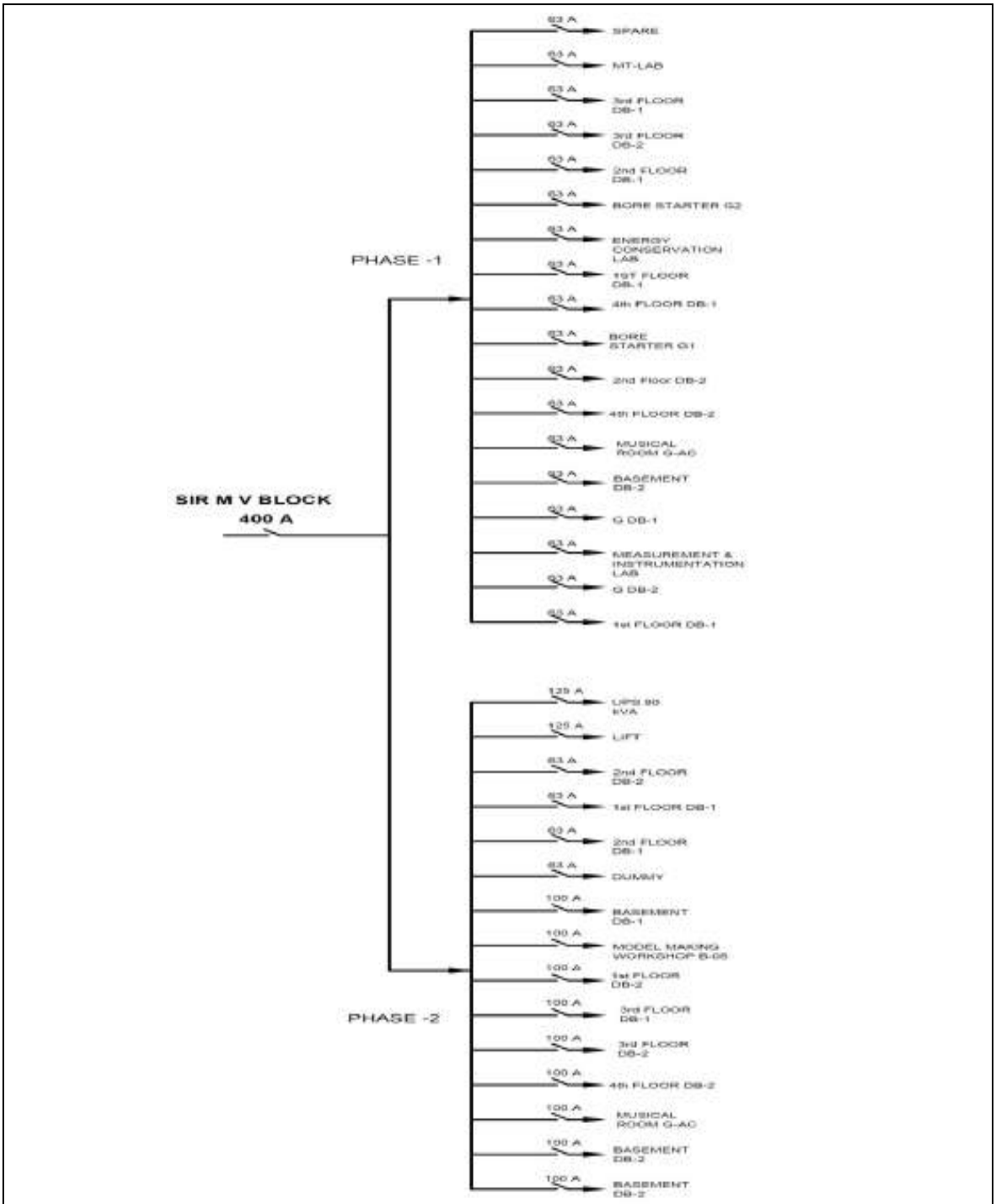

Figure 12: Electrical distribution at Sir MV Block.

Figure 13 gives the variation of incoming voltage on 11 kV side on a typical day and is varying between 10.1 to 11.6 kV (-8.1% - +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 varying between 0.58

to 0.66 (Figure 14) and is also lower than the International standards EN-50160 < 2% for LV & MV system and < 1% for HV system.

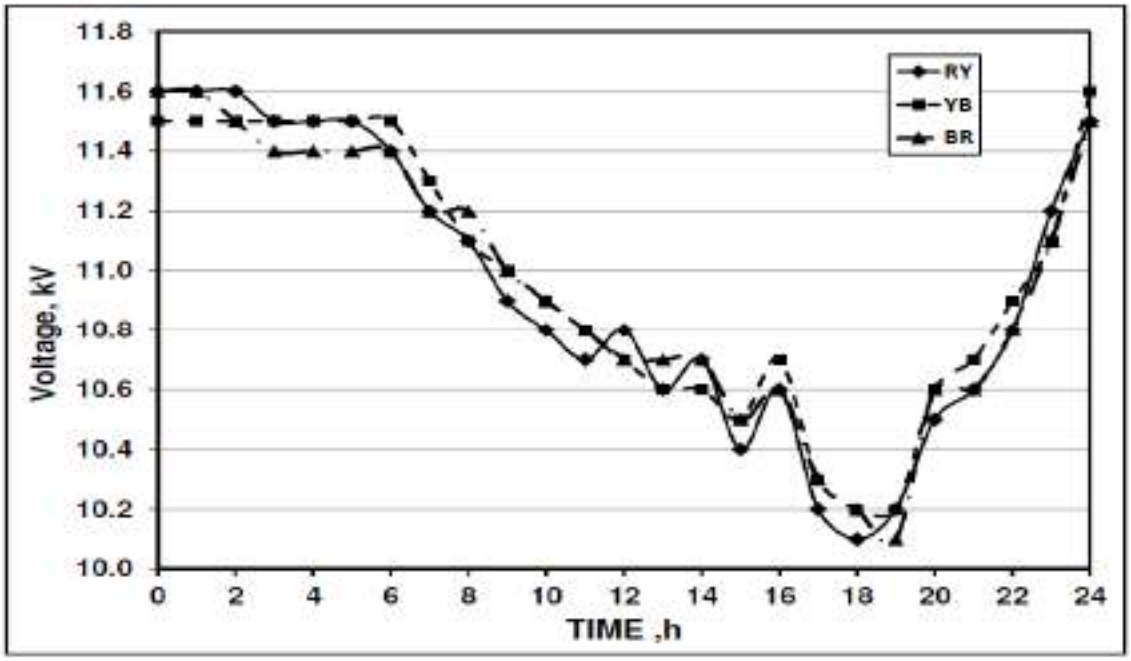

Figure 13: Variation of voltage at main incomer from BESCOM.

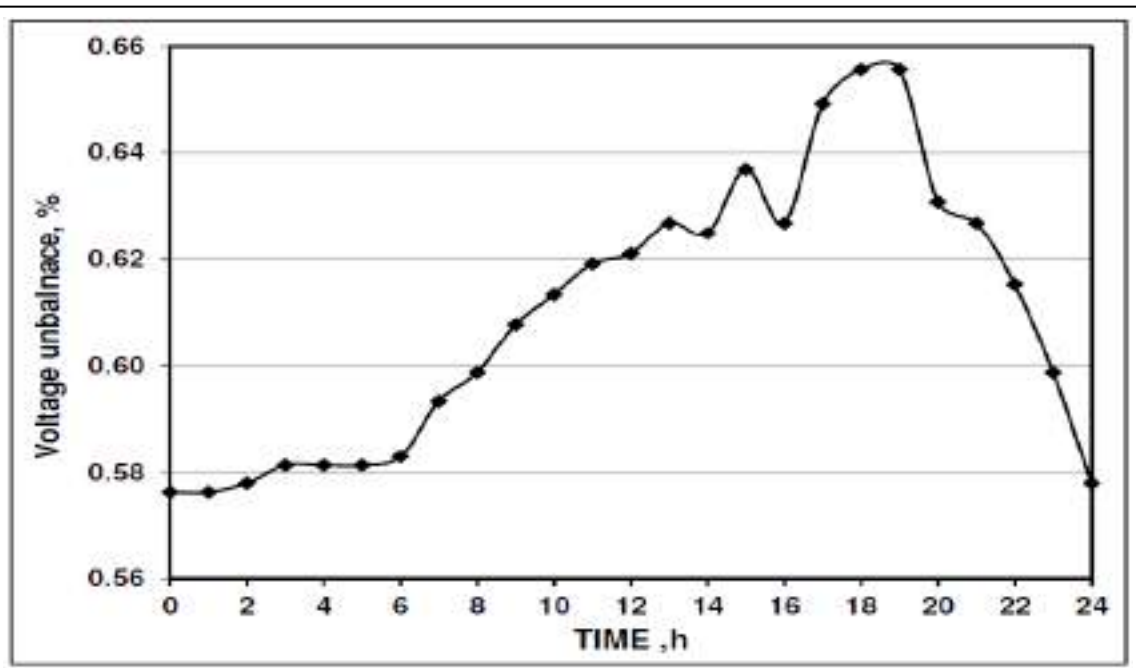

Figure 14: Variation of voltage unbalance at main incomer from BESCOM.

Figure 15 shows the variation of measured current at 11 kV side and is varying between 9.8 to 28.2 A. The load unbalance between 3-phases is varying between

1.5 to 5.9% and is also normal (Figure 16). The capacity reduction of transformers due to load unbalance is about 12%.

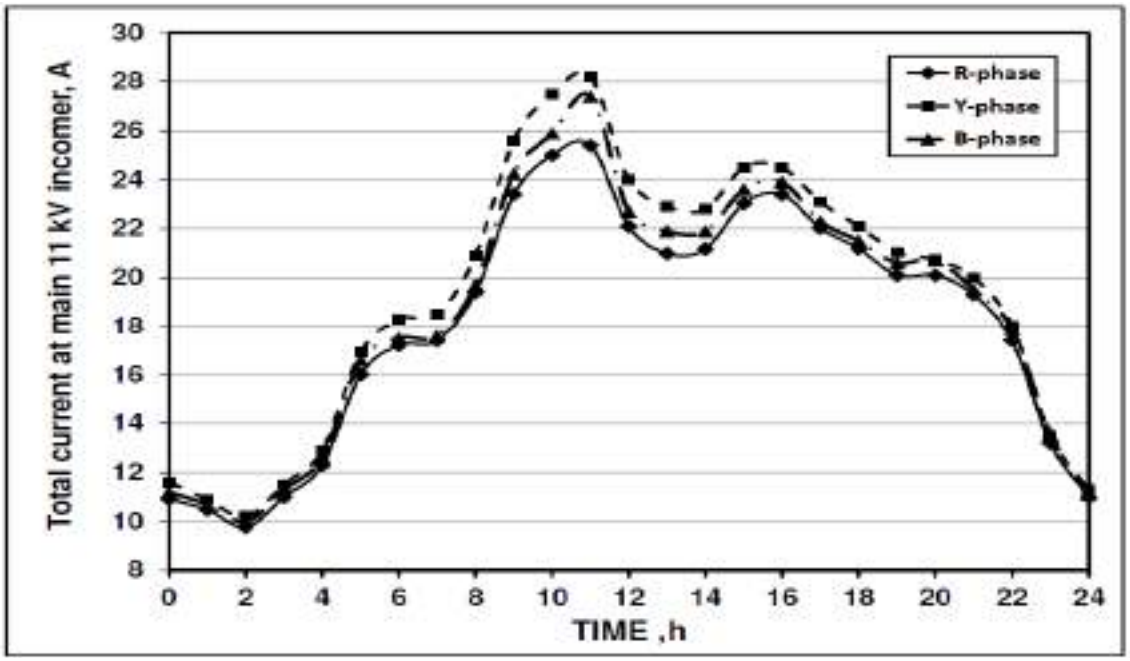

Figure 15: Variation of current at main incomer.

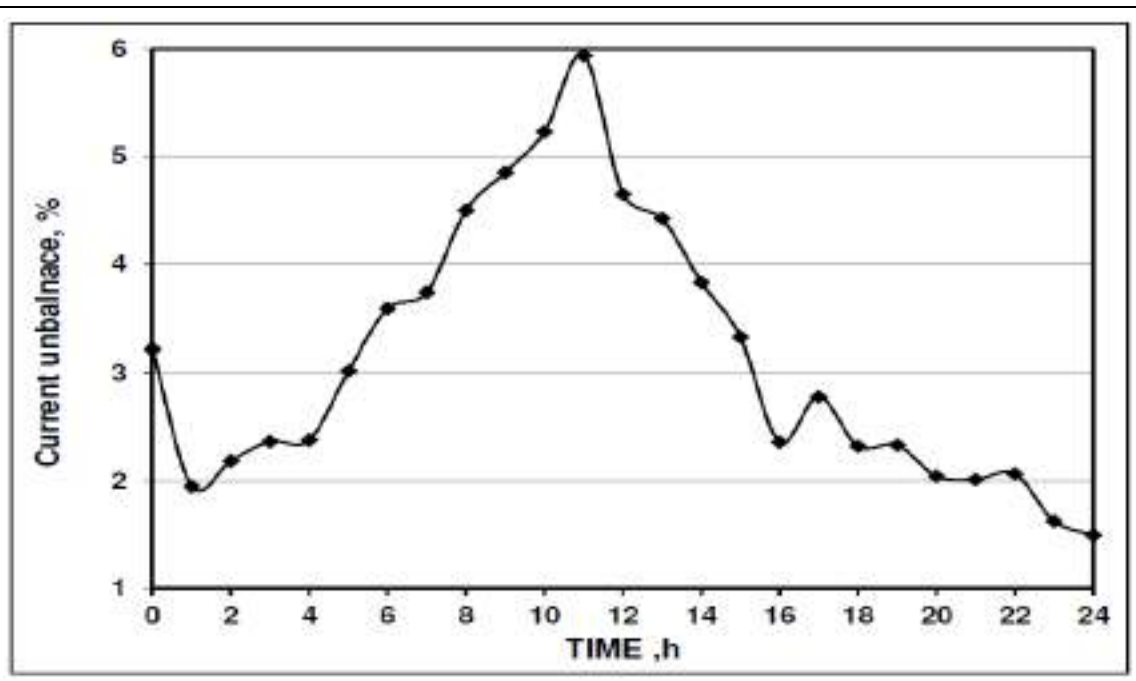

Figure 16: Variation of current unbalance at main incomer.

The peak current through the feeder is 104A and the circuit breaker loading is 41.7%. The cable laid is 3½ core aluminium PVC 400 mm^2 and cable conductor loading is 22.3%. The circuit breaker and cable loading is good. Figure 17 gives the variation of power at RISM feeder for a typical and is varying between 3.6 to 49.0 kW (7.0% of peak demand). The peak power is during 10:00 to 15:00 hours. The computed energy consumption is 375.3 kWh/day that forms about 4.0% of total energy consumption. The built area is 4,704 m^2 and the energy performance index (EPI) is 26.9 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006

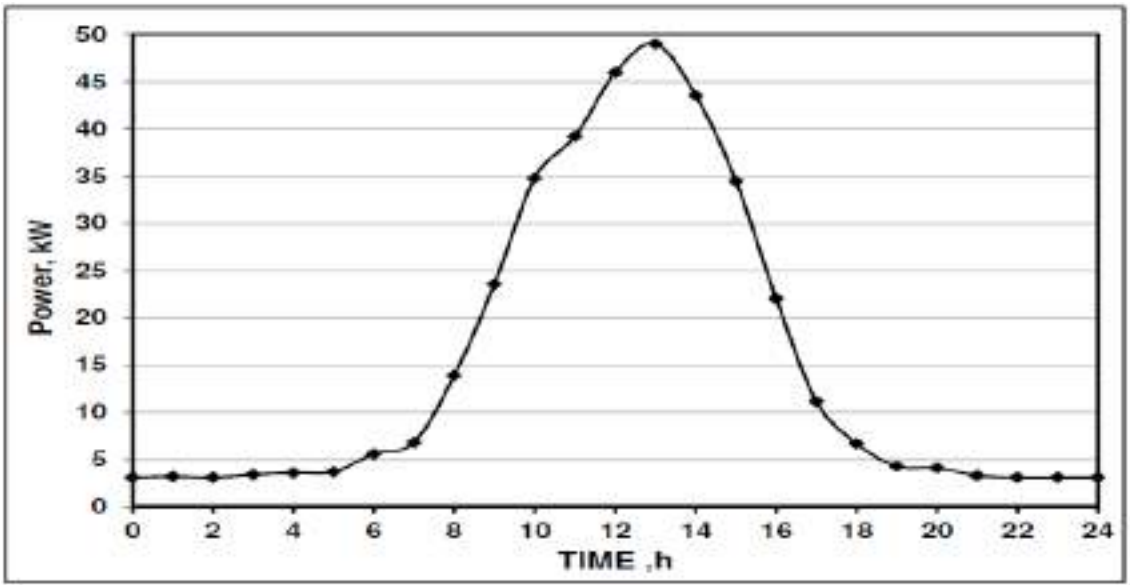

Figure 17: Variation of power at RISM feeder.

The peak current through the feeder is 143A and the circuit breaker loading is 57.2%. The cable laid is 3½ core aluminium PVC 400 mm^2 and cable conductor loading is 30.6%. The circuit breaker and cable loading is good. Figure 18 gives the variation of power at Administrative block feeder for a typical and is varying between 3.5 to 67.3 kW (9.6% of peak demand). The peak power is during 08:00 to 17:00 hours. The computed energy consumption is 633.6 kWh/day that forms about 6.7% of total energy consumption. The built area is 6,836 m^2 and the energy performance index (EPI) is 31.0 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006.

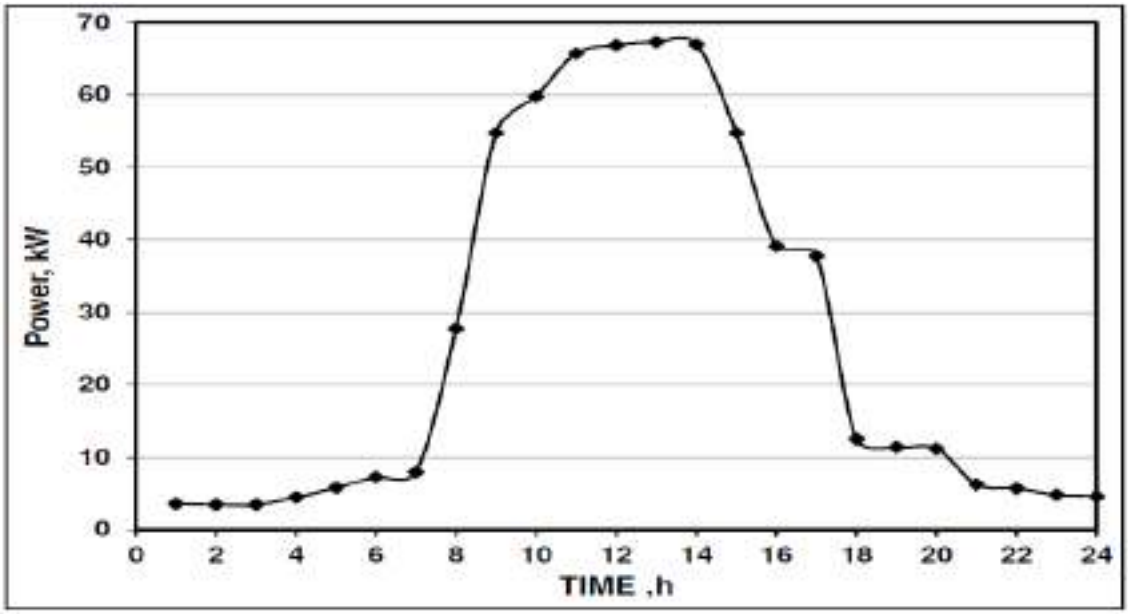

Figure 18: Variation of power at Administration block feeder.

The peak current through the feeder is 264A and the circuit breaker loading is 33.0%. The cable laid is 3½ core aluminium PVC 400 mm^2 and cable conductor loading is 56.5%. The circuit breaker and cable loading is good. Figure 19 gives the variation of power at Vivekananda block feeder for a typical and is varying between 4.3 to 124.0 kW (17.7% of peak demand). The peak power is during 10:00 to 17:00 hours. The computed energy consumption is 1156.1 kWh/day that forms about 12.3% of total energy consumption. The built area is 28,372 m^2 and the energy performance index (EPI) is 13.7 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2 as per ECBC code 2006.

The peak current through the feeder is 194A and the circuit breaker loading is 48.5%. The cable laid is 3½ core aluminium PVC 400 mm^2 and cable conductor loading is 41.5%. The circuit breaker and cable loading is good. Figure 20 gives the variation of power at Sir C V Raman Block feeder for a typical and is varying between 5.0 to 91.2 kW (13.0% of peak demand). The peak power is during 08:00 to 16:00 hours. The computed energy consumption is 824.8 kWh/day that forms about 8.8% of total energy consumption. The built area is 17,785 m^2 and the

energy performance index (EPI) is 15.65 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006.

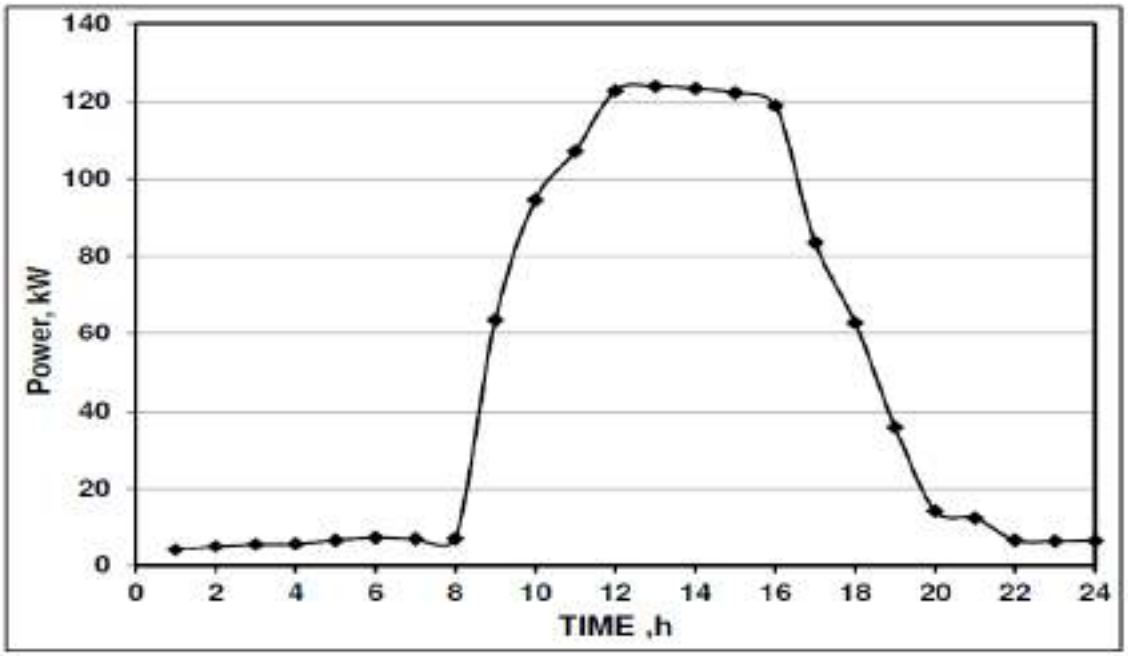

Figure 19: Variation of power at Vivekananda block feeder.

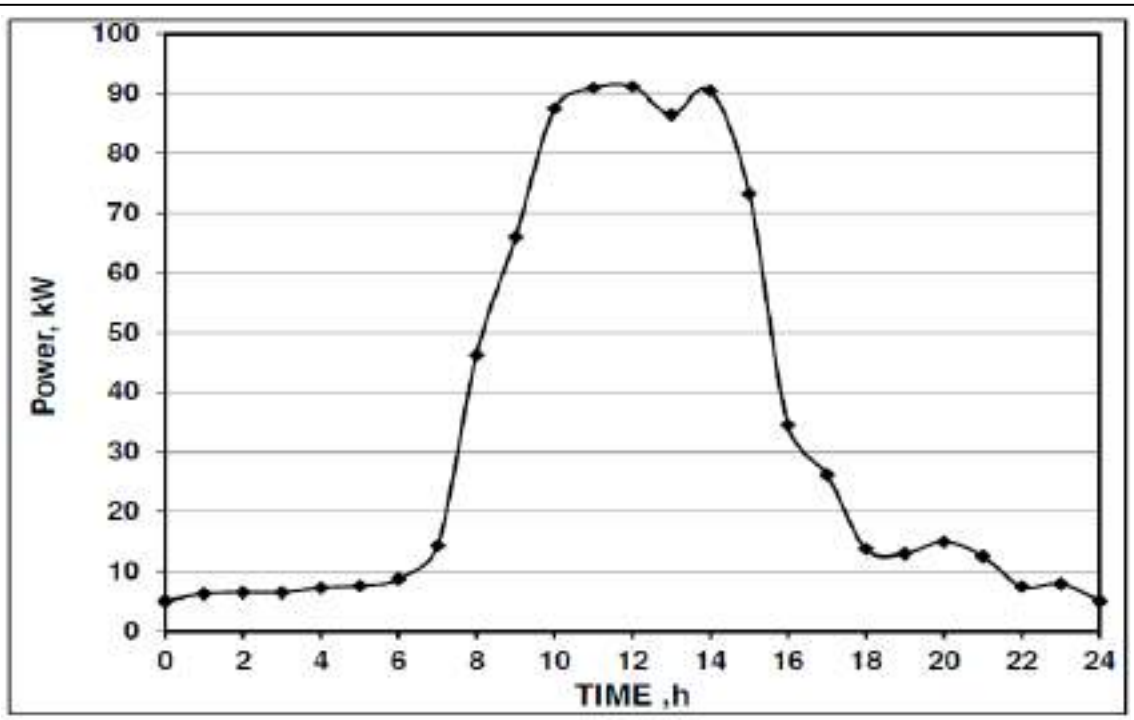

Figure 20: Variation of power at Sir CV Raman block feeder.

The peak current through the feeder is 207A and the circuit breaker loading is 51.8%. The cable laid is 3½ core aluminium PVC 400 mm^2 and cable conductor loading is 44.3%. The circuit breaker and cable loading is good. Figure 21 gives the variation of power at Sir M Visvesvaraya Block feeder for a typical and is varying between 5.0 to 97.3 kW (13.9% of peak demand). The peak power is during 09:00 to 16:00 hours. The computed energy consumption is 821.2 kWh/day that forms about 8.7% of total energy consumption. The built area is 18,218 m^2 and the energy performance index (EPI) is 15.11 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006.

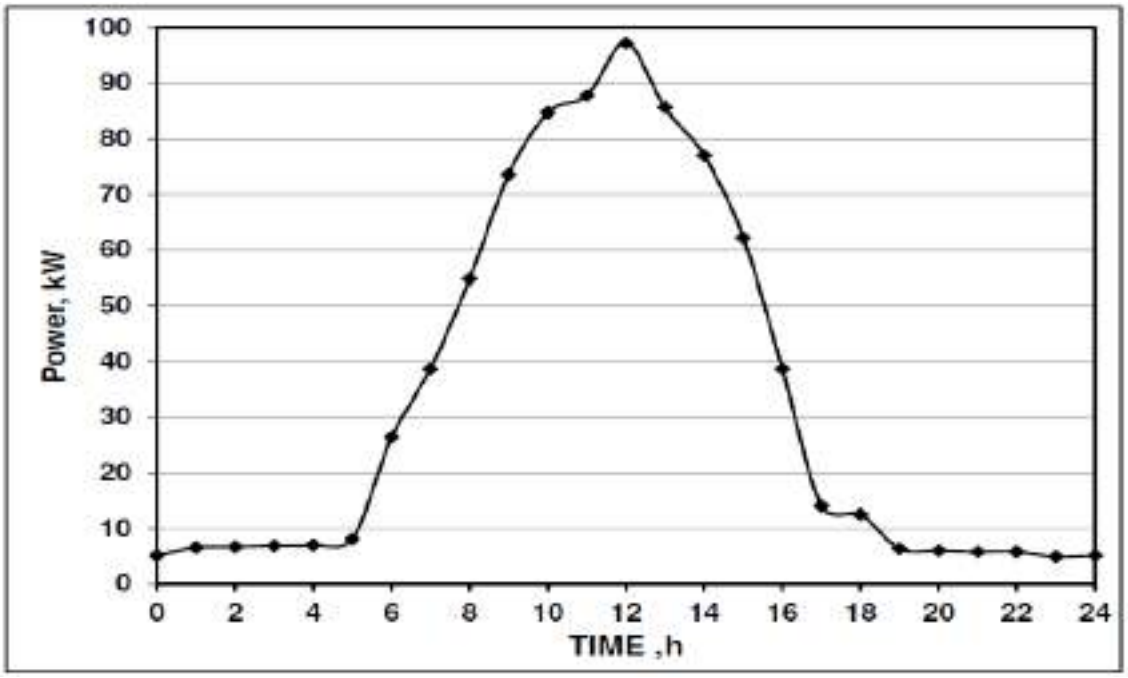

Figure 21: Variation of power at Sir M Visvesvaraya block feeder.

The peak current through the feeder is 33A and the circuit breaker loading is 13.2%. The cable laid is 3½ core aluminium PVC 50 mm^2 and cable conductor loading is 24.6%. The circuit breaker and cable loading is less than the allowable limit of 50%. Figure 22 gives the variation of power at KBL & pump house feeder for a typical and is varying between 1.7 – 15.3 kW (2.2% of peak demand). The peak power is during 09:00 to 13:00 hours and 20:00 to 22:00 hours. The computed energy consumption is 177.6 kWh/day that forms about 1.9% of total energy consumption. The built area is 440 m^2 and the energy performance index

(EPI) is 136.6 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.

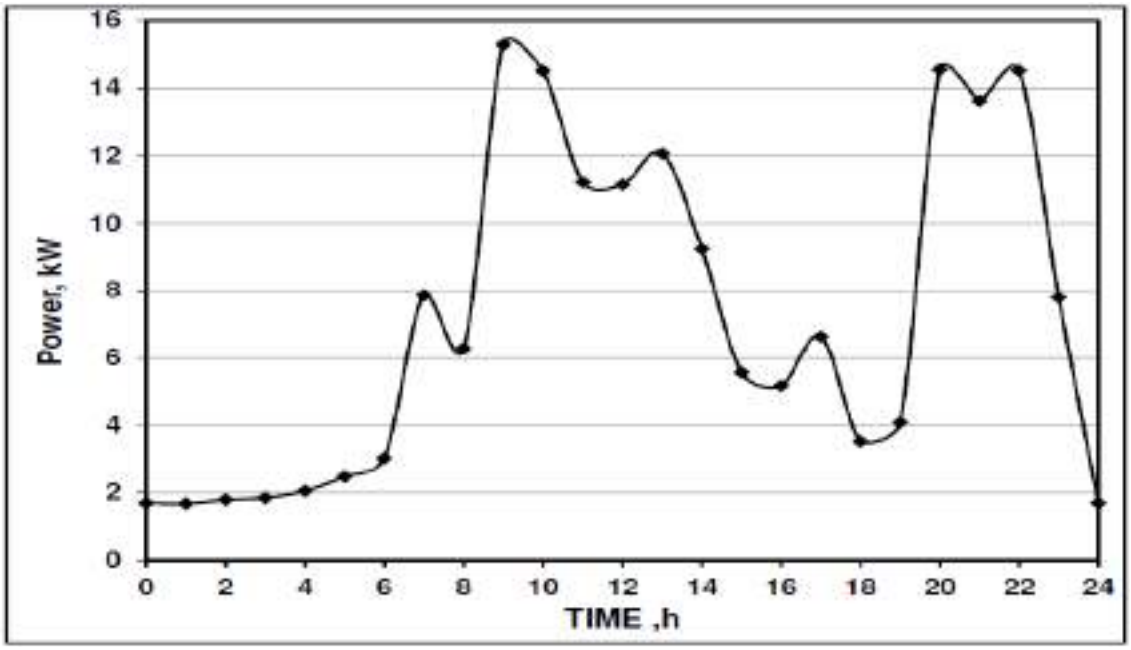

Figure 22: Variation of power at KBL & pump house feeder.

The peak current through the feeder is 384A and the circuit breaker loading is 48.1%. Two parallel runs of 3½ core aluminium PVC 400 mm^2 cables are used and cable conductor loading is 41.1%. The circuit breaker and cable loading is good. Figure 23 gives the variation of power at Hostel Panel 1 feeder for a typical and is varying between 90.3 – 180.7 kW (25.8% of peak demand). The peak power is during 10:00 to 17:00 hours. The computed energy consumption is 3457.8 kWh/day that forms about 36.8% of total energy consumption. The built area is 42,918 m^2 and the energy performance index (EPI) is 27.12 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006.

The peak current through the feeder is 250A and the circuit breaker loading is 62.6%. The cable laid is 3½ core aluminium PVC 400 mm^2 and cable conductor loading is 53.5%. The circuit breaker and cable loading is good. Figure 24 gives the variation of power at Boys Hostel D, girls hostel 1, guest house & STP feeder for a typical and is varying between 28.3 – 117.7 kW (16.8% of peak demand). The

peak power is during 08:00 to 17:00 hours. The computed energy consumption is 1961.3 kWh/day that forms about 20.8% of total energy consumption. The built area is 28,010 m^2 and the energy performance index (EPI) is 23.49 kWh/m^2-year and is lower than the EPI of 120 kWh/m^2-year as per ECBC code 2006.

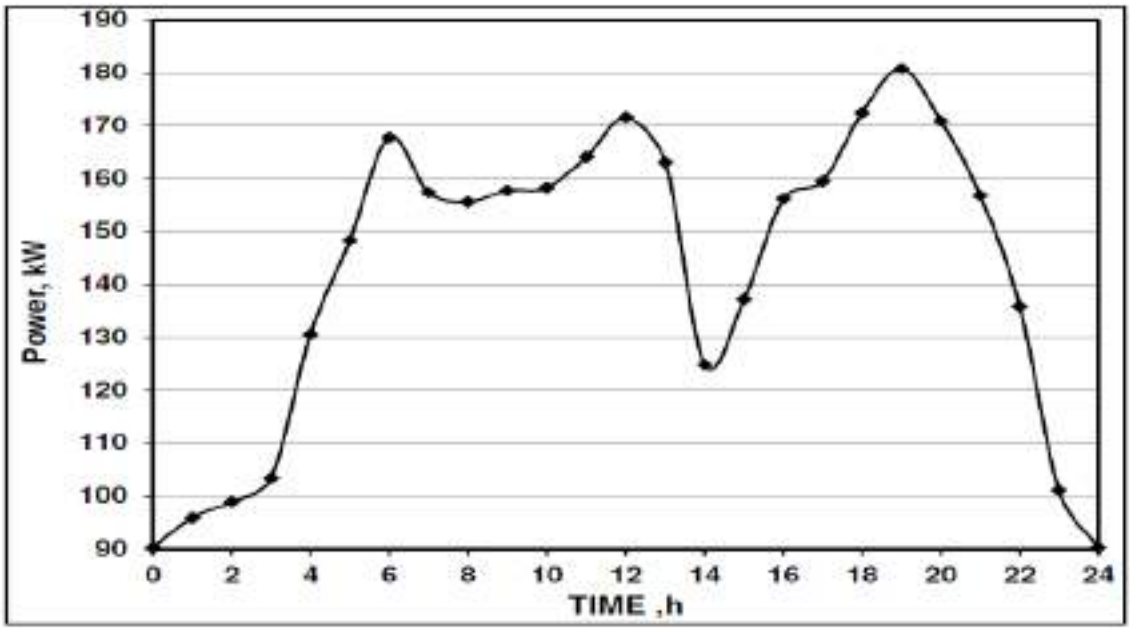

Figure 23: Variation of power at Hostel panel 1 feeder.

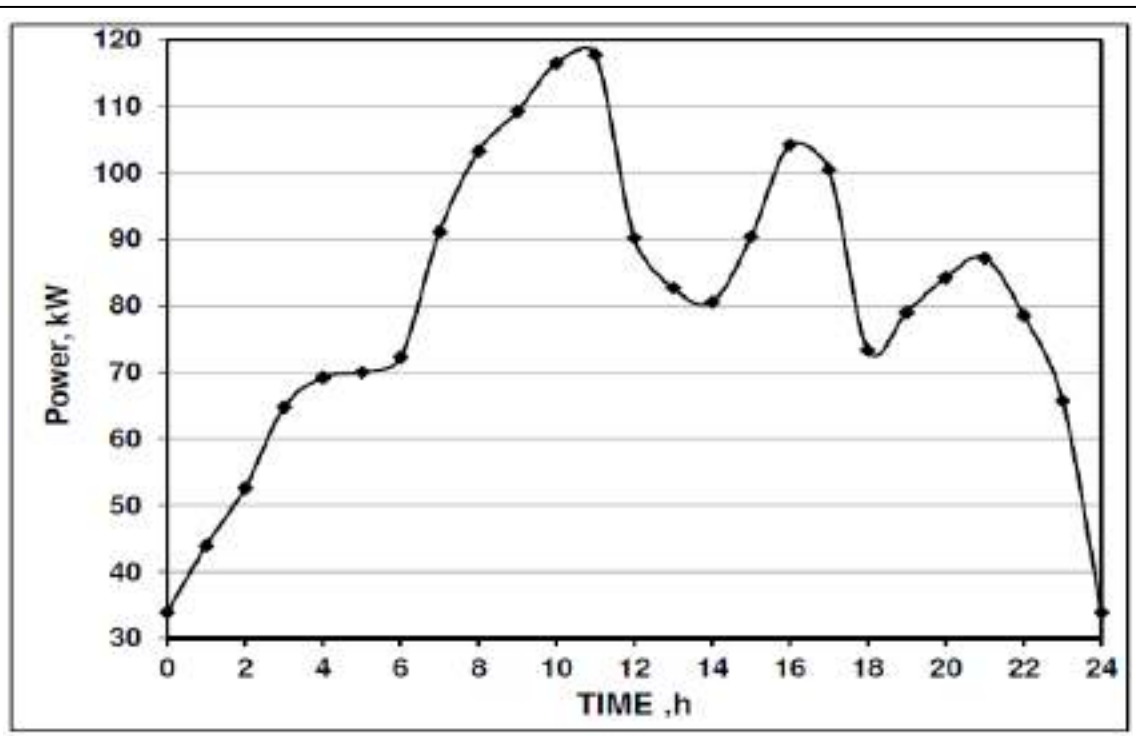

Figure 24: Variation of power at Boys Hostel D block panel feeder.

3.3 Transformers

There are two distribution transformers to step down high voltage of 11 kV to 433 V at main incoming. Figure 25 gives the view of Transformers. The energy loss in transformer is computed as 5,190 kWh/month that forms 0.17% of total energy input. Both transformers are provided with on load tap changers (OLTC) to maintain the secondary voltage. The transformer OLTCs are working properly and the secondary voltage is fixed as 415 V as standard voltage for the distribution which is suitable for operation of equipment even though the transformer secondary is designed as 433 V. OLTCs are adjusting the secondary voltage in the range of 403 to 425 V (-2.9% - +2.4%).

Figure 41: View of Transformers.

Figures 26 and 27 give the variation of voltage at secondary of transformers. The voltage at Tr. 1 secondary is varying between 403 to 425 V (-2.9 to +2.4%) on a typical day whereas at Tr.2 is varying in the range of 406 to 428 V (-2.2 to +3.1%). The voltage variation is quite good. The voltage unbalance between 3-phases (Figure 28) is varying between 0.24 to 0.58% at Tr.1 and at Tr.2 is in the range of

0.32 to 0.56% 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.

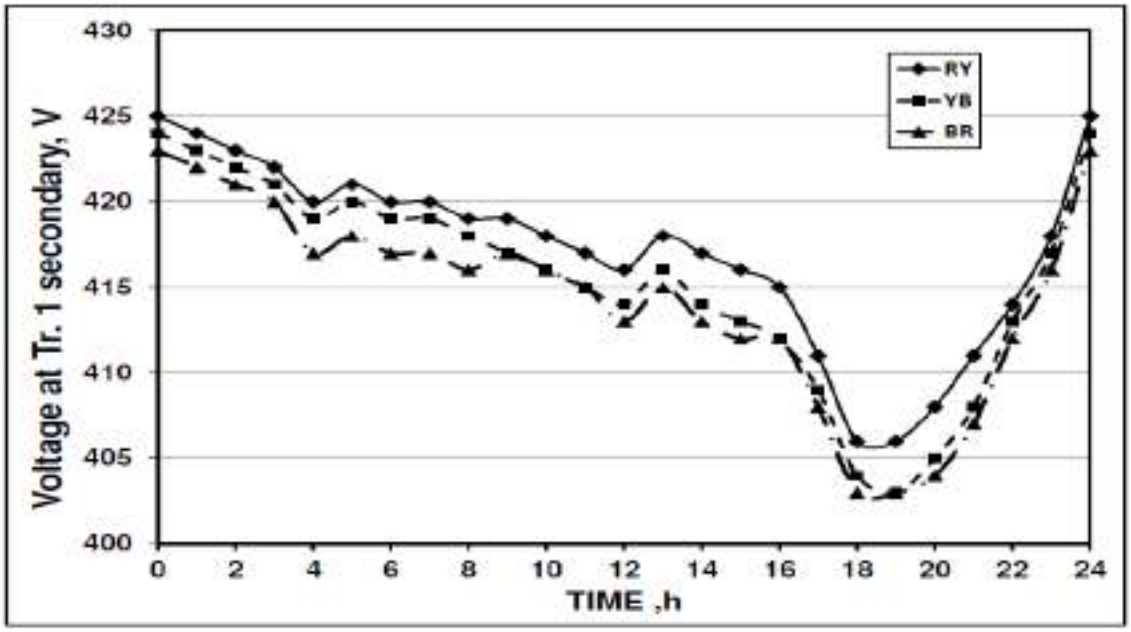

Figure 26: Variation of voltage at Tr.1 secondary.

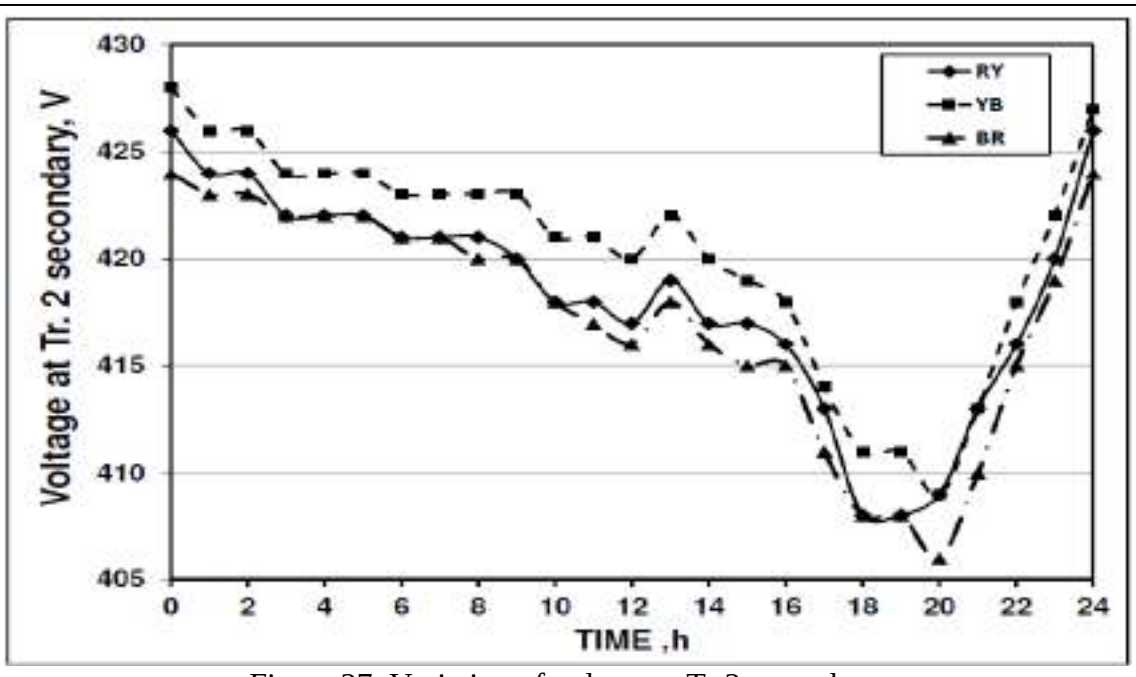

Figure 27: Variation of voltage at Tr.2 secondary.

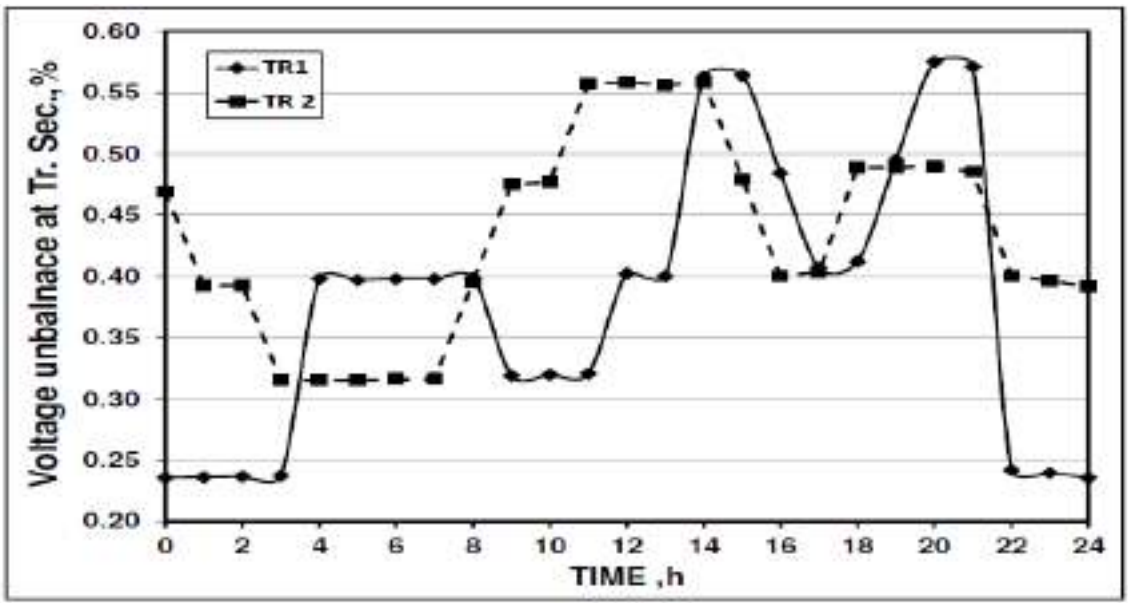

Figure 28: Variation of voltage unbalance at Tr.1 & Tr.2 secondary.

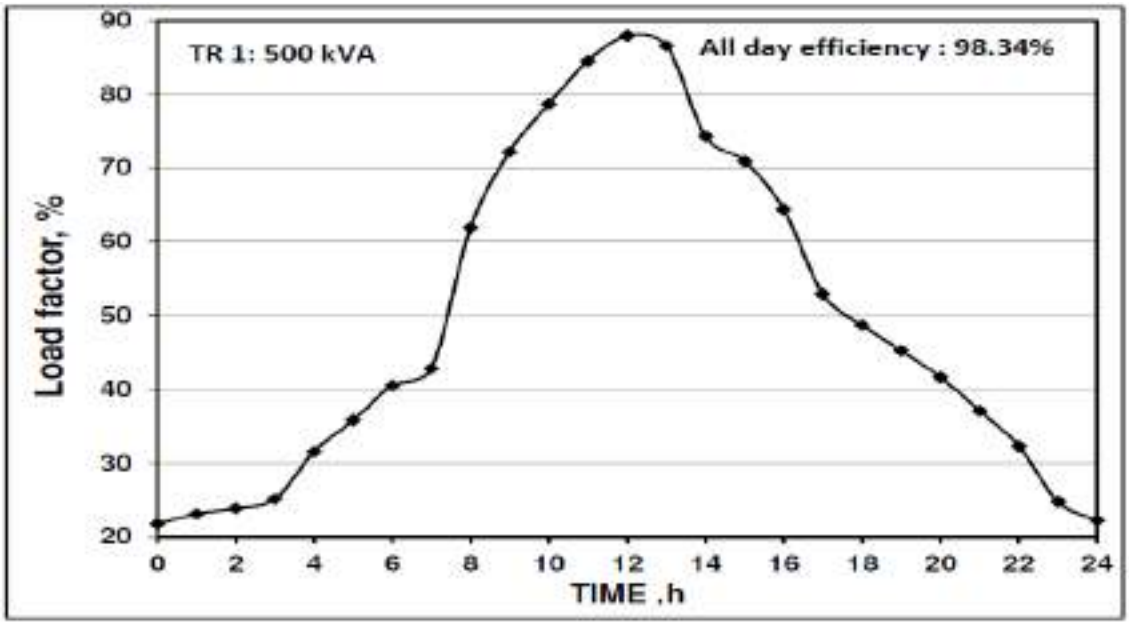

Figure 29: Variation of load factor of Tr.1.

Figures 29 and 30 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 21.8 to 87.9% 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 4.1 to 30.0% but on this transformer the newly renovated Kuvempu auditorium is connected whose load of about 120 – 130 kW will get added. The all day efficiency of transformer 1 is 98.34% which is slightly better than that of transformer 2 of 97.88% because the load on Tr. 2 is less.

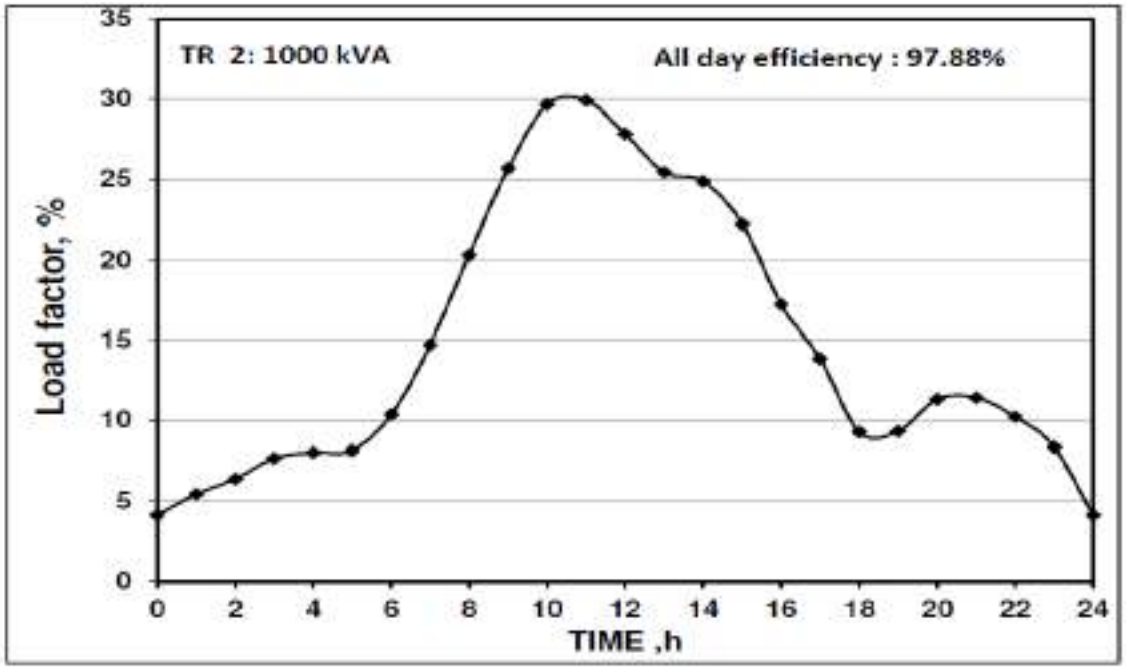

Figure 30: Variation of load factor of Tr.2.

The power factor on transformer secondary is good in the range of 0.91 to 0.96 due to use of automatic power factor controller (APFC) panel. The transformer winding temperature of Tr.1 is varying between 35.6 to 67.3 ^{o}C and at Tr. 2 is recorded in the range of 34.3 to 55.6 ^{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 32.1 to 56.1 ^{o}C at Tr.1 and 30.1 to 53.4 ^{o}C at Tr. 2 which is lower than the limit of 50 ^{o}C above ambient temperature.

Recommendations: It is suggested to divert all the loads on to Tr. 2 (1000 kVA) during day time between 08:00 to 17:00 hours and during evening hours between 17:00 to next day 08:00 hours, the Tr. 1 can be charged with full load. The implementation of this suggestion will change the load factor of Tr.1 in the range of

12.6 to 38.3% (refer Figure 31) and that of Tr. 2 will be in the range of 23.6 to 38.3%. This will reduce the ***energy consumption by 3,045 kWh/month***.

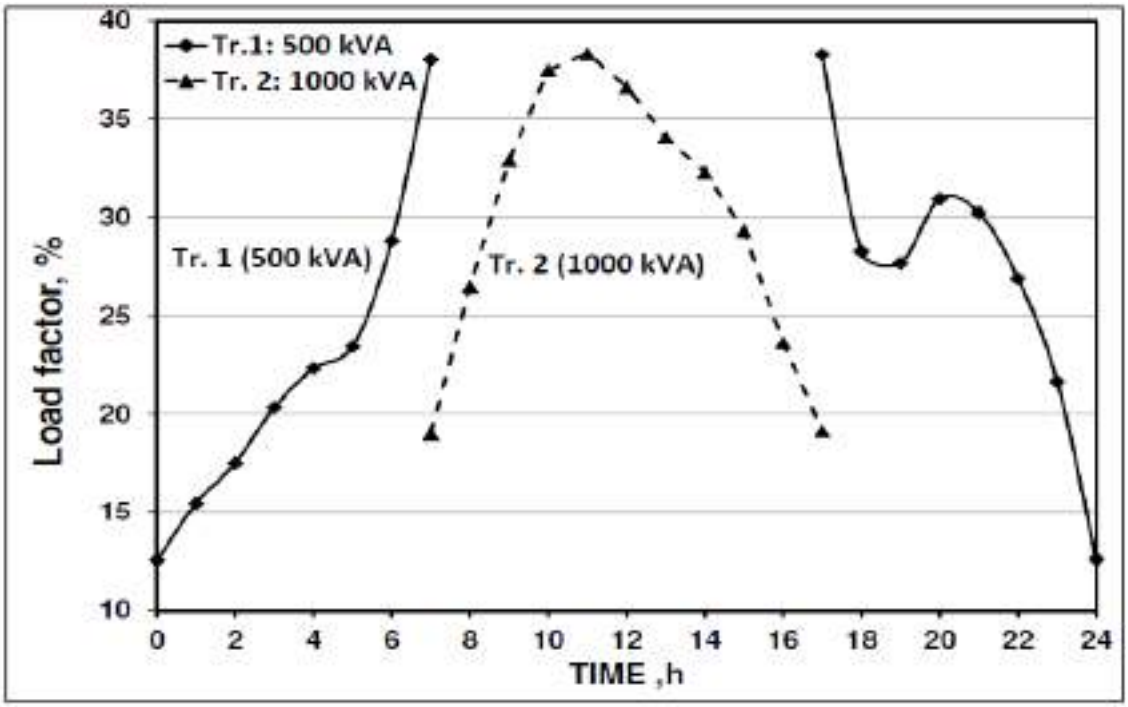

Figure 31: Variation of load factor of transformer after implementation.

3.4 Power factor management

It can be seen from the Figure 4 that the average power factor at main incoming is varying between 0.90 to 0.96 and is good. The automatic power factor controller (APFC) panel with capacitor banks of four numbers of 50 kVAR and two numbers of 25 kVAR. 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 0.92 to 0.98 at LT panels.

3.5 Diesel generator (DG) sets

In order to provide the back-up power supply during BESCOM power supply failure, there are two DG sets of 500 kVA are connected at two LT panels. Figure

32 shows the view of DG sets installed at Campus. Both DG sets are provided with auto close panels. DG sets provide the power supply to entire University including Hostel and quarters during the BESCOM power failure. Figure 33 gives the monthly energy generation by DG sets. The energy generation by DG set 1 is varying between 1,394 to 12,077 kWh/month whereas the energy generation by DG set 2 is in the range of 9.15 to 14,864 kWh/month. The total energy generation by DG sets is varying between 1.6 to 24.7 MWh/month that forms 0.6 to 9.3% of total energy consumption which is less.

Figure 32: View of 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 43.8 & 31.8 % but based on peak phase current the load factor of these DG sets are in the range of 48.1 & 35.7 %. The loading of DG sets is on lower side.
2. The Specific energy generation (SEG) of DG 1 is 3.04 kWh/l whereas SEG of DG 2 is 2.80 kWh/l which is slightly low. The SEG of both DG sets are slightly on lower side may be due to lower loading during the performance tests conducted during energy audit study.

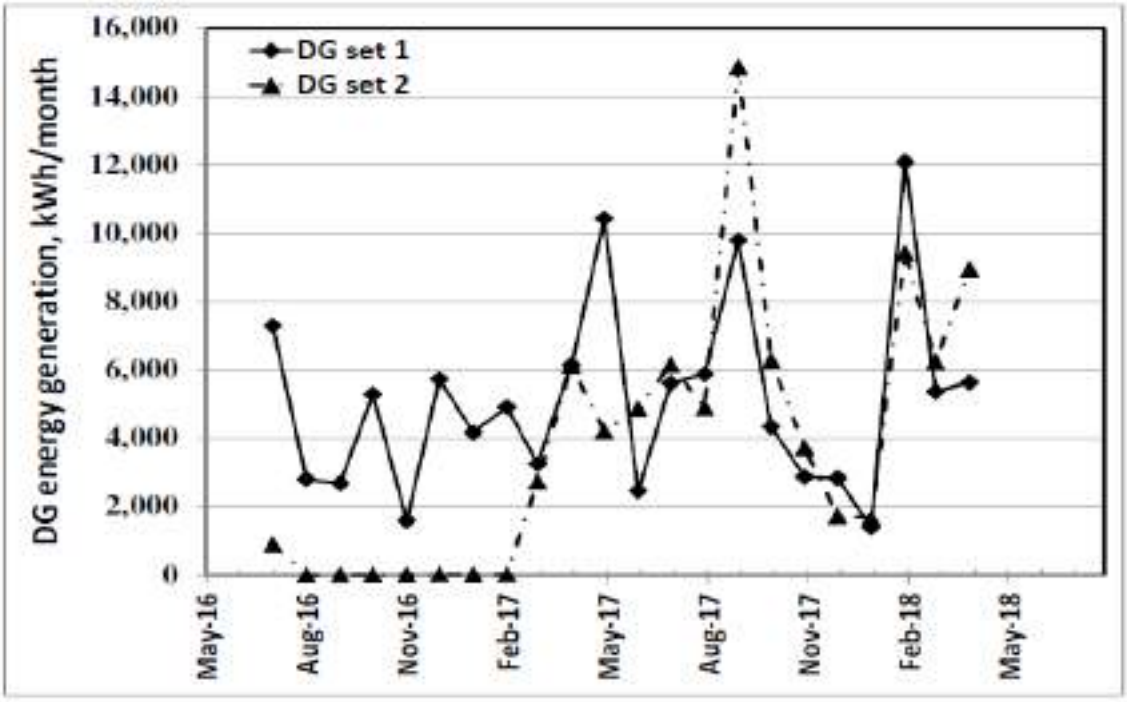

Figure 33: Variation of monthly energy generation by DG sets.

Table 1: Performance results of DG sets.

Sl. No.	Particulars	Unit	DG Set 1	DG Set 2
1	Rating	kVA	500	500
2	Voltage RY	V	410.2	411.1
3	Voltage YB	V	410.6	410.9
4	Voltage BR	V	409.6	411.0
5	Current R	A	313	223
6	Current Y	A	291	238
7	Current B	A	321	209
8	Power factor R	-	0.93	0.91
9	Power factor Y	-	0.93	0.93
10	Power factor B	-	0.95	0.92
11	Power	kW	205.2	146.3
12	Load Factor based on average load	%	***43.8***	***31.8***
13	Load Factor based on peak phase current	%	***48.1***	***35.7***
14	Energy generation	kWh/h	185.6	128.7
15	Oil Consumption	l/h	61	46
16	Specific Energy Generation	kWh/l	3.04	2.80
17	Radiator outlet air temperature	^{o}C	60-62	52-64
18	Radiator inlet air temperature	^{o}C	37-44	35-41
19	Exhaust gas temperature	^{o}C	142-257	113-207
20	Alternator body temperature	^{o}C	48-63	42-54

3.6 Water pumping system

The water is received through water tankers from outside to various sumps and also from borewells inside the campus. The average water received through tankers is about 6.5 to 7.0 lakh litres per day. The energy used for water pumping system is 188.7 kWh/day that forms 2.01% of total energy consumption.

Table 2: Performance results of water pumps

Sl. No.	Particulars	Type	Rating, HP	Measured power, kW	Load factor, %	Control
1	Girls hostel 1	Borewell	5	2.8	75.1	Manual
2	Play ground	Borewell	7.5	3.9	69.7	Manual
3	Play ground	Borewell	5	2.9	77.7	Manual
4	RISM	Borewell	5	3.2	85.8	Manual
5	Sir MV Block	Borewell	5	3.1	83.1	Manual
6	Sir MV Block	Borewell	7.5	4.2	75.1	Manual
7	Hostel B Block	Borewell	5	3.2	85.8	Manual
8	Girls Kitchen	Borewell	5	3.1	83.1	Manual
9	UG sump (PH)	Sump	7.5	4.1	73.3	auto
10	UG sump (A Block)	Sump	7.5	4.2	75.1	auto
11	UG sump (A Block)	Sump	10	6.7	89.8	auto
12	UG sump (B Block)	Sump	7.5	4.5	80.4	auto
13	UG sump (B Block)	Sump	5	3.4	91.2	auto
14	UG sump (A Block)	Sump	5	3.3	88.5	auto
15	UG sump (A Block)	Sump	5	2.9	77.7	auto
16	UG sump (A Block)	Sump	7.5	4.8	85.8	auto
17	UG sump (B Block)	Sump	7.5	4.3	76.9	auto
18	UG sump (C Block)	Sump	7.5	4.5	80.4	auto
19	UG sump (C Block)	Sump	7.5	4.7	84.0	auto
20	UG sump (C Block)	Sump	5	2.9	77.7	auto
21	UG sump (G1 Block)	Sump	7.5	4.5	80.4	auto
22	UG sump (Admin Block)	Sump	5	3.3	88.5	auto
23	UG sump (Admin Block)	Sump	5	3.2	85.8	auto
24	UG sump (Vivekananda Block)	Sump	2	1.4	93.8	auto
25	UG sump (Vivekananda Block)	Sump	2	1.1	73.7	auto
26	UG sump (Vivekananda Block)	Sump	2	1.3	87.1	auto
27	UG sump (Vivekananda Block)	Sump	5	3.4	91.2	auto

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

a) There are about 8 numbers of borewell pumps (5HP – 6 Nos. & 7.5HP – 2 Nos.) to lift the water from ground and are operated manually for about 2 – 3 hours/day.
b) The load factor of these borewell pumps is varying in the range of 69.7 to 85.8% and the water pump 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 UG sump at pump house, 7.5 HP water pump is installed and its load factor is 73.3% which is normal.
e) At UG sump at A Block hostel, 10HP – 1 No., 7.5 HP – 2 Nos. & 5 HP – 2 Nos. water pumps are installed and their load factor of motors is varying between 75.1 – 88.5% which is normal.
f) At UG sump at B Block hostel, 7.5 HP – 2 Nos. & 5 HP – 1 Nos. water pumps are installed and their load factor of motors is varying between 76.9 – 91.2% which is normal.
g) At UG sump at C Block hostel, 7.5 HP – 2 Nos. & 5 HP – 1 Nos. water pumps are installed and their load factor of motors is varying between 77.7 – 84.0% which is normal.
h) At UG sump at G1 Block hostel, 7.5 HP water pump is installed and its load factor of motors is 80.4% which is normal.
i) At UG sump at Admin Block, two numbers of 5 HP water pumps are installed and their load factor of motors is varying between 85.8 to 88.5% which is normal.
j) At UG sump at Vivekananda Block, three numbers of 2HP water pumps are installed and their load factor of motors is varying between 73.7 – 93.8% which is normal.
k) At few places, the gland seal leakage was observed which needs to arrested by replacing the gland seals.
l) The water pump – motors can be overhauled at regular intervals to enhance the energy efficiency of water pumps which will save the energy consumption.

3.7 UPS and Computers & peripherals

The energy used for computers and peripherals is 1679.2 kWh/day that forms about 17.8% of total energy consumption. All these computers are powered through uninterrupted power supply (UPS). The energy consumption at UPS is about 1320 kWh/day that forms 14.0% of total energy consumption. The UPS details are:

a) Sir C.V. Raman Block: 80 kVA x 2 Nos – Avg. load factor: 60-70%.
b) Sir M Visvesvaraya Block: 60 kVA + 80 kVA – Avg. load factor: 40-70%.
c) Vivekanand Block: 80 kVA x 2 Nos – Avg. load factor: 60-70%.
d) Library: 60 kVA x 1 No – Avg. load factor: 60-75%.
e) RISM Block: 30 kVA x 1 No – Avg. load factor: 40-50%.
f) Admin Block: 80 kVA+40 kVA – Avg. load factor: 50-70%.

There are about 2,196 systems and 134 printers of different sizes. The power consumption for the system varies between 350 to 400 W. The power used by printers varies between 300 to 1100 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 energy used for Air-conditioning system is 1328.4 kWh/day that forms about 14.1% of total energy consumption. The total installed cooling capacity of air-conditioning units in REVA University Kattigenahalli campus is 517.1 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) – 2 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) – 2 Nos., 11TR (CSU) – 1 No. & 2TR (split) – 6 Nos.
k) Admin Block GF: 1.5TR (split) – 1 No.
l) Admin Block 5^{th} floor: 7.5TR (CSU) – 3 Nos., 11TR (CSU) – 1 No., 10TR (CSU) – 1 Nos., & 12.5TR (CSU) – 2 No.
m) Admin Block 6^{th} floor: 2TR (cassette) – 16 Nos. & 1TR (cassette) – 2 Nos.
n) Vivekananda Block: 2.5TR (cassette) – 5 Nos., 3TR (cassette) – 2 Nos. & 2TR (split) – 6 Nos.
o) Vivekananda Block 7^{th} floor seminar hall: 3TR (cassette) – 4 Nos.
p) Vivekananda Block GF & FF: 2.5TR (split) – 3 Nos., 3TR (split) – 4 Nos., 3TR (cassette) – 1 No., 0.8TR (split) – 4 Nos., 1TR (split) – 8 Nos., 1.5TR (split) – 3 Nos., 2.5TR (cassette) – 4 Nos. & 2.0TR (cassette) – 2 Nos.

The specific cooling capacity of air-conditioning system varies between 1231 to 1698 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 1.25 to 1.67 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 22 – 23 ^{o}C which should be maintained above 25^{o}C (human comfortable) which will reduce the energy consumption by 3% per degree of room temperature. The anticipated ***energy saving is 400 kWh/month***. The relative humidity in the air-conditioning room is being maintained in the range of 40 to 58 % and is good.

3.9 Renewable energy Systems

3.9.1 Present 55 kW Solar PV power plant

At Administrative block 55 kW solar power plant is installed to provide the power supply to loads at administrative block. There are four inverters of 15 kVA each and 220 Numbers of 250 W_p each solar photovoltaic panels are installed. Figures 34 & 35 show the view for 55 kW solar PV power plant. Figure 36 shows the variation of energy at inverters and the energy generation at inverters are:

a) Inverter 1: 1203 to 1867 kWh/month
b) Inverter 2: 1503 to 2208 kWh/month
c) Inverter 3: 1632 to 2312 kWh/month
d) Inverter 4: 1391 to 2024 kWh/month

Figure 34: View of solar PV panels for 55kW Solar PV power plant at Admin Block

Figure 35: View of inverters of 55 kW Solar PV power plant at Admin Block

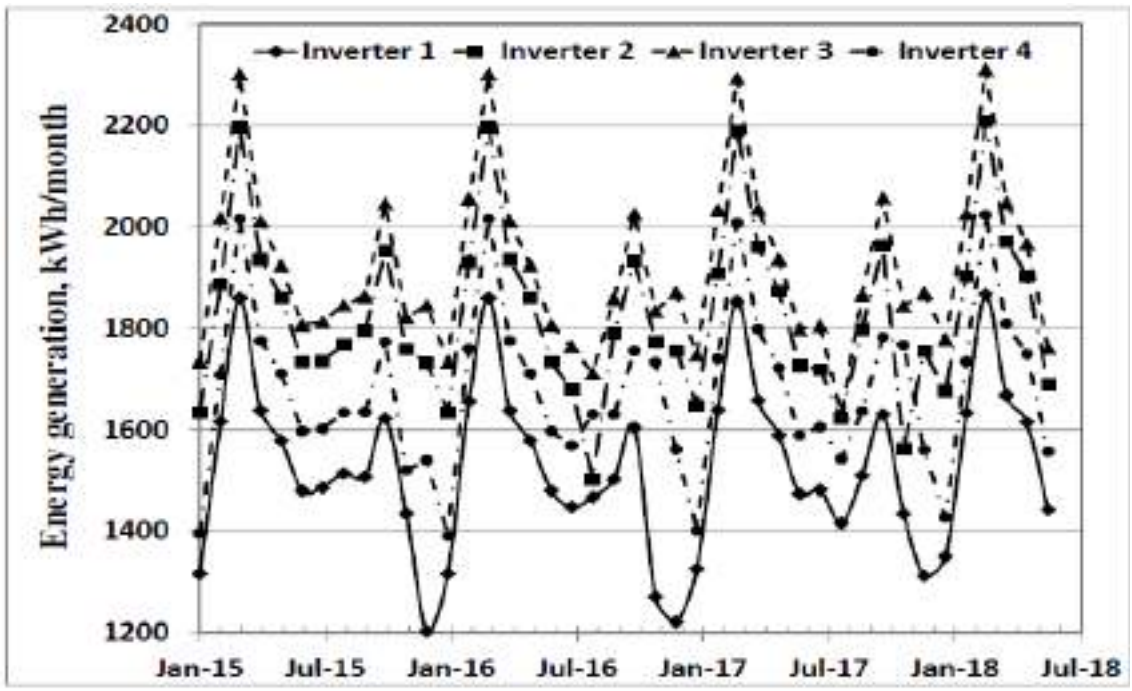

Figure 36: Variation of monthly energy at Solar PV inverters.

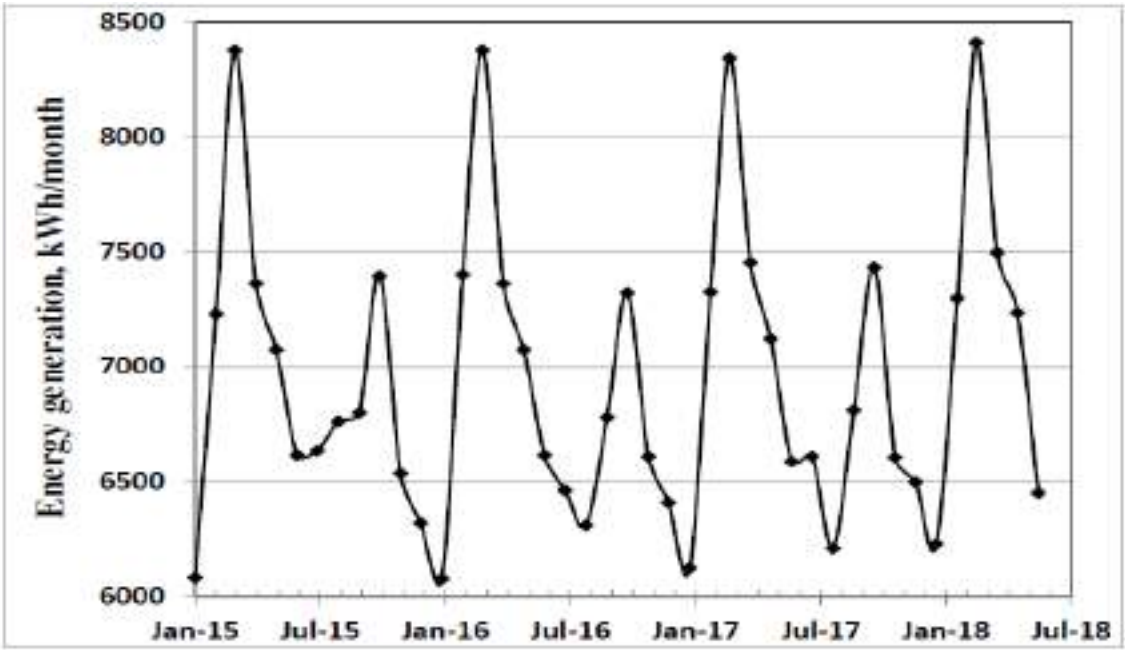

Figure 37: Variation of total energy generation by 55 kW Solar PV power plant.

The energy generation is less during Jan. month and is high during March month. Figure 37 gives the variation of monthly total energy generation by solar PV power plant for last three years. The generation varies between 6076 to 8411 kWh/month. The annual solar energy generation and its share are:

a) Year 2015: 83,197 kWh/y (4.08% of total energy consumption)
b) Year 2016: 82,808 kWh/y (3.03% of total energy consumption)
c) Year 2017: 83,136 kWh/y (2.78% of total energy consumption)
d) Year 2018 upto June: 43,123 kWh/y (2.92% of total energy consumption)

This solar PV power plant reduced the CO_2 emission in the range of 86.9 t/y to 87.4 t/y (average of 2.92% of total CO_2 emission). The average specific energy generation by solar PV power plant is slightly lower in the range of 4.12 kWh/kW-day to 4.14 kWh/kW-day.

3.9.2 New 500 kW Solar PV power plant proposed

The electrical energy from conventional source cause environmental pollution like CO_2 emission. The average CO_2 emission in Indian coal based thermal power

plants is 1.05 t/MW. At REVA University, the energy consumption is 3,163.3 MWh/month that contribute CO_2 emission of 3,320 t/y.

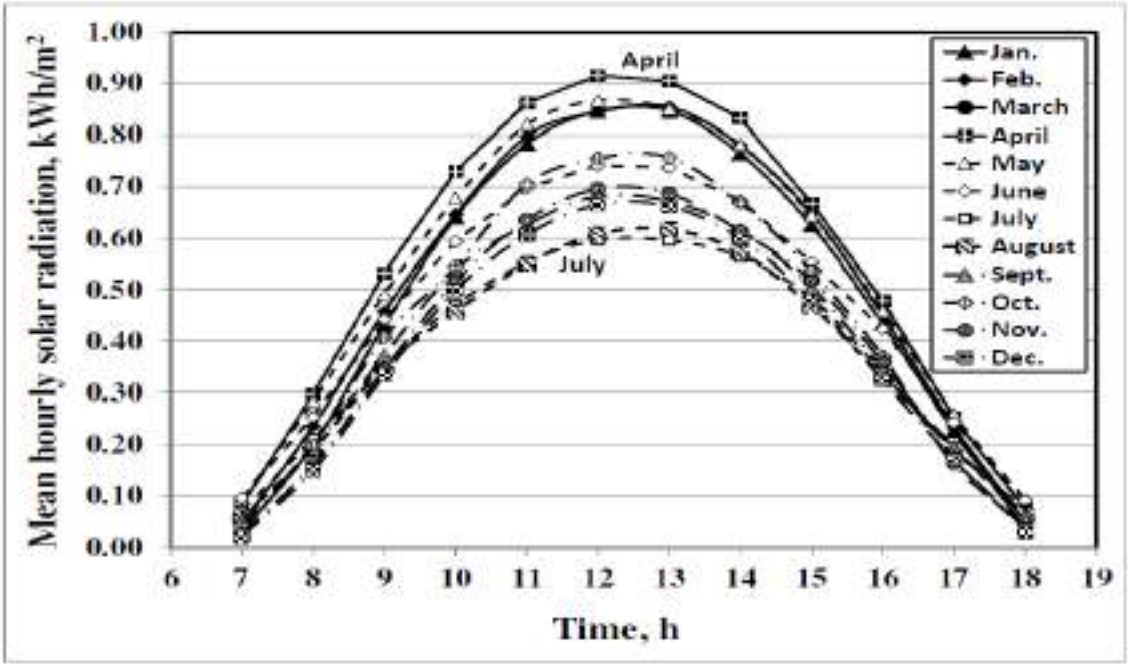

Figure 38: Variation of solar insolation at site.

The hourly solar insolation is measured at site for a typical one year and computed monthly average energy availability (refer Figure 38). The solar power output depends on the availability of solar insolation for the whole year because during winter seasons the solar insolation will be less whereas during summer it will be more. The solar power generation starts at 7:00 hours morning, gradually increases to peak value i.e., near to 915 W/m^2 around 12:00 to 13:00 hours at standard test condition at about 25^{o}C ambient condition and then starts decreasing the solar power till about 18:00 hours. The solar insolation is high during the months of March & April whereas during July & August the insolation is less. The sun hour can also be represented as specific energy generation (SEG) i.e., the total energy generation per m^{2}per day. The sun hours depends on the climatic conditions, during summer the sun hour is high whereas winter it is less (in India that varies between 3 to 7 hours).

The monthly average of daily specific energy generation at the site is given in Figure 39 and is varying between 4.46 kWh/m^2-day to 6.72 kWh/m^2-day.

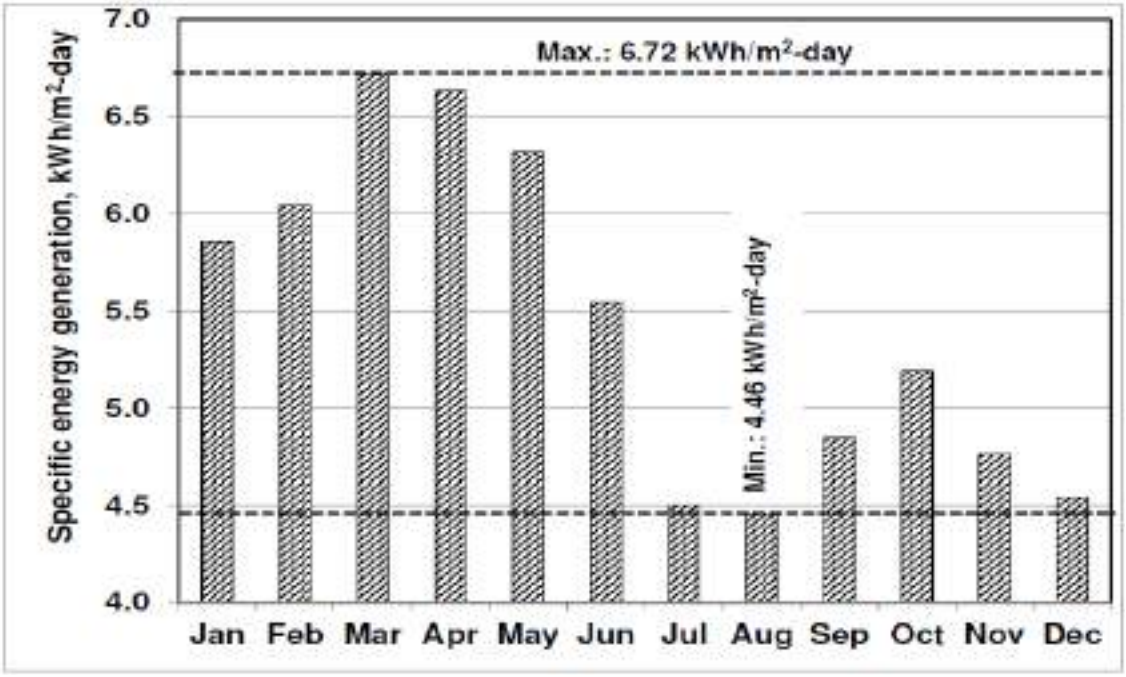

Figure 39: Variation of monthly average SEG.

The SPV power plant is designed considering the optimum SEG. The average daily energy consumption for Institute is 9407.6 kWh/day and the maximum power is 700 kW (April 2017). The SPV power plant size (m^2) is computed by

$$PS = \frac{LE_d}{SEG} \times \frac{100}{\eta_{SPV}}$$

Where LE_d is the daily energy consumption by the load (kWh/day), SEG is the daily specific energy generation (kWh/m^2-day) and η_{SPV} is the overall SPV power plant efficiency (%) which is considered as 12.5%.

The peak power rating (kW) of SPV power plant is computed as:

$$P_{SPV} = \frac{PS}{SA}$$

Where SA is specific area to produce unit power (m^2/kW) and generally considered as 6 m^2/kW

If the SPV power plant is designed considering the minimum SEG of 4.46 kWh/m^2-day, the area required will 16,875 m^2, the peak power rating of SPV power plant

will be 2,812 kW, the average energy generation will be 4,7948 MWh/y and the excess energy generation will be 1631 MWh/y (51.6% of energy requirement) which need to be exported to grid. On the other hand if the SPV power plant is designed considering the maximum SEG of 6.72 kWh/m^2-day, the area required will be 11,200 m^2, the peak power rating of SPV power plant will be 1867 kW, the average energy generation is 3,183 MWh/y and the excess energy generation will be 20 MWh/y (0.6% of energy requirement) which need to be exported to grid.

Figure 40: Free roof top available for solar PV at REVA University .

But the actual free roof available area on the buildings is 3,160 m^2 (Figure 40). The maximum solar PV power plant that can be installed is about 527 kW. The solar PV power plant is chosen is 500 kW.

The energy generation by SPV power plant of 500 kW is estimated by using HOMER software as well as modelled using MATLAB Simulink tool. The energy consumption for the year 2017 is considered for energy requirement.

Figure 41 shows the variation of monthly average daily power variation for the year 2017. It can be seen from the Figure that the load is less during Jan. (208.7 MWh/month) and is more during April (284.7 MWh/month) month.

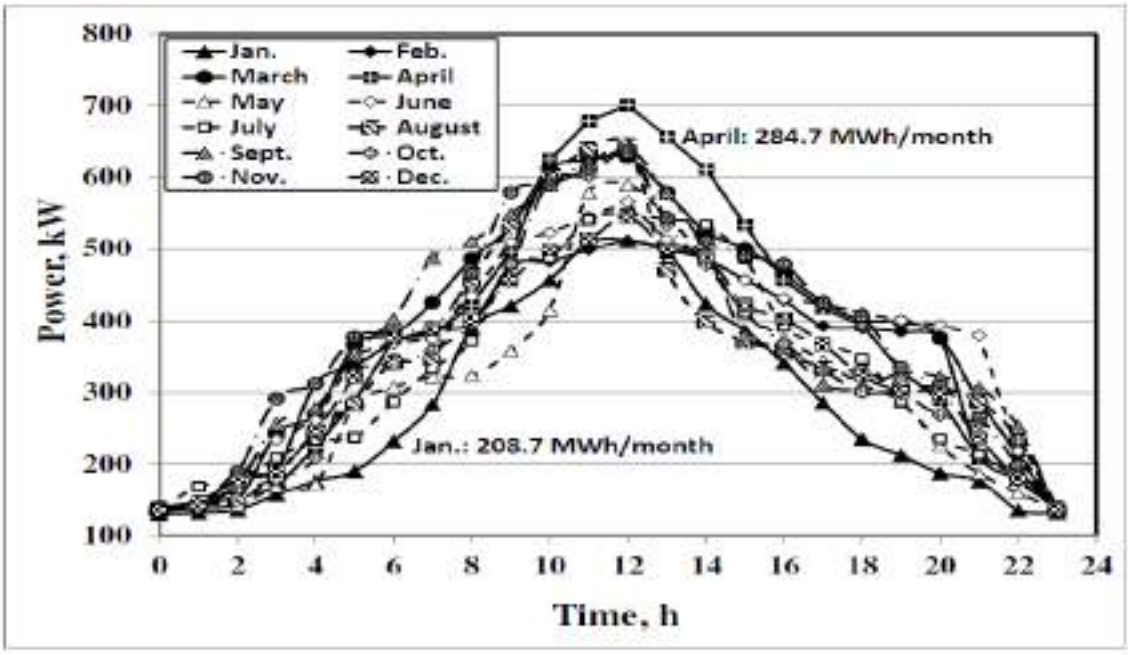

Figure 41: Variation of monthly average daily power.

Figures 42*a* to 42*l* show the variation of monthly average daily power requirement by load, power generated by SPV plant and power import from grid for all twelve months. During night hours the power is imported from grid whereas during day hours, the power is supplied by SPV power plant. The peak power requirement is between 10:00 to 13:30 hours and also the power generation by solar PV power plant is also peak during 11:00 to 13:00 hours.

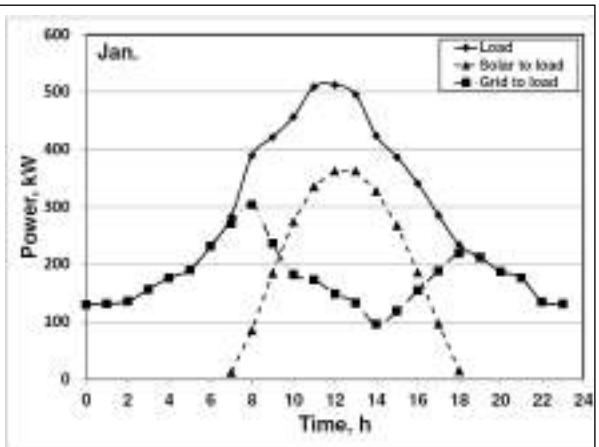

Figure 42 a)

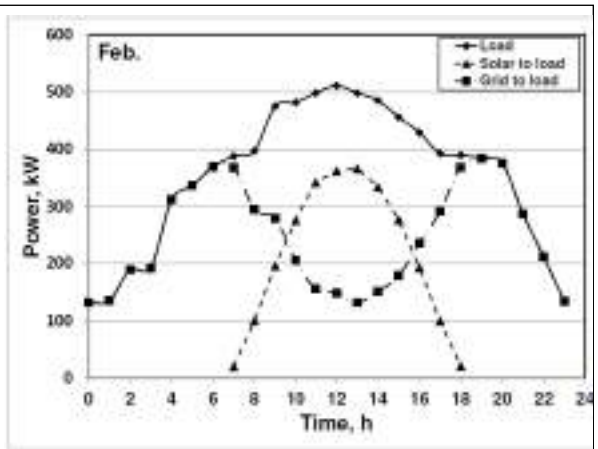

Figure 42 (b)

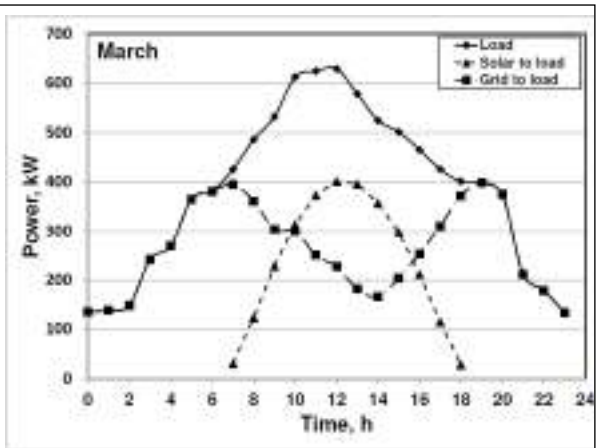

Figure 42 (c)

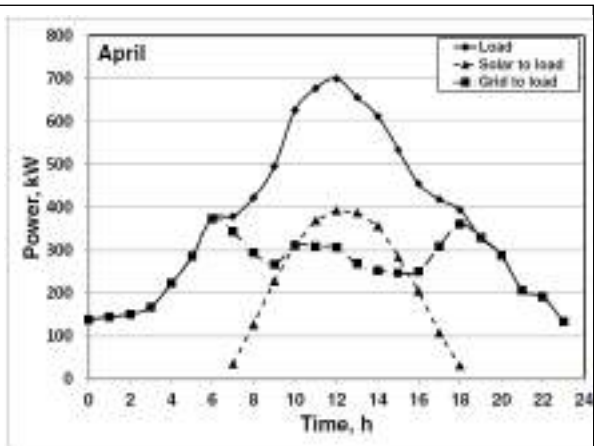

Figure 42 (d)

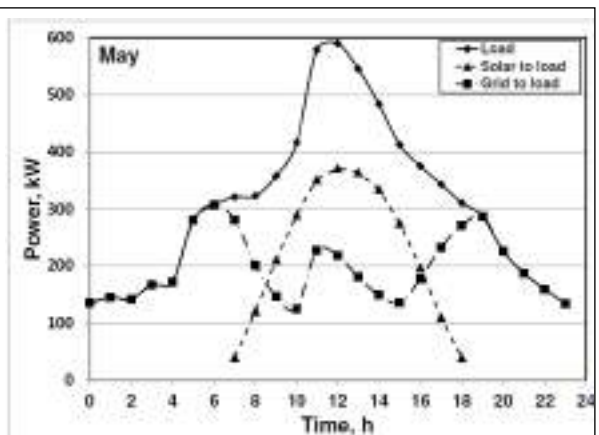

Figure 42 (e)

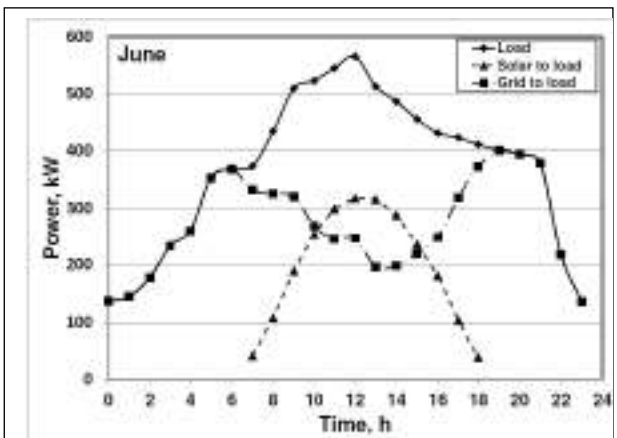

Figure 42 (f)

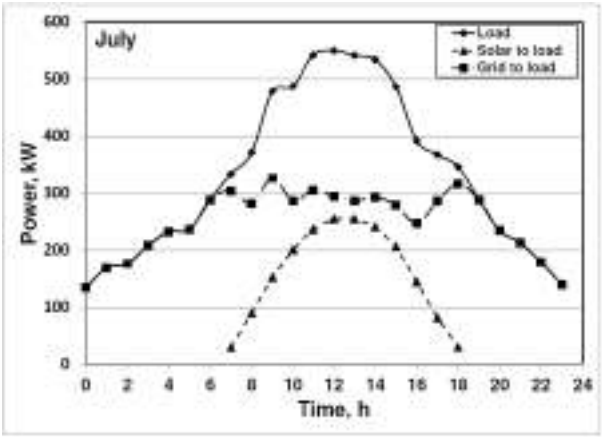

Figure 42 (g)

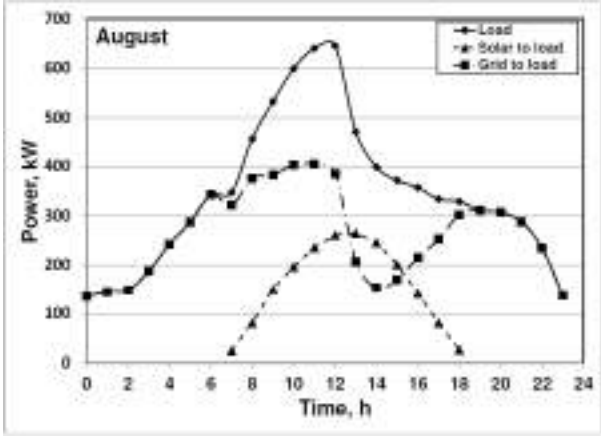

Figure 42 (h)

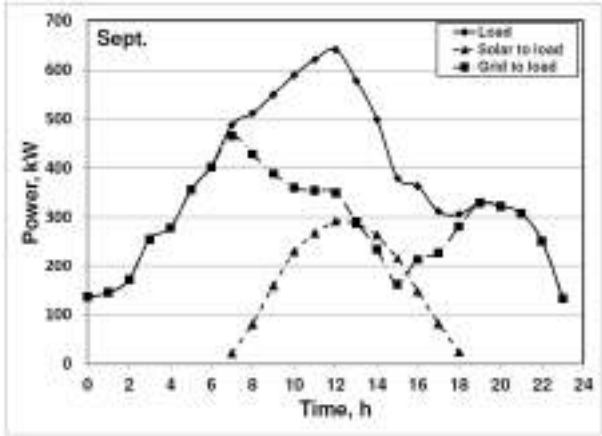

Figure 42 (i)

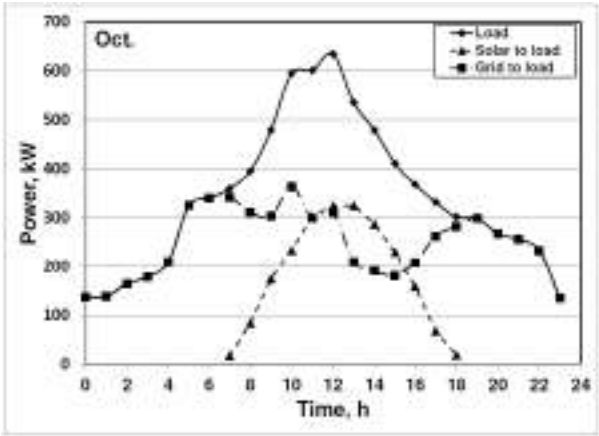

Figure 42 (j)

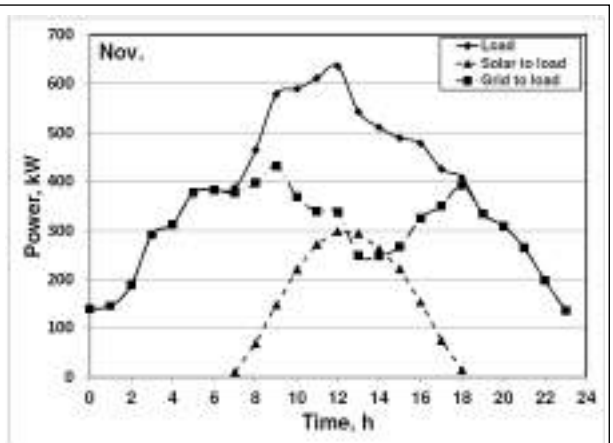

Figure 42 (k)

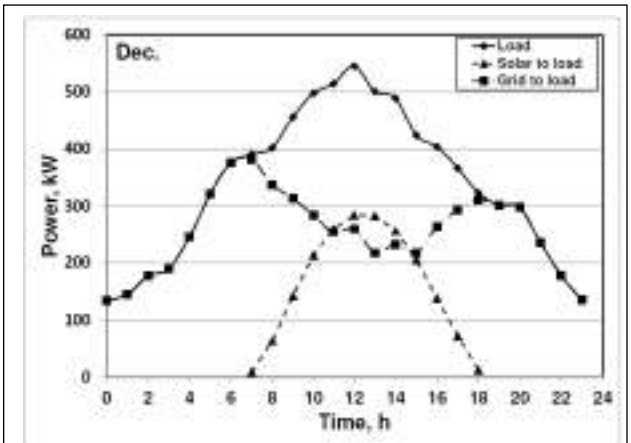

Figure 42 (l)

Figure 43 presents the bar graphs of monthly SPV power plant energy generation, load demand and energy share by SPV power plant during one year. Table 3 gives the balance of the solar PV power plant and grid energy. The energy consumption varies between 208.7 MWh/month (Jan.) to 284.7 MWh/month (March) and the deviation in energy consumption is 20.8% which is normal. The energy generation by SPV power plant varies between 59.23 MWh/month (August) and 89.27 MWh/month (March) that forms in the range of 22.2 – 37.3% of total energy consumption. The deviation in energy generation by SPV power plant is 42.3% which is slightly high due to variation in climatic condition. The energy import from grid varies between 130.8 MWh/month (Jan.) to 221.9 MWh/month (Nov.). The deviation in energy import from grid is 33.9% and is high due to variation in energy demand by the institute. The specific annual energy generation by SPV power plant is 4.67 kWh/day/kW or 1.70 MWh/kW/y which is quite good.

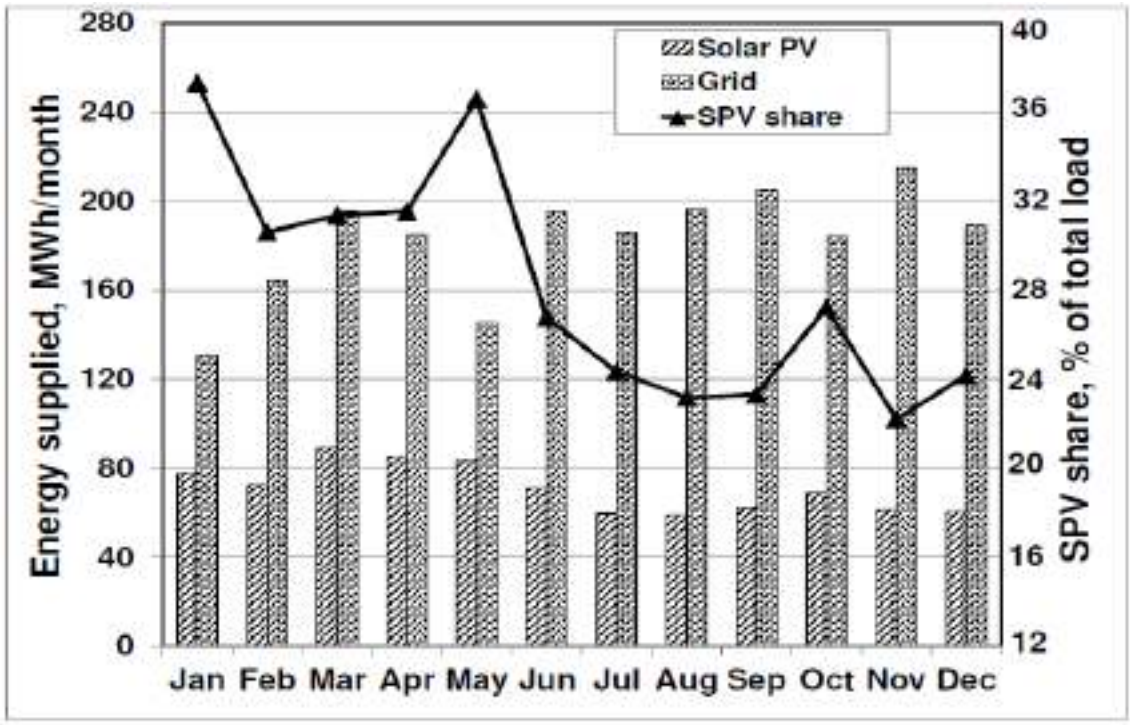

Figure 43: Total energy generation by SPV & energy import from grid.

Table 3: Energy balance of solar PV & grid energy

Months	Load energy (MWh/month)	SPV energy gen.		Grid to load, (MWh/month)
		MWh/month	%	
Jan	208.7	77.89	37.32	130.8
Feb	237.0	72.56	30.61	182.1
Mar	284.7	89.27	31.35	195.5
Apr	270.4	85.26	31.53	191.3
May	229.6	84.00	36.58	145.6
Jun	266.4	71.33	26.77	201.6
Jul	245.8	59.82	24.33	186.0
Aug	255.6	59.23	23.18	196.3
Sep	267.7	62.41	23.32	212.1
Oct	253.4	68.98	27.22	184.4
Nov	276.0	61.29	22.21	221.9
Dec	249.7	60.34	24.17	189.3
Total	**3045.02**	**852.38**	**27.99**	**2236.94**

The economics for the implementation of SPV power plant is computed. The average cost for 500 kW SPV power plant after considering the 30% subsidy offered by Solar Energy Corporation of India (SECI) of Ministry of New and Renewable Energy (MNRE) is Rs. 195 lakhs. The average energy cost for utility grid power is Rs. 8.5 per kWh and demand charges of Rs. 200 per kVA. The Life of solar panels and structures is considered as 25 years and 5 years for electronic components. The payback period is computed by considering the average increase in energy charges by 3% every year and the additional investment of 30% of capital cost after every 5 years for replacement of electronic components. The payback period is computed as:

$$PAYBACK = \frac{C}{\left(E_{SPV} \times C_E\right) - \left(C \times \frac{I}{100}\right) - C_{O\&M}}$$

Where C is the capital investment (Rs.), E_{SPV} is the energy supplied by SPV power plant (kWh/y), I is the annual interest rate (%) i.e., 11% and $C_{O\&M}$ is the operation and maintenance cost (Rs./y) is 1% of capital investment.

The installation of solar PV power plant will reduce the energy consumption from utility grid is 852.4 MWh/y that forms about 26.9% of total energy consumption. The implementation of solar PV power plant reduces the CO_2 emission by 895 t/y which helps in green energy concept.

The annual net amount saving is computed based on the prevailing energy charges and also considering the increase in energy cost of 3% every year. Figure 39 shows the variation of net amount saving for 11 different offers collected. The initial investment for offer 11 is Rs. 195 lakhs and Rs. 119.73 lakhs/y.

The net cumulative amount saving is computed by considering the life of solar PV power plant is 25 years and life of electronics components as 5 years i.e., considered an additional investment for electronic components after five years. Figure 44 shows the variation of net cumulative life time gain for 11 different offers collected. The life time gain for 11th offer is Rs. 17.48 crores which is almost 9 times that of initial investment.

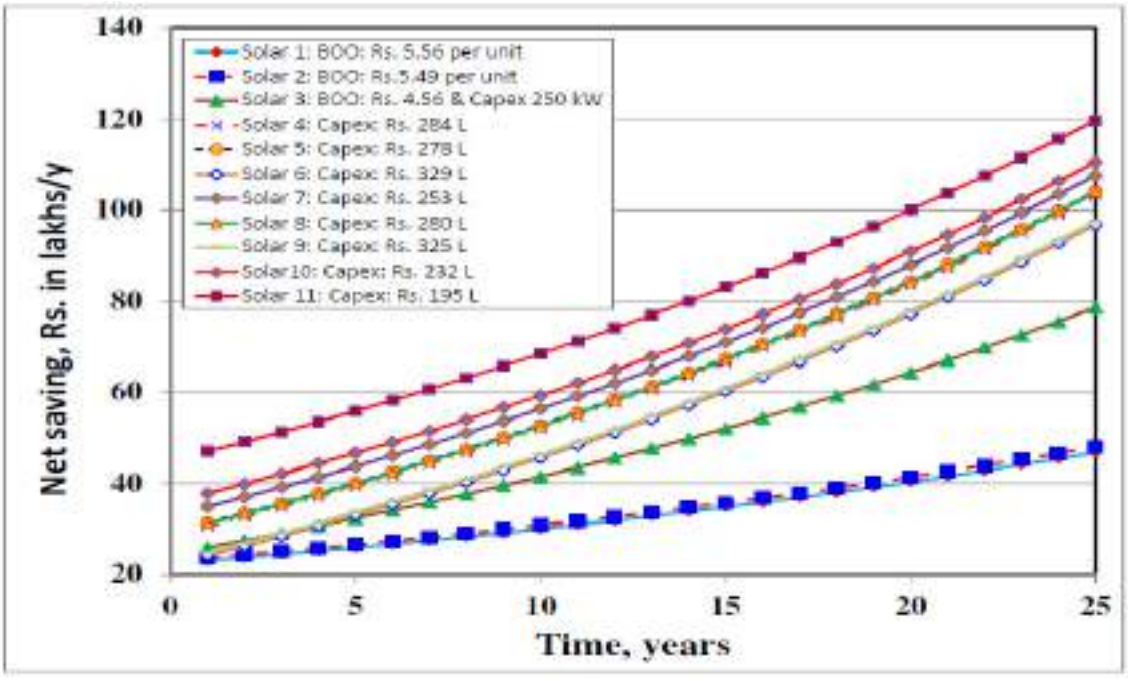

Figure 44: Net amount saving for 11 different offers.

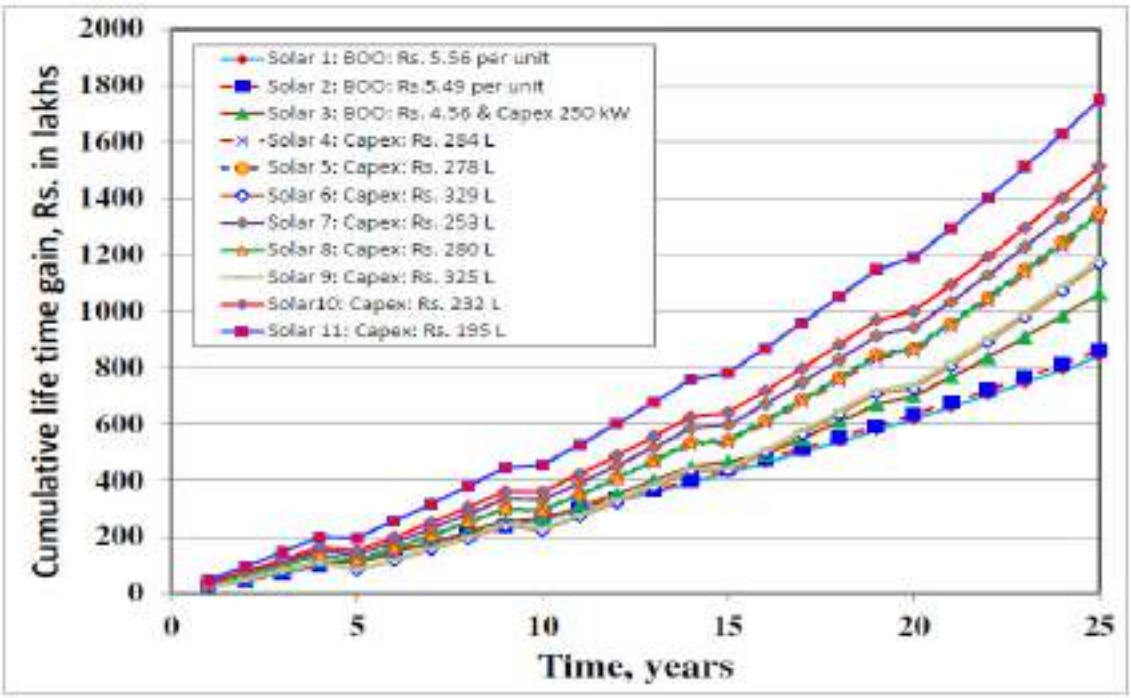

Figure 45: Cumulative life time gain for implementation of 500 kW SPV plant.

The payback period is 3 years and 11 months (Figure 46). The cumulative savings at the end of 25 years of life of solar PV power plant is Rs. 17.48 crores and the life time gain is Rs. 15.53 crores.

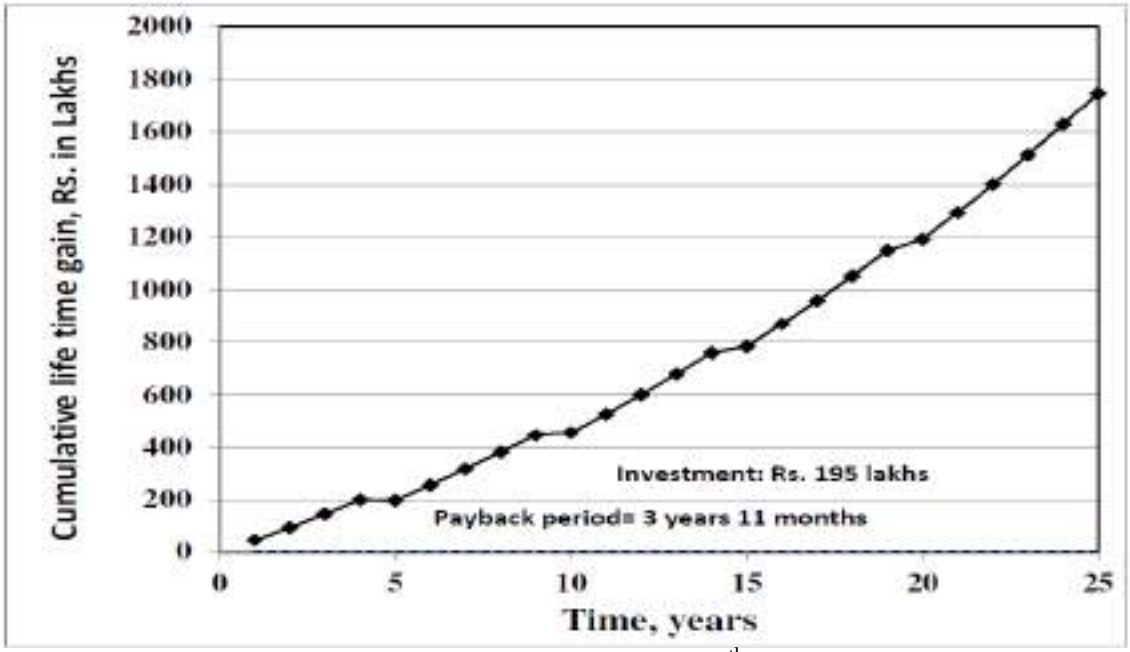

Figure 46: Payback period for 11th offer.

3.9.3 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 47 shows the view of solar hot water system installed at Hostel block. The total solar hot water capacity of 80,000 litres/day (LPD) for the total student strength of 3293 with specific hot water of 24.3 LPD/student.

a) Boys Hostel A block: 10,000 LPD, students: 384 Nos. : Specific water: 26.0 LPD/student
b) Boys Hostel B block: 10,000 LPD, students: 384 Nos. : Specific water: 26.0 LPD/student
c) Boys Hostel C block: 10,000 LPD, students: 552 Nos. : Specific water: 18.1 LPD/student
d) Boys Hostel D block: 30,000 LPD, students: 1040 Nos. : Specific water: 28.8 LPD/student
e) Girl Hostel G1: 10,000 LPD, students: 453 Nos. : Specific water: 22.1 LPD/student
f) Girl Hostel G2: 10,000 LPD, students: 480 Nos. : Specific water: 20.8 LPD/student

The specific hot water is varying between 18.1 to 26.0 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 56, 411 kWh/month that forms 14.4% of total energy consumption.

Figure 47: View of Solar hot water system.

3.10 Lighting System

The energy is used for lighting system is 1923.1 kWh/day that forms 20.4% of total energy consumption. 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 1230 kWh/day that forms 13.1% of total energy consumption. The energy used for other end use & lab equipment is 1769.6 kWh/day that forms 18.8% 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:

Figure 48: View of Solar hot water system.

1. In the Sir CV Raman block Amphi theatre roof is provided with transparent polycarbonate sheets for the approximate area of 1025 m^2. Figure 48 shows the view of transparent polycarbonate sheets installed at sir CV Raman block Amphi theatre. This had allowed very good natural light

during day hours. This had reduced the average electrical energy of 490 kWh/month which is commendable.

2. Similarly at Vivekananda block Rangasthala roof is provided with transparent polycarbonate sheets for the approximate area of 900 m^2. This had allowed very good natural light during day hours and had reduced the average electrical energy of 430 kWh/month.
3. The energy used for lighting in class rooms is very less because of good amount of natural light is available in all blocks. The window curtains are used are of light colours.
4. The wall paints in all class room is of light colour whose reflectance factor is good (refer Table 11).
5. At Visvesvaraya block, at class rooms about 612 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 150 to 213 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 1,469 kWh/month***. The anticipated investment is Rs. 2.20 lakhs and the payback period is 18 months.
6. At Visvesvaraya block other labs and rooms, 277 numbers of 36W T8 TFL and 102 numbers of 5W CFL are installed. The illumination level is varying between 107 to 313 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 665 kWh/month. The anticipated investment is Rs. 1.00 lakhs and the payback period is 18 months.
7. At RISM block, at class rooms about 263 numbers of T8 TFL are installed. The illumination level is varying between 126 to 312 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 631 kWh/month. The anticipated investment is Rs. 0.95 lakhs and the payback period is 18 months.

8. At RISM other labs and rooms, 308 numbers of 36W T8 TFL and 20 numbers of 5W CFL are installed. The illumination level is varying between 98 to 249 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. 1.11 lakhs and the payback period is 18 months.
9. At Admin block, at class rooms about 106 numbers of T8 TFL and 298 numbers of 15W CFL are installed. The illumination level is varying between 150 to 213 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 254 kWh/month. The anticipated investment is Rs. 0.38 lakhs and the payback period is 18 months.
10. At Admin block other labs and rooms, 106 numbers of 36W T8 TFL, 198 numbers of 5W CFL and 293 numbers of 28W CFL are installed. The illumination level is varying between 45 to 256 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 254 kWh/month. The anticipated investment is Rs. 0.38 lakhs and the payback period is 18 months.
11. At Vivekananda block, at class rooms about 295 numbers of 18W LED lamps, 135 numbers of T8 TFL and 234 numbers of 15W CFL are installed. The illumination level is varying between 126 to 225 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 324 kWh/month. The anticipated investment is Rs. 0.49 lakhs and the payback period is 18 months.

12. At Vivekananda block other labs and rooms, about 62 numbers of 18W LED lamps, 234 numbers of 36W T8 TFL, 15 numbers of 5W CFL and 293 numbers of 28W CFL are installed. The illumination level is varying between 105 to 309 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 562 kWh/month. The anticipated investment is Rs. 0.84 lakhs and the payback period is 18 months.
13. At Sir C.V. Raman block, at class rooms about 673 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 136 to 285 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 1,615 kWh/month. The anticipated investment is Rs. 2.42 lakhs and the payback period is 18 months.
14. At Sir C.V. Raman block other labs and rooms, about 232 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 118 to 309 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 557

kWh/month. The anticipated investment is Rs. 0.84 lakhs and the payback period is 18 months.

15. In order to conserve the energy consumption at Hostel blocks, at each room one number of 36W T8 TFL lamp was replaced with 18W LED lamp. This had reduced the total energy consumption for 3360 numbers of lamps by 15,120 kWh/month with an investment of Rs. 12.10 lakhs and the payback period was 10 month which is a very good payback period.
16. At Boys Hostel block A, B & C, 128 numbers of 18W LED lamps and 512 numbers of 5W CFL lamps are installed. The illumination level is varying between 136 to 211 lumens/m^2 and is normal. There are 128 numbers of comfort air fans are installed in labs.
17. At Boys Hostel block D, 520 numbers of 18W LED lamps and 780 numbers of 5W CFL lamps are installed. The illumination level is varying between 108 to 201 lumens/m^2 and is normal. There are 260 numbers of comfort air fans are installed in labs.
18. At Girls Hostel 1, 185 numbers of 18W LED lamps and 683 numbers of 5W CFL lamps are installed. The illumination level is varying between 157 to 218 lumens/m^2 and is normal. There are 128 numbers of comfort air fans are installed in labs.
19. At Girls Hostel 2, 120 numbers of 18W LED lamps and 360 numbers of 5W CFL lamps are installed. The illumination level is varying between 134 to 256 lumens/m^2 and is normal. There are 120 numbers of comfort air fans are installed in labs.
20. For street lighting system, 16 Nos. of 110W, 20 Nos. of 200W, 22 Nos. of 50W and 80 Nos. of 24W LED lamps are installed. These streetlights are operated through timers and the timing is set depending on season. The following timings are set for different streetlights:
    a) 110W & 200W lamps: ON time: 10:40 PM – OFF time: 5:30 AM
    b) 24W lamps: ON time: 6:50 PM – OFF time: 10:40 PM
    c) 50W lamps (dome): ON time: 6:50 PM – OFF time: 5:30 AM

21. The energy used for street lighting system is 61 kWh/day that forms 0.6% of total energy consumption. **Recommendations**: It is suggested to put OFF the dome lights at 11:00 PM that will reduce the ***energy consumption by 231 kWh/month***.

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	295	135	234	534	163, 150,126, 225, 182, 138	
DBMS Project Lab		2			185, 176, 208, 175, 224, 176,	2 TV, 1 Biometric, 5 Purifiers
OOPS Lab		2			115,105,67,178, 126, 134, 108	
DBMS Lab		8			128, 108, 123, 187, 178, 201,	
WEB Lab		4			117, 207, 189, 209, 278, 203,	
Staff Room		108	7	132	188, 134, 187, 239, 216, 179,	Projector, PC
Corridors	62	110			184, 178, 203, 309, 115, 202,	16 Purifiers,7 Projectors, 2 Coffee Machines,2 Vending Machines
Computer Lab		2			212, 187, 145, 166, 167, 204,	
CCP Lab		2			287, 175, 167, 261, 211, 207,	
Research Centre			8	3	128, 123, 176, 175, 187, 165	
Programming Lab		6			138, 142, 178, 165, 178, 145	2 Projector

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**
	TFL (36 W)	**CFL (5 W)**			
Rooms	612	18	606	213, 150,156, 205, 182, 178	
HOD & staff room		28		205, 176, 208, 175, 204, 176,	
corridor	94			45,105,67,178, 156, 134, 108	
Wash rooms	37	74		98, 108, 123, 167, 178, 201,	
exam control room	4		4	167, 207, 189, 209, 218, 209,	
CAD hall 1,2,3	20		26	178, 134, 187, 239, 256, 179,	Projector, PC
Material science lab	8		12	134, 178, 203, 309, 115, 207,	
Fluid mechanics lab	18		20	112, 167, 145, 156, 187, 204,	
Machine shop	18		20	187, 155, 167, 201, 211, 209,	
Skill development center	11		10	178, 123, 176, 155, 187, 165	
Measurement and instruments	4		4	108, 122, 178, 165, 178, 145	
Manufacturing technology lab	8		4	134, 85, 200, 178, 165, 118	
Energy conversion lab	8		8	189, 109, 96, 156, 208, 218	
HMT lab	5		6	110, 211 , 107, 109, 114, 145	
Design lab	7		6	211, 201, 178, 234, 217, 210	
CAED Lab and Auto CADD lab	18		13	178, 156, 208, 207, 134, 187	Projector
CAMA, CIM, Automation lab	9		6	156, 176, 207, 211, 208, 165	Projector, PC
Physics Lab 1 & 2	8		10	201, 211, 156, 178, 165, 145	

Table 6: Lighting level measurement at Admin Block

Particulars	**Light fitting**			**Fans, (60 W)**	**Illumination level, lumens/m^2 (lux)**	**Remarks / Other equipment**
	TFL (36 W)	**CFL**				
		(15W)	**(28W)**			
Rooms	106	298		127	222, 214, 187, 203, 198, 108	
Corridor	57	163	158	2	215, 136, 218, 115, 224, 196,	2 TV, 1 Biometric, 5 Purifiers
Washrooms	24			8	145,195, 167,188, 116, 174	
Auditing Office	6				128, 188, 193, 157, 168, 201,	
VC Visitor Lounge			7		187, 207, 109, 229, 258, 219,	
ERP & HR Office			35		148, 174, 127, 289, 256, 139,	Projector, PC
HR Interview Room			26		124, 168, 223, 319, 125, 217,	
Admission and public relations	4		5	7	152, 117, 155, 136, 197, 224,	
Office of the administration & establishment	4			5	157, 115, 177, 281, 211, 209,	
Registrar office			4	2	118, 163, 176, 165, 187, 163	
Conference hall and Board room		33	6		108, 122, 178, 165, 178, 146	2 Projector
Accounts office	5			5	134, 185, 200, 178, 165, 111	
university office			1		119, 109, 96, 196, 208, 218	
Advisor			9	1	180, 211 , 157, 109, 114, 155	
Vice chancellor			11		231, 241, 198, 234, 227, 210	1 TV
Chancellor office	3		31			1 TV
Pantry	3			1		2 Purifiers

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**
	TFL (36 W)	**CFL (5 W)**			
Rooms	263		140	126, 178, 234, 178, 218,234, 195, 278, 312, 234, 267, 167	
Principal ,Admin office	2	8	3	115, 186, 218, 156, 214, 216,	
Exam control room and pantry	7		4	145,125,167,178, 186, 154	Vending machine
Corridor	96			98, 108, 87, 97, 78, 111,	
Wash rooms	22		2	147, 217, 165, 169, 178, 176,	
Seminar halls		12		188, 194, 167, 209, 226, 189,	Projector
Sports room	20		9	156, 188, 213, 249, 165, 217,	
Chemistry lab 1,2,3,4,5,6	33		28	165, 123, 145, 167, 204, 211, 213, 156,156, 205, 182, 178,	Conductivity meter, ,temp controller, colorimeter, spectro photo meter, Chemical analyser, UV visible spectroscope, Shaker's incubator, Hot air incubator, Deep freezer
Physics Lab 1 ,2,3	12		9	167, 175, 197, 211, 216, 189,	Digital inverter, Hot air oven, ultrasonicator, Quartz furnace, signal generators, Fermi energy set up, Michelson Intereferometer
Plant tissue culture lab	17			168, 133, 186, 185, 197, 145	Silica beed sterilizer, Laminar air flow
Biology lab, Genetic Lab	15		6	128, 142, 168, 175, 198, 195	Hot air incubator, AC, Potarymictrotome
Basic Material lab	42		18	164, 185, 209, 178, 175, 118	Two span simply supported beem,,Venture flame and OGEE wier
Geo technical engineering lab	42		18	109, 178, 196, 156, 218, 207	Unconfines compression tester, Butimen stripping

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		673	66	14	102			401	183, 160,136, 285, 182, 178	6 Projectors
Labs		89			22			22	195, 176, 208, 175, 264, 176,	4 Exhaust Fans
Corridor	24	58		4	22		4	16	167, 267,198, 156, 154, 108	4 Purifiers,1 TV, 3 Biometric Machines
Washrooms		16							98, 108, 183, 167, 118, 201,	3 Exhaust Fans
Training rooms		24						12	147, 207, 189, 209, 218, 209,	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	224, 178, 203, 319, 115, 207,	
Amphitheatre					4	1	1		232, 157, 145, 156, 187, 204,	
Main gate dome						15			217, 155, 167, 271, 211, 209,	
Pantry									218, 193, 176, 165, 187, 165	2 Exhaust Fans

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	512	128	128	153, 160,156, 215, 182, 118	1 Camera,1Vending Machine, 7 Purifiers
B Block	512	128	128	215, 136, 211, 165, 204, 176,	1 Camera,1Vending Machine, 7 Purifiers
C block	512	128	128	165,105,67,178, 156, 134, 108	1 Camera,1Vending Machine, 7 Purifiers
D block	780	520	260	128, 108, 123, 167, 178, 201,	1 Camera,1Vending Machine, 4 Purifiers
Girls hostel 1	683	185	185	157, 207, 189, 209, 218, 209,	1 Camera,2Vending Machine, 2Purifiers
Girls hostel 2	360	120	120	188, 134, 187, 219, 256, 179,	1 Camera,2Vending Machine, 2 Purifiers
Corridors		325		163, 63, 156, 181, 177, 93, 55	

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

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 Aluminium	62	17	Pale blue	44
06	Lime stone	35 - 38	18	Medium grey	42
07	Polished marble	30 - 70	19	Sky blue	34
08	Tracing cloth	30	20	Olive green	21
09	Grey cement	20 - 30	21	Medium brown	17
10	Granite	20 - 25	22	Cardinal red	19
11	Red brick	10 - 15	23	Dark grey	17
12	Black paper	5			

3.11 Energy Management System

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

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

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

4.0 CONCLUSIONS

The main conclusions from the study are as follows:

1. The electrical distribution system is well maintained.
2. The total energy consumption (BESCOM+DG) is varying between 203.8 and 292.3 MWh/month. The total energy consumption during 2017 is 31,63,318 kWh/y which is taken as base energy consumption for energy audit study. The total built area is 1,46,548 m^2. The energy performance index (EPI) for total REVA University campus is 21.59 kWh/m^2-year which is lower than the EPI specified by Energy Conservation Building Code (ECBC) 2006 of 120 kWh/m^2-year.
3. The recorded maximum demand (MD) is varying between 410 kVA and 856 kVA. The contract demand can be reduced to 1000 kVA that reduce the minimum chargeable MD to 850 kVA which will *reduce the MD charges by Rs. 30,600 per month***.**
4. The load of transformers is varying between 21.8 to 87.9%.The all day efficiency of Tr.1 is 98.34% which is slightly better than that of Tr. 2 of 97.88%. The diverting of all the total loads on to Tr. 2 (1000 kVA) during day time between 08:00 to 17:00 hours and during evening hours between 17:00 to next day 08:00 hours will reduce the *energy consumption by 3,045 kWh/month*.
5. The load factor of DG sets are in the range of 31.8 to 48.1% and the Specific energy generation (SEG) of DG sets in normal in the range of 2.80 to 3.04 kWh/l.
6. The specific air-conditioning system varies between 1231 to 1698 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 1.25 to 1.67 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 22 – 23 ^{o}C which should be maintained above 25^{o}C which will reduce the energy consumption by 3% per degree of room temperature. The anticipated *energy saving is 400 kWh/month*.

7. The 55 kW solar power plant generates energy in the range of 6076 to 8411 kWh/month that forms 2.78% during 2018 to 4.08% during 2015.
8. The energy used for lighting system of 1923.1 kWh/day that forms 20.4% of total energy consumption.
9. The energy used for comfort air fans is 1230 kWh/day that forms 13.1% and for other end use & lab equipment is 1769.6 kWh/day that forms 18.8% of total energy consumption.
10. The illumination level is good because many room natural light is available and is being used appropriately. At rooms and labs, about 2946 numbers of 36W T8 fluorescent lamps (TFL) are installed, if these T8 lamps are replaced by 18W LED lamps will reduce the total energy consumption by 7,070 kWh/month. The anticipated investment is Rs. 10.61 lakhs and the simple payback period is 18 months. Putting off of dome lights during 11:00 PM to 5:30 AM will reduce the energy consumption by 231 kWh/month.
11. 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.
12. The installation of 500 kW solar power plant will reduce the energy consumption by 8,52,000 kWh/y with an investment of Rs. 195 lakhs will be paid back in 47 months. This reduces the CO_2 emission by 895 t/y.

At present the installation of ***renewable energy system had reduced the electrical energy consumption of 56,411 kWh/month that forms 17.6% of total energy consumption and reduced the CO_2 emission of 59.2 t/month***.

The implementation of energy conservation measures at REVA University Kattigenahalli campus and installation of 500 kW solar PV Power plant will reduce the ***energy consumption by 81,746 kWh/month (31.0 % of total energy input)***. This will reduce the CO_2 emission by 85.8 t/month.

Annexure I

Table 12: 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 13: 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